PASCO scientific

2015 Physics and Engineering Catalog



NEW Products

550 Universal Interface

UI-5001

Pages 2-3



Polarizer Demonstrator Accessory

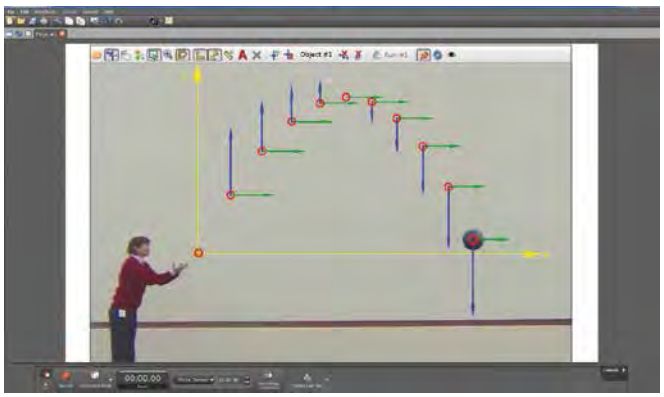
OS-8172

Page 275



PASCO Capstone™ 1.2 Vectors on Video Analysis

Page 75



Smart Gate

PS-2180 (PASPORT)

Pages 38, 106



Smart Gate Pulley System

PS-3702 (PASPORT)

Pages 38, 106



3-Axis Acceleration/ Altimeter

PS-2136A

Page 37



Advanced Water Quality

PS-2230

Page 72



Advanced Physics through Inquiry 1 Teacher Guide

PS-2848

Page 82

Advanced Physics I Starter Bundle

PS-2815

Page 83



Polarimeter

PS-2235

Page 60



Zeeman Effect

SE-9654

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New Products and Table of Contents

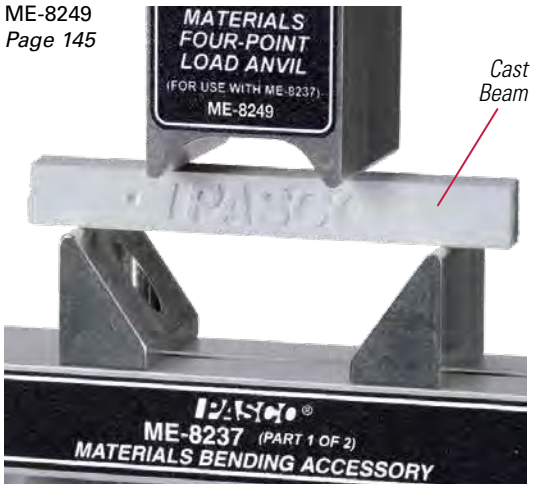
Comprehensive Materials Testing System

ME-8244
Page 142



Four-Point Bending Accessory

ME-8249
Page 145



Compression Accessory

ME-8247
Page 144



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New 550 Universal Interface

The PASCO 550 Universal Interface

NEW

UI-5001

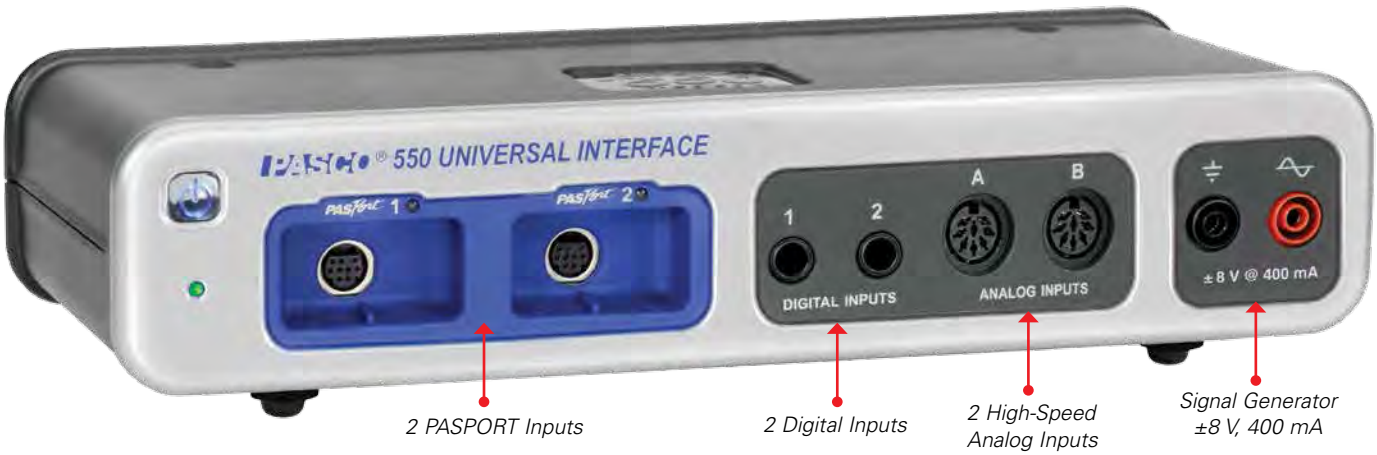
It is possible to have an interface that is all things to all people!

The 550 Universal Interface is

- *Fast*
- *Powerful*
- *Economical*

Available May 2015

Runs on PASCO Capstone Software:
See page 6



The 550 Universal Interface is the economical interface that has something for everyone.

ScienceWorkshop 500 and 750 users gain:

- Higher sample rates (up to 1 MHz)
- Higher power built-in signal generator (8V, 0.4 A)
- Ability to use new blue PASPORT multi-sensors simultaneously with your black sensors





750 users should also consider the more advanced 850 interface
See page 14

PASPORT users gain:

- Two high speed voltage ports (up to 1 MHz)
- Use your PASPORT interface and the 550 simultaneously
- Two photogate ports (no adapter required)
- Ability to use the ScienceWorkshop Sound Sensor to see waveforms
- Use ScienceWorkshop sensors at sample rates higher than 1 kHz



PASPORT USB Link

NEW users get all this:

- A great value for an all-in-one interface
- Signal generator output for speakers or circuit experiments
- Combined with Capstone software, an oscilloscope and FFT for sound experiments
- Download 32 FREE experiments written by teachers



PASPORT Xplorer GLX

Experiments for the 550 Universal Interface

Look at all the experiments that have been written by teachers that can be performed with either the 850 or the 550 Universal Interface! And these experiments can be downloaded for free at www.pasco.com/CapstoneExperiments.

See pages 302-359 for details.

Page	Part#	Experiment	Sensors Used
303	EX-5501	Atwood's Machine	Photogate Port
305	EX-5503	Newton's Laws	Motion and Force
306	EX-5504A	Hooke's Laws & Energy Stored in a Spring	Motion
307	EX-5505A	Centripetal Force on a Pendulum	Rotary Motion and Force
308	EX-5506	Centripetal Force	Photogate, Force, and Signal Generator
309	EX-5507A	Motion Graph Matching	Motion
310	EX-5508	Sliding Friction	Motion and Force
311	EX-5509	Impulse	Photogate and Force
312	EX-5510A	Conservation of Momentum	2 Rotary Motion
313	EX-5511A	Ballistic Pendulum	Rotary Motion
315	EX-5512	Conservation of Energy II	Motion
316	EX-5513A	Work-Energy Theorem	Motion and Force
319	EX-5515A	Materials Stress Strain	Force and Rotary Motion
320	EX-5516A	Rotational Inertia	Rotary Motion
321	EX-5518A	Physical Pendulum	Rotary Motion
322	EX-5517A	Conservation of Angular Momentum	Rotary Motion
323	EX-5520A	Large Amplitude Pendulum	Rotary Motion
324	EX-5519A	Variable-g Pendulum	Rotary Motion
325	EX-5521A	Torsional Pendulum	Rotary Motion
330	EX-5526A	Frictional Energy Transfer	Force and Temperature
331	EX-5527	Ideal Gas Law	Pressure and Temperature
334	EX-5530A	Heat Engine Cycle	Dual Pressure, Rotary Motion, 2 ScienceWorkshop Temperature
335	EX-5531	Ratio of Specific Heats	Dual Pressure
341	EX-5536	RC Circuit	Voltage and Signal Generator
345	EX-5539A	Earth's Magnetic Field	2-axis Magnetic Field and Rotary Motion
348	EX-5541A	Faraday's Law of Induction	2-axis Magnetic Field, Rotary Motion, and Voltage
354	EX-5543A	Polarization of Light	Rotary Motion and High Sensitivity Light
355	EX-5544A	Brewster's Angle	2 High Sensitivity Light and ScienceWorkshop Rotary Motion
356	EX-5545A	Interference and Diffraction of Light	Rotary Motion and High Sensitivity Light
357	EX-5546A	Atomic Spectra	Rotary Motion and High Sensitivity Light
358	EX-5547A	Light Intensity vs. Distance	Rotary Motion and High Sensitivity Light
359	EX-5549A	Photoelectric Effect	DC Power Supply and Current Amplifier





550 Universal Interface Specifications:

Connections: USB or Wireless

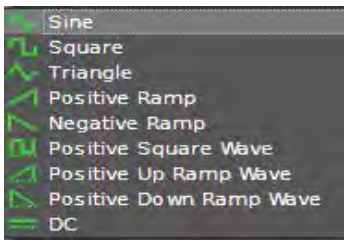
2 high-speed analog inputs:
Measurement Range: ±10 V differential input
Input Impedance: 1 MΩ
Input Protection: ±250 V continuous
Selectable Voltage Gain: X1, X10, X100
Resolution: 14-bit, 0.12 mV
Auto detects new UI analog sensors

2 Digital Inputs: Digital sensors such as Photogates and Time-of-Flight plug directly into the 550 Interface. Compatible with all ScienceWorkshop digital sensors

2 PASPORT Inputs: Compatible with PASCO's complete line of more than 70 PASPORT sensors. Sample rates depend on sensors

Signal Generator:
Waveforms: sine, triangle, square wave, positive and negative ramps, DC
Frequency Range: 0.001 Hz to 100 kHz; 1 mHz resolution
Amplitude Range: ±8 V; Resolution: 1.3 mV.
Max Output Current: 400 mA at 8 V.
Selectable Voltage Limit
Selectable DC Offset
Frequency Sweep Function
Measures Output Current, Voltage

Available Waveforms



Order Information

550 Universal Interface.....UI-5001
Required:
PASCO Capstone Software.....see p. 6

Interfacing Overview

These charts will help you choose the interface you need for your lab.

Interface Choices *(pages 14-23)*

Do you have desktop or laptop computers?

Any interface will work on a computer, so what are your specific needs?

Do you want a comprehensive interface with a signal generator?

Connect by USB



850 Universal Interface
UI-5000 *(pages 14-17)*

Sample rate up to 10 MHz; Accepts both ScienceWorkshop and PASPORT Sensors; Three signal generator outputs.



NEW

550 Universal Interface
UI-5001 *(pages 2-3)*

1 MHz sampling rate, Accepts both ScienceWorkshop and PASPORT Sensors; One signal generator output.

Do you only need to plug in one or two sensors?

Connect by USB



USB Link
PS-2100A *(page 21)*



SPARKlink
PS-2009A *(page 21)*

Wireless Bluetooth or USB



Air Link
PS-2010 *(page 21)*



SPARKlink Air
PS-2011 *(page 22)*

Do you need a stand-alone interface that does not require a computer?

Do you do most of your work in lab but you also want the option of going outside? These also connect to a computer USB port to act as an interface.

Designed for Physics

Xplorer GLX
PS-2002 *(pages 18-20)*

Datalogger with display includes four sensor ports, dual signal generators, oscilloscope, speaker, and built-in sensors (voltage, two temperature, and sound).



Designed for K-12

SPARK Science Learning System
PS-2008A *(page 23)*

Datalogger with touchscreen includes electronic work-books, two sensor ports, and built-in voltage and temperature sensors.



Need more ports?

All the interfaces can be used simultaneously with each other on one computer. So you can mix and match interfaces to expand the number of ports available.

The Sensors *(pages 26-74)*

PASCO has two lines of sensors:

ANALOG sensor

1. The analog ***ScienceWorkshop*** sensors, which are black, output a voltage which is calibrated to correspond to the measurement. The sample rates of these sensors can be up to 10 MHz depending on the interface used.

DIGITAL sensor

2. The digital **PASPORT** sensors, which are blue, contain an analog-to-digital converter and are automatically identified when plugged into an interface. Many of these PASPORT sensors contain multiple sensing elements and are called "multi-measure" sensors, requiring only one interface port. The maximum sample rate is sensor-dependent and usually does not exceed 1000 Hz.



Economy Force Sensor
ScienceWorkshop
CI-6746 (*page 30*)



Force Sensor
PASPORT
PS-2104 (*page 30*)

The 850 Universal Interface and NEW 550 Universal Interface can use both types of sensors without need of a special adapter.

Do you have black *ScienceWorkshop* sensors?

Uses *ScienceWorkshop* as well as PASPORT sensors



850 Universal Interface
UI-5000 (*pages 14-17*)

NEW



550 Universal Interface
UI-5001 (*pages 2-3*)

Looking for the 750 or 500 legacy interfaces?

The 850 and new 550 are the replacement interfaces.

Connect the 500 Interface to USB.

USB/Serial Converter
CI-6759A

Order Information

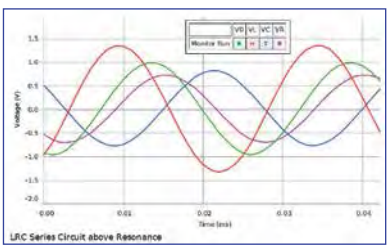
USB/Serial Converter CI-6759A



The Software *(pages 6-13)*

PASCO capstone™ software

All PASCO interfaces are controlled by PASCO Capstone Software. The software collects the data, displays it, and allows you to analyze it and write reports.



PASCO capstone™

New in Version 1.2

New Features In Version 1.2

Hardware Setup
The setup shows the interfaces and sensors you have connected. You can also select hardware that is not connected, so you can create files when you don't have the apparatus available.

Photogates/Timer Setup
This wizard helps you set up a photogate timer. Choose from an assortment of standard timers (such as Photogate with Picket Fence) or create your own timing sequence.

Tool Palette
Tool panels slide open.

Data Summary
This is a list of the sensors and their measurements; their properties can be changed here.

Calibration
This wizard steps you through the calibration sequence, making it clear what you should do at each point.

Calculator
The calculator has the usual scientific functions, as well as special functions (period, amplitude, filters, and logic statements) required for analyzing data.

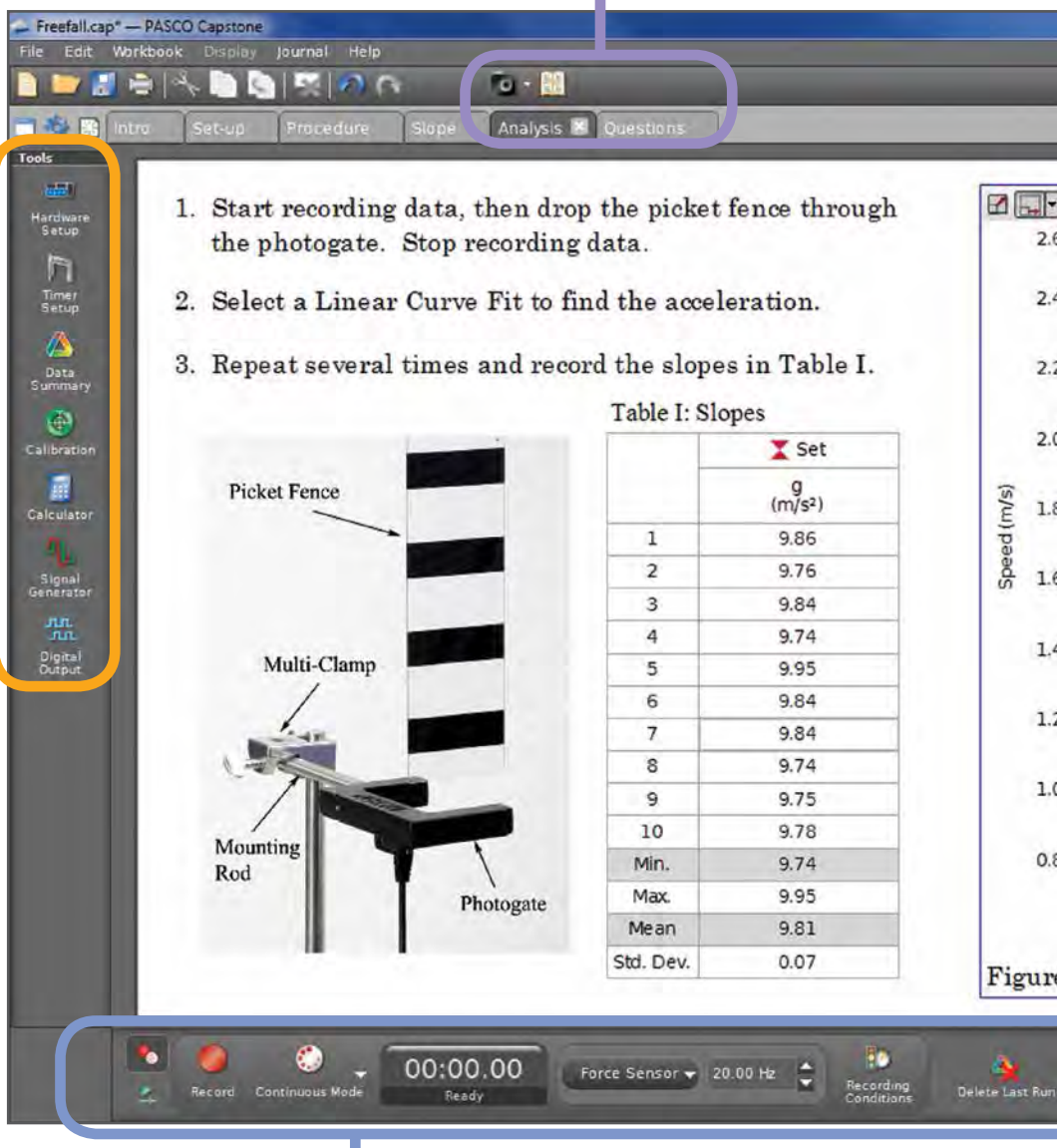
Signal Generator
For an interface that has a function generator, this is where you choose the wave type and settings such as DC offset or frequency sweep.

Now has positive wave forms and ability to set the phase.

New in Version 1.2

Digital Output
Control the digital output of the 850 Interface Expansion Port.

Create Multiple Pages



Control Bar

Choose Sampling Mode
- Continuous Recording
- Keep Samples (manual Sampling)
- Fast Monitor

Set Sample Rate
By default, all sensors are at the same rate but each sensor can have its own sample rate.

Recording Conditions
Set start and stop conditions.

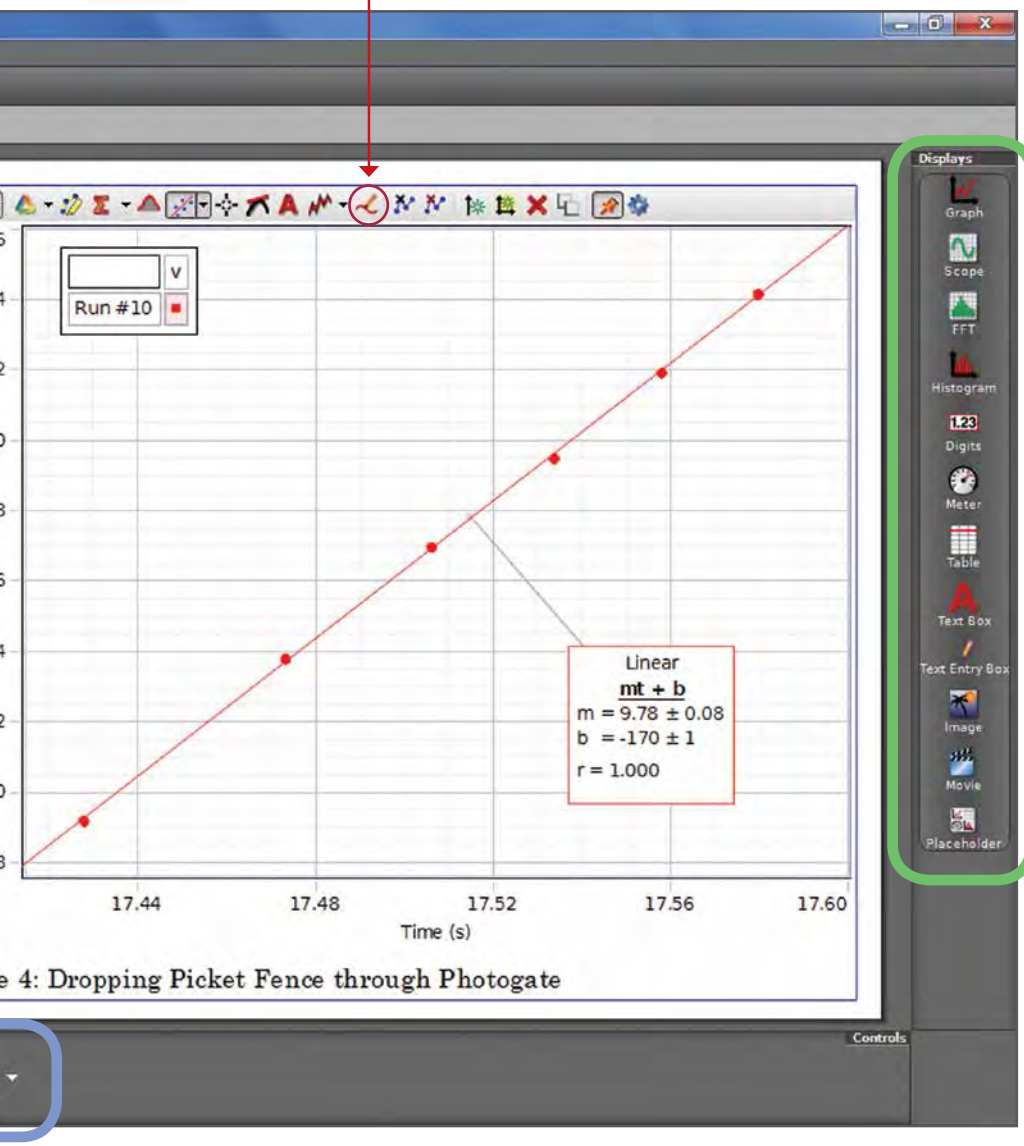
Delete Runs
Just click to delete last run or use drop-down menu to select runs to delete.

Try it!
Download a FREE 60-day trial at pasco.com/capstone

Looking for DataStudio? PASCO Capstone has superceded DataStudio. Please see the following pages for reasons you may want to switch to PASCO Capstone →

New in Version 1.2

NEW. Create Predictions (saved as data) and compare to actual data.



Graph
Create graphs with multiple y-axes and multiple stacked plot areas.

Oscilloscope
The scope can be scaled directly by dragging the axes.

FFT
Create FFTs with multiple measurements, and zoom in on the data to get more resolution.

Histogram
Bin data for statistical experiments and display statistics.

Digits
Increase/decrease the precision of the display by clicking a button.

Meter
Choose from small arc to full circle; includes special angle display.

Display Palette
Drag and drop displays onto the page. Automatic guidelines will appear to help arrange the displays.

Table
Add or subtract columns and rows with the click of a button. Also add calculated columns.

Text Box
Choose font type, size, and color to make the text more readable.

Text Entry Box
This box is for students to enter answers to questions.

Picture
Add a picture from a file and resize it to fit your layout.

Movie
Take a snapshot of your apparatus, load a movie from a file, record a webcam movie to explain something, or record a movie from a webcam simultaneously with recording data from sensors and synch them together.

New in Version 1.2

Perform video analysis with velocity and acceleration vectors. Now can auto-track the object, too.

Minimum System Requirements
Windows: Windows XP SP2 or higher
Macintosh: MAC OSX (v. 10.6 or higher)
2 GHz processor, 200 MB available disk space, 2 GB RAM, minimum display size 1024 x 786

Supported Languages
French, Spanish and Simplified Chinese,
Arabic, German, and Brazilian Portuguese

New in Version 1.2

Order Information

PASCO Capstone Software

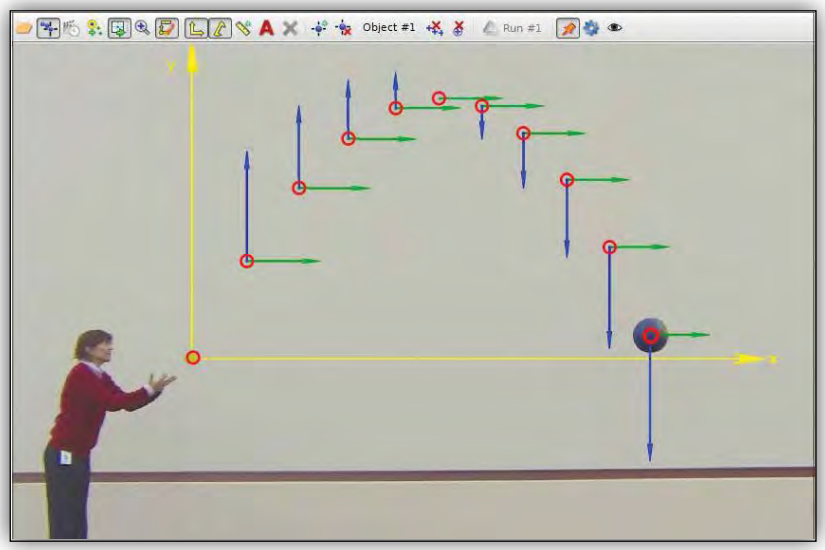
Single User License	UI-5401
Site License	UI-5400

Version 1.2 upgrade is available free to all current PASCO Capstone owners.

Version 1.2 adds new features — Free upgrade for Capstone owners.

1 Video Analysis Vectors

New in Version 1.2



Measure position, velocity, and acceleration in two dimensions using video analysis.

New in Capstone 1.2, velocity and acceleration vectors can be displayed on the object position points. You can choose to show the components and/or the resultant vector.

- Intuitive user interface
- Track more than one object
- XY data includes position, velocity, and acceleration
- Rotate the coordinate axes to compensate for a camera that is not level
- Make measurements of the length or diameter of objects
- The Magnifying Tool allows for unobstructed placement of data points, improving your analysis of video data

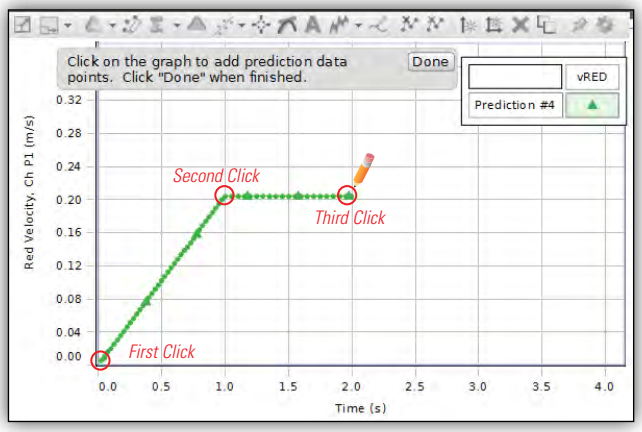
Please see page 75 for details.

2 Predictions

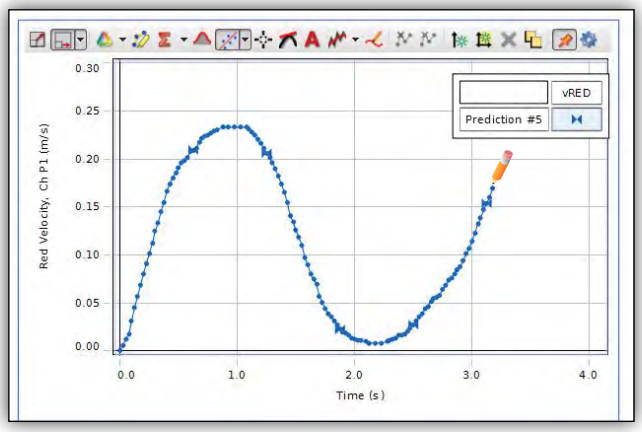
New in Version 1.2

Predictions are a powerful tool for learning. Students can draw their predictions of what they think the data will look like on the graph. Then they collect the data run and compare it to their prediction.

- Predictions are stored as run data and can be used in calculations or displayed at a later time.
- Predictions can be made on non-time graphs, such as Force vs. Distance.
- There are two methods for drawing predictions:
  1. Point-by-Point
     Click points and the program fills in a straight line between them.
  2. Free-form
     Use the mouse to draw a continuous line and when you release the mouse button, your prediction data run is complete.



1. Point-by-Point



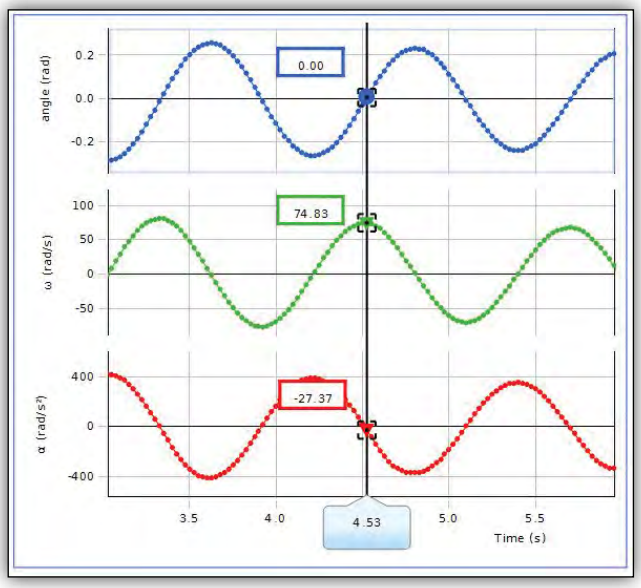
2. Free-form

3 Multi-Coordinates Tool

New in Version 1.2

Often it is desired to compare values of different measurements at the same time (for instance, position, velocity, and acceleration of an oscillating mass). The Multi-Coordinates Tool shows values for any data set, whether they are on the same plot area or separate ones.

- Works for non-time dependent data such as distance on the horizontal axis.
- Reads between data points



4 Capture Video and Sync it to Data

Any webcam can be used as a "video sensor" to record movies at the same time as data.

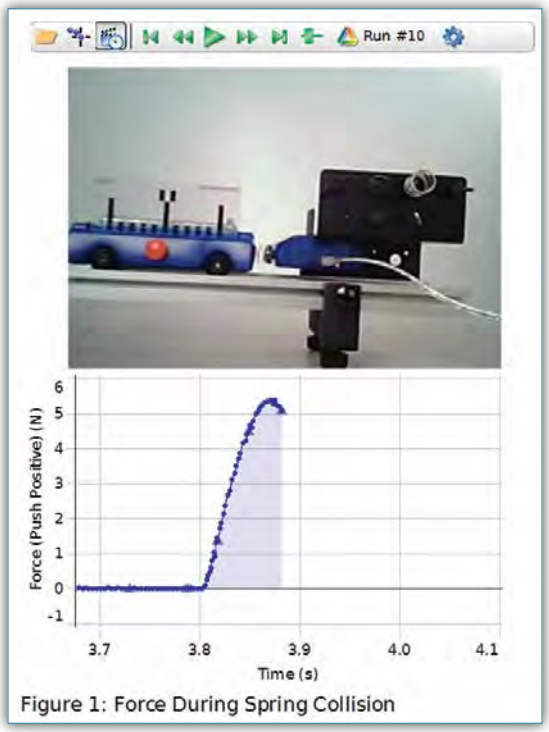


Figure 1: Force During Spring Collision

Data Replay Playback Mode

Replay data in slow motion, normal speed, or high speed.

5 Create Text and Calculated Columns with Ease

Insert a column in the table by simply clicking a button. Insert a calculated column and create an equation directly in the table.

Table II: Energy

Kinetic Energy=1/2*(0.5) [Speed (m/s)]^2

	Run #10 Speed (m/s)	Run #10 Kinetic Energy (J)
1	0.91765	0.21
2	1.37779	0.47
3	1.69595	0.72
4	1.94795	0.95
5	2.19135	1.20
6	2.41453	1.46

More

6 Open your DataStudio (.ds) and Xplorer GLX (.glx) files in PASCO Capstone

DataSTUDIO®

Xplorer GLX®

Open files you have created in the .ds or .glx format. They will be transformed into the Capstone workbook format and you can easily rearrange the displays as you like.

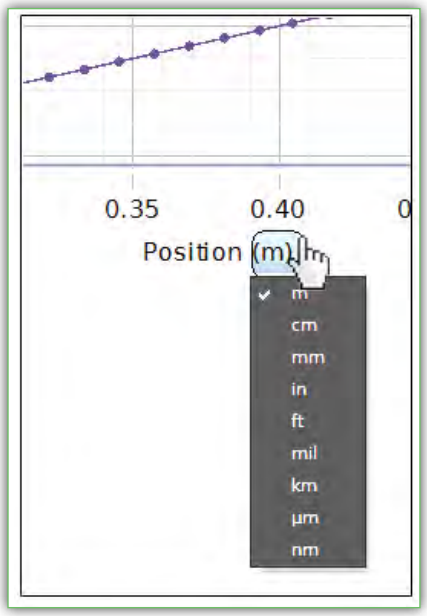
8 Made a Mistake? Just Undo!

Undo! Redo!

Being able to undo actions gives students the freedom to explore, allowing them to learn the program faster.

7 Change units by clicking directly on them

Capstone has the modern navigation familiar to students, allowing them to quickly learn how to get the items they need.



Change units and rename measurements and runs by editing them in place.

You don't have to search menus for what you need.

More

9 Capstone supports *PASCO* USB interfaces, *ScienceWorkshop®* Sensors, and PASPORT® Sensors

There is no need to change your hardware. You can continue to use your black ScienceWorkshop interface and sensors (the 500 Interface requires a USB-to-serial adapter). If you adopt the 850 Universal Interface, you can use the black ScienceWorkshop sensors in the same experiment as the blue PASPORT sensors. Capstone Software is required for the 850 Universal Interface.



850 Universal Interface
UI-5000



550 Universal Interface
UI-5001



750 USB interface
CI-7650
(Legacy Product)
SCSI version requires Series-to-USB Converter



500 interface
CI-6400
(Legacy Product)
Requires Series-to-USB Converter



SPARKlink®
PS-2009A



USB Link
PS-2100A



Xplorer GLX®
PS-2002



Xplorer™
PS-2000
Works as computer interface only.



SPARK Science Learning System™
PS-2008A
Works as computer interface only.



AirLink 2
PS-2010



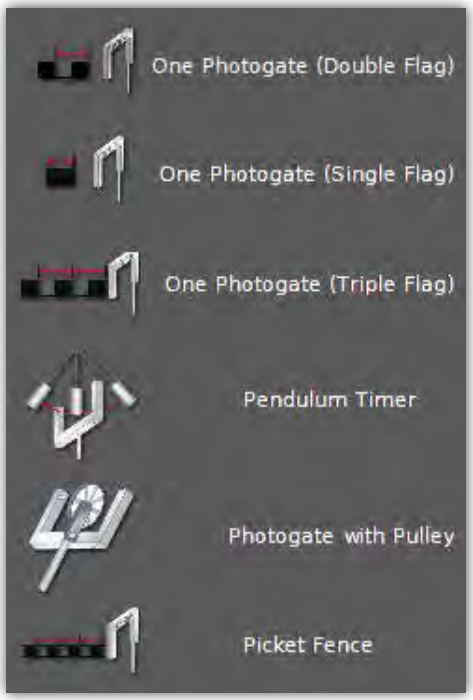
SPARKlink Air
PS-2011



PowerLink
PS-2001

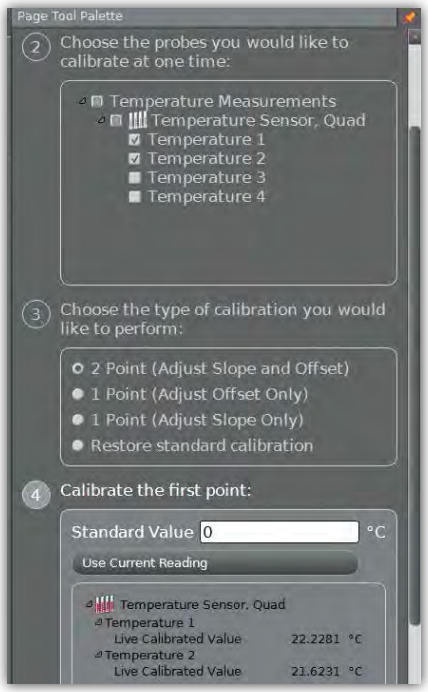
10 Photogate Timer Setup Wizard

The wizard takes you through the steps of creating a timer for the photogates, using graphics to make it clear which timing mode you are choosing.



11 Calibration Wizard

The wizard makes sure you are sampling the correct standard at the correct time.



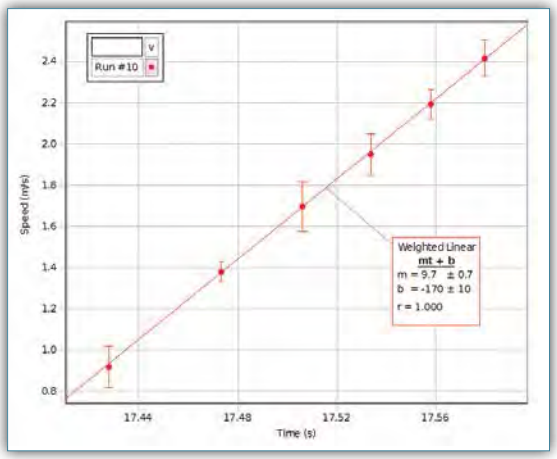
12 Sophisticated Calculator

Type calculations using Greek symbols, subscripts and superscripts, making equations look more like they do in textbooks.



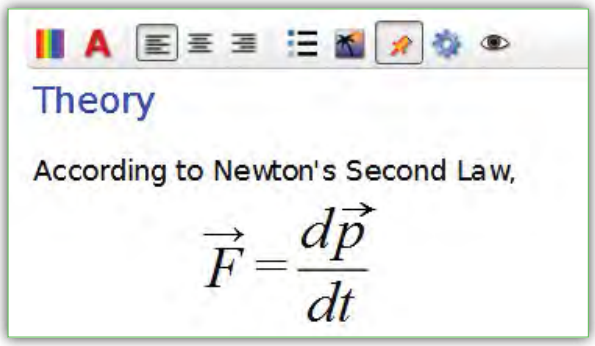
13 User-defined Error Bars and Weighted Linear Fit

- Enter individual error values for each data point.
- Weighted Linear Fit takes error bars into account.



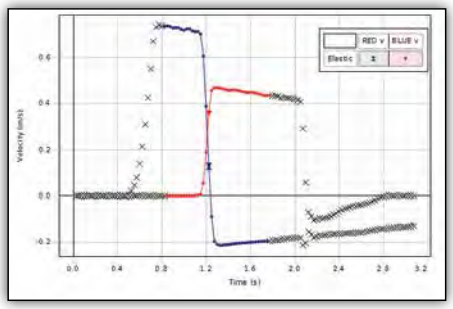
14 A Put Equations in Text Boxes

Equations created in a word processor can be copied into a text box.



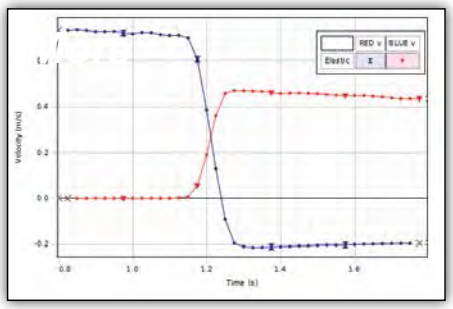
15 Exclude or Delete Data Points from Analysis

- Temporarily exclude errant data points from curve fits and then re-include them to see the difference in the curve fit.
- Delete extraneous data at the beginning or end of a run.



Highlight the points you want to exclude. Excluded points are shown here as gray X's.

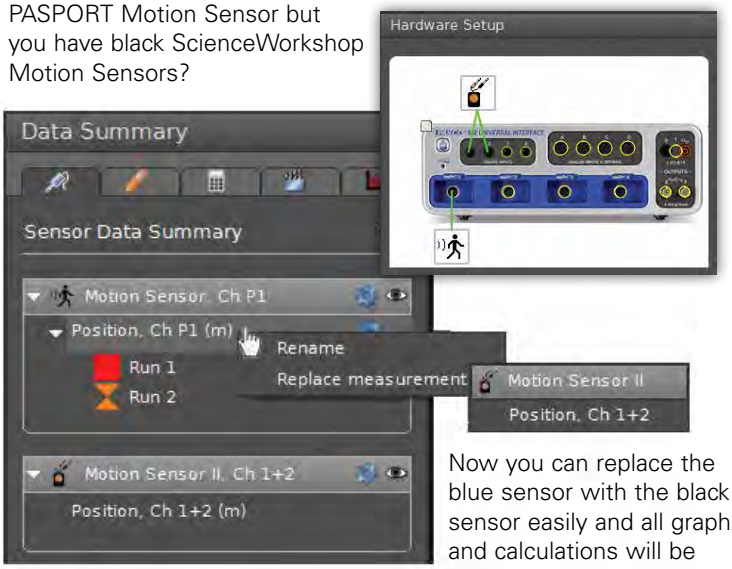
Autofit



After excluding extraneous leading and trailing data, the excluded points will be ignored when you push auto-scale.

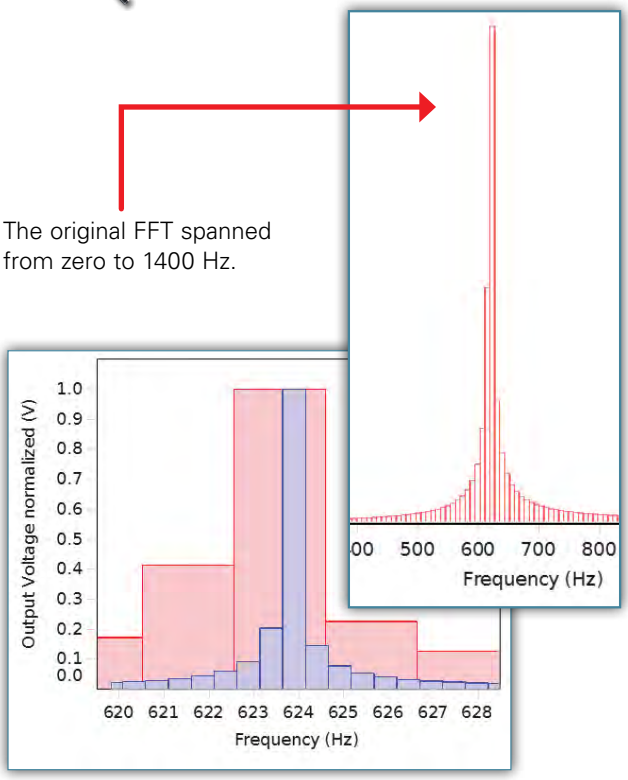
16 Substitute One Sensor for Another

Was the lab written for a blue PASPORT Motion Sensor but you have black ScienceWorkshop Motion Sensors?



Now you can replace the blue sensor with the black sensor easily and all graphs and calculations will be automatically updated.

17 Zoom in on the FFT

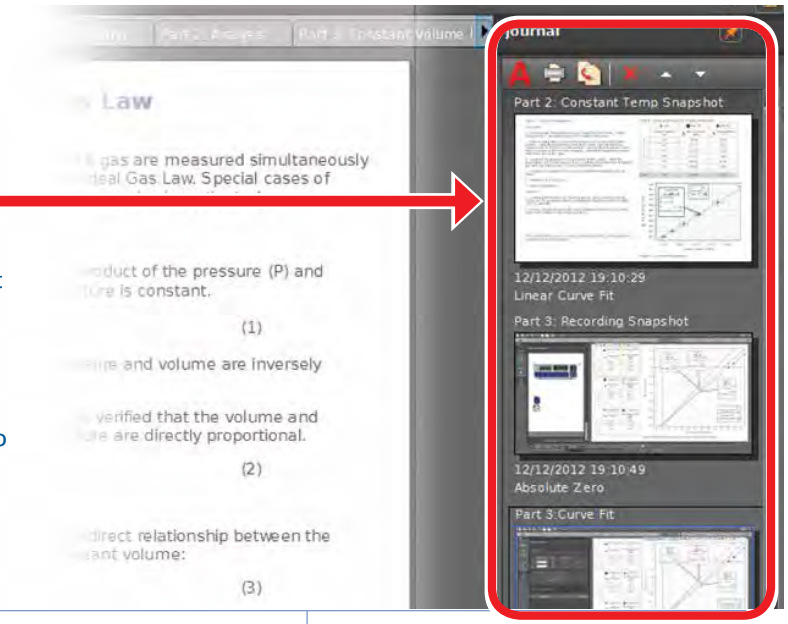


The original FFT spanned from zero to 1400 Hz.

As you zoom in on the FFT, initially the bins are large (in pink), but the software automatically adjusts the bins to give greater detail (in blue).

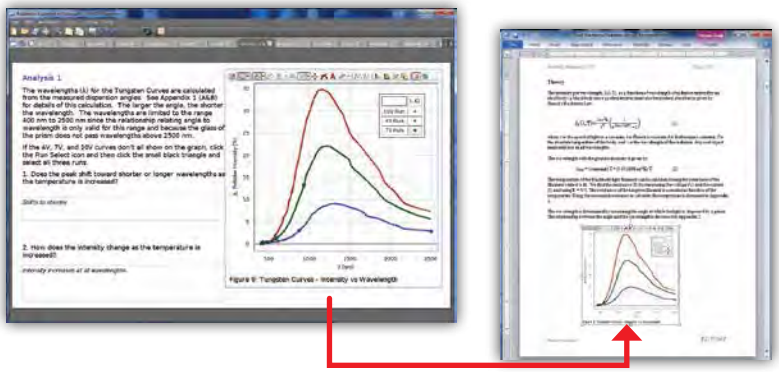
18 Journal

Snapshot your workspace pages into the Journal and save or print them.



- Take a snapshot of a page once you have done the analysis, analyze another run, then snapshot the page again to preserve the way you did the analysis.
- Choose to snapshot an individual display or a whole page.
- Save as a set of .png pictures and an html file so you can view the journal pages with an internet browser.

19 CTRL C Copy Graphs and Other Displays and Paste into Word Processing or Presentation Software.



20 Import and export .csv data files.

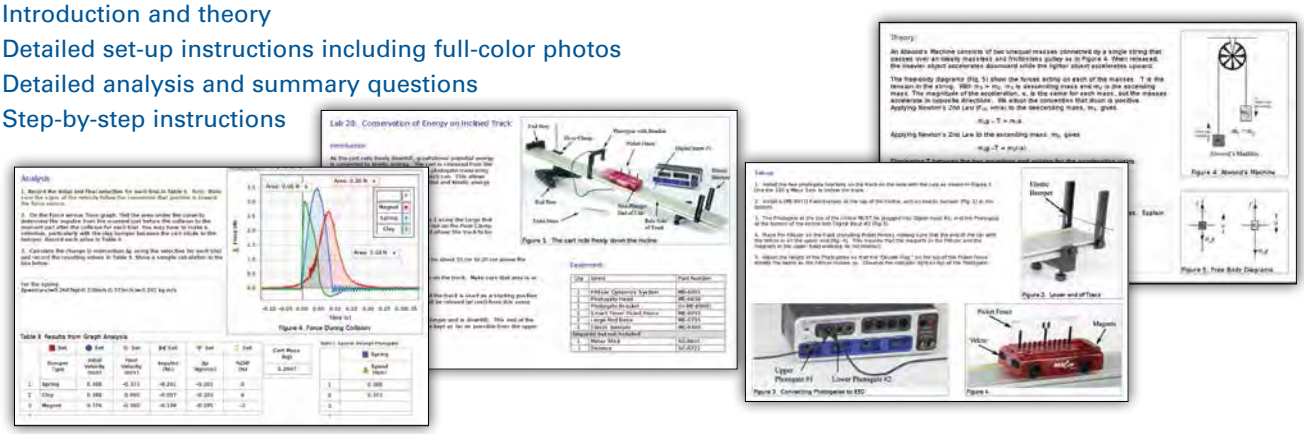
Import and export .txt, .csv data files.
Import movies, images, and videos.

21 Download FREE PASCO Capstone Experiments

Workbooks include all instructions needed to perform the experiment:

www.pasco.com/CapstoneExperiments

- Introduction and theory
- Detailed set-up instructions including full-color photos
- Detailed analysis and summary questions
- Step-by-step instructions



The 850 Universal Interface UI-5000

For when you need the very best!

- Rugged Design
- An Incredible Value
- Fully Compatible
- Runs on PASCO Capstone™

Introducing the most powerful educational lab interface in the world. Compatible with over 120 PASCO *ScienceWorkshop*® and PASPORT® Sensors.

High Speed Sampling
Simultaneously measure voltages on two channels with sample rates of 10 MHz. Simultaneously measure voltages on four channels at 1 MHz.

4 Photogate Ports
Digital sensors such as Photogates and Time-of-Flight plug directly into the 850 Interface.
- Compatible with all ScienceWorkshop digital sensors
- Sensor Connect Detection
- No Digital Adapters required!

4 PASPORT Sensor Ports
Compatible with PASCO's complete line of more than 70 PASPORT sensors.
- Sample rates depend on sensors.
- Sample rate of the ports can be greater than 1000 Hz.

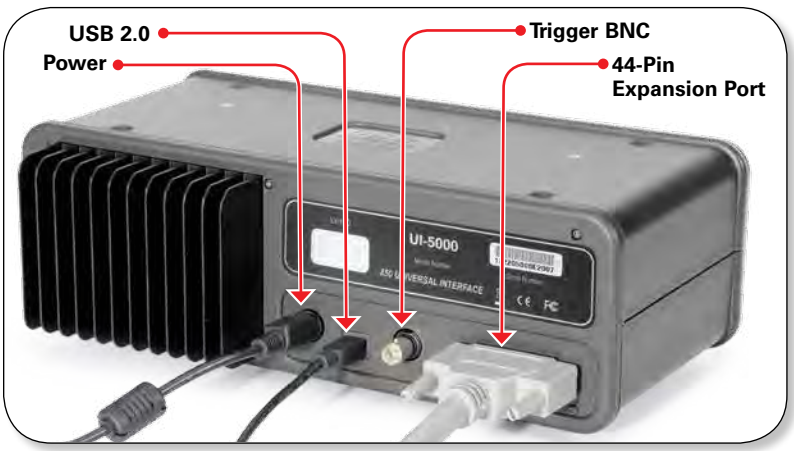


850 Universal Interface shown actual size.

850 Back-Panel Features

850 Power Adapter: 20 VDC, 6 A
Computer Connection: USB 2.0 (480 Mbps)
External Trigger Input/Output: BNC Jack
- Synchronize multiple 850s.
- Signal direction controlled by software
- 3.3 V TTL, 51Ω
- ESD Protection

44-Pin Expansion Port: For connecting future accessories to control and monitor a variety of new devices such as stepper motors and circuit boards *(see page 16 for details)*.
- Access to the 3 Signal Generators
- 8 Additional Digital I/O Pins
- 3 Additional Analog Differential Inputs (±10 V)
- High Speed PASPORT Channel for Self-Identification of Plug-in Modules
- Power Sources: +5 V @ 500 mA, ±12 V @ ± 300 mA



It's fast! It's powerful!

10 MHz Sampling!

4 Analog Ports with 10 MHz Sampling
For use with all analog ScienceWorkshop sensors, such as Voltage, Force, and Sound.
(Not for use with CI-6552A Power Amplifier)

Measurement Range: ±20 V differential input
Input Impedance: 1 MΩ
Input Protection: ±250 V continuous
Selectable Voltage Gain: X1, X10, X100, X1000
Resolution: 14-bit, 0.01 mV

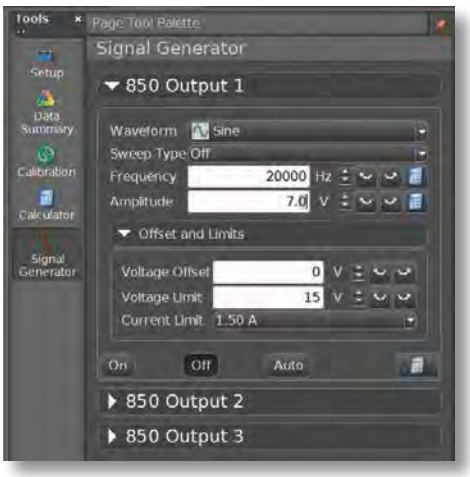


15 Watt Function Generator

Waveforms: sine, triangle, variable duty-cycle square wave, positive and negative ramps, DC
Frequency Range: 0.001 Hz to 100 kHz; 1 mHz resolution
Amplitude Range: ±15 V; Resolution: 7.3 mV, 12-bit DAC.
Max Output Current: 1 A at 15 V, over-current detection
Selectable Short-Circuit Current Limit: 1.5 A, 1.1 A, 0.55 A
Selectable Voltage Limit
Selectable DC Offset
Frequency Sweep Function
Measure Output Current: 61 µA resolution

Dual Independent High Frequency Function Generators

Independent control of frequency, waveform, and amplitude.
Waveforms: sine, triangle, variable duty-cycle square wave, positive and negative ramps, DC
Frequency Range: 0.001 Hz to 500 kHz; 1 mHz resolution
Amplitude Range: ±10 V
Resolution: 2.5 mV, 12-bit DAC.
Max Output Current: 50 mA at 10 V



PASCO Capstone Features

In PASCO Capstone, all three of the 850 Universal Interface outputs can be controlled independently.

Choose the waveform or DC, set the amplitude, set a voltage offset, and limit the voltage and the current.

The frequency can be set up to sweep through a range by setting a duration and a frequency step size.

A calculator expression can be entered for the frequency and the amplitude, as well as to set the condition of the start of the generator.

ScienceWorkshop 750

750 users should consider upgrading to the 850. The 750 has been discontinued because its parts are obsolete. So, after 14 years of service, we can no longer build it.

Order Information

850 Universal Interface UI-5000
Required:
PASCO Capstone Software ..... see p. 6

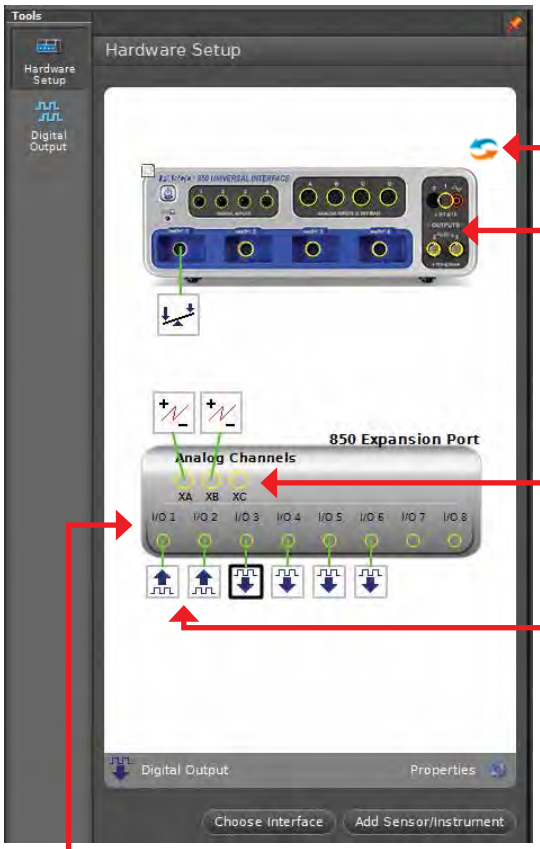
850 Universal Interface Expansion Port

850 UI Expansion Port control

Make your own devices to plug into the back of the 850 Universal Interface and control them with PASCO Capstone Software.

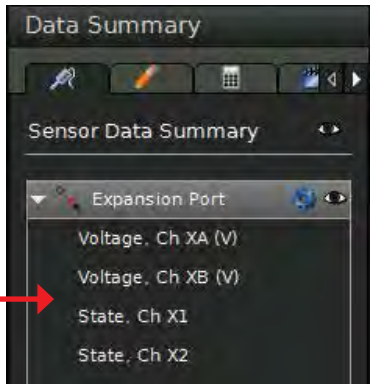
- Eight Digital Input/Output Ports
- Three Signal Generators
- Three Analog Voltage Inputs
- Controlled by PASCO Capstone Software





Click on icon to open back expansion port

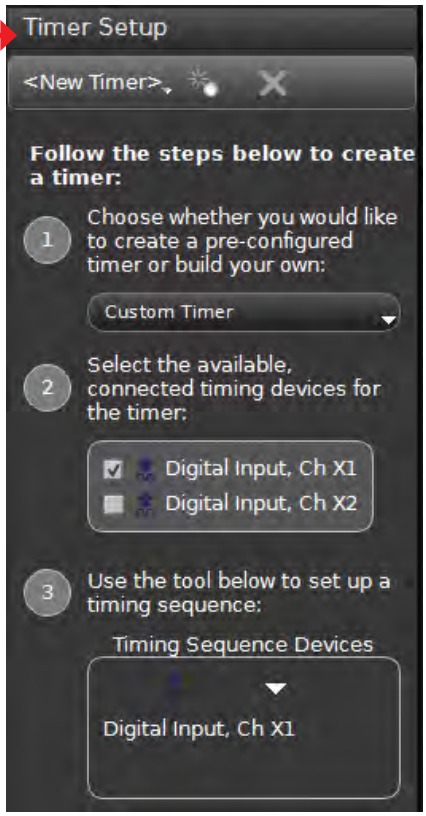
Three Signal Generators
The same three signal generators available on the front of the 850 are also available from the Expansion Port on the back of the 850.



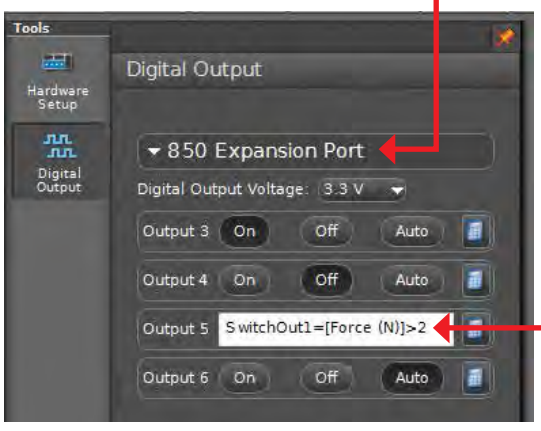
Three Analog Voltage Inputs
These ±10 V inputs are in addition to the four ± 20 V inputs on the front of the 850.

These show up in the Data Summary, just as other voltage sensors do.

Digital Inputs
are configured using the Timer Setup Wizard.



Eight Digital Input/ Output Ports
These I/O ports can be configured as inputs or outputs using PASCO Capstone. The output voltage can be configured to 3.3 V or 5.0 V.



The 850 Expansion Port is controlled by PASCO Capstone.
Shown at left is the Expansion Port Digital Output control panel in PASCO Capstone.

The Output State
can be controlled by a calculation that contains conditional statements.

Ideal for the physics and engineering labs!

Rugged Design

It's hard to imagine any normal use that would damage the 850. Analog inputs are protected up to ±300 volts. Outputs and power supplies are short-circuit proof. And, of course, the 850 is protected by PASCO's five-year warranty.

Fully Compatible & Expandable

The 850 accepts all PASCO sensors ("black" and "blue" series), and PASCO Capstone™ works with all PASCO USB interfaces. The expansion port on the back panel provides full expandability for the future.

An Incredible Value

The 850 and PASCO Capstone are the greatest value for instrumentation in the student lab. When connected to your computer, the 850 becomes a digital multimeter; a 500 kHz oscilloscope (with multiple traces); a 100 kHz power function generator (drives speakers and mechanical drivers); dual function generators (for studying interference, beats, etc.); a nuclear counter, etc. And with over 120 compatible PASCO sensors, your students have the instrumentation you need for almost any experiment.

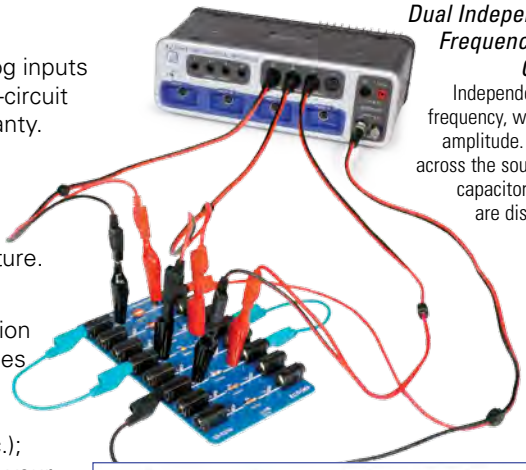
The 850 can replace an entire lab bench of instrumentation, saving you lots of space... and money, too!



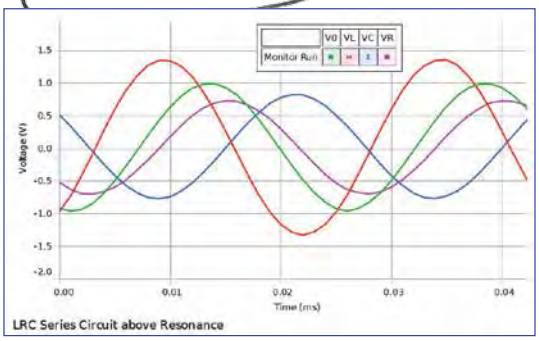
=



A Great Value!



Dual Independent High Frequency Function Generators
Independent control of frequency, waveform, and amplitude. The voltages across the source, inductor, capacitor, and resistor are displayed in the oscilloscope.



Four Channel Oscilloscope in PASCO Capstone

BNC Function Generator Output Cable

UI-5119 (unshrouded) UI-5129 (shrouded)

- Converts the BNC output to two banana cords for the 850's function generators #2 and #3.





Shown in use with the 850 Universal Interface.

Order Information

BNC Function Generator Output Cable
(Set of 2 unshrouded) UI-5119
(Set of 2 shrouded) UI-5129

8-Pin DIN Extension Cable

UI-5218



- Use to connect analog sensors to ports A through D on the 850.
- Analog sensors can also be plugged in directly to the 850 ports.

The 1.8 m long Extension Cable allows ScienceWorkshop Sensors to be used even further away from the interface. Multiple cables CAN be used in series. Also works with 750 and 500 interfaces.

Order Information

8-Pin DIN Extension Cable UI-5218

Resistor Capacitor Inductor Network

UI-5210



Board components can be used to investigate Kirchhoff's Circuit Laws, Ohm's Law, RC circuits, and A.C. LRC circuit theory with resonant frequencies between 55 kHz and 135 kHz, depending on values used.

Includes

Two inductors: 6.8 mH, 2.5 mH
Two capacitors: 3900 pF, 560 pF
Four resistors: 47 kΩ, 3.3 kΩ, and two 1.0 kΩ.



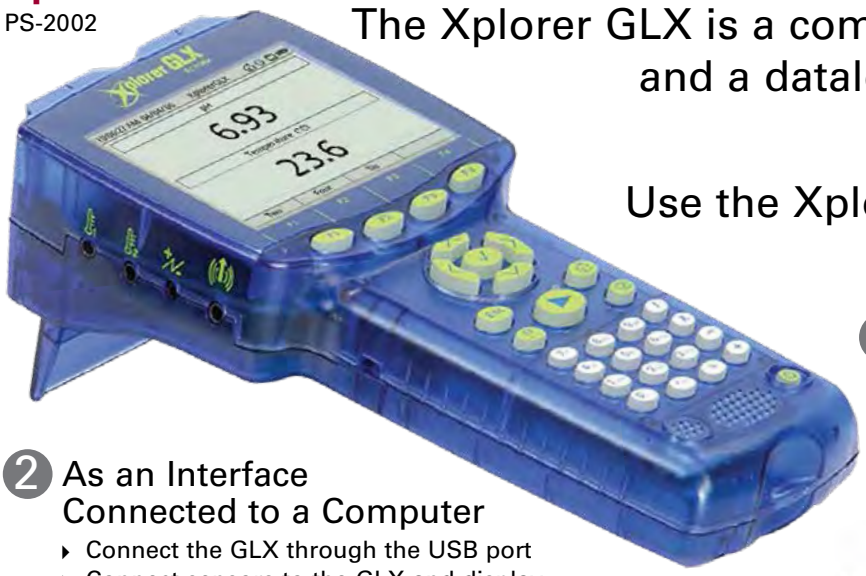
Shown in use with the 850 Universal Interface.

Order Information

Resistor Capacitor Inductor Network UI-5210

Xplorer GLX®

PS-2002



The Xplorer GLX is a computer, an interface, and a datalogger, all rolled into one.

Use the Xplorer GLX three ways:

1 Instead of a Computer

- Collect data
- Analyze data
- Print directly from the GLX
- Add a keyboard/mouse
- No networking problems



2 As an Interface Connected to a Computer

- Connect the GLX through the USB port
- Connect sensors to the GLX and display real-time data on the computer



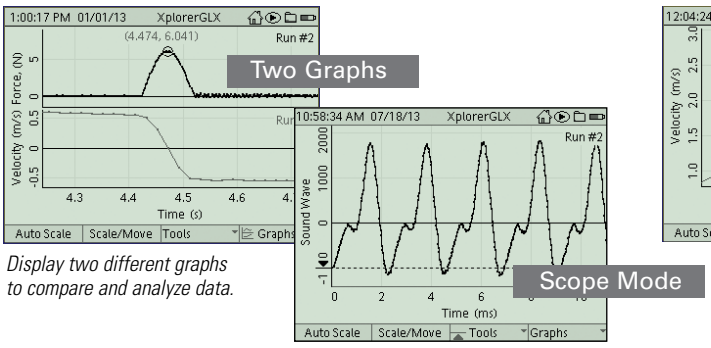
3 As a Remote Datalogger

- Rechargeable battery operation
- Collect data anywhere
- Analyze data in the field
- Copy data to a USB flash drive
- Connect the GLX to a computer and download logged data into PASCO Capstone for further analysis



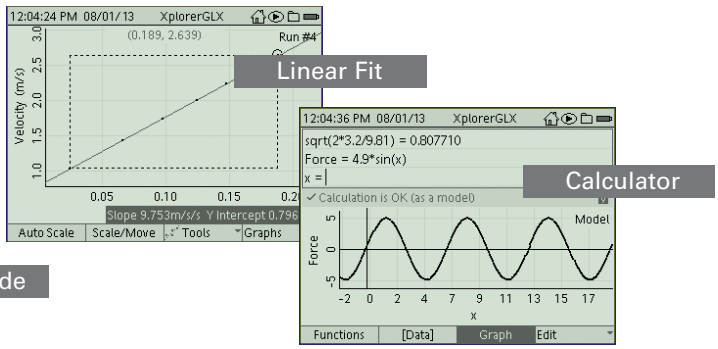


The Xplorer GLX has many powerful tools to display and analyze data:



Display two different graphs to compare and analyze data.

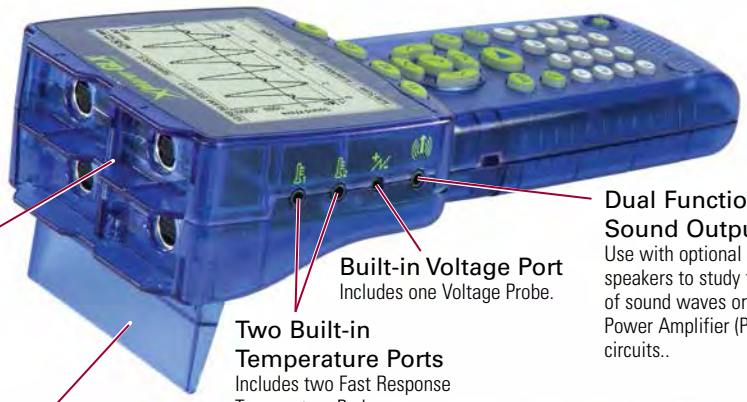
Use your GLX as an oscilloscope. Set trigger criteria and go. Display two measurements simultaneously.



Perform any single calculation or create a calculated data set based on measurements from a sensor.

Xplorer GLX® Handheld Computer/ Datalogger

- Collect and analyze data away from the computer
- Print directly from the Xplorer GLX
- Also functions as a computer interface



Four Universal Ports
Connect up to four PASPORT sensors.

Built-in Fold-Away Kick Stand

Two Built-in Temperature Ports
Includes two Fast Response Temperature Probes.

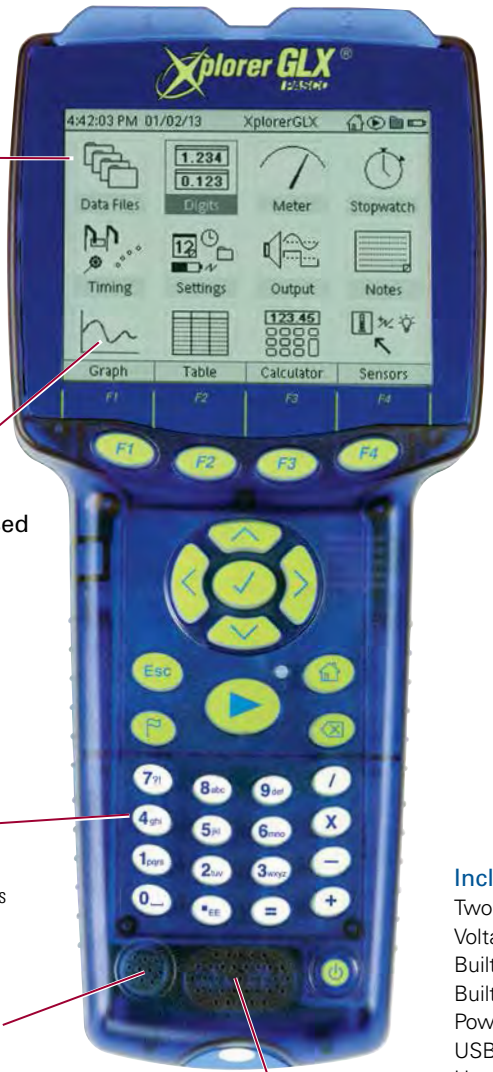
Built-in Voltage Port
Includes one Voltage Probe.

Dual Function Generators Sound Output
Use with optional external speakers to study the properties of sound waves or plug in an optional Power Amplifier (PS-2006) to power circuits..



Two USB Ports
- Print directly to an HP printer
- Use a mouse and/or keyboard
- Save data to a flash drive
- Connect to a computer using the included USB cable.

High-Resolution Screen
- Crisp, clear output allows for easier data analysis
- 320 x 240 grayscale
- Transflective technology for optimal visibility in all lighting conditions—even sunlight!
- Backlit for use in darkened optics lab



Intuitive Icon-Based Navigation

Up to 50,000 Hz Max Sampling Rate

Calculator and Alphanumeric Keys
- Annotate graphs
- Create experiment notes pages
- Perform calculations

Microphone/Sound Sensor
- Display sound waveforms
- Voice annotate an experiment

Speaker
For sound output.

Xplorer GLX Experiment Bundles:

See pages 84-85

See page 20 for accessories.

Includes

Two fast response temperature probes
Voltage probe
Built-in sound sensor
Built-in speaker
Power adapter and battery charger
USB "A" to USB "B" cable
Users guide and tutorial CD

Order Information

Xplorer GLX PS-2002

Xplorer GLX Power Amplifier

PS-2006

- Amplifies the signal output from the Xplorer GLX
- DC, sine, square, triangle, ramp
- Built-in current sensor

The GLX Power Amplifier amplifies the signal generated by the Xplorer GLX. Output current is measured directly by the Power Amplifier.



Typical Applications

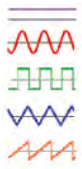
- Power AC or DC Circuits and Measure Power Input
- Power Motors
- Vary Driving Frequency of a String Vibrator
- Power a Speaker for a Resonance Tube

In the experiment shown below, the Xplorer GLX and the GLX Power Amplifier are used as a variable frequency sine wave power supply for the String Vibrator (WA-9857). The Force Sensor (PS-2104) is used to measure the tension in the string. All parameters can be varied, including tension, amplitude, frequency, and the number of vibrating segments.

Specifications

Output Power: ±1 A @ ±10 V
DC Offset: ±10 V
Waveform Maximum Frequency: 5000 Hz
Waveform Maximum Period: 1 Hour

Waveforms:



DC
Sine
Square
Triangle
Ramp

Includes

GLX Power Amplifier
Power Adapter



Order Information

GLX Power Amplifier	PS-2006	
Required:		
Xplorer GLX	PS-2002	p. 18
Recommended:		
RLC Circuit	CI-6512	p. 209
String Vibrator	WA-9857	p. 243

Tripod Stand (5-pack)

SE-7397A

Use this portable tripod to support the Xplorer GLX or just about any PASCO sensor. The lightweight tripod (0.18 kg) stands 17 cm high with a 25 cm footprint.

The adjustable tripod head provides support for the Xplorer GLX or a sensor in many orientations.



Order Information

Tripod Stand (5-pack)	SE-7397A

Xplorer GLX 20-unit charging station

PS-2557

Dimensions: 12" x 24" x 5.25"
Weight: 10 lbs
Designed and manufactured for PASCO by TriBeam Technologies.

Conveniently store and charge your set of Xplorer GLX graphing dataloggers with this 20-unit charging station. Just one outlet required to charge all 20 units.



Order Information

Xplorer GLX 20-Unit Charging Station	PS-2557

Lab Stand

PS-2526

Slide the Xplorer GLX into the cradle of this sturdy metal stand to position the screen at the ideal angle for desktop experiments.



Order Information

Lab Stand	PS-2526

Xplorer Vest

PS-2517

Keeps the Xplorer or Xplorer GLX secure during outdoor activities.

Includes extra pockets for safely storing sensors.



Xplorer GLX not included

Order Information

Xplorer Vest	PS-2517

Xplorer GLX replacement parts *(not shown)*

Order Information

Power Adapter	PS-2529
Voltage Probe	PS-2165
Fast Response Temperature Probes (3)	PS-2135
Rechargeable Battery	PS-2527

850 Universal Interface

UI-5000

Sample rate up to 10 MHz; Accepts both ScienceWorkshop and PASPORT Sensors; Three signal generator outputs.



Order Information

850 Universal Interface UI-5000
Required:
PASCO Capstone Software ..... see p. 6

550 Universal Interface

NEW

UI-5001



1 MHz sampling rate; Accepts both ScienceWorkshop and PASPORT Sensors; One signal generator output; USB and Wireless Connection

Order Information

550 Universal Interface UI-5001
Required:
PASCO Capstone Software ..... see p. 6

Xplorer GLX

PS-2002

Datalogger with display includes four sensor ports, dual signal generators, oscilloscope, speaker, and built-in sensors (voltage, two temperature, and sound).



Order Information

Xplorer GLX PS-2002

USB Link:
Connects one sensor to a computer

PS-2100A

- Directly link one PASPORT Sensor to a USB port
- Use multiple links for more sensors
- 1000 Hz maximum sampling rate with PASPORT Sensors



Order Information

USB Link PS-2100A

sparklink®

Connects two sensors to a computer

PS-2009A

- Two PASPORT Sensor ports
- Built-in temperature and voltage sensors with probes
- Simple USB connectivity to computer



The SPARKlink is a two-port computer interface with a USB-to-computer connection, which gives you an easy way to use multiple sensors simultaneously. Plus, the built-in Temperature and Voltage Sensors enable you to take measurements right out of the box with no additional sensors.

Specifications

Power: Powered through the USB port
Maximum Sample Rate: 1000 Hz

Order Information

SPARKlink PS-2009A

Bluetooth® Interfaces

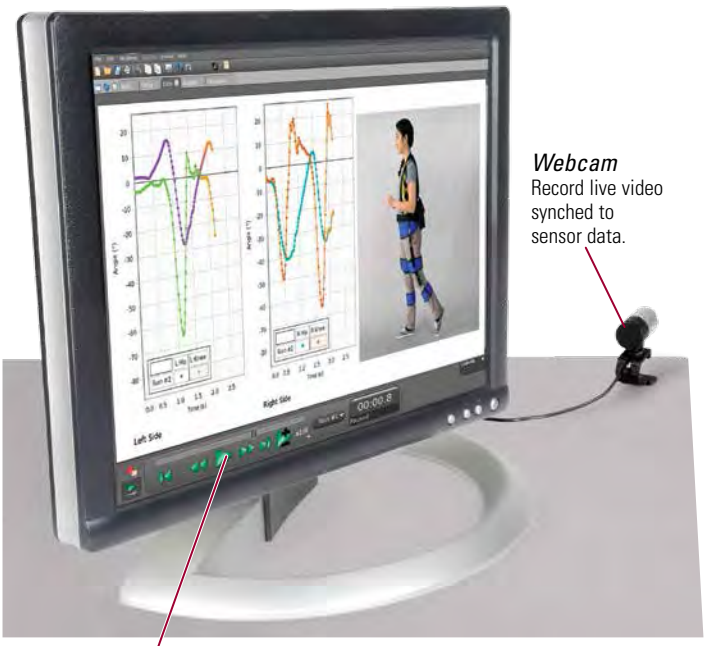
SPARKlink® Air

PS-2011

Capture data remotely using PASCO's wireless Multi-Port Interface

With the SPARKlink Air Interface students can record the sensor data, and send it to the computer via Bluetooth. Used here with two Angle Sensors, part of the PS-2137 Goniometer System. The data is sent via Bluetooth to the desktop computer, and displayed live with the video being recorded by the web cam.

The SPARKlink Air allows students and teachers to connect any of PASCO's 70+ sensors to their computer via USB or Bluetooth. This single device allows students to collect data both inside the classroom when using a desktop or laptop.



Webcam
Record live video synched to sensor data.

Data Playback
Play back the synched data and video at normal or slow speed.



Goniometer Probes
The probes are fastened in place using the blue Velcro® straps, and can be positioned to measure the motion of the knee, hip, or elbow.

Features

- Fast Response Temperature and Voltage Sensors included.
- USB and Bluetooth support for Mac and Windows desktops or laptops.
- Rechargeable battery that provides four to six hours of continuous data collection between charges.

Includes

Two Sensor Ports
Built-in Temperature and Voltage Sensors with Probes
USB and Bluetooth Connection
Rugged Polycarbonate Case



Order Information

SPARKlink Air	PS-2011	
Goniometer	PS-2137	p. 65
Additional Goniometer Probe	PS-2138	p. 65
Field Bag	PS-2549	
Required:		
PASCO Capstone Software		pp. 6-13

SPARKlink® Air Charging Station

PS-2577



Conveniently store and charge up to five SPARKlink Air interfaces with a single power source.

SPARKlink Air sold separately.

Order Information

SPARKlink Air Charging Station	PS-2577

PASPORT® AirLink 2

PS-2010



Connects one sensor to a computer through USB or Bluetooth

The AirLink 2 allows any single PASPORT sensor to be connected via Bluetooth to a Bluetooth-enabled computer running PASCO Capstone. The AirLink 2 conforms to Bluetooth connection protocols and has a maximum range of 10 m. Newly designed internal antenna decreases overall size of the unit and increases signal integrity.

Specifications

Case Dimensions: 2.5 cm x 4.0 cm x 10.5 cm
Power: Rechargeable lithium-ion battery; charge via USB
Data Rate: Maximum 1,000 Hz, sensor-dependent
On/Off Switch
Connectivity Indicator
Maximum Transmission Distance: 10 m

Order Information

PASPORT AirLink 2 ..... PS-2010

SPARK Science Learning System™

PS-2008A

More than just hardware and software, it's an integrated science solution!

- Portable datalogger – Use with or without a computer
- Full-color touch-screen display with large screen: 5.7" (14.5 cm) diagonal display, 640 x 480 resolution
- Temperature and voltage sensors included
- Two ports for additional PASPORT® Sensors
- Pre-loaded with 61 SPARKlabs®

See Physics Manuals on pages 80-81.



USB Port
Print or share data and images using a flash drive.

PASPORT Sensor Ports
Two sensor ports provide connection to the PASPORT line of over 70 sensors.

Tactile Data Control
Control data collection with dedicated buttons.

Large Display
Full-color 5.7 " (14.5 cm) display.

Touch-screen
Just use a finger, no stylus to lose!

Handles
Rubberized handles built into the body make the system rugged and easy to pick up, move around, and share with other students.

Specifications

Weight: 21 oz. (595 grams)
Hand Straps: 6.7" x 5.5" x 1.7" (17 cm x 14 cm x 4.5 cm)
Resolution: 640 x 480
Power Supply: AC/rechargeable battery

Includes

Voltage Sensor
Temperature Sensor
AC power supply
Pre-installed experiment activities with teacher background material



Order Information

SPARK Science Learning System PS-2008A

SPARK Charging Station

PS-2570

- Charges up to 10 SPARK Science Learning Systems simultaneously with a single power source.



Order Information

SPARK Charging Station PS-2570

PASCO Spectrometry Software

PASCO's Free Spectrometry Software Puts Learning First

PASCO's own software for the PASCO Spectrometer and Red Tide works on iPad and computers.

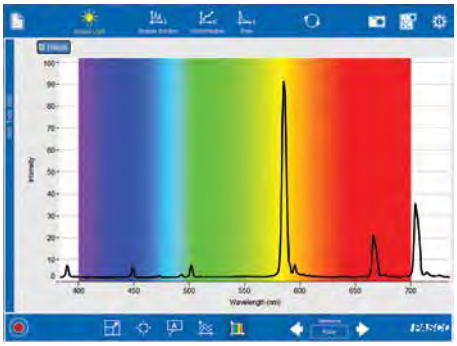
- Designed by teachers
- Specialized software specifically targets spectrometry activities
- Program guides students through the four common types of spectrometer uses
- Calibration routine is made obvious

The four specially targeted activities are:

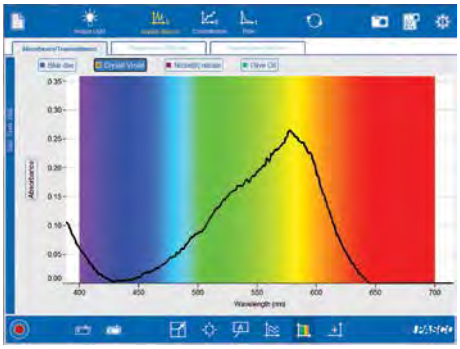
1. Analyze light sources with the optional fiber optics cable.
2. Analyze the absorbance, transmittance, and fluorescence of colored solutions.
3. After the analysis wavelength is set, you can easily create calibration curves and determine the unknown concentration
4. Observe the kinetics of a reaction involving a colored solution. Easily create the required graphs (ln(x), 1/x) to determine the order of the reactants.

PASCO Spectrometry Software works with the PASCO Spectrometer or the Red Tide.

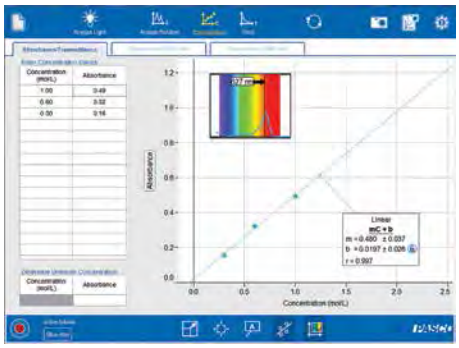




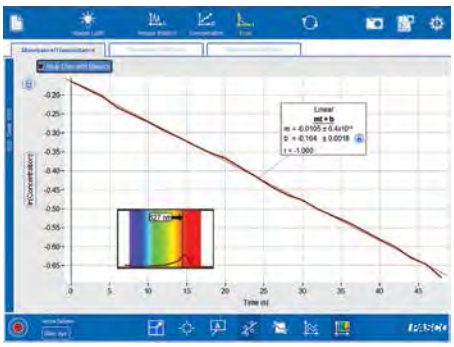
1. Analyze light sources with the optional fiber optics cable.



2. Full visible spectrum analysis of solutions

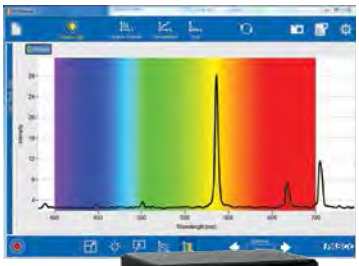


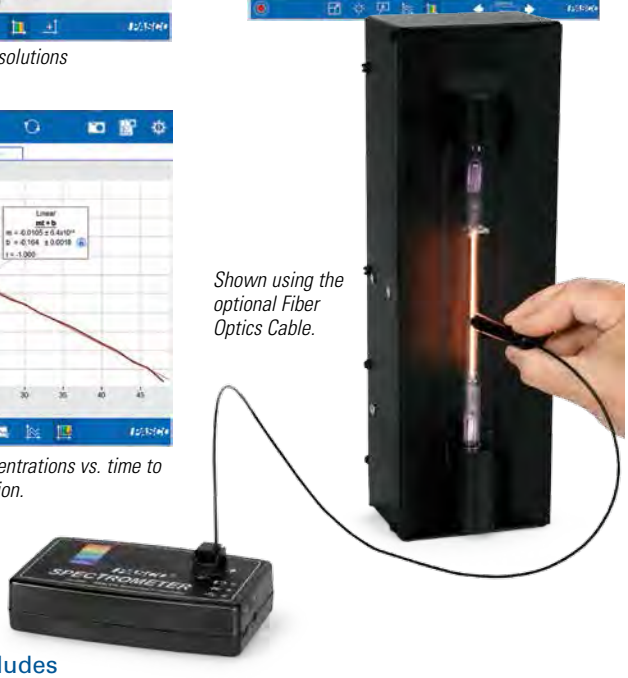
3. Create Beer's Law plots to relate absorbance and concentration.



4. Quickly plot calculations of concentrations vs. time to determine the order of the reaction.

Helium Spectrum





Shown using the optional Fiber Optics Cable.

The Wireless Spectrometer comes with **PASCO's new FREE Spectrometry software**.

- PC and Mac versions included with purchase.
- FREE for iOS tablets

Includes

PASCO Spectrometer, 10 cuvettes, and Spectrometry Software

Order Information

PASCO Spectrometer	PS-2600	p. 60
Required for External Light Sources:		
Fiber Optics Cable	PS-2601	p. 279
Red Tide	PS-2635	

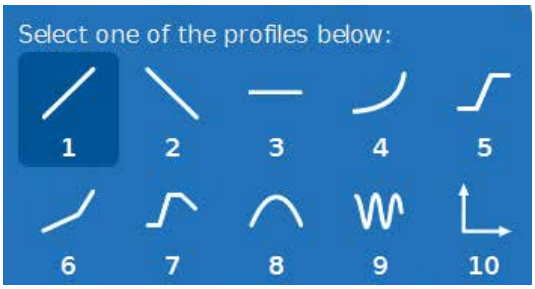
PASCO Match Graph

UI-5404

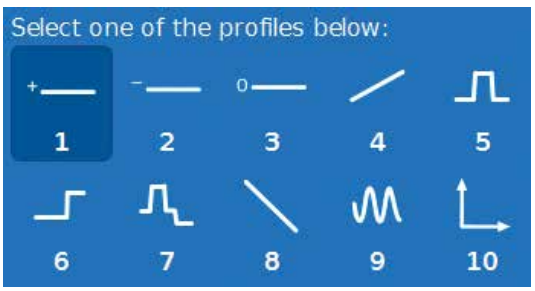
- Students feel the motion first-hand and learn to interpret motion graphs! Watch your students compete to get the best match score.
- The sample graphs to match include both position vs. time and velocity vs. time.
- The student moves back and forth in front of a motion sensor in an attempt to match the motion represented on the graph.



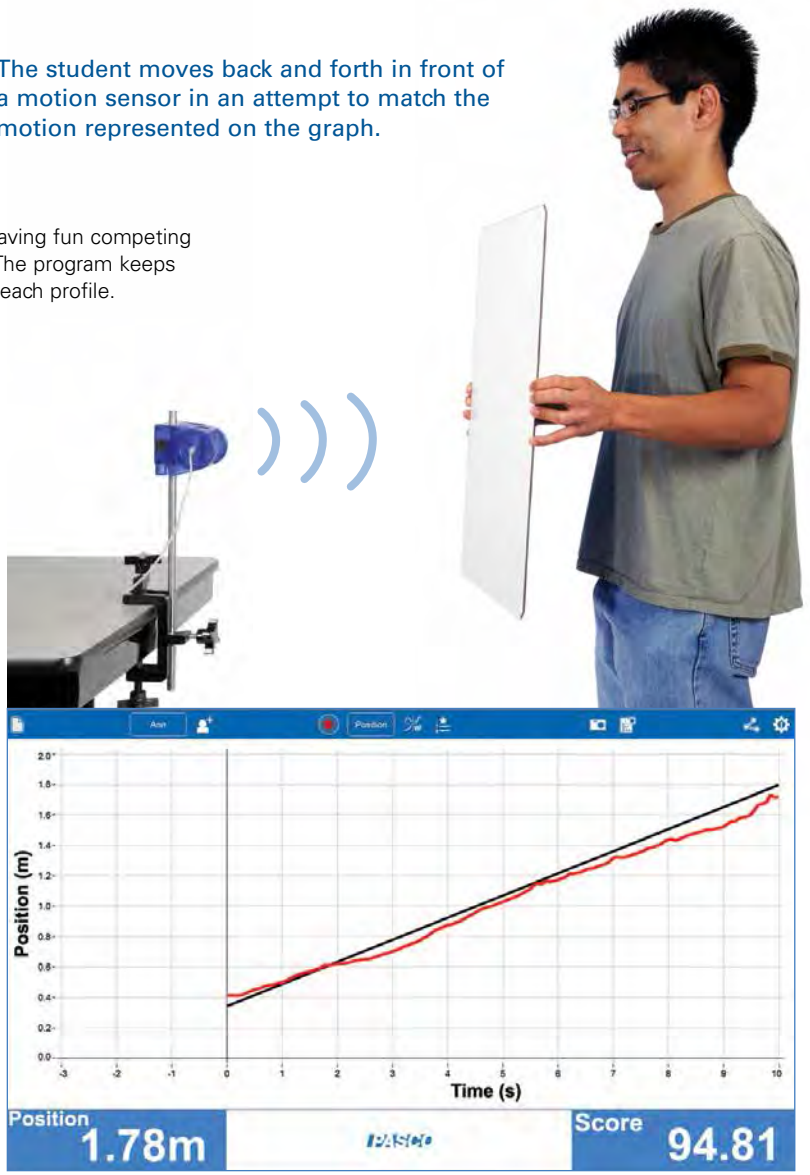
Students learn while having fun competing for the highest score. The program keeps track of the scores for each profile.



There are nine position profiles to match. The tenth choice allows the students to use the motion sensor without a profile on the graph.



Velocity profiles to match correspond to the position profiles.



The students get to see their motion for a few seconds before the matching starts so they can get lined up. Here the black line is the match profile and the red line is the student's attempt to match it.

Order Information

Match Graph Bundles

Match Graph USB Kit UI-5822
(Includes Match Graph app, USB Link & Motion Sensor)

Match Graph Wireless Kit UI-5823
(Includes Match Graph app, AirLink 2 & Motion Sensor)

Order Information

Match Graph Site License UI-5404
(For Windows/Mac computers)

Match Graph Free for iPad: Download on iTunes

Required:

Motion Sensor* (PASPORT) PS-2103A ..... p. 27

USB Interface OR Bluetooth Interface ..... See pages 14-23

Recommended:

Motion Sensor Reflector Board ..... PS-6809 p. 27

**Note: This software is not compatible with ScienceWorkshop Sensors.*

PASPORT™ *Series*

PASPORT sensors have **digital** outputs that allow multiple measurements per channel and reduced noise.

Over 70 PASPORT Sensors

DIGITAL *sensor*

Look for these icons...

ANALOG *sensor*

***ScienceWorkshop®* Series**

ScienceWorkshop sensors are **analog** and thus are perfect for teaching about sensing elements. Since they output a voltage, students can use them in their own circuits.

Over 40 *ScienceWorkshop* Sensors

8-Pin DIN Extension Cable

UI-5218



The 1.8 m long Extension Cable allows ScienceWorkshop Sensors to be used even further away from the interface. Multiple cables CAN be used in series.

Order Information

8-Pin DIN Extension Cable UI-5218

PASPORT Sensor Extension Cable

PS-2500



The two meter PASPORT Extension Cable extends the distance a sensor can reach from a computer. Two cables CANNOT be connected together, and the cable CANNOT be used on a sensor that already has a cable, such as the PS-2103A Motion Sensor.

Order Information

PASPORT Sensor Extension Cable PS-2500

Sensor Handles (4 pack)

CI-9874



These convenient handles screw into virtually any ScienceWorkshop or PASPORT sensor and can be used with any standard lab clamp.



The Sensor Handle is hollow and fits onto the shaft of the Rotary Motion Sensor.

Order Information

Sensor Handles (4 pack) CI-9874

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Motion Sensor
PS-2103A

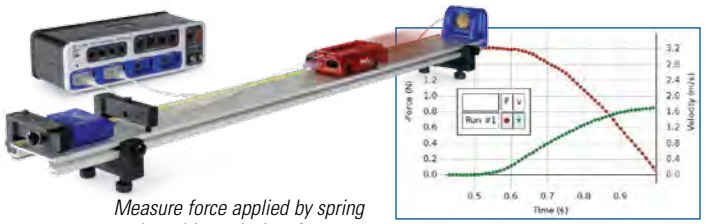


Motion Sensor II
CI-6742A



PASCO's PASPORT and ScienceWorkshop Motion Sensors are used to measure position, velocity and acceleration. Ultrasonic pulse-ranging technology has a switch-selectable Standard Beam or Narrow Beam to reject false signals and produce cleaner data. The Motion Sensor sits firmly on a desktop or easily mounts to a rod stand or PASCO Dynamics Track.

Typical Applications
- Study conservation of energy and momentum during collisions
- Monitor the sinusoidal motion of a mass on a spring
- Measure the motion of large objects, such as students



Measure force applied by spring and resulting velocity of cart.

Specifications
Minimum Range: 0.15 meters
Maximum Range: 8 meters
Resolution: 1 mm
Transducer Rotation: 360°
Cable Length: 1.8 meter
Near/Far Switch Settings:
Narrow: For distances up to 2 meters to reject false target signals or ignore air track noise.
Standard: For longer distances up to 8 meters.
Mounting Options:
- 12.7 mm diameter rod or smaller
- Directly to the PASCO Dynamics Track
- Non-skid rubber feet for table mount

CI-6538 ScienceWorkshop:
Connector: Dual stereo phone plug for ScienceWorkshop Interfaces.

Order Information

Motion Sensor (PASPORT)	PS-2103A
Motion Sensor II (ScienceWorkshop)	CI-6742A
Recommended (for PS-2103A and CI-6742A):	
Motion Sensor Guard	SE-7256
Magnetic Motion Sensor Bracket	PS-2546
Cart Adapter Accessory	ME-6743
Recommended (for CI-6742A):	
Accessory Cable	CI-6748

Allows CI-6742A to be used with CBL/EA100.

Motion Sensor Accessories

Magnetic Motion Sensor Bracket
PS-2546

This magnetic bracket allows a Motion Sensor to be easily hung from a drop ceiling. Simply screw the bracket into the 1/4"-20 threads on the sensor and use the included adjustment nut to hold the sensor in the desired orientation.



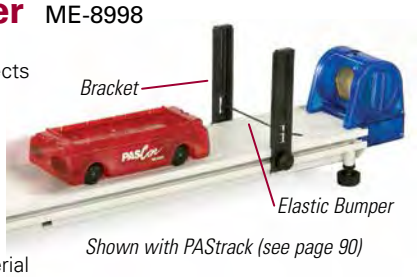
The bracket can also be used to hold the Motion Sensor on vertical surfaces such as filing cabinets and magnetic whiteboards.

Order Information

Magnetic Motion Sensor Bracket	PS-2546

Elastic Bumper ME-8998

The Elastic Bumper protects the Motion Sensor from the carts, but doesn't interfere with the ultrasonic pulse.



Shown with PAStrack (see page 90)

Includes
Two pairs of brackets
10 meters of elastic material

Order Information

Elastic Bumper	ME-8998

Motion Sensor Guard
SE-7256

Use this wire guard to protect the Motion Sensor when dropping objects from above.

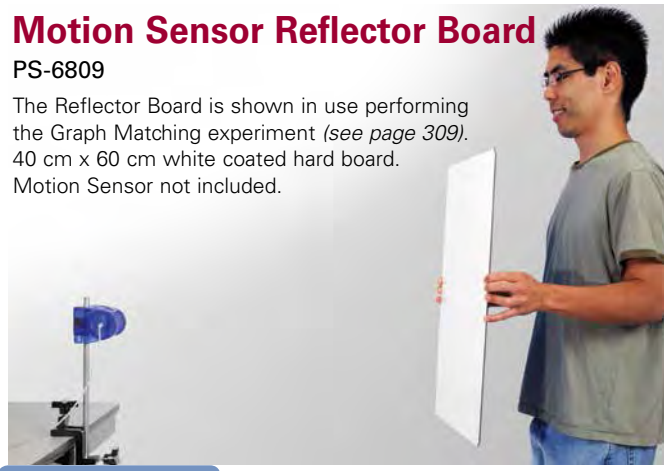


Order Information

Motion Sensor Guard	SE-7256

Motion Sensor Reflector Board
PS-6809

The Reflector Board is shown in use performing the Graph Matching experiment *(see page 309)*. 40 cm x 60 cm white coated hard board. Motion Sensor not included.



Order Information

Motion Sensor Reflector Board	PS-6809

Cart Adapter Accessory ME-6743

A Motion Sensor can be directly mounted to Dynamics Carts, PAScars or GOcars using the Cart Adapter Accessory. Mounting a Motion Sensor on a cart is ideal for the study of relative motion.



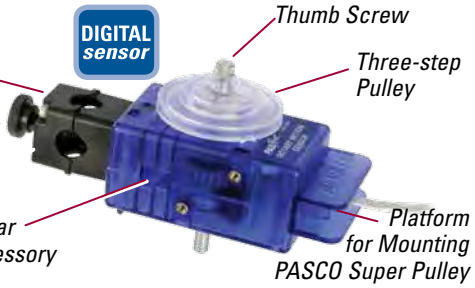
The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Order Information

Cart Adapter Accessory	ME-6743

Rotary Motion

PS-2120A



Rotary Motion

CI-6538



PASCO's PASPORT and ScienceWorkshop Rotary Motion Sensors are the most versatile position and motion-measuring devices available for the physics lab. Measure angle and angular velocity or measure distance and linear velocity using the rack or the pulley. These sensors are also bi-directional, indicating the direction of motion.

The 6.35 mm diameter, dual ball-bearing shaft extends from both sides of the unit and provides an excellent platform for rotational experiments. The rod clamp (which can be attached on three sides of the sensor) allows the unit to be mounted in almost any orientation. A three-step pulley and a mount for the PASCO Super Pulley make it easy to perform torque experiments.

Specifications

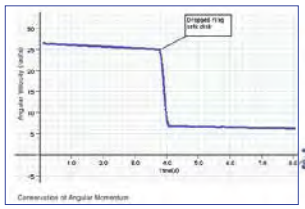
Three-step Pulley: 10 mm, 29 mm and 48 mm diameter
Sensor Dimensions: 10 cm x 5 cm x 3.75 cm, 6.35 mm diameter shaft

PS-2120A PASPORT:

- Resolution: 0.09°/0.0078 mm
- Maximum Speeds: 30 revs/sec
- Optical Encoder: bidirectional, indicates direction of motion; 4000 divisions/rev

CI-6538 ScienceWorkshop:

- Resolution: 1°/0.087 mm and 0.25°/0.022 mm (software selectable)
- Maximum Speeds: 13 rev/sec at 1° resolution (360 data points/revolution); 3.25 rev/sec at 0.25° resolution (1440 data points/revolution)
- Optical Encoder: Bidirectional, indicates direction of motion
- Connector: Dual stereo phone plug for ScienceWorkshop Interfaces



Conservation of Angular Momentum

The angular speed of the disk decreases when the ring is dropped onto the disk.



Order Information

Rotary Motion Sensor (PASPORT)	PS-2120A
Rotary Motion Sensor (ScienceWorkshop)	CI-6538
Recommended:	
Linear Accessory Kit	CI-6688A
Three-step Pulley	CI-6693

Equipment used with a Rotary Motion Sensor

Linear Accessory Kit

CI-6688A



Includes rod clamp and solid aluminum rack.



Shown in use measuring magnetic field from a coil.

See page 54.

Order Information

Linear Accessory Kit	CI-6688A

Mini Rotational Accessory

CI-6691

Use the Mini Rotational Accessory to study rotational inertia, pendulum oscillations, and conservation of angular momentum.

See page 157.



Order Information

Mini Rotational Accessory	CI-6691

Damped Pendulum

CI-6689A

Magnetically damped pendulum disk for studying exponential damping, driven harmonic motion, and chaos.

See page 159.



Order Information

Chaos/Driven Harmonic Accessory	CI-6689A

Centripetal Force

ME-9821

The Force Sensor mounts onto the Rotary Motion Sensor to directly measure Centripetal Force.

See page 155.



Order Information

Centripetal Force	ME-9821

Equipment used with a Rotary Motion Sensor

Ballistic Pendulum Accessories

Ballistic Pendulum Accessory
ME-9892
Mini Launcher Ballistic Pendulum Accessory
ME-6829



See page 127.

Turn your PASCO Launcher into a Ballistic Pendulum using the Rotary Motion Sensor.

Order Information

Ballistic Pendulum Accessory ME-9892
Mini Launcher Ballistic Pendulum Accessory ME-6829

Track String Adapter

ME-6569

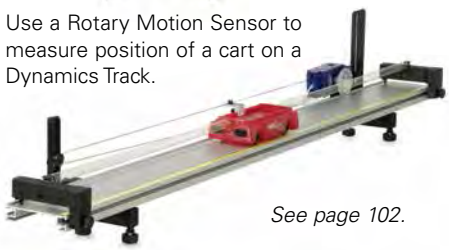


Dynamics Track Mount

CI-6692



Use a Rotary Motion Sensor to measure position of a cart on a Dynamics Track.



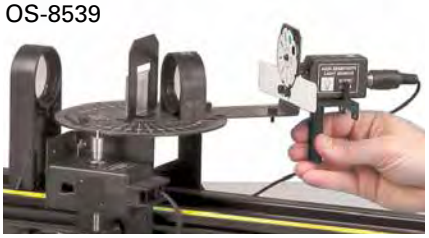
See page 102.

Order Information

Track String Adapter ME-6569
Dynamics Track Mount CI-6692

Spectrophotometer

OS-8539



60:1 gear ratio of rotating disk and pin gives the Rotary Motion Sensor a higher resolution for spectrophotometry.

See pages 276-277.

Order Information

Educational Spectrophotometer System OS-8539

Linear Translator

OS-8535A

See page 266.



The Rotary Motion Sensor's built-in gear system accepts the geared rack to create a high-resolution linear translator for optics.

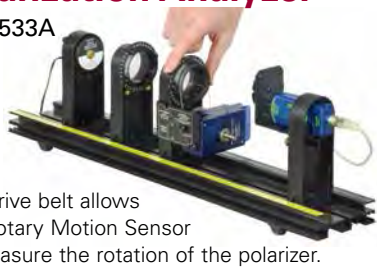
Order Information

Linear Translator OS-8535A

Polarization Analyzer

OS-8533A

See page 261.



The drive belt allows the Rotary Motion Sensor to measure the rotation of the polarizer.

Order Information

Polarization Analyzer OS-8533A

Gyroscope

ME-8960

Use two Rotary Motion Sensors to measure both the nutation and precession of this demonstration gyroscope.

See page 162.



Order Information

Gyroscope ME-8960

Materials Stress/ Strain Apparatus

AP-8213B



Plot Stress vs. Strain in real-time for several different materials.

See page 141.

Order Information

Materials Stress/Strain Apparatus (PASPORT) AP-8213B

Computer-Based Thermal Expansion

TD-8579A



Rotary Motion Sensor measures the expansion of the tube.

See page 186.

Order Information

Computer-based Thermal Expansion TD-8579A

Heat Engine

TD-8572

Use a Rotary Motion Sensor with PASCO's Heat Engine Apparatus to graph a real Heat Engine Cycle.

See page 198.



Order Information

Heat Engine TD-8572

Force Sensor

PS-2104

DIGITAL sensor



- Binocular force beam minimizes side force measurements

The Force Sensor is ideal for the student lab. Finger holes are provided for hand-held use. It will mount directly to a PASCO Dynamics Cart or 1.2 cm rod.

Typical Applications

- Measure force exerted by an oscillating mass
- Measure force during elastic and inelastic collisions
- Measure force of a swinging pendulum

Specifications

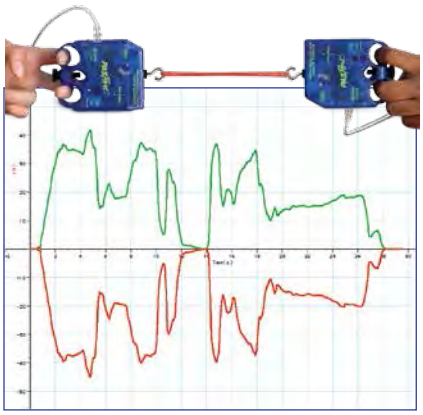
Range: ±50 N

Resolution: 0.03 N or 3.1 grams

Zero (Tare) Function: Push-button

Max Sample Rate: 1000 Hz; 5000 Hz for Xplorer GLX and 850 Interface

Force Overload Protection: Up to 75 N without damage



This graph displays Newton's Third Law during a "Tug of War" experiment.

Order Information

Force Sensor (PASPORT) PS-2104

Recommended:

Force Accessory Bracket ..... CI-6545 p. 32

Rocket Engine Test Bracket ..... ME-6617 p. 31

Force Sensor Balance Stand ..... CI-6460 p. 31

High Resolution Force

PS-2189

DIGITAL sensor



- 0.002 N resolution
- Dynamic over-sampling

Although this Force Sensor has the same case as the PS-2104 and can perform all of the same experiments, it has much better resolution. And the dynamic variable over-sampling greatly reduces the measurement noise at low sample rates.

Specifications

Range: ±50 N

Measurement Resolution: 0.002 N or 0.2 g

Zero (Tare) Function: Push-button

Max Sample Rate: 1000 Hz

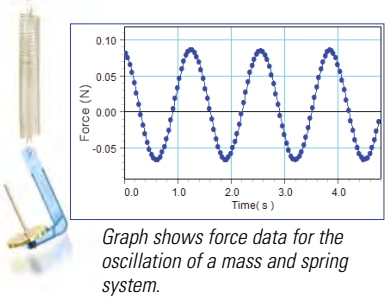
Force Overload Protection: Up to 75 N without damage

The digital design of the PS-2189 results in very little drift, ensuring that the tare will hold for hours. You can use this force sensor as a pan balance for long-term experiments, like investigating the evaporation of liquids such as alcohol or liquid nitrogen, and the sublimation of dry ice!

The High Resolution Force Sensor has 10 times the resolution of the PS-2104, and can measure changes in force of less than 0.01 N.







Graph shows force data for the oscillation of a mass and spring system.

Order Information

High Resolution Force Sensor (PASPORT) PS-2189

Shown in use with:

Mass and Hanger Set ..... ME-8979 p. 181

Spring Set ..... ME-8999 p. 104

Force Sensor Balance Stand ..... CI-6460 p. 31

Economy Force

CI-6746

ANALOG sensor



- ±50 N range
- Convenient finger grip

The Economy Force Sensor is an excellent, low-cost, general-purpose force sensor for the student lab. The finger holes make it ideal for hand-held use. The Economy Force Sensor can mount on a PASCO Dynamics Cart. Ideal for measuring force in one-axis experiments.

Specifications

Force Range: -50 to +50 N

Resolution: 0.03 N or 3.1 grams

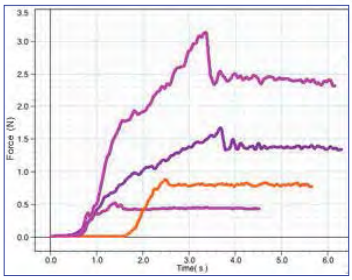
Zero (Tare) Function: Push-button

Force Overload Protection: Up to 75 N without damage

Pin Configuration: 8-pin DIN plug

Mounts on standard 12.7 mm support rods





Students can quickly measure the peak of the graph, which represents the maximum static frictional force. Once the friction tray begins to move, the kinetic frictional force becomes evident, so that students can compare the two forces.

Order Information

Economy Force Sensor (ScienceWorkshop) CI-6746

Force Sensor Spares Kit

CI-6463

Includes

Hook, rubber bumper and screw to attach to a cart; six each.



Order Information

Force Sensor Spares Kit (Set of 6 each) CI-6463

Force Sensor

CI-6537

ANALOG sensor



- ±50 N range
- Built-in accessory tray

PASCO's durable, reliable Force Sensor was designed specifically for the student physics lab. Wide-range, high-frequency response and a low noise transducer help generate excellent impulse graphs, smooth harmonic motion data, and more. The sensor's special strain gauge consistently generates the same output for the same force and is designed to minimize side loads. Damping materials reduce vibrations caused by collisions without affecting results. Any dynamics cart accessories can be mounted on top of the Force Sensor.

Specifications

Force Range: -50 to +50 N

Resolution: 0.03 N or 3.1 grams

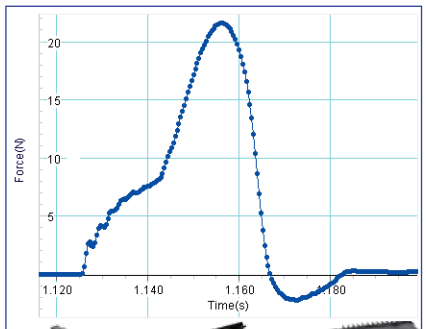
Zero (Tare) Function: Push-button

Force-overload Protection: Mechanical stop prevents forces of more than 50 N from damaging the sensor

Pin Configuration: 8-pin DIN plug

Mounts on standard 12.7 mm support rods

Force time data for a clay collision.





Order Information

Force Sensor (ScienceWorkshop) CI-6537

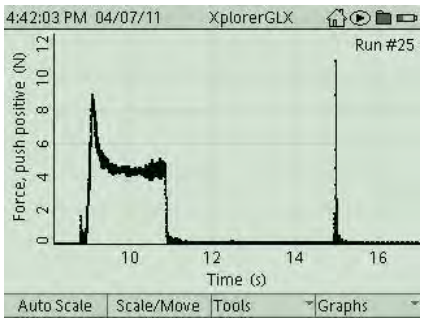
Rocket Engine Test Bracket

ME-6617

- A perfect supplement for rocketry studies

With the Rocket Engine Test Bracket attached to a Force Sensor (Science-Workshop or PASPORT), students can measure and graphically display the impulse of Estes™ and other model rocket engines. A perfect supplement for rocketry studies. Accommodates rocket engine sizes A, B, C and D.

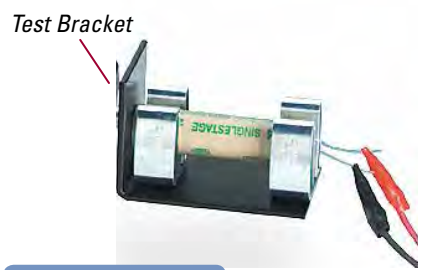




The Xplorer GLX is shown with the Rocket Engine Test Bracket attached to a Force Sensor. Students can measure and graphically display the impulse of Estes™ and other model rocket engines.

For outdoor use only.

The Force Sensor must always be securely mounted when a rocket engine is fired. We suggest the PASCO Large Rod Stand and 45 cm Rod (p. 170).



Order Information

Rocket Engine Test Bracket ME-6617

Force Sensor Balance Stand

CI-6460

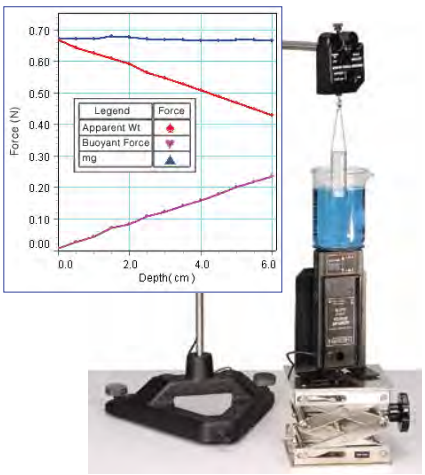
ANALOG sensor



Force Sensor CI-6537

- Use any PASCO Force Sensor as a pan balance
- Investigate buoyancy and Archimedes' Principle

Connect any PASCO Force Sensor to this convenient stand and students have an electronic balance for a wide variety of physics experiments. Connect an Acceleration Sensor for studies of angle vs. normal force. The mounting screws and balance pan can be stored on the stand when not in use.



As the cylinder is lowered into the water, the Apparent Weight measured by the top Force Sensor decreases, while the Buoyant Force measured by the bottom Force Sensor increases. The addition of the two (actual mg) stays constant.

Typical Applications

- Pan Balance
- Measure Buoyant Force
- Demonstrate the change in normal force as the angle of support changes

Includes

Force Sensor Stand

Balance Pan



Order Information

Force Sensor Balance Stand (ScienceWorkshop) CI-6460

Force Sensor Accessories

Force Accessory Bracket

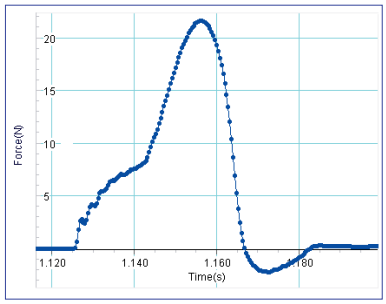
CI-6545

The Force Accessory Bracket with Bumpers mounts the CI-6746 Economy Force Sensor or CI-6537 Force Sensor directly to a dynamics track. Includes five collision attachments for the Force Sensor and conveniently stores each attachment on the bracket itself.



Note the bumper springs and various mounting options.

Using any of these attachments, the bracket serves as an excellent support or target for collision studies using the Force Sensor.



Force time data for a clay collision.



Includes

Spring Bumpers (2) (different spring constants)

Magnetic Bumper (1)

Rubber Bumper (1)

Clay Cup for Inelastic Collisions (1) (clay included)

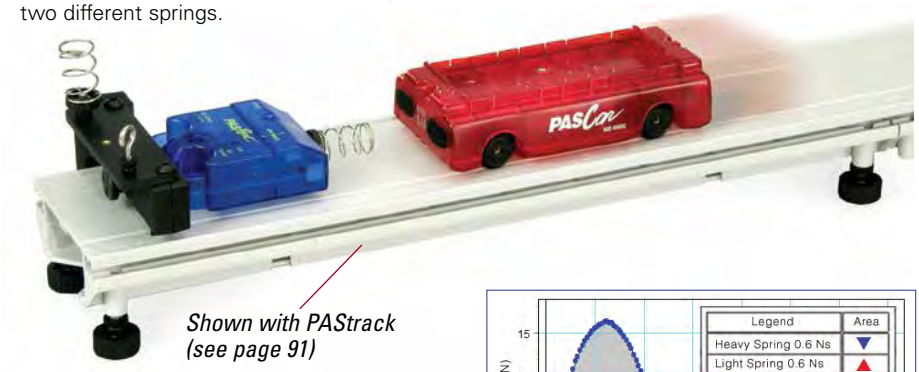
#0 Phillips Head Screwdriver (to attach to Force Sensor)

Order Information

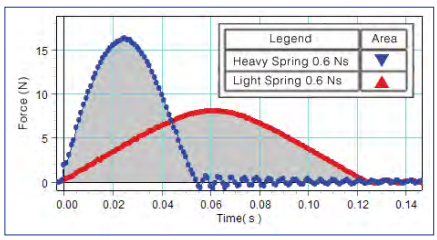
Force Accessory Bracket CI-6545

Discover Collision Bracket ME-8973A

The Collision Bracket fastens to the T-slot of a dynamics track, securely holding the Force Sensor for measuring collisions with a Cart. Includes two different springs.



Shown with PAStrack (see page 91)



The cart collides with the force sensor at the same initial speed for both of the springs. The area under the Force vs. Time graph is the change in momentum (impulse) of the cart, and is the same for both collisions.



Includes

Two Springs

Bracket

Order Information

Discover Collision Bracket ME-8973A

Bumper Accessory Set

ME-9884



This set of bumpers can be used with any PASCO Force Sensor to perform both elastic and inelastic collisions. The standard hook for each Force Sensor can be easily removed and replaced with any of these bumpers. Use a spring and a cup for elastic collisions. Combine two cups with clay to explore inelastic collisions.

Includes

Stiff Spring

Light Spring

Empty Cup (2)

Modeling Clay



Order Information

Bumper Accessory Set ME-9884

Magnetic Bumper Set

ME-9885A



This set of magnetic bumpers can be used with any PASCO Force Sensor to perform elastic collisions without any contact. The bumpers screw directly into the beam of the sensor. They can also be used with the Force Accessory Bracket (see above).



Includes

Magnetic Bumper (2)

Order Information

Magnetic Bumper Set ME-9885A

Force Platform

ANALOG sensor

CI-6461

- Large jumping and landing surface
- Rugged design



The Force Platform is an excellent tool for exploring forces on the human body. The platform measures the force exerted on any object in contact with it. The sturdy glass-filled nylon platform is supported by four force beams that combine to measure the total force on the platform. The optional Handle Set (below) allows students to push and pull on the Force Platform while holding it vertically.

Typical Applications

- Students determine their "hang time" by jumping off the platform, then landing on it
- Use two Force Platforms to investigate Newton's Third Law as two students push against one another
- Measure the normal force on a person riding in an elevator

Specifications

Range: -1000 N to +4000 N
Maximum Update Rate: 200 Hz
Platform Size: 35 cm x 35 cm
Zero (tare) Function: Push-button
Force Overload Protection
Pin Configuration: 8-pin DIN plug

Order Information

Force Platform (ScienceWorkshop) CI-6461

Force Platform Handle Set

PS-2548



By standing on a 2-Axis Force Platform while pushing against the wall with a 1-Axis Force Platform, a real-life statics problem can be analyzed.



Confirm Newton's Third Law by pushing on a Force Platform using two sets of handles (available separately). Handles bolt onto the Force Platform and can be mounted on either side or both sides.

Includes

Set of sturdy metal handles (2)

Order Information

Force Platform Handle Set PS-2548

Force Platform

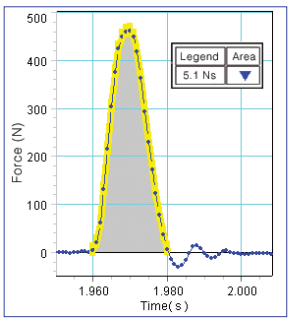
DIGITAL sensor

PS-2141



- Large jumping and landing surface
- Rugged design
- Force overload protection

The sturdy glass-filled nylon platform is supported by four force beams that combine to measure the total force on the platform. The Force Platform has two loops on the side to hang it on a wall.



Impulse data for a bouncing playground ball.

Typical Applications

- Determine "hang time" by jumping up from the platform, then landing on it
- Measure impulse and maximum force when jumping
- Use two Force Platforms to investigate Newton's Third Law as two students push against each other
- Measure the normal force on a person riding in an elevator
- Use a Motion Sensor and a bouncing ball to compare the impulse and change in momentum as the ball collides with the platform

Specifications

Range: -1100 N to +4400 N
Platform Size: 35 cm x 35 cm
Zero (tare) Function: Push-button
Force Overload Protection
Max Sample Rate: 1000 Hz (2000 Hz with the Xplorer GLX or 850 Interface)
Resolution: 0.1 N
Mass: 4 kg (without handles)

Order Information

Force Platform (PASPORT) PS-2141
Recommended:
Handle Set PS-2548

2-Axis Force Platform

DIGITAL sensor

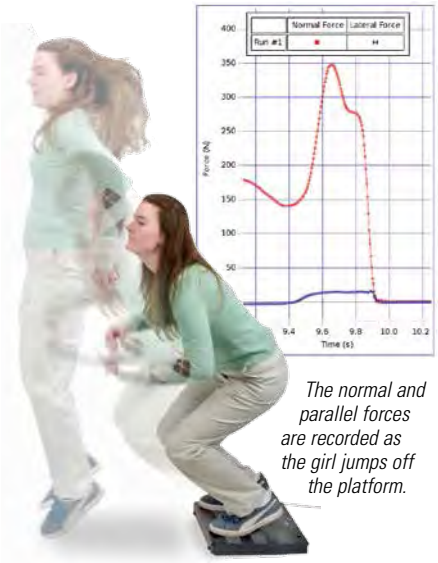
PS-2142



The 2-axis Force Platform has a second plate that rides on rollers on the base force platform to measure the force parallel to the platform. There are a total of five force beams: four corner beams to measure the normal force and a fifth beam to measure the parallel (sideways) force.

Typical Applications

- Measure the sideways force during a broad jump
- Measure the normal and parallel forces on a wall as a ladder leans against the wall
- Measure the normal and parallel forces as a person walks or runs across the platform
- Pull an object across the platform and measure the normal and frictional forces



The normal and parallel forces are recorded as the girl jumps off the platform.

Specifications

Range: -1100 N to +4400 N
(in normal direction)
-1100 N to +1100 N
(in parallel direction)
Platform Size: 35 cm x 35 cm
Platform Mass: 6.4 kg (without handles)
Zero (tare) Function: Push-button
Force Overload Protection
Max Sample Rate: 1000 Hz (2000 Hz with the Xplorer GLX or 850 Interface)
Resolution: 0.1 N

Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.

Order Information

2-Axis Force Platform (PASPORT) PS-2142
Recommended:
Handle Set PS-2548

Structures System: Amplifiers and Load Cells

Choice of Load Cell Amplifiers:

Load Cell Amplifier (6 ports)

DIGITAL sensor

PS-2198



This Load Cell Amplifier can accommodate up to six load cells and only needs a single USB Link (PS-2100A) to connect to the USB port on a computer. This is useful for doing an extensive analysis of a bridge by inserting six load cells at various points in the structure to see if theory matches reality.

The Amplifier accepts either the 100N load cell or the 5N load cell or a combination of both. The maximum data sample rate is 500 Hz for each port.

Shown in use with Structures Systems Truss Set (ME-6990). See page 134.





Display of the forces measured using the four load cells shown above.

The top two numbers are the left and right diagonals and the bottom two numbers are the left and right horizontal forces.

Includes

Load Cell Amplifier

100 N Load Cell (4)

Order Information

Load Cell Amplifier (6 ports) PS-2198

Required for Use:

Load Cell 100N PS-2200

Load Cell 5N PS-2201

Also Available

Load Cell and Amplifier Set PS-2199



Set Includes

Load Cell Amplifier

Load Cells 100N (4)

Instruction manual

Dual Load Cell Amplifier

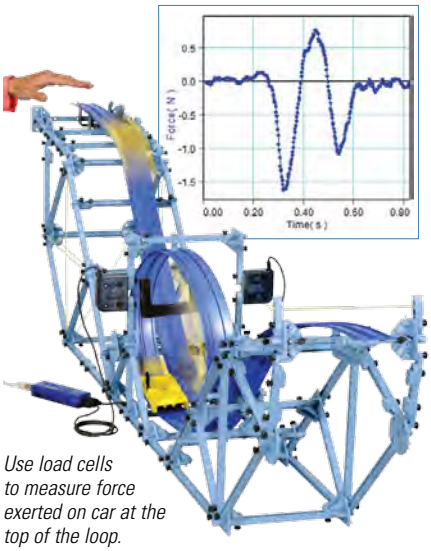
DIGITAL sensor

PS-2205



This Amplifier is for applications where only one or two load cells are needed, such as measuring the force on the track at the top of a roller coaster loop. If you only want to examine the forces in a bridge one at a time, you can move a single load cell around in the bridge.

The Amplifier accepts either the 100N load cell or the 5N load cell or a combination of both. The maximum data sample rate is 1000 Hz for each port.



Use load cells to measure force exerted on car at the top of the loop.

Shown in use with Physics Structures Set (ME-6989). See page 138.

Includes

Dual Load Cell Amplifier

Order Information

Dual Load Cell Amplifier PS-2205

Required for Use:

Load Cell 100N PS-2200

Load Cell 5N PS-2201

Also Available

Load Cell and Dual Amplifier Set PS-2206

Set Includes

Dual Load Cell Amplifier

Load Cell 100N (1)



CI Load Cell Amplifier

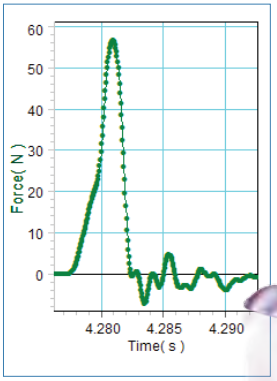
ANALOG sensor

CI-6464



This amplifier allows users of the *850* and *ScienceWorkshop* Interfaces to collect data using the Structures System 100N and 5N Load Cells. This system has been successfully used at sample rates over 10,000 Hz.

A separate amplifier is required for each load cell.



Impulse delivered to inverted toy "popper" as it launches. Sample rate is 20,000 Hz



Shown in use with the Structures System. See pages 134-141.

Includes

CI Load Cell Amplifier

Order Information

CI Load Cell Amplifier CI-6464

Required for Use:

Load Cell 100N PS-2200

Load Cell 5N PS-2201

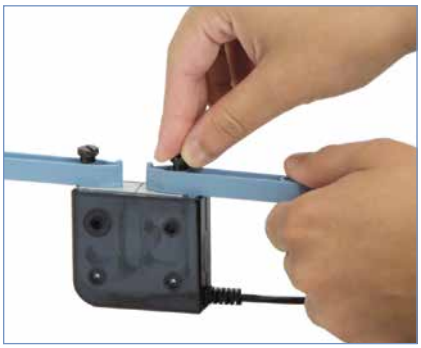
Two ranges of load cells

Load Cell 100N
PS-2200

Load Cell 5N
PS-2201



Load cells are available in two different ranges: ±100 N and ± 5 N. Both types of load cells can be used with the same amplifier in any combination. The semi-transparent case lets students see the strain gauge and beam inside.



I-Beams key into the load cell and are fastened with thumb screws.

Specifications (PS-2200)
Range: -100 N to +100 N
Accuracy: ±1% (±1 N)
Resolution: 0.02 N
Safe Overload: -150 N to +150 N

Specifications (PS-2201)
Range: -5 N to +5 N
Accuracy: ±1% (±0.05 N)
Resolution: 0.001 N
Safe Overload: -7.5 N to +7.5 N

Order Information

100 N Load Cell	PS-2200
5 N Load Cell	PS-2201

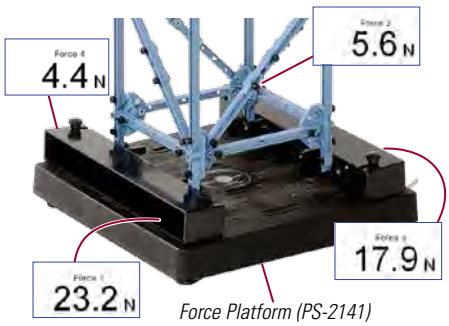
Measure support forces with a Force Platform

Force Platform Structures Bracket
ME-6988A

Measure the support forces of a crane by connecting it to a Force Platform (PS-2141) using the special Force Platform Structures Bracket (ME-6988A). The Force Platform is supported by four individual load cells that combine to measure the total vertical force on the platform. These four readings can also be viewed separately, to measure the unequal forces on the crane supports.



Tower Crane (2.3 m tall) built using the Large Structures Set (ME-7003) *See page 139.*



Force Platform (PS-2141)

Includes
Brackets (2)
Screws (4)



Order Information

Force Platform Structures Bracket	ME-6988A	
Shown in use with:		
Force Platform	PS-2141	p. 33
Large Structures Set	ME-7003	p. 135

Measure bridge deflection with a Displacement Sensor

Displacement Sensor
PS-2204

The Displacement Sensor measures the travel of a spring-loaded indicator pressed against a bridge as the bridge is loaded. It consists of a PASPORT sensor that plugs into the included Digital Indicator, a digital travel indicator that has its own digital LED readout and can be used as a stand-alone device. When the PASPORT sensor is plugged into an interface, the reading can be recorded.



See page 136 for more uses.

Specifications
Maximum Travel: 10 mm
Maximum Sample Rate: 5 Hz
Resolution: 0.013 mm (0.0005 in)

Includes
Sensor
Bracket
Dial Gauge



Order Information

Displacement Sensor	PS-2204	
Shown in use with:		
Hooked Mass Set	SE-8759	p. 181
Small "A" Base	ME-8976	p. 170
Steel Rod 60 cm long (threaded)	ME-8977	p. 170

Visual Accelerometer

DIGITAL sensor

PS-2128

- LEDs indicate direction and magnitude of acceleration
- 1-axis acceleration sensor



The Visual Accelerometer provides acceleration data and visual clues that allow students to better understand the concept of acceleration. The sensor features 10 high output, wide-angle LEDs that indicate the magnitude and direction of acceleration. The case of the sensor fits directly into a dynamics cart, and features ties for pendulum motion and a pass-through so the sensor can be thrown vertically along a rope.

The Visual Accelerometer features three fixed ranges, an auto-scale and a peak-hold option. The peak-hold mode stores the maximum acceleration experienced by the sensor after a countdown appears on the LEDs. The zero button on the sensor negates the effect of changing the orientation of the sensor.

The Visual Accelerometer can also be used in stand-alone mode. While away from the computer, the LEDs give students a meaningful, visual measurement of acceleration.

Typical Applications

- Real-time measurement of acceleration during simple harmonic motion
- Measure acceleration due to gravity
- Measure acceleration of a cart on an inclined plane
- Discover the acceleration of an elevator

See page 104 for more applications.



For freefall studies, the bottom of the Visual Accelerometer has a channel that accepts a cord or small rope.

Specifications

Ranges: ±1.0 m/s^2, ±5.0 m/s^2, ±20 m/s^2
Accuracy: 0.2 m/s^2
Resolution: 0.01 m/s^2
Max Sample Rate: 100 Hz
Includes sensor extension cable
Requires three AA batteries (included)

Order Information

Visual Accelerometer (PASPORT) PS-2128

Visual Accelerometer Accessory Kit

PS-2516

- Pendulum mount
- Rod stand mount



The four-string pendulum plate from the Visual Accelerometer Accessory Kit keeps the unit level as it oscillates, showing its horizontal acceleration.

The Accessory Kit allows the Visual Accelerometer to be mounted in various ways, including as a pendulum. It can also be attached to PASCO's Rotating Platform (ME-8951) for studies in rotation.



The Visual Accelerometer can be mounted to a rod stand using the Accessory Kit, for measurements inside a moving reference such as a car or an elevator. Shown here with the Xplorer GLX (PS-2002).

Includes

Four–String Pendulum Plate
Plastic Rod Clamps (2)
M-5, 4 cm long mounting thumbscrews (2)
1/4-20, 5 cm long thumbscrews with nuts (4)
Roll of thread



Order Information

Visual Accelerometer Accessory Kit PS-2516

Acceleration

ANALOG sensor

CI-6558

- ±5 g range
- 0.01 g resolution



The Acceleration Sensor can be used to record acceleration data for almost any application. Plug the sensor directly into the 850 Universal Interface to produce a portable acceleration monitoring device.

Typical Applications

- Dynamic cart collisions
- Study acceleration in elevators
- Measure acceleration in cars and roller coasters

Includes

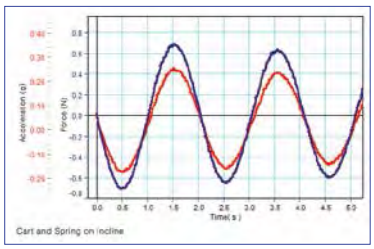
Acceleration Sensor with two meter detachable cable
Bracket and hardware for attaching to a dynamics cart



Acceleration Sensor mounted on an ME-9454 Collision Cart

Specifications

Range: ±5 g range
Resolution: 0.01 g range
Zero Function: Push-button, nulls out gravity
Sensor Response Settings: Switch-selectable
Slow: Reduces high frequency vibrations and noise in experiments measuring acceleration of elevators, roller coasters, automobiles, etc.
Fast: Use for short duration events such as cart collisions
Pin Configuration: 8-pin DIN plug on case



This graph shows simultaneous Force and Acceleration data for a cart oscillating on an inclined track.

Order Information

Acceleration Sensor (ScienceWorkshop) CI-6558

3-Axis Acceleration/Altimeter

PS-2136A



DIGITAL sensor

NEW

- 3-axis acceleration data to 500 Hz
- 16 g on each axis
- 10 cm resolution altitude data

This one acceleration sensor does it all! Measure acceleration in all three dimensions, as well as changes in altitude. Measure acceleration data up to 500 Hz. Dynamic variable over-sampling automatically reduces the measurement noise at slower sampling rates.

Typical Applications

- Attach to a dynamics cart for the study of Newton's Laws.
- Investigate centripetal acceleration on a rotating platform
- Sports physics
- Roller coaster amusement park physics

Specifications

Acceleration for each axis 16 g with 0.002 g resolution

10 cm altitude resolution

Acceleration readout in g or m/s/s.

Sample Rate:

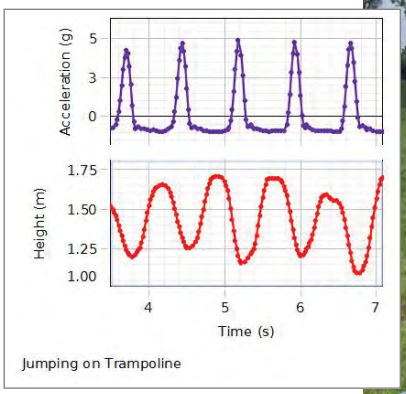
Max sample rate for acceleration: 500 Hz

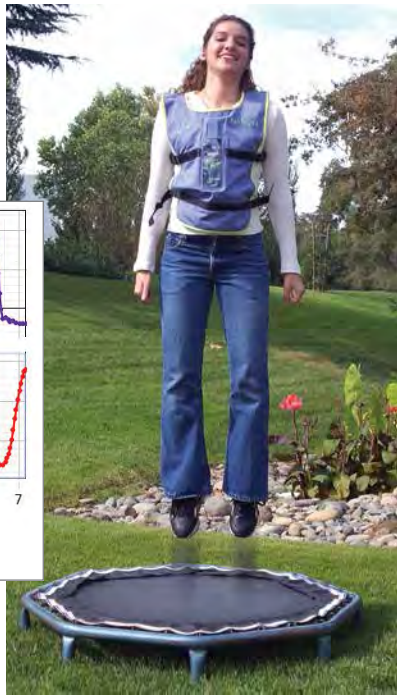
Max sample rate for acceleration with simultaneous altitude data: 100 Hz

Max data rate for altitude: 20 samples/second

Five Simultaneous Measurements:

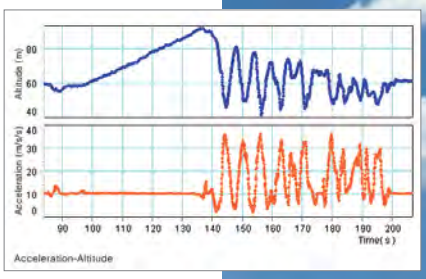
Acceleration in x, y and z axes, resultant acceleration and altitude.

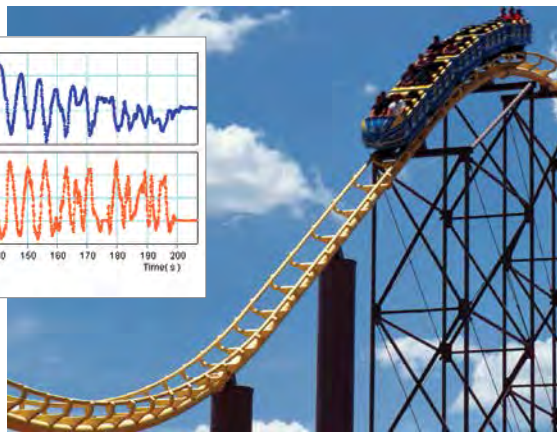




Trampoline

Altitude and acceleration are simultaneously measured on a trampoline.



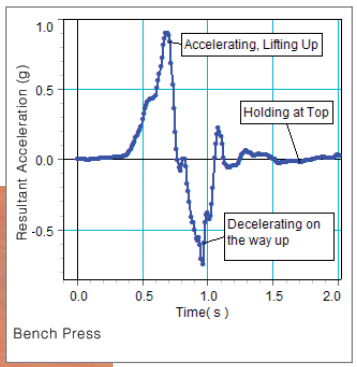


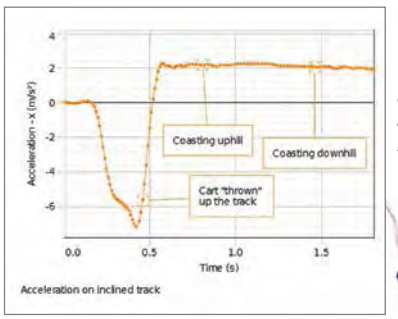
Roller Coaster

Acceleration and altitude data from a roller coaster.

Weight Lifting

During a bench press, the weight lifter accelerates and then decelerates the weights. The acceleration is zero at the top of the lift where the weights are held at rest. This graph shows the resultant acceleration calculated from all three axes, so the orientation of the sensor does not affect the measurement. The acceleration due to gravity has been subtracted out.





Inclined Track

The cart acceleration parallel to the track is measured as the cart is "thrown" up the incline and allowed to coast up and back down the track.





Order Information

3-Axis Acceleration/Altimeter	PS-2136A	
Shown in use with:		
Xplorer GLX	PS-2002	p. 18-19
Xplorer Vest	PS-2517	p. 20

Photogates

Smart Gate

PS-2180 (PASPORT)

NEW

Four photogates in one!

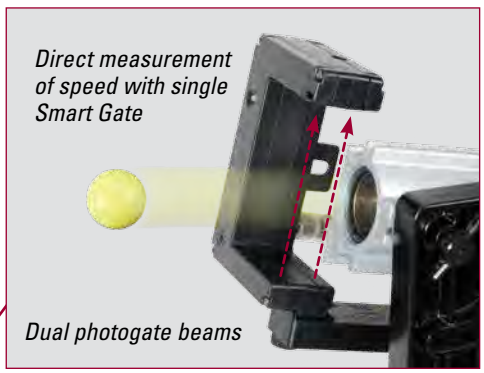
- Dual Photogate beams
- Laser switch
- Photogate Tape Slot
- Daisy chain auxiliary Photogate or Time-of-Flight

The Smart Gate has dual Photogate beams spaced at 1.5 cm to accurately measure speed. Built-in laser switch (when used with any laser) allows you to time objects too large to fit through the standard Photogate. Other features include a slot for Photogate Tape, and an auxiliary port for an additional Photogate or the Time of Flight Accessory.

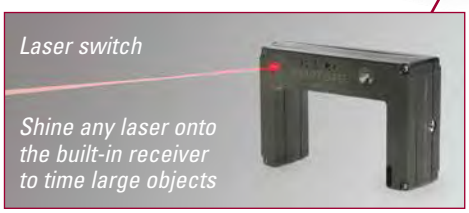












Includes

Smart Gate
Interface Cord



Order Information

Smart Gate	PS-2180	
Recommended:		
Photogate Tape	ME-6663	p. 40
High Resolution Photogate Tape	ME-6666	p. 40
Required:		
PASPORT Interface		

Smart Gate System

PS-3701 (PASPORT)

NEW

Needs only one PASPORT connection. Photogate daisy-chains to Smart Gate.



Includes

Smart Gate (1) PS-2180
Photogate Head (1) ME-9498A

Order Information

Smart Gate System PS-3701

Smart Gate Pulley System

PS-3702 (PASPORT)

NEW

The Super Pulley attaches directly to the Smart Gate, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.

Includes

Smart Gate (1) PS-2180
Super Pulley (1) ME-9450A
Super Pulley Rod (1) ME-8736



Order Information

Smart Gate Pulley System PS-3702

Photogate Head

ME-9498A

ANALOG sensor DIGITAL sensor with Digital Adapter*



Specifications

Photogate Width: 7.5 cm
Fall Time: < 50 ns
Spatial Resolution: < 1 mm
Timing Resolution: 0.1 millisecond
Connector: Stereo phone plug

Order Information

Photogate Head (ScienceWorkshop) ME-9498A
Recommended:
Photogate Stand ME-9805
**Required for use with PASPORT Interfaces:*
Digital Adapter ..... PS-2159 p. 41

Accessory Photogate

ME-9204B

ANALOG sensor DIGITAL sensor with Digital Adapter*



Includes both a Photogate Head and a Photogate Stand for flexible experiment design. The Photogate Stand is also sold separately.

Order Information

Accessory Photogate (ScienceWorkshop) ME-9204B
Photogate Stand ME-9805
**Required for use with PASPORT Interfaces:*
Digital Adapter ..... PS-2159 p. 41

Relay

CI-6462



- Single-pole double-throw switch
- For sense and control projects

The relay plugs into a PASPORT interface with a Digital Adapter using a ¼" stereo phone plug. The device to be controlled is connected to two of three banana jacks on the front of the relay; one jack is the common, one jack is for a normally open connection, and the third jack is for a normally closed connection. There is a push-button for manually activating the relay to test your connection. An LED indicates when the relay is activated.

Specifications

30 V, 5 A maximum
1.7 m long cord
10 cm x 7 cm x 3 cm





The Xplorer GLX controls the Relay to turn a light on when the temperature sensor above the bulb reads less than 25°C.

Order Information

Relay (ScienceWorkshop) CI-6462
**Required for use with PASPORT Interfaces:*
Digital Adapter ..... PS-2159 p. 41

Photogate/Pulley System

ME-6838A

ANALOG sensor DIGITAL sensor with Digital Adapter*



Specifications

Pulley:
Rotational inertia: 1.8×10^{-6} kg m^2;
Coefficient of friction: $<7 \times 10^{-3}$;
Diameter: 5 cm, Mass: 5.5 g
Photogate:
Width: 7.5 cm; Fall time: < 50 ns;
Spatial resolution: < 1 mm
Timing Resolution: 0.1 millisecond
Connector: Stereo phone plug

Includes

Photogate Head
Super Pulley with Rod

Order Information

Photogate/Pulley System (ScienceWorkshop) ME-6838A
**Required for use with PASPORT Interfaces:*
Digital Adapter ..... PS-2159 p. 41

Photogate Pendulum Set

ME-8752

The Photogate Pendulum Set is a unique set of pendula that have exactly the same shape and size, but different masses. These pendula are ideal for use with photogates due to their cylindrical shape. One pendulum each of brass, plastic, wood and aluminum is included. *See page 149 for more information.*



Photogate not included.

Order Information

Photogate Pendulum Set ME-8752

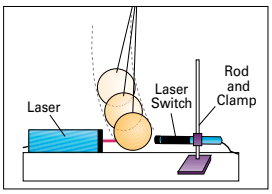
Laser Switch

ME-9259A

ANALOG sensor DIGITAL sensor with Digital Adapter*



This Laser Switch acts as a large photogate so you can time objects too large to pass through a standard photogate. Use the Red Laser Pointer below or other laser as your light source.



Order Information

Laser Switch (ScienceWorkshop) ME-9259A
Required:
Laser such as X-Y Adjustable Diode Laser OS-8526A
**Required for use with PASPORT Interfaces:*
Digital Adapter ..... PS-2159 p. 41

Timer Switch ME-9819

ANALOG sensor DIGITAL sensor with Digital Adapter*

This push-button switch has a 1.7 m cable ending in a "Y" with two stereo phone plugs. When the button is pressed, the Timer Switch sends a start signal to both devices to which it is connected.



Order Information

Timer Switch (ScienceWorkshop) ME-9819
**Required for use with PASPORT Interfaces:*
Digital Adapter ..... PS-2159 p. 41

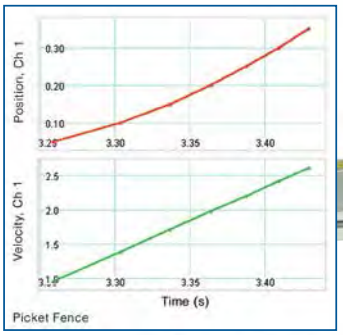
Photogates and Fences

Photogates and Fences

ANALOG sensor DIGITAL sensor with Digital Adapter*

ME-9471A

When used with the computer for data recording, display, and analysis, the photogate/pulley timing system can provide a wide range of time, speed, and velocity measurements. The photogates mount to the dynamics track using the provided brackets. The picket fences provided mount directly to the dynamics carts.





Position and velocity graphs are obtained using a Picket Fence and Photogate.



Includes

Photogate Heads (2)
Photogate Brackets (2)
Picket Fences (2)
Super Pulley with attachment screw (attaches Super Pulley to Photogate)
Pulley Mounting Rod

Order Information

Photogates and Fences (ScienceWorkshop)	ME-9471A	
Individual Components:		
Photogate Head	ME-9498A	p. 39
Photogate Brackets (2)	ME-9806	p. 107
Cart Picket Fences (2)	ME-9804	
Super Pulley	ME-9450A	p. 133
Pulley Mounting Rod	SA-9242	p. 133
**Required for use with PASPORT Interfaces:*		
Digital Adapter	PS-2159	p. 41

Cart Picket Fences (set of 2)

ME-9804



Order Information

Cart Picket Fences (set of 2) ME-9804

Smart Timer Picket Fences (set of 2)

ME-8933



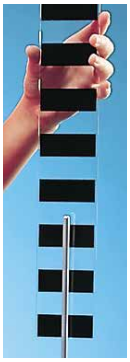
See Smart Timer on pages 120-121.

Order Information

Smart Timer Picket Fences (set of 2) ME-8933

Large Picket Fence

ME-9377A



Conduct free fall experiments by dropping this Picket Fence through the PASCO Photogate.

The distance from the leading edge of each black bar to the leading edge of the next black bar is 5.0 cm. The Picket Fence has eight black bars and is 40 cm long.

Order Information

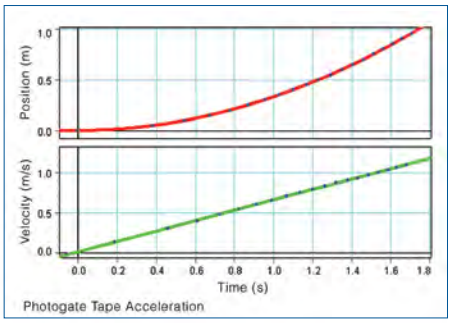
Large Picket Fence ME-9377A

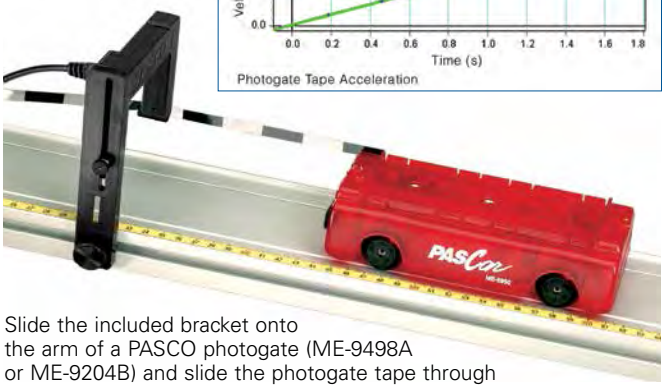
Photogate Tape Set

ME-6664

Flexible Mylar® picket fence tape can be cut to any length. Tape guide slides onto the arm of PASCO photogates to more accurately measure the motion of a cart.

Photogate tape can be used as a picket fence "string" to continuously measure the acceleration of the cart.



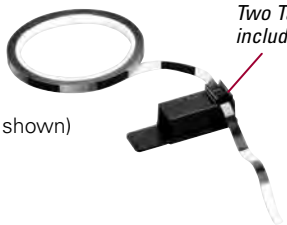


Slide the included bracket onto the arm of a PASCO photogate (ME-9498A or ME-9204B) and slide the photogate tape through the slot to measure position, velocity, and acceleration. The band spacing on the tape is 5 cm from edge to edge, which is identical to the Large Picket Fence (ME-9377A).

The High Resolution Photogate Tape, available separately, has a distance of 1 cm between edges for more data points during high velocity or acceleration phenomena.

Includes

Photogate Tape (30 m)
Photogate Tape Guide (2)
Double-Adhesive Tape (not shown)
Velcro Strips (not shown)



Two Tape Guides included

Order Information

Photogate Tape Set	ME-6664	
High Resolution Photogate Tape	ME-6666	
Photogate Tape	ME-6663	
Required:		
Photogate Head	ME-9498A	p. 39
or Accessory Photogate	ME-9204B	p. 39

Time-of-Flight Accessory

ME-6810

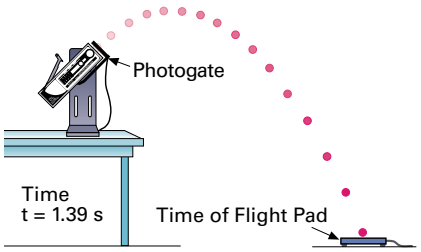
ANALOG sensor | DIGITAL sensor with Digital Adapter*



The Time-of-Flight Accessory is designed primarily for freefall or projectile experiments. When an object hits the plate, a signal is sent to the interface Note: When used with the Projectile Launcher, a photogate is used to start the timer and the 20′ extension cable is recommended.

Typical Applications

- Find Time-of-Flight for a ball shot from a Projectile Launcher
- Conduct freefall experiments



Order Information

Time-of-Flight Accessory (ScienceWorkshop).....ME-6810

**Required for use with PASPORT Interfaces:*

Digital Adapter.....PS-2159 p. 38

Phone Jack Extender Cable

PI-8117



This six meter phone jack-to-phone jack extension cord can be used with any Photogate/Timing accessory.

Order Information

Phone Jack Extender Cord (20′ cable).....PI-8117

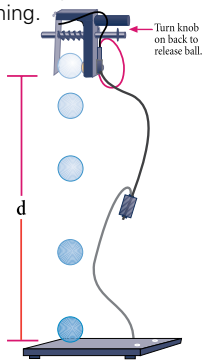
Freefall Adapter

ME-9207B

ANALOG sensor | DIGITAL sensor with Digital Adapter*



When the steel ball is dropped from the release mechanism, the computer automatically starts timing. When the ball hits the receptor pad, timing stops. Timer measurements of "g" are accurate and repeatable.



Order Information

Freefall Adapter (ScienceWorkshop).....ME-9207B

**Required for use with PASPORT Interfaces:*

Digital Adapter.....PS-2159

G-M Tube/Power Supply

SN-7927A

ANALOG sensor | DIGITAL sensor with Digital Adapter*

- Ideal general purpose nuclear sensor



The G-M Tube/Power Supply senses alpha, beta, and gamma radiation. Power for the tube is supplied through the connection to an interface that supplies an operating voltage of +5 V.

Specifications

Sensitivity: Beta, gamma, alpha

Count Detection: Audio signal

Window Thickness: 1.5 to 2 mg/cm^2, mica

Gas Filling: Neon, argon, and halogen

Starting/Operating Voltage for Tube: 450 VDC/500 VDC

Dead Time: 90 µs

Order Information

G-M Tube/Power Supply (ScienceWorkshop).....SN-7927A

**Required for use with PASPORT Interfaces:*

Digital Adapter.....PS-2159

Digital Adapter

PS-2159

DIGITAL sensor



- Required for counting and timing sensors
- Allows digital ScienceWorkshop Sensors to be used with PASPORT Interfaces

The Digital Adapter is required when photogates, timing and counting sensors are used with any PASPORT interface. Each Digital Adapter accommodates two sensors at once. Each port on the Digital Adapter automatically "senses" a connection and initiates a selection of pre-configured or user-defined options. Several Digital Adapters can be used simultaneously when required. See next page for a list of counting/timing sensors that require a Digital Adapter.

Specifications and Special Features

2 µs resolution for counting and timing

1 µs resolution for motion sensing

Two 1/4" stereo phone jacks

Order Information

Digital Adapter.....PS-2159

Also shown:

Photogate Head	ME-9498A	p. 39
Photogate Tape Set	ME-6664	p. 40
Xplorer GLX	PS-2002	p. 18

Analog Adapter

PS-2158



- Use your **black** ScienceWorkshop Sensors with **blue** PASPORT Interfaces
- No need to buy new sensors

Use an Analog Adapter to connect any black ScienceWorkshop sensor having an 8-pin or 5-pin DIN connector to a PASPORT interface.



Order Information

Analog Adapter.....PS-2158

Dual Pressure

PS-2181

DIGITAL sensor



The Dual Pressure sensor is capable of reading two absolute pressures, one gauge pressure, or one differential pressure. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.

Typical Application

- Measure pressure in Heat Engine (TD-8572). See pages 334-335.
- Measure pressure drops in pipes



Instrument your pipe network with the Pressure Taps (pages 166-167) connected to the Dual Pressure Sensor.

Specifications

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability

Differential Pressure: ±100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability

Maximum Sample Rate: 1000 Hz

Order Information

Dual Pressure Sensor (PASPORT) PS-2181

Pressure Taps (Set of 6) ME-2224

Diffusion/Osmosis Apparatus

Patent Pending

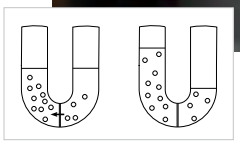
ME-6940

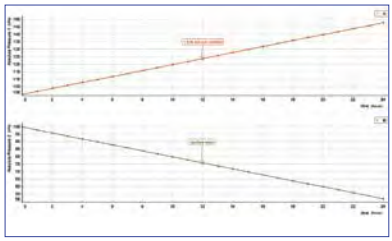


Diffusion/Osmosis Apparatus shown in use with Dual Pressure Sensor PS-2181.

PASCO's Diffusion/Osmosis Apparatus is a U-shaped apparatus consisting of two cylinders separated by a semi-permeable membrane. The transparent, graduated cylinders allow students to observe and measure volume changes due to osmosis. In conjunction with PASCO's Dual Pressure Sensor, the apparatus allows students to measure the changes in pressure and volume caused by the osmotic movement of water across a semi-permeable membrane.







In this experiment, cylinder #1 was filled with 40 mL of 1.0 M sucrose solution. Cylinder #2 was filled with 40 mL of distilled water. The two cylinders were separated by a semi-permeable membrane and the pressure within the cylinders was monitored using the Dual Pressure Sensor.

Order Information

Diffusion/Osmosis Apparatus ME-6940
(includes 20 membranes)

Diffusion/Osmosis Kit ME-6942
(includes Diffusion/Osmosis Apparatus and Dual Pressure Sensor)

Replacement Membranes (20 membranes) ME-6941

Dual Pressure Sensor PS-2181

Relative Pressure

PS-2114

DIGITAL sensor



The Relative Pressure Sensor measures gas pressure compared to atmospheric pressure, which is commonly known as gauge pressure. Includes quick connect tubing for a variety of pressure activities. The limited pressure range of the sensor provides excellent accuracy and resolution for measuring small pressure changes.

Typical Applications

- Heat Engine Cycles
- Measure pressure changes in a Venturi Tube
- Conduct air foil studies

Specifications

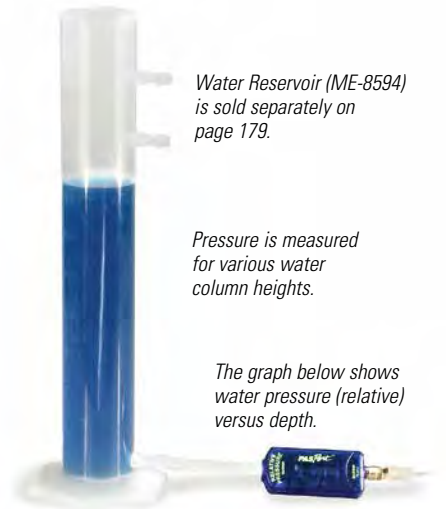
Range: 0 to 10 kPa

Accuracy: ±0.1 kPa

Maximum Sample Rate: 20 Hz

Resolution: 0.001 kPa

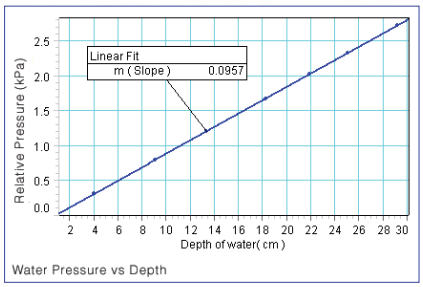
Repeatability: 0.01 kPa



Water Reservoir (ME-8594) is sold separately on page 179.

Pressure is measured for various water column heights.

The graph below shows water pressure (relative) versus depth.



Order Information

Relative Pressure Sensor (PASPORT) PS-2114

Barometer/ Low Pressure

PS-2113A



Low Pressure

CI-6534A



- Gauge pressure
- Ideal for small pressure changes

The Barometer Sensor measures changes in atmospheric pressure over long and short periods of time. The sensor reports measurements in units of in Hg, hPa, or mBar. It can also be used as a Low Pressure Sensor.

The Low Pressure Sensor measures gas pressure compared to atmospheric pressure, which is commonly known as gauge pressure. Includes quick connect tubing for a variety of pressure activities. The limited pressure range of the sensor provides excellent accuracy and resolution for measuring small pressure changes.

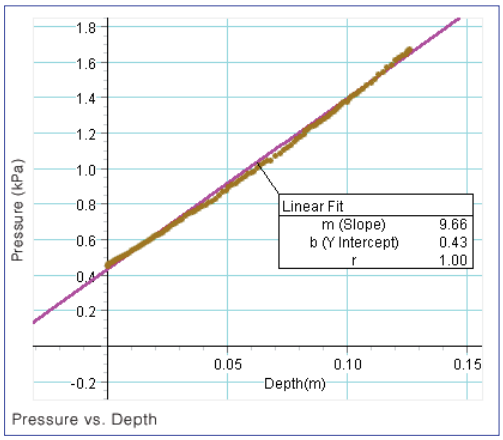
Typical Applications

- Conduct weather station experiments
- Measure changes in elevation
- Compare classroom data to local weather reports to predict weather
- Heat Engine Cycles
- Measure pressure changes in a Venturi Tube
- Conduct air foil studies

Specifications

PS-2113A (PASPORT):
- Range: 4.4 in Hg to 34 in Hg
- Accuracy: ±0.03 in Hg
- Resolution: 0.001 in Hg
- Maximum Sample Rate: 20 Hz
- Operating Temperature: 0°C to +40°C

CI-6534A (ScienceWorkshop):
- Pressure Range: 0 to 10 kPa above atmospheric
- Number of Pressure Ports: One
- Pin Configuration: 8-pin DIN plug on case



Pressure is measured for various water column heights.

Order Information

Barometer Sensor (PASPORT)	PS-2113A
Low Pressure Gauge Sensor (ScienceWorkshop)	CI-6534A

Absolute Pressure

PS-2107



CI-6532A



- Measure absolute pressure up to seven atmospheres
- Includes syringe for Gas Laws

The Absolute Pressure Sensor measures the gas pressure in a container or the surroundings. Includes a 20 cc syringe and quick connect tubing for investigating the Gas Laws. The sensor's wide range makes it an excellent general purpose pressure device.

Typical Applications

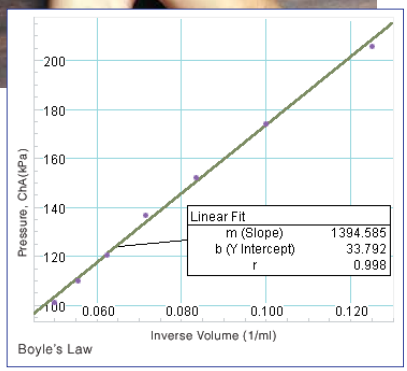
- Measure chemical reaction rates
- Verify Gas Laws (Ideal, Charles', Boyle's)
- Study Vapor Pressure vs. Temperature

Specifications

PS-2107 (PASPORT):
- Range: 0 to 700 kPa
- Accuracy: ±2 kPa
- Resolution: 0.1 kPa
- Maximum Sample Rate: 200 Hz
- Repeatability: 1 kPa

CI-6532A (ScienceWorkshop):
- Pressure Range: 0 to 700 kPa
- Reference Vacuum Pressure: 40 mTorr
- Number of Pressure Ports: One
- Pin Configuration: 8-pin DIN plug on case





The Absolute Pressure Sensor is used in a Boyle's Law experiment in which a syringe is compressed.

Order Information

Absolute Pressure Sensor	
(PASPORT)	PS-2107
(ScienceWorkshop)	CI-6532A

Quad Pressure

PS-2164



The 4-port Quad Pressure sensor is capable of reading up to four absolute pressures, or two gauge pressures, or two differential pressures. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.

Typical Application

- Study pressure through a fluid circuit

Specifications

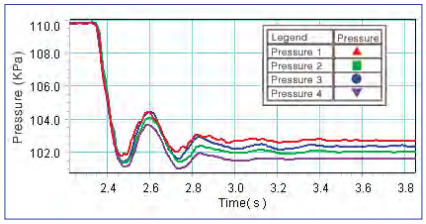
Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Differential Pressure: ±100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Maximum Sample Rate: 1000 Hz



Blue dye added to the water for clarity.



Shown above with the Venturi Apparatus ME-8598. The pressure at various points in the Venturi tube decreases as the water flow is turned on. Pressure variability due to cross-sectional area and fluid friction are readily seen in the data.

Order Information

Quad Pressure Sensor (PASPORT) PS-2164

Recommended:

Venturi Apparatus ..... ME-8598 p. 165

Absolute Pressure/ Temperature

PS-2146



This combination sensor is specifically designed for use in studying gas laws. The included thermistor temperature probe has both a fast response and very low thermal mass.

Typical Applications

- Extrapolate absolute zero
- Explore Gas Laws (Ideal, Charles', Boyle's)

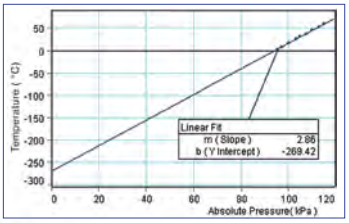
Specifications

Pressure: 0 to 700 kPa with ±2 kPa accuracy, 0.1 kPa resolution and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Maximum Sample Rate: 100 Hz

Temperature with Included Fast Response Probe: -10 to 70°C with ±0.5°C accuracy (displays Temperature in °C, K and °F)

Sensor Extension Cable: Included



Extrapolating Absolute Zero



See page 45 for more probes for this sensor

Measure pressure and temperature of air in the sphere.

Order Information

Absolute Pressure/Temp Sensor (PASPORT) PS-2146

Recommended:

Absolute Zero Sphere ..... TD-8595 p. 194

Ideal Gas Law Apparatus ..... TD-8596A p. 193

Temperature

PS-2125



PASCO's Stainless Steel Temperature Sensor offers fast response and superior range, resolution and accuracy. It reports temperature (in °C, °F, or K) whether it is immersed in liquids, held in the air, or touching a solid surface. Teflon® covers, for use in harsh liquids or strong chemical solutions, are available as an accessory.

Typical Applications

- Conduct general temperature experiments
- Measure rapid temperature changes found in endothermic-exothermic reactions
- Conduct environmental studies

Specifications

Range: -35°C to +135°C

Accuracy: ±0.5°C

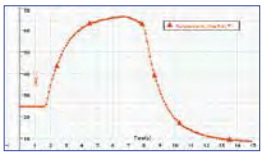
Resolution: 0.0025°C

Maximum Sample Rate: 10 Hz

Displays: °C, K and °F

Repeatability: 0.1°C

Teflon® covers available as an accessory



Graph showing the immediate temperature change when the PS-2125 Temperature Sensor is placed in a hot water bath and then plunged into a cold bath.

Order Information

Temperature Sensor (PASPORT) PS-2125

Recommended:

Teflon Sensor Covers (10-pack) CI-6549

Temperature

CI-6605A



- Quick response
- Rugged sensor

This low thermal mass Temperature Sensor ensures a quick response and negligible impact on measured temperatures. Teflon® covers, for use in harsh liquids or chemical solutions, are available as an accessory.

Specifications

Temperature Range: -35°C to +135°C

Accuracy: ±0.5°C

Resolution: 0.05°C

Pin Configuration: 8-pin DIN plug

Order Information

Temperature Sensor (ScienceWorkshop) CI-6605A

Temperature Probes*

Skin/Surface Temperature*

DIGITAL sensor

PS-2131



- Flat sensing element ideal for surfaces
- Quickly reaches equilibrium temperature with surface

Range: -10 to +70°C



Make a temperature profile of the human hand.

Order Information

Skin/Surface Temperature Probe* (PASPORT) PS-2131

Fast Response Temperature Probe* (3 pack)

DIGITAL sensor

PS-2135



- Accurately measures temperature changes in real time
- Ideal for small or hard-to-reach spaces
- Includes 10 Adhesive Patches

Range:
-30 to +105°C



Adhesive patches hold the Temperature Probe in place.

Order Information

Fast Response Temperature Probe* (3 pack) (PASPORT)... PS-2135

Recommended:

Replacement Adhesive Patches (100 pack) PS-2525

Stainless Steel Temperature Probe*

DIGITAL sensor

PS-2153



Range: -35 to +135°C

Order Information

Stainless Steel Temperature Probe* (PASPORT) PS-2153

Recommended:

Teflon® Sensor Covers (10 Pack) CI-6549

All of the probes above require one of the following temperature sensors:

Temperature Sensor ..... PS-2125 p. 44
Quad Temperature Sensor PS-2143
Temperature Array PS-2157

Temperature, Quad

DIGITAL sensor

PS-2143



Connect up to four Temperature Probes for an experiment. Use with any combination of Stainless Steel, Fast Response or Skin/Surface Temperature probes for a wider variety of temperature measurements in the classroom or in the field. Sensor includes two Stainless Steel Temperature Probes (PS-2153) and three Fast Response Probes.

Typical Applications

- Thermal heat flow (one or two dimension)
- Comparative body temperatures
- Side-by-side chemical reactions
- Solar radiation
- Properties of insulation

Specifications

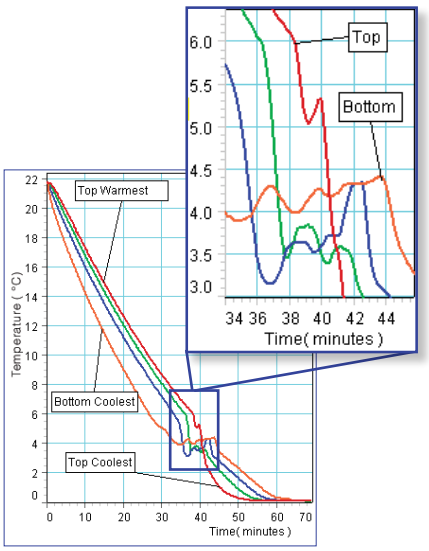
Accuracy: -35 to +135°C at ±0.5°C

Displays: °C, K and °F

Resolution: .0025°C

Maximum Sample Rate: 100 Hz

Teflon® covers available as an accessory



Four Fast Response Temperature Probes were used to study the temperature in a glass of water at four different levels as the water was cooled.

Order Information

Quad Temperature Sensor (PASPORT) PS-2143

Recommended:

Teflon Sensor Covers (10-pack) CI-6549

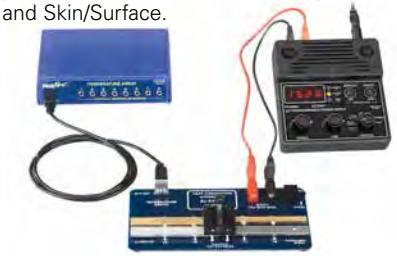
Temperature Array

PS-2157

DIGITAL sensor



This array has eight 3.5 mm stereo jacks to plug in temperature probes. Only one PASPORT Channel is required to measure eight temperatures at once! Applications include measuring temperatures along the length of a metal rod as one end is heated, or measuring surface temperature at eight different points on a body. The Temperature Array also has a "multiport" for plugging in a special cable (included) with eight color-coded thermistor sensors connected to a single 8-pin mini-DIN plug. The Temperature Array accepts PASPORT temperature probes: Stainless Steel, Fast Response and Skin/Surface.



Shown in use with:
Heat Conduction Apparatus (see page 188) and DC Power Supply (see page 231).

Specifications

Range: -35°C to 135°C*

Accuracy: ±0.5°C

Resolution: 0.0025°C

Repeatability: 0.01°C

Maximum Sample Rate: 100 Hz per Temperature Sensor

Displays: °C, K and °F

**Sensor Dependent*

Includes

Temperature Array Cable Assembly
Fast Response Temperature Probe (3)
Adhesive Patches (10)

Order Information

Temperature Array (PASPORT) PS-2157

Recommended:

Stainless Steel Temperature Probe PS-2153
Fast Response Temperature Probe PS-2135
Skin/Surface Temperature Probe PS-2131
Replacement Temperature Array Cable PS-2552
Replacement Adhesive Patches (100 Pack) PS-2525

Thermistor Temperature

ANALOG sensor

CI-6527A



- Convert resistance to temperature

The Thermistor Sensor is designed to read the resistance from a thermistor (100 kΩ or 10 kΩ at 25°C) and convert it to temperature. The computer displays the temperature in real-time in °C, eliminating the need for an ohmmeter and the use of a conversion lookup table. The sensor also reads in ohms so it can be used to read any resistance between 3 kΩ and 360 kΩ.

The Thermistor Sensor reads the type of thermistors (100 kΩ or 10 kΩ at 25°C) featured in PASCO equipment, such as:

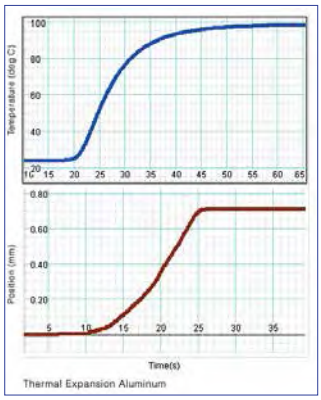
Thermal Radiation Cube (TD-8554A)
Mechanical Equivalent of Heat (TD-8551A)
Thermal Efficiency Apparatus (TD-8564)
Thermal Expansion (TD-8558A)
Compact Thermal Expansion (TD-8578 and TD-8579A)
Thermal Cavity (TD-8580)

Specifications

Resistance Range: 3.0 kΩ to 360.0 kΩ ±0.2 kΩ
Temperature Range: 0°C to 120°C
Resolution: 0.05°C at 25°C
Pin Configuration: 8-pin DIN plug on case

Includes

BNC-to-2 Banana Cable
Two Alligator Clips – Banana
One Sample 10 kΩ Thermistor
One Sample 100 kΩ Thermistor



In the Thermal Expansion Apparatus, the temperature changes in a rod, causing a change in length.

Order Information

Thermistor Temperature Sensor (ScienceWorkshop) CI-6527A

Non-Contact Temperature

DIGITAL sensor

PS-2197

- Non-contact
- -70°C to 380°C



The Non-Contact Temperature Sensor measures surface temperature by detecting the emitted infrared light. Record the temperature of objects without touching them!

Typical Applications

- Compare temperature of hands, skin, face and clothes
- Measure the temperature of different outdoor ground surfaces
- Map the temperature profile of an exterior wall

Specifications

Range: -70°C to 380°C
Accuracy: ±0.5°C
Response Time: Less than 0.1 s
Maximum Sample Rate: 200 Hz
Field of View: ±35°



The student measures the ground temperature (late morning) over four distinct surfaces. Starting in the shade under the distant tree, she then crosses bare dirt (in sun), a rock border, pavement, and lawn.

Order Information

Non-Contact Temperature Sensor (PASPORT) PS-2197

Shown in use with:
Xplorer GLX ..... PS-2002 p. 18
PASCO Capstone™ Software ..... pp. 6-13

Type K Temperature

DIGITAL sensor

PS-2134

- Extra-long probe



The PS-2134 is a single channel sensor that uses the same Type K thermocouple probe as the PS-2127 shown on this page. Includes one Type K Thermocouple.

Typical Applications

- Measure temperatures down to -200°C
- Measure temperatures in hard-to-reach places
- Use in high temperature applications where the narrow tip of the probe can be applied without burning the insulation cover (such as a candle flame)

Specifications

Temperature Range: -200°C to +1000°C
Maximum Sample Rate: 10 Hz
Accuracy: ±3°C or 3%, whichever is greater



The Type K Temperature Sensor can be used to measure the temperature of a flame. Works with any industry standard Type K thermocouple.

Order Information

Type K Temperature Sensor PS-2134

Replacement Supply:
Type K Thermocouple PS-2155

General Science Sensor

DIGITAL sensor

PS-2168



Simultaneously measure temperature, light, sound level, and voltage. Great for a variety of general science explorations.

Specifications

Temperature*: –35°C to +135°C; ±0.5°C

*Range is probe dependent.

Light: 3 user selectable light ranges:
0 to 100; 0 to 10,000;
0 to 150,000 Lux

Sound Level: 50 to 100 dbA

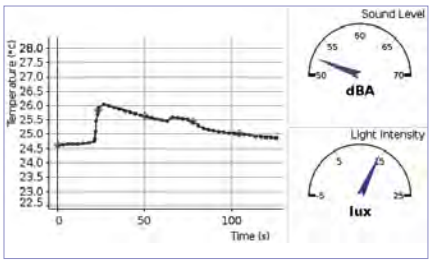
Voltage: ±24 V

Voltage Protection: up to 240 V

Maximum Sample Rate: 200 Hz



Sensor has three selectable ranges for low, indoor, and outdoor measurements.



Includes

Stainless Steel Temperature Probe

Voltage Probe

Order Information

General Science Sensor (PASPORT) PS-2168

Recommended:

Charge/Discharge Circuit ..... EM-8678A p. 208

General Flow Sensor

DIGITAL sensor

PS-2222 General Flow Sensor Only
PS-2225 General Flow Sensor with Venturi Tube
PS-2226 General Flow Sensor with Pitot Tube

The General Flow Sensor determines fluid velocity in air or water by measuring the difference in pressure between the two input tubes. Either the Venturi Tube or the Pitot Tube must be connected to the General Flow Sensor. The type of fluid (air or water) being used is selectable in the software.

Applications

The Venturi Tube is used in a pipe network that carries water or air. The Pitot Tube is used in an open water channel or in air.

Specifications

Pressure Range: 0 to 50 kPa

Pressure Accuracy: ± 2.5% of Full Scale (0 to 85°C)

Resolution: 0.2% of Full Scale

Venturi Range: 0 to 84 gpm (water); 0 to 773 gpm (air)

Venturi Accuracy: ± 2.1 gpm (water); ± 2.5 cf/min (air)

Pitot Range: 0 to 9.98 m/s (water); 0 to 92.1 m/s (air)





Venturi Tube

ME-2220



The Venturi Tube is made of clear PVC so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor by the matching couplers. The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network.

Pitot Tube

ME-2221



The Pitot Tube is designed to be placed in the air flow or water flowing in a channel. The General Flow Sensor, connected to the Pitot Tube, measures the pressure difference between the fluid inlet and the static side taps of the Pitot Tube and the software calculates the fluid velocity from the pressure difference.

See page 166 - 167 for more applications.

Pressure Taps



Instrument your pipe network with the Pressure Taps connected to the Dual Pressure Sensor (PS-2181). See pages 166-167.

Order Information

General Flow Sensor with Venturi Tube PS-2225
General Flow Sensor with Pitot Tube PS-2226

Required:

PASPORT Interface ..... pp. 14-23
PASCO Capstone Software ..... pp. 6-13

Also Available Separately:

General Flow Sensor without Probes PS-2222
Venturi Tube ME-2220
Pitot Tube ME-2221
Pressure Taps (set of 6) ME-2224

Temperature/ Sound Level/ Light

DIGITAL sensor

PS-2140



Launch students into an instant exploration of their environment! The Temperature/ Sound Level/Light Sensor allows students to conduct all three measurements simultaneously and continuously. Students can instantly display measurements on an Xplorer or take readings over time, anywhere, and display the data on a computer. Add an optional Stainless Steel Temperature Probe (PS-2153) to conduct water studies.

Typical Applications

- Measure the temperature difference between the floor and ceiling
- Determine the light level on a sunny versus cloudy day
- Compare sound levels of students whispering, singing loudly, or applauding

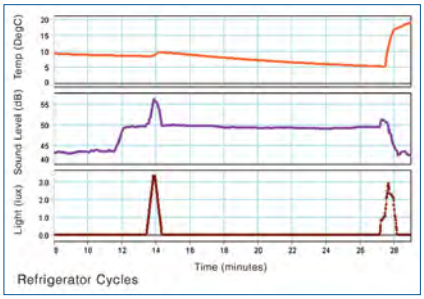
Specifications

Temperature (internal) Range:
-10 to +50°C

Sound Level Range: 40 to 90 dBA

Light Range: 0 to 5000 lux

Maximum Sample Rate: 5 Hz



The temperature, light intensity, and sound level are simultaneously measured inside a refrigerator. Note the changes in measurements as the compressor starts and as the door is opened.

Order Information

Temperature/Sound Level/Light Sensor (PASPORT) PS-2140

Recommended:
Stainless Steel Temperature Probe PS-2153

Light

PS-2106A

DIGITAL sensor



CI-6504A

ANALOG sensor



General purpose Light Sensor

The Light Sensor is ideal for indoor and outdoor relative light intensity experiments. Data is displayed in lux, a unit of illuminance that is a measure of luminous flux per unit of area. The Light Sensor can be used in three different ranges depending on the intensity level of the light source.

Typical Applications

- Compare light intensity vs. distance
- Study interference/diffraction/polarization
- Measure relative light intensities in daylight
- Monitor a solar eclipse

Specifications

PS-2106A (PASPORT):

Range: 0 to 2.6 lux (candle);
0 to 260 lux (bulb);
0 to 26,000 lux (sun)

Accuracy: > ±1 db of max value of selected range

Resolution: 1/10,000 of max value of selected range

Maximum Sample Rate: 1000 Hz

CI-6504A (ScienceWorkshop):

Sensing Element: Si PIN photodiode

Spectral Response: 320 nm to 1100 nm

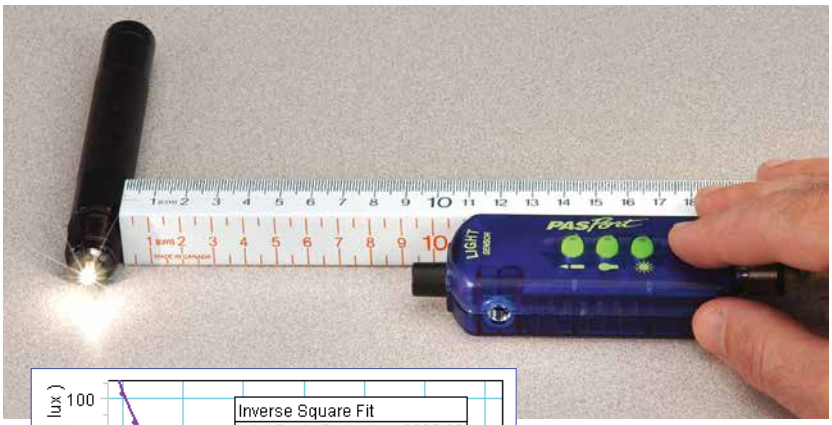
Gain Levels: 100x, 10x, 1x, switch-selectable

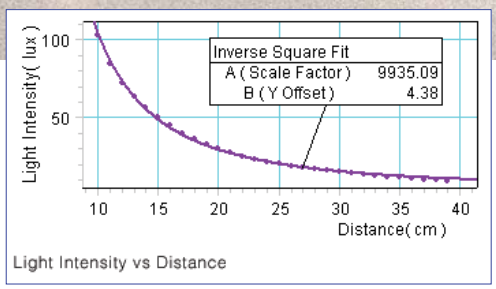
Output Voltage: 0 V to 5 V

Pin Configuration: 5-pin DIN plug on case

Maximum Light Intensity Levels (lux):

Gain Setting:	1x	10x	100x
Approximate Lux:	500	50	5





The graph shows that light intensity varies as the inverse square of the distance from the light source.

Order Information

Light Sensor
(PASPORT) PS-2106A
(ScienceWorkshop) CI-6504A

High Sensitivity Light

PS-2176



CI-6604



Ideal for low light experiments

The High Sensitivity Light Sensor is designed to perform visible light studies from low intensity spectral studies to daylight. Built-in automatic variable oversampling reduces noise.

Typical Applications

- Spectrophotometry
- Interference and Diffraction patterns
- Measure light intensity vs. distance

Specifications

PS-2176 (PASPORT)

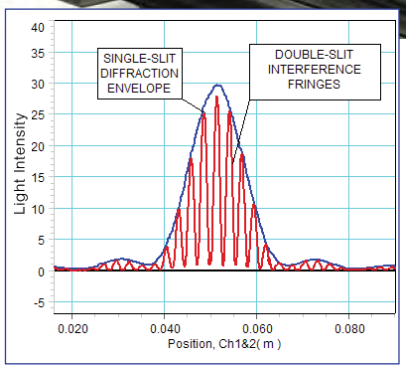
Sensing Element: Si PIN photodiode
Spectral Response: 320 nm to 1100 nm
Gain Levels: 10,000x, 100x, 1x, switch selectable
Approximate Lux Ranges: 0 to 1, 0 to 100, 0 to 10,000
Maximum Sample Rate: 1000 Hz
Resolution: ± 0.01 Lux at 1000 Hz on 0 to 100 scale; ± 0.0005 Lux at 5 Hz on 0 to 100 scale

CI-6604 (ScienceWorkshop)

Sensing Element: Si PIN photodiode
Spectral Response: 320 nm to 1100 nm
Gain Levels: 100x, 10x, 1x, switch-selectable
Output Voltage: 0 V to 5 V
Pin Configuration: 8-pin DIN plug on case
Maximum Light Intensity Levels (lux):

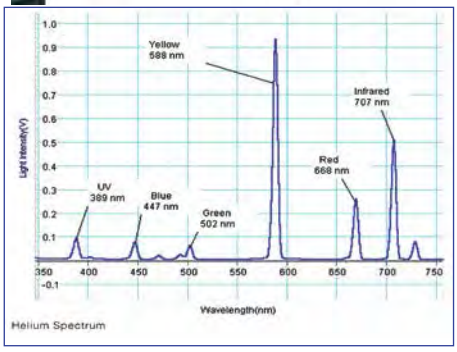
Gain Setting:	1x	10x	100x
Approximate Lux:	5	0.5	0.05





Computer scan of a single-slit and double-slit having the same slit width.





Helium spectrum recorded using the High-Sensitivity Light Sensor and the OS-8539 Educational Spectrophotometer System.

Order Information

High Sensitivity Light Sensor
(PASPORT) PS-2176
(ScienceWorkshop) CI-6604

Light Level

PS-2177



The Light Level Sensor measures illuminance in lux. The readings of this sensor mimic the wavelength sensitivity of the human eye, which is most sensitive in the green part of the spectrum. This is achieved with a green filter in the light sensor.

Some typical readings are shown in the table:

Condition	Illuminance *(lux)*
Sunlight	100,000
Full Daylight	10,000
Overcast Day	1,000
Very Dark Day	100
Twilight	10
Deep Twilight	1
Full Moon	0.1
Quarter Moon	0.01
Starlight	0.001
Warehouses	150
Offices, Laboratories	500
Supermarkets	750
Normal Drawing Work, Operation Rooms	1,000
Detailed Drawing Work	1500-2000

Specifications

Maximum Sample Rate: 250 Hz
Accuracy: ±10%
Three Ranges:
Candle:
0 to 1,500 lux Resolution 0.5 lux
Light Bulb:
0 to 15,000 lux Resolution 5 lux
Sun:
0 to 150,000 lux Resolution 50 lux

Order Information

Light Level Sensor
(PASPORT) PS-2177

Broad Spectrum Light

PS-2150



CI-6630



- For use with Spectrophotometer
- Ideal for Black Body Spectrum

The Broad Spectrum Light Sensor is designed specifically for use with our Educational Spectrophotometer System OS-8539 and Prism Spectrophotometer Accessory OS-8543 for Black Body experiments. The Broad Spectrum Light Sensor uses a thermopile and window combination that respond to both the near infrared and visible light necessary for the Black Body experiment.

Typical Applications

- Black Body Experiment

Specifications

PS-2150 (PASPORT):

Sensing Element:
BaF_2 window, xenon gas-filled thermopile

Spectral Response:
300 to 10,000 nm

Maximum Sample Rate:
100 Hz

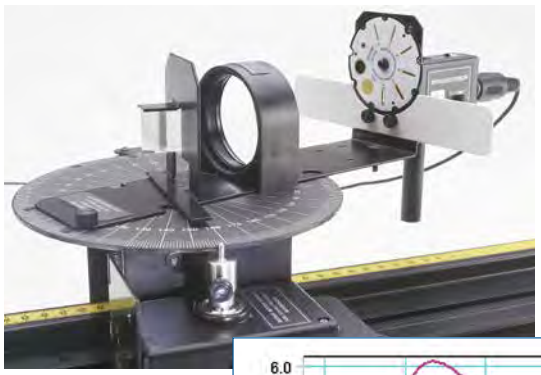
CI-6630 (ScienceWorkshop):

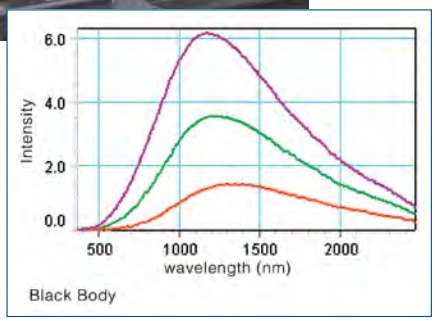
Sensing Element:
BaF_2 window, xenon gas-filled thermopile

Output Voltage: $+10^V$

Spectral Response:
300 to 10,000 nm.

Pin Configuration: 8-pin DIN on case





The classic textbook diagram of the intensity versus wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the black-body curve shifts as the source temperature is lowered. See page 278.

Order Information

Broad Spectrum Light Sensor
(PASPORT) PS-2150
(ScienceWorkshop) CI-6630

UVA Light

PS-2149



CI-9784



- Directly measure UV radiation

The Ultraviolet Light Sensor employs a filter to measure the UVA band (315 nm - 400 nm). With the UVA filter removed, the sensor detects the visible as well as the UVA. The sensor includes the UVA filter, a collimator, and a sensor handle.

Typical Applications

- Conduct a sky survey of UV light
- Check the amount of UV blocked by windows or sunscreen lotion
- Detect UV lines in the mercury spectrum using a spectrophotometer

Specifications

PS-2149 (PASPORT):

Spectral Response:
With included UVA filter–
315 nm to 400 nm

Photodiode sensing element

Maximum Sample Rate:
1000 Hz

Gain Levels:
10,000x, 100x, 1x

CI-9784 (ScienceWorkshop):

Sensing Element: Photodiode

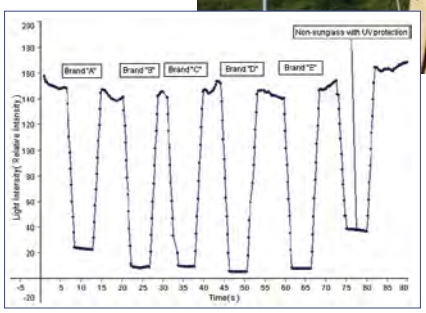
Spectral Response:
With included UVA filter–
315 nm to 400 nm

Gain Levels:
100x, 10x, 1x, switch selectable

Output Voltage: 0 V to 5 V

Pin Configuration:
8-pin DIN plug on case





The graph shows the difference in UV protection with various brands of sunglasses.

Order Information

UVA Light Sensor
(PASPORT) PS-2149
(ScienceWorkshop) CI-9784

Infrared Light

PS-2148



CI-6628



For heat studies

The Infrared Sensor is sensitive in the infrared portion (up to 40,000 nm) of the spectrum, but also detects the visible spectrum. It can detect the radiation from a person's hand. The response is linear over its entire frequency range.

Typical Applications

- Measure black body radiance
- Perform Leslie's Cube experiments
- Measure solar radiance
- Evaluate heat flow into or out of the sensor
- Simulate a non-contact temperature sensor

Specifications

PS-2148 (PASPORT):

Measure intensity in Watts/Meter

Maximum Sample Rate: 100 Hz

Spectral Response: 580 to 40,000 nm

Built-in thermistor to measure temperature of the "cold" side of the thermopile in °C, °F or K

CI-6628 (ScienceWorkshop):

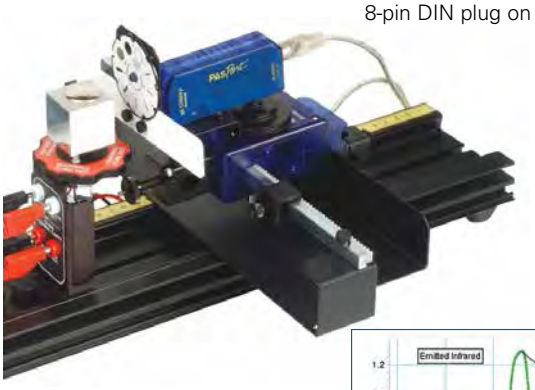
Sensing Element: 48 junction, KRS-5 window, argon gas-filled thermopile

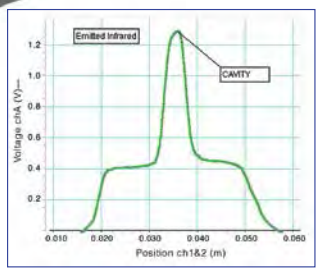
Spectral Response: 580 to 40,000 nm (linear)

Gain Levels: 100x, 10x, 1x, switch-selectable

Output Voltage: 0 V to 5 V

Pin Configuration: 8-pin DIN plug on case





In the infrared part of the spectrum, the hot cavity is brighter than the surrounding matte aluminum surface. See page 202.

Order Information

Infrared Light Sensor

(PASPORT) PS-2148

(ScienceWorkshop) CI-6628

Charge

PS-2132



CI-6555



Ideal for electrostatics

The Charge Sensor is designed for experiments in electrostatics such as inductive charging, charge production/distribution, and charge on a capacitor. The sensor features automatic scaling, eliminating the need for a gain switch. Designed with highly efficient input over-voltage protection, the Charge Sensor is virtually "blow-out" proof and will provide many years of use in the student lab.

When used with the Faraday Ice Pail, the Charge Sensor can measure the total charge on an object by the induction method.

The Charge Sensor can also be used as a high impedance voltmeter (10^{12} Ω). It includes a 0.9 m shielded cable with alligator clips to eliminate stray fields.

Typical Applications

- Measure charge by induction
- Quantify the charge on a capacitor plate
- Discover the charge distribution on a conducting sphere

See pages 206-207 for additional applications.

Specifications

PS-2132 (PASPORT):

Charge Range: ±0.1 µC

Voltage Range: ±10 V

Input Resistance: 10^{12} Ω

Maximum Input Voltage: 150 V

Maximum Sample Rate: 100 Hz

Input Connector: BNC

Input Cable: 0.9 m length; shielded with alligator termination

CI-6555 (ScienceWorkshop):

Input Capacitance: 0.01 µF ±5%

Input Resistance: 10^{12} ohms (1000 gigaohms)

Maximum Input Voltage: 150 V

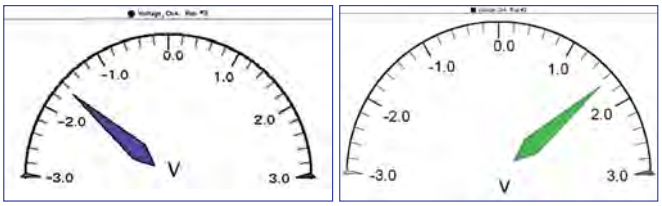
Input Connector: BNC

Input Cable: Shielded, 0.9 m, alligator clip termination

Pin Configuration: 8-Pin DIN plug on case

Sensor Gain:

1x	5x	20x
Voltage Range:		
±10 V	±2 V	±0.5 V
Charge Range:		
±0.1 µC	±0.02 µC	±0.005 µC



The Charge Sensor measures equal yet opposite charge on two objects.

Order Information

Charge Sensor

(PASPORT) PS-2132

(ScienceWorkshop) CI-6555

Recommended:

Faraday Ice Pail ..... ES-9042A p. 207

Voltage

UI-5100

ANALOG sensor

- For use with 500, 750, 850 and 550 interfaces
- Standard banana plugs and alligator clips



This voltage sensor plugs into any analog channel on a ScienceWorkshop Interface, the 850 Universal Interface, and the 550 Universal Interface. The voltage range and frequency response depend on the interface. When the voltage sensor is plugged into either the 550 or 850 Universal Interface, the sensor is automatically recognized.

Specifications

Voltage Range: ±15 V AC/DC (850 interface)
±10 V AC/DC (other than 850)
Pin Configuration: 8-pin DIN plug
Probe ends are standard banana plugs.
Two alligator clip adapters included.

Order Information

Voltage Sensor UI-5100

Voltage

UI-5110 (Shrouded)

ANALOG sensor

- For use with 500, 750, 850 and 550 interfaces
- Shrouded banana plugs and alligator clips



Similar to the UI-5100 shown above, but has shrouded banana jacks and shrouded alligator clips.

Order Information

Voltage Sensor (Shrouded) UI-5110

Voltage/Current

PS-2115

DIGITAL sensor



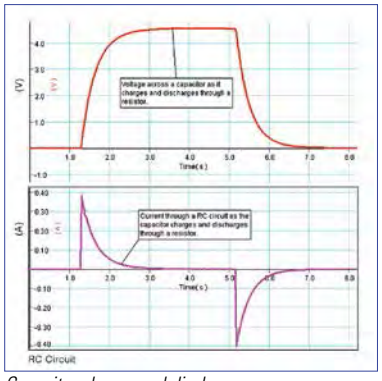
The Voltage/Current Sensor combines both sensors in one case. This multi-measure probe uses only one connection so a single USB link can be used. With overload protection, audible overload notification and automatic reset this sensor provides an ideal student measurement tool.

Typical Applications

- Study circuit properties for both series and parallel electrical circuits
- Study the relationship of voltage and current in series-parallel circuits (Ohm's Law)
- Measure power used by an electrical device (P = I * V)
- Measure resistance of any circuit element (R = V / I)

Specifications

Voltage Range: ±10 V, resolution of 0.005 volts
Current Range: ±1 A, resolution of 0.5 mA
Current Channel Series Resistance: 0.6 ohms, < 0.9 ohms at room temperature
Maximum Common Mode Voltage: 10 V
Maximum Sample Rate: 1000 samples/sec
Voltage Input Impedance: 2 MΩ



Capacitor charge and discharge across an RC circuit and resulting voltage change.

Order Information

Voltage/Current Sensor (PASPORT) PS-2115

Recommended:
Alligator Clip Leads (set of 10) EM-8634

Current

CI-6556

ANALOG sensor



- 1 Ω sensing resistor

The Current Sensor determines the current through it by measuring the voltage across the internal 1.00 Ω resistor. Up to 1.5 A can be measured.

Specifications

Maximum Current Input: 1.5 A*
Maximum Differential Voltage: 1.5 V*
Maximum Common Mode Voltage: 10 V
Resolution: 5 mA (1X gain), 0.5 mA
(*DC or AC RMS (root mean square)

Order Information

Current Sensor (ScienceWorkshop) CI-6556

High Current

CI-6740

ANALOG sensor



- Measures up to 10 A
- Isolated circuit

The High Current Sensor is ideal for circuits in which the current exceeds 1 A. It uses a Hall Effect chip, and thus it has a negligible internal resistance and will not influence the current measurements from the circuit. The sensor includes a 10 A fuse which can be easily replaced.

Specifications

Maximum Current Input: +/- 10 A
Maximum Voltage Input: +/- 30 V
Frequency Response: DC – 10 KHz
Fuse: 10 A, Fast Acting (Replaceable)

Order Information

High Current Sensor (ScienceWorkshop) CI-6740

BNC Adapter

CI-6685

ANALOG sensor



This adapter allows BNC-terminated cables (such as oscilloscope probes) to be connected to a ScienceWorkshop Interface.

Order Information

BNC Adapter (ScienceWorkshop) CI-6685

High Current

PS-2193

DIGITAL sensor



- 10 Amp
- Over-current LED

The High Current Sensor has a low (0.01 Ω) resistance sensing element, can measure up to 10 A, and has an LED over-current indicator. Dynamic variable over-sampling greatly reduces the measurement noise at low sample rates.

Specifications

Current Range: ± 10 A, resolution of 0.5 mA

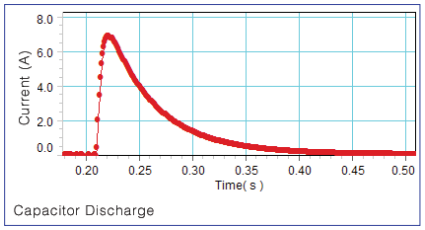
Sensing Element Series Resistance: 0.01 Ω

Maximum Common Mode Voltage: 10 V

Maximum Continuous Current Without Damage: 12 A

Maximum Continuous Overvoltage Without Damage: ±40 V

Maximum Sample Rate: 1000 samples/second



The capacitor is charged with a power supply to 10 volts, and then discharged through the Air Core Solenoid. The graph of the data shows the effect of the coils inductance on the rise time of the current.



Order Information

High Current Sensor (PASPORT) PS-2193

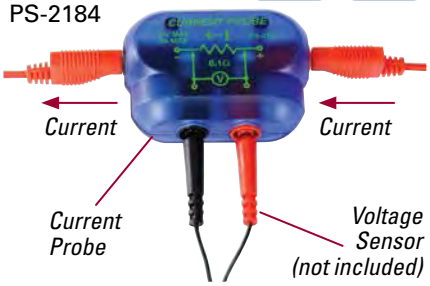
Shown in use with:

Capacitor (0.025 F) 2 pack	EM-8632	p. 215
Switch Set (SPST) 6 pack	EM-8815	p. 216
Air Core Solenoid	SE-7585	p. 226

Current Probe

DIGITAL sensor ANALOG sensor

PS-2184



The PS-2184 attaches to a PASCO voltage sensor to allow the measurement of current between -4 A and +4 A. The probe contains a precision 0.10 ohm resistor and allows the precise measurement of the voltage drop across the resistor.

Specifications

Resistor: 0.10 Ohm, 3.0 W, 1.0%
Maximum Current: 4 A
Maximum Voltage Without Damage: 30 V
Terminals: 4 mm Banana Jacks

Order Information

Current Probe PS-2184
(PASPORT/ScienceWorkshop)

1 MHz 2-Channel Voltage Sensor

PS-2190

DIGITAL sensor



- Measure two channels at sample rates up to 1 MHz



The Voltage Sensor measures two channels simultaneously at up to 1 MHz sampling rate. It has three gain settings with full-scale input ranges of ±10 V, ±1 V, and ±0.1 V. Shown in use with the RLC Circuit Board.

Specifications

Two differential channels
1 MHz max sample rate
±10 V max input
Three gain settings
Overvoltage protection

Order Information

1 MHz 2-Channel Voltage Sensor (PASPORT) PS-2190

Shown in use with:

RLC Circuit	CI-6512	p. 209
Short Patch Cords	SE-7123	p. 214

Galvanometer

DIGITAL sensor

PS-2160



The Galvanometer Sensor is designed to measure small voltages with high resolution. Dynamic variable over-sampling greatly reduces the measurement noise at low sampling rates. Shunt resistors are included to allow measurement of current.

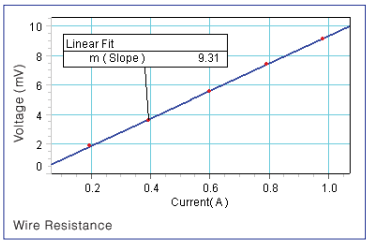
Specifications

Voltage Range: ±2000 mV, resolution of 0.1 mV

Maximum Sample Rate:
5000 Hz with the 850 and Xplorer GLX
1000 Hz with other interfaces

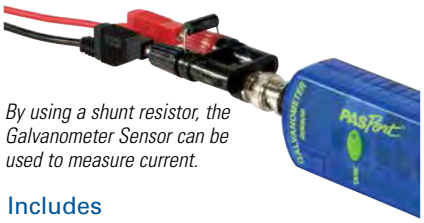
Input Impedance: 1 MΩ





Galvanometer Sensor can measure the voltage drop across a short piece of wire.

A linear fit of voltage versus current yields the resistance of 0.0093 Ω for the wire.



By using a shunt resistor, the Galvanometer Sensor can be used to measure current.

Includes

BNC-to-banana plug cable
BNC-to-banana jack adapter
0.1 Ω and 10 Ω resistors

Order Information

Galvanometer Sensor (PASPORT) PS-2160

Recommended:
Alligator Clip Leads (set of 10) EM-8634

Magnetic Field

PS-2112



The Magnetic Field Sensor provides magnetic field measurement in a compact package. The sensor at the tip of the probe measures magnetic field strength along the axis of the probe.

Typical Applications

- Study the field strength of bar magnets and electromagnets
- Understand the field strength of a solenoid
- Measure the field strength of a Helmholtz coil

Specifications

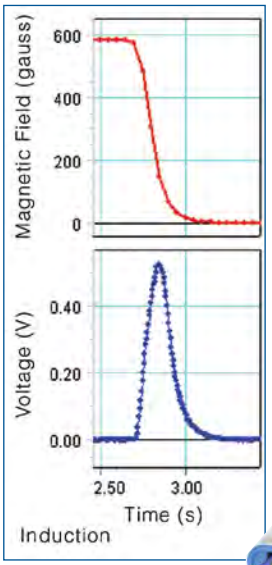
Range: ±1000 gauss

Accuracy: ±3 gauss or 5% of reading, whichever is greater @ 25°C (after four minute warm-up)

Resolution: 0.1 gauss (0.01% full-scale)

Maximum Sample Rate: 20 Hz

Repeatability: 0.05%



As the magnet is removed from the coil, a voltage is induced in the coil. The graph shows both the sudden decrease in magnetic field, as well as the voltage curve using a Voltage/ Current Sensor.



Shown with: SPARKlink (PS-2009), Coil (3200 turn) (SF-8613), Bar Magnet (EM-8620), and Voltage/Current Sensor (PS-2115).

Order Information

Magnetic Field Sensor PS-2112

Magnetic Field

CI-6520A



- Measures radial or axial fields
- Tare button

PASCO's Magnetic Field Sensor is sensitive enough to detect Earth's magnetic field.

Its application in the physics lab includes measuring and plotting fields in single or Helmholtz coils, solenoids, electromagnets and magnets.

Features

Measures radial or axial fields:
Two switch-selectable Hall Effect sensors measure either radial or axial fields.

Tare button: Zeroing or nulling out existing fields is accomplished by pushing the Tare button.

Three switchable ranges of sensitivity: Full scale ranges of 10, 100 and 1,000 gauss. Measurements from Earth's magnetic field to strong magnets.

7.5 cm probe: Sensors are mounted at the end of a fully encapsulated 7.5 cm long probe.

Specifications

Sensitivity:
± 10 gauss, 50 mG resolution;
± 100 gauss, 50 mG resolution;
± 1000 gauss, 500 mG resolution

Measurement Modes: Axial and Radial

Probe Length: 7.5 cm

Pin Configuration: 8-Pin DIN plug on case

Order Information

Magnetic Field Sensor CI-6520A

Recommended:
Zero Gauss Chamber EM-8652

Zero Gauss Chamber

EM-8652



This double-walled, high permeability metal chamber produces a zero gauss field within the chamber. By placing the Magnetic Field Sensor probe into the chamber and pushing the "Tare" button, the sensor may be zeroed. Highly recommended for measurement of Earth's magnetic field.

Order Information

Zero Gauss Chamber EM-8652

2-Axis Magnetic Field

PS-2162



- Measures radial and axial fields
- Tare button

Measure Radial and Axial Fields simultaneously. Dynamic variable over-sampling greatly reduces noise at low sample rates.

Typical Applications

- Measure Earth's magnetic field.
- Measure magnetic field (magnitude and direction from a coil or a bar magnet).

Specifications

Range: ±1000 gauss

Accuracy: 5% of reading @ 25°C (after four minute warm-up and Tare using Zero Gauss Chamber)

Resolution: 0.01 gauss @ 10 Hz

Maximum Sample Rate: 1000 Hz

Repeatability: 0.05%

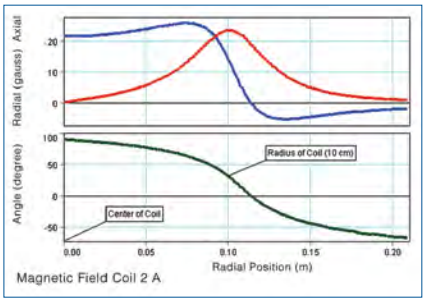
Includes

Sensor handle and sensor extension cable.

Shown with: Rotary Motion Sensor (PS-2120), Linear Motion Accessory (CI-6688), Field Coil (EM-6711).



Magnetic field is measured from the center out to twice the radius of the coil. The angle of the resultant field is calculated.



Order Information

2-Axis Magnetic Field Sensor (PASPORT) PS-2162

Recommended:
Zero Gauss Chamber EM-8652
Linear Accessory Kit ..... CI-6688A p. 28

Sound Level

PS-2109

DIGITAL sensor

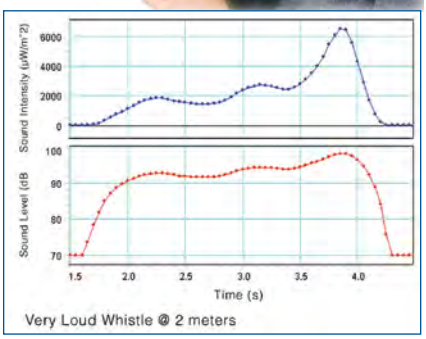


The Sound Level Sensor is designed to measure the intensity level of sound sources within proximity to the sensor. The sensor features three range switches to match the intensity range of the measured phenomena.

The sensor measures sound level in both the dBA and dBC scales. The dBC scale includes all frequencies incident on the Sound Level Sensor, whereas the dBA scale filters out some frequencies to more closely match the frequency response of the human ear.

The sensor also reports a measurement of sound intensity in µW/m2, which is calculated from the dBC measurement of the sound level.





Graph shows sound level from a loud whistle in both intensity (µWatts/m²) and in decibels. Notice the difference in scales.

Typical Applications

- Explore sound levels outside the classroom
- Discover the logarithmic relationship between sound level and sound intensity

Specifications

Range: Sound Level Intensity
30 dB to 70 dB; 10^{-3} µW/m² to 10 µW/m²
50 dB to 90 dB; 1 µW/m² to 1000 µW/m²
70 dB to 110 dB; 10 µW/m² to 10,000 µW/m²
Max Sample Rate: 20 Hz
Accuracy: ±2 dB at 94 dB (1000 Hz)
Resolution: 0.1 dB

Order Information

Sound Level Sensor (PASPORT) PS-2109

Sound

CI-6506B

ANALOG sensor



Measures sound waveform

The Sound Sensor houses a sensitive microphone designed to display audio waveforms of sound levels between 45 and 100 dB.

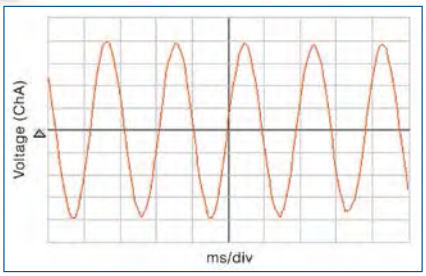
Typical Applications

- Measure basic sound intensity
- Measure speed of sound measurement
- Measure beats
- Study the doppler effect
- Conduct voice studies
- Learn musical instrument overtones

Specifications

Frequency Response: 20 to 7,200 Hz
Decibel Range: 45 to >100 dB
Signal-to-Noise Ratio: < 60 dB
Amplification: Two stages condition low-level signals
Pin Configuration: 8-pin DIN plug on case





This oscilloscope display shows the sinusoidal nature of a "middle C" tuning fork (261 Hz).

Order Information

Sound Sensor (ScienceWorkshop) CI-6506B

Temperature/Sound Level/Light

PS-2140

DIGITAL sensor



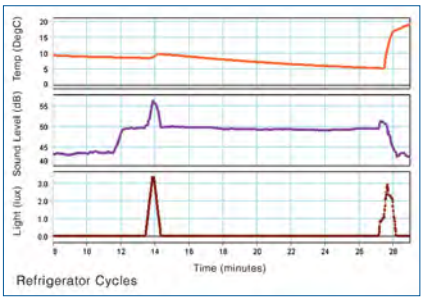
Launch students into an instant exploration of their environment! The Temperature/Sound Level/Light Sensor allows students to conduct all three measurements simultaneously and continuously. Add an optional Stainless Steel Temperature Probe (PS-2153) to conduct water studies.

Typical Applications

- Measure the temperature difference between the floor and ceiling
- Determine the light level on a sunny versus cloudy day
- Compare sound levels of students whispering, singing loudly or applauding

Specifications

Temperature (internal) Range: -10 to +50°C
Sound Level Range: 40 to 90 dBA
Light Range: 0 to 5000 lux
Maximum Sample Rate: 5 Hz



The temperature, light intensity, and sound level are simultaneously measured inside a refrigerator. Note the changes in measurements as the compressor starts and as the door is opened.

Order Information

Temperature/Sound Level/Light Sensor (PASPORT) PS-2140

Recommended:
Stainless Steel Temperature Probe PS-2153

General Science Sensor

PS-2168



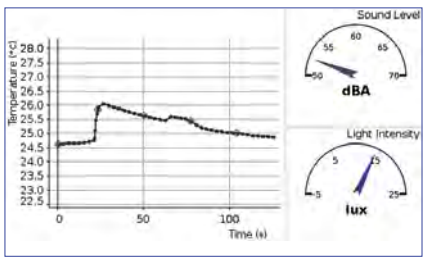
Simultaneously measure temperature, light, sound level and voltage. Great for a variety of general science explorations.

Specifications

Temperature*: –35°C to +135°C; ±0.5°C
*Range is probe dependent.
Light: 3 user selectable light ranges:
0 to 100; 0 to 10,000; 0 to 150,000 Lux
Sound Level: 50 to 100 dbA
Voltage: ±24 V
Voltage Protection: up to 240 V
Maximum Sample Rate: 200 Hz



Sensor has three selectable ranges for low, indoors, and outdoor measurements.



Includes

Stainless Steel Temperature Probe
Voltage Probe

Order Information

General Science Sensor (PASPORT) PS-2168

Recommended:
Charge/Discharge Circuit ..... EM-8678A p. 208

Chemistry

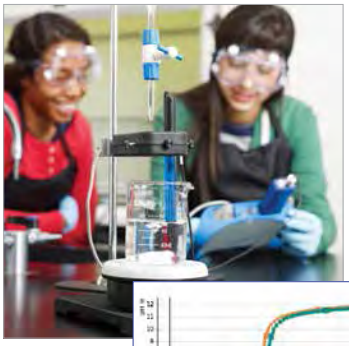
PS-2170

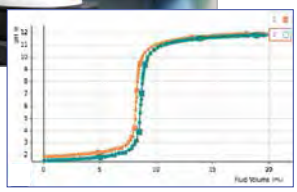


Gas laws, acid/base, thermochemistry and redox all with one sensor! Measure temperature, pH, gas pressure and voltage. Easy to store. Easy to use. All measurements can be made simultaneously.

Specifications

Temperature*: –35°C to +135°C, ±0.5°C
pH*: 0 to 14, ±0.1 (with calibration)
Absolute Pressure: 0 to 700 KPa
Voltage: ±10 V
Maximum Sample Rate: 100 Hz
*Ranges are probe dependent.





Multiple trials of titration curves can easily be collected in one class period using the High-Accuracy Drop Counter, Magnetic Stirrer and PASCO's software tools.

Includes

pH Probe
Stainless Steel Temperature Probe
Voltage Probe
Gas Law Syringe with Tubing

Order Information

Chemistry Sensor (PASPORT) PS-2170

Advanced Chemistry Sensor

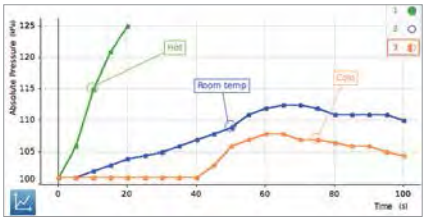
PS-2172



The Advanced Chemistry Sensor measures pressure, temperature, pH, and conductivity. Explore electrolytes, acid-base reactions, gas laws, and thermochemistry. Acid-base, thermometric, and conductometric titrations are now possible individually or simultaneously, all with this one sensor!

Specifications

Temperature*: –35°C to +135°C, ±0.5°C
pH*: 0 to 14, ±0.1 (with calibration)
Absolute Pressure: 20 to 400 KPa
Voltage: -2000 mV to +2000 mV
Maximum Sample Rate: 100 Hz
*Ranges are probe dependent.



Determine the effect of temperature on the rate of a reaction.

Includes

Stainless Steel Temperature Probe
pH Probe
Conductivity Probe
Built-in Pressure Sensor
60cc syringe, tubing and quick-release connectors (not shown)

Order Information

Advanced Chemistry Sensor (PASPORT) PS-2172

Micro Stir Bar

PS-2565

The Micro Stir Bar maintains a constant flow of solution over the end of the electrode, such as in the pH and conductivity probes.
For use with a standard stir plate and cylindrical probes of about 13 mm diameter.

Magnet is completely sealed to prevent damage from the chemicals.



Order Information

Micro Stir Bar (set of 5) PS-2565

pH

PS-2102 DIGITAL sensor

CI-6507A ANALOG sensor





PASCO's pH Sensor measures the hydronium ion concentration in a solution and reports it as a pH value. This sensor is well-suited for a variety of activities where testing or monitoring of acidity is important.

Typical Applications

- Titrate an acid into a base
- Investigate the chemistry of buffers
- Monitor water quality

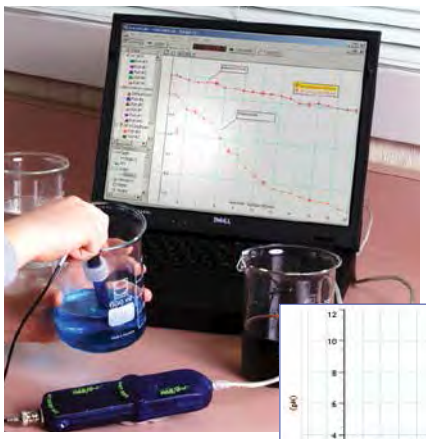
Specifications

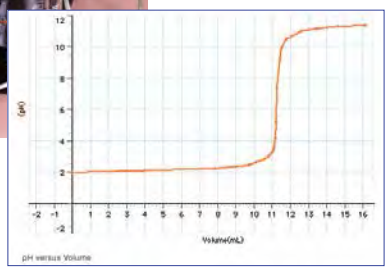
PS-2102 (PASPORT):

Range: 0 to 14
(Probe dependent)
Accuracy: ±0.1*
Resolution: 0.01
Repeatability: 0.02
Electrode: gel-filled Ag-AgCl combination electrode
Maximum Sample Rate: 50 Hz
*After calibration

CI-6499 (ScienceWorkshop):

pH Range: 0 to 14
Electrode: Gel-filled (nonrefillable) Ag-AgCl combination electrode with a membrane resistance of 50 MΩ at 25°C
pH-to-voltage Ratio:
5 pH = 0.1 V
Pin Configuration: 8-pin DIN plug on case





pH vs. volume graph

Order Information

pH Sensor
(PASPORT) PS-2102
(ScienceWorkshop) CI-6507A

pH Replacement Electrode

PS-2573

This is a replacement Electrode for PASCO's pH Sensors. It was previously listed as part number 699-195.



Order Information

pH Replacement Electrode PS-2573

Drop Counter (High Accuracy)

PS-2117 DIGITAL sensor



At last, a professional Drop Counter can become part of your student lab. Our Drop Counter has a wider (18 x 13 mm) drop window for better drop detection and easier alignment with burettes. Works equally well with large or small, fast or slow drops. Easy calibration requires entering just one number into the computer. Includes a Micro Stir Bar for use with our pH and Conductivity Probes (see previous page).

- Measures up to 40 drops per second with drops as small as 0.64 mm.
- Silicone rubber-sealed polypropylene is fluid resistant and protects sensor from mild acids and bases.
- Automatically recalibrates for maximum sensitivity each time the unit is turned on.

Typical Applications

- Determine the equivalence point
- Simple count activities

Specifications

Measures up to 40 drops per second with drops as small as 0.5 mm.

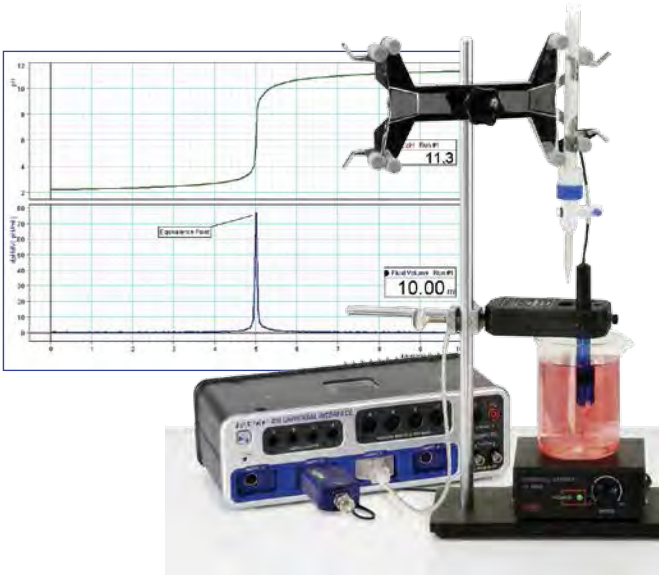
Silicone rubber-sealed polypropylene is fluid resistant and protects sensor from mild acids and bases.

Automatically recalibrates for maximum sensitivity each time the unit is turned on.

Holds up to three probes in a 150 mL beaker.

LED drop indicator

IR filter rejects all visible light – not susceptible to variations in room lighting.



Order Information

High Accuracy Drop Counter
(PASPORT) PS-2117

ISE – Precision pH/ORP/ISE Amplifier with Temperature

PS-2147

DIGITAL sensor



This high-precision sensor is ideal for Chemistry. Right out of the box students will be able to measure pH and temperature with the same sensor because the PS-2147 comes with a pH probe and a Fast Response Temperature Probe. The new ORP probe (CI-6716) can be purchased separately to measure the Oxidation Reduction Potential of a sample. With the addition of Ion-Selective Electrodes (not included) students will be able to measure ion concentration in upper division Chemistry classes or samples brought back from the field.

Because all Ion-Selective Electrodes use the same amplifier box, each lab group needs one amplifier box plus the desired electrodes. See below for a complete list of available Ion-Selective Electrodes.

Typical Applications

- Determine the concentration of a specific ion in a solution
- Conduct water quality studies

Special Features

The PS-2147 functions with PASCO Ion-Selective Electrodes, PASCO pH Electrode, and most third-party ion-selective electrodes.

Specifications

Electrode Connector: Standard BNC
Input Impedance: 10^{12} ohms (preserves output voltage of the electrode)
Range: -2000 mV to 2000 mV; 0.1 mV resolution
Range: 0 to 14 pH 0.001 pH resolution (probe dependent)
Temperature Range: -10°C to +70°C*
Temperature Resolution: .0025°C
Temperature Accuracy: 0.5°C
Maximum Sample Rate: 50 Hz
Range is probe dependent.

ORP Probe CI-6716 can be used with the PS-2170 Chemistry Sensor and the PS-2147 ISE/ORP Amplifier.

Order Information

Precision pH/ORP/ISE Temperature Sensor (PASPORT) PS-2147
ORP Probe CI-6716

Ion-Selective Electrodes:
Can be used with the PS-2170 Chemistry Sensor and the PS-2147 ISE/ORP Amplifier.

Electrode	Molar Range	pH Range	Interfering Ions	Part #
Ammonium (NH_4^+)	1.0 to $5x10^{-6}$	4-10	Cs^+, K^+, $T1^+$, H^+, Ag^+, $+Tris^+$, Li^+, Na^+	CI-6717
Carbon Dioxide (CO_2)	$1x10^{-2}$ to $1x10^{-4}$	4.8-5.2	Volatile weak acids	CI-6726
Calcium (Ca^{+2})	1.0 to $5x10^{-6}$	3-10	Pb^{+2}, Hg^{+2}, Cu^{+2}, Ni^{+2}	CI-6727
Chloride (Cl^-)	1.0 to $5x10^{-5}$	2-12	S^{-2}, I^-, CN^-, Br^-	CI-6732
Lead (Pb^{+2})	$1x10^{-1}$ to $1x10^{-6}$	3-8	Ag^+, Hg^{+2}, Cu^{+2}, CD^{+2}, Fe^{+2}	CI-6736
Fluoride (F^-)	Saturated to $1x10^{-6}$	5-8	OH^-	CI-6728
Nitrate (NO_3^-)	1.0 to $7x10^{-6}$	2.5-11	ClO_4^-, I^-, CN^-, BF_4^-	CI-6735
Potassium (K^+)	1.0 to $7x10^{-6}$	2-12	Cs^+, NH_4^+	CI-6733
Sodium (Na^+)	Saturated to $1x10^{-6}$	5-12	H^+, K^+, Li^+, Ag^+, Cs^+, Tl^+	CI-6734

G-M Tube/Power Supply

SN-7927A

ANALOG sensor DIGITAL sensor *with Digital Adapter**

- Ideal general purpose nuclear sensor

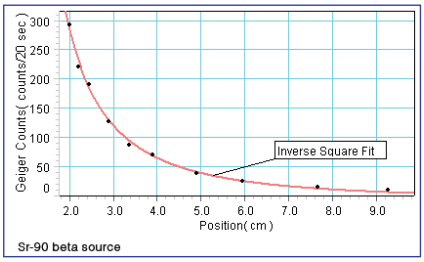


The G-M Tube/Power Supply senses alpha, beta and gamma radiation. Power for the tube is supplied through the connection to an interface that supplies an operating voltage of +5 V.



Specifications

Sensitivity: Beta, Gamma, Alpha
Count Detection: Audio signal
Window Thickness: 1.5 to 2 mg/cm^2, mica
Gas Filling: Neon, Argon and Halogen
Starting/Operating Voltage for tube: 450 VDC/500 VDC
Dead Time: 90 µs



The number of counts per time interval drops off as the distance between the detector and the radioactive source is increased.

The G-M Sensor can be attached directly to the rack on a Rotary Motion Sensor to measure (real-time) the count rate as a function of distance from the source.

Order Information

G-M Tube/
Power Supply SN-7927A

**Required for use with PASPORT Interfaces:*
Digital Adapter ..... PS-2159 p. 41

Colorimeter

PS-2121

DIGITAL sensor



The Colorimeter Sensor allows a solution's concentration to be determined based on the ability of the solution to transmit or absorb colored light. PASCO's PASPORT Colorimeter is the perfect tool for analyzing reactions indicated by color changes, or reactions where concentration changes over time. The sensor's black, opaque housing assures accuracy of data. The Colorimeter is packaged in a sturdy plastic case with five empty glass cuvettes so students can begin experimenting immediately.

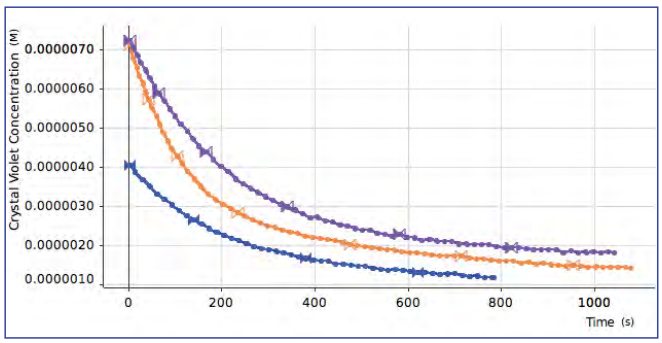
Typical Applications

- Study absorbance vs. concentration (Beer's Law experiments)
- Determine the concentration of an unknown solution
- Measure reaction rates
- Measure four wavelengths simultaneously

Specifications

Range: 0 to 100% transmittance
Accuracy: ±0.5% transmittance
Resolution: 0.1% transmittance
Operating Temperature: 0°C to 40°C





The concentration of crystal violet decreases as it reacts with the sodium hydroxide in the cuvette. The various starting conditions allow the order of the reaction to be calculated using the initial rate method.

Order Information

Colorimeter Sensor (PASPORT) PS-2121
Replacement Cuvettes/Caps (6 each) PS-2509

Colorimeter

CI-6747

ANALOG sensor



PASCO's ScienceWorkshop Colorimeter shines a light through a solution and measures the percent transmittance. Connect to an interface or operate portably in a stand-alone mode. A two-line LCD display prompts you through the measurement process. Automatic calibration saves time and improves accuracy. Water resistant cuvette holder reduces exposure of optics and electronics to sample spills.

Typical Applications

- Verify Beer's Law
- Monitor reaction rates for reactions that involve color changes, water clarity, etc.

Specifications

Transmittance Range: 0 to 100% transmittance with 0.1% resolution

Wavelengths: 470 nm (blue), 565 nm (green), 635 nm (orange) and 697 nm (red)

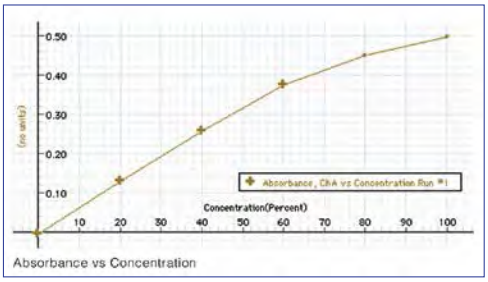
LCD Display: Updates every 0.5 seconds

Pin Configuration: 6-pin mini-DIN socket

Includes 15 cuvettes and a six foot cable (6-pin mini-DIN to 8-pin DIN) for connection to ScienceWorkshop Interfaces.

Batteries (four "AA" cells) not included.





Typical Beer's Law Standardization curve showing absorbance vs. concentration.

Order Information

Colorimeter Sensor (ScienceWorkshop) CI-6747

Replacement Supplies:

Cuvettes and Caps SE-8739
(includes 100 cuvettes and 20 caps)

Chemistry

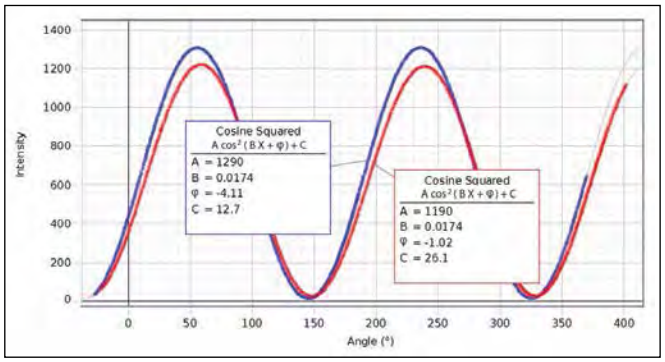
Polarimeter

PS-2235



- For Chromebook™, iPad® and Computers
- Measure the optical rotation of chiral compounds.

PASCO's new Polarimeter has both Bluetooth® and USB connectivity, so it works on your iPad®, Chromebook™, and computers. It is ideal for introductory Organic and Biochemistry experiments with chiral compounds. Plane polarized light is passed through a sample which contains a chiral compound, to an analyzer and a detector. The degree of optical rotation of the plane polarized light is based on the type and amount of sample present. Determine the concentration of a sugar solution based on the optical rotation of plane polarized light.



Determine the concentration of a sugar solution based on the optical rotation of plane polarized light

Specifications

Bluetooth® and USB connectivity
589 nm LED light source
Accuracy = ± 0.09° optical rotation
SPARKvue- and Capstone-compatible
Industry-standard, horizontal polarimeter sample cell (100 mm)



Includes

Polarimeter and one Sample Cell

Order Information

Polarimeter PS-2235
Also available:
Polarimetry Sample Cell Replacement PS-2234

Polarimetry Demonstration

Introduce the concept of polarimetry with this colorful demonstration. Fill one jar with water and the other with a sugar solution. Rotate the front polarizer to show the optical rotation.



Light source not included.
See page 275 for more details.

Order Information

Polarimetry Demonstration
Required:
Polarizer Demonstrator OS-9477A
Polarization Demonstrator Accessory OS-8172

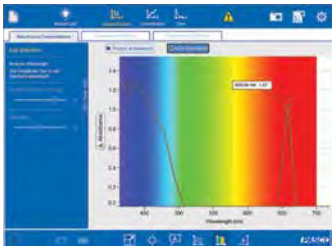
Wireless Spectrometer

PS-2600



- For iPad®, and Computers
- Measure intensity, absorbance, transmittance, and fluorescence

The Bluetooth and USB connectivity enable use with your iPad and computers, which makes this a powerful and intuitive tool for your spectrometry needs.





Absorbance spectrum of chlorophyll

Perform these labs with the PASCO Spectrometer:

Quantify photosynthesis with DPIP
Measure the absorption spectrum of plant pigment
Calculate concentration of DNA and proteins in solution
Determine the rate of an enzyme-catalyzed reaction
Follow the growth of a cell culture

Specifications

Connectivity: Bluetooth and USB connectivity
Resolution: 2–3 nm FWHM
Range: 380–950 nm
Optical Resolution: 2 fluorescence excitation wavelengths at 405 nm and 500 nm
Light Source: LED-boosted tungsten

The PASCO Spectrometer comes with PASCO's new FREE spectrometry software.

- PC and Mac versions included with purchase.
- FREE for iOS tablets.
- Designed specifically for spectrometry experiments.

Includes

Includes PASCO Spectrometer, Spectrometry software, and 10 cuvettes.



Order Information

Wireless Spectrometer PS-2600
Required for External Light Sources:
Fiber Optics Cable ..... PS-2601 p. 279

CO_2 Gas

PS-2110



The CO_2 Gas Sensor measures carbon dioxide concentration in the atmosphere or in an enclosed volume, such as a terrarium. Using the included 250-ml sample bottle, students can even measure the exhalation of small organisms such as crickets. PASCO's proprietary design uses infrared detection to measure the energy absorbed by carbon dioxide molecules.

Typical Applications

- Measure CO_2 uptake during photosynthesis in a terrarium
- Compare indoor vs. outdoor CO_2 levels
- Study cellular respiration of yeast

Specifications

Range: 0 ppm to 300,000 ppm

Accuracy: For range of 0 to 10,000 ppm: 100 ppm or 10% of value, whichever is greater

Calibration: User presses one button while sampling outside air

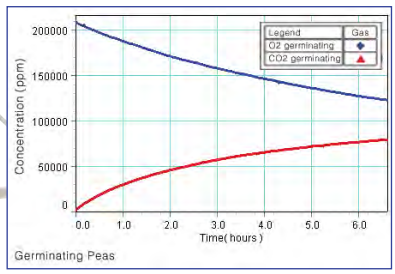
Default Sample Rate: CO_2 concentration updates once each second

Operating Temperature: 20°C to 30°C

Maximum Sample Rate: 10 Hz



Place 25 germinating Alaska peas in the Metabolism Chamber at room temperature. Measure CO_2 gas and O_2 gas in the chamber with the Carbon Dioxide Gas sensor and the Oxygen Gas sensor. Collect and analyze the data for oxygen gas consumption and carbon dioxide gas production by the germinating pea seeds.



O_2 and CO_2 Concentration (ppm) vs. Time (hours)

O_2 Gas

PS-2126A



PASCO's Oxygen Gas Sensor accurately measures oxygen concentration in the atmosphere or in enclosed spaces, such as terrariums. The sensor's wide range (0-100%) means students can use it with any experiment or investigation. Use in combination with the CO_2 Gas Sensor to perform an even wider variety of environmental and physiology activities in the classroom or in the field.

Specifications

Flow Range: 0 to 100% oxygen concentration

Accuracy: ±1% (at constant temperature)

Resolution: 0.025%

Maximum Sample Rate: 100 Hz

Probe Shelf-life: Three years

Typical Applications

- Measure the respiration of animals, insects or germinating seeds
- Study the catalase breakdown of hydrogen peroxide
- Monitor O_2 level changes during photosynthesis in a terrarium
- Study cellular respiration of yeast

Special Features

Single point calibration requires just the touch of a button

Automatic temperature compensation ensures consistent measurements

Usable in any orientation

Ethanol Sensor

PS-2194



The PASPORT Ethanol Sensor measures the concentration of gaseous ethanol up to 3%. In biology and environmental science labs, students can learn about anaerobic respiration by measuring the production of ethanol by bacterial or yeast fermentation. Physics and chemistry students can begin to explore combustion and thermodynamics. Connect your students to the study of respiration and alternative energy sources with the PASPORT Ethanol Sensor.

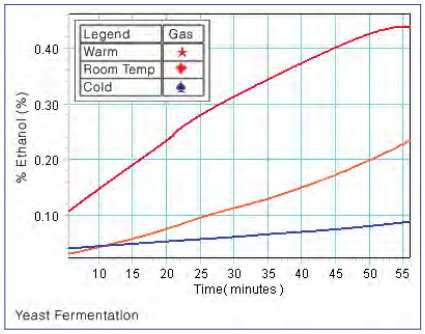
Specifications

Accuracy: 20% of reading

Range: 0% to 3% gaseous ethanol



Students can vary environmental conditions such as temperature and determine the impact on the rate and type of cellular respiration taking place. In this example, as the temperature increases, the rate of ethanol production is also increasing.



Order Information

CO_2 Sensor (PASPORT)	PS-2110
O_2 Sensor (PASPORT)	PS-2126A
Shown in use with:	
Metabolism Chamber	ME-6936
Replacement Oxygen Electrode	PS-6524
PASPORT Extension Cable	PS-2500

Order Information

Ethanol Sensor (PASPORT)	PS-2194
Shown in use with:	
EcoChamber	ME-6667
Magnetic Stirrer	SE-7700

Optical Dissolved Oxygen

PS-2196

DIGITAL sensor



The PASCO Optical Dissolved Oxygen Sensor makes it easier than ever before to measure dissolved oxygen in the field or lab environment. The luminescent technology has several advantages over galvanic DO sensors including;

- No flow dependency – no stirring required
- No warm-up time
- No calibration required
- Low maintenance – no filling solution and electrode polishing
- Built-in temperature and pressure compensation
- Ability to measure gaseous as well as dissolved oxygen

Specifications

Cable Length: 3 m
Response Time: 90% in 25 sec
Operating Temperature: 0–50°C
Operating Pressure: 375–825 mmHg
Range: 0–20 mg/L or 0–300% saturation
Accuracy:
±0.6 mg/L or ±3.0% out of box
±0.1 mg/L or ±1.0%, whichever is greater after calibration
Above 200% ± 10%

Order Information

Optical Dissolved Oxygen Sensor (PASPORT) PS-2196
Recommended:
Optical Dissolved Oxygen Sensor Replacement Cap PS-2587

Optical Dissolved Oxygen Sensor Metal Guard

PS-2588

Includes

Stainless steel sleeve



Order Information

Optical Dissolved Oxygen Sensor Metal Guard PS-2588

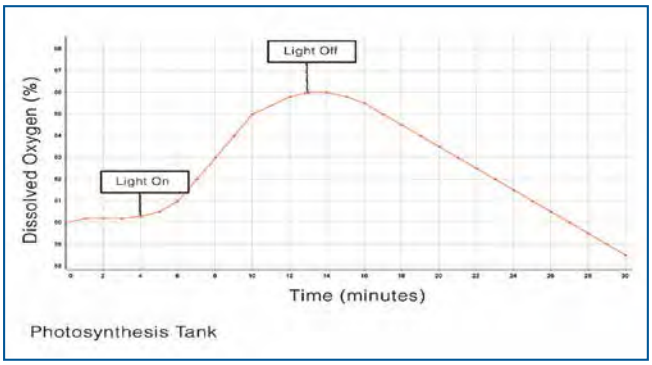
Photosynthesis Tank

PS-2521B

- Measure O_2 production directly
- Control the environment of the aquatic plant
- Study changes in photosynthesis/respiration rates

Typical experiments involving photosynthesis require students to infer photosynthetic rate changes by using chloroplasts and dye. Help students understand this concept more completely by directly measuring the production of oxygen.





Water in the outer tank is used to control large fluctuations in temperature when the light is used. Students can further their understanding of photosynthetic rates by adding dyes as colored filters.

Includes

Acrylic chamber
Rubber stoppers



Order Information

Photosynthesis Tank PS-2521B
Shown in use with:
Optical Dissolved Oxygen Sensor PS-2196
Magnetic Stirrer SE-7700

p. 61

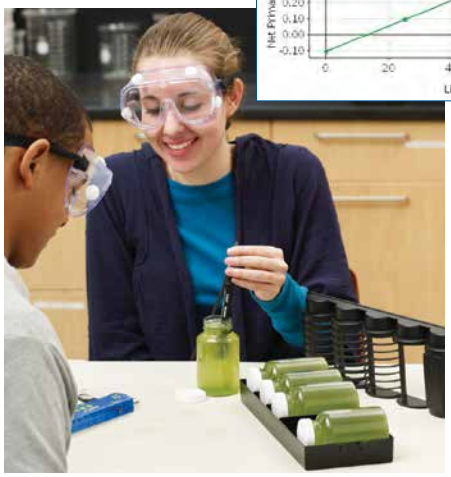
Aquatic Productivity Bottles

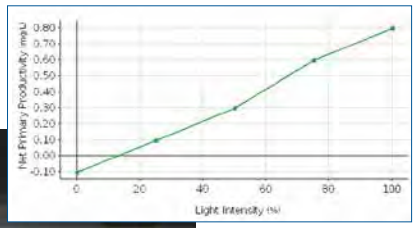
ME-6937

The Aquatic Productivity Bottles rest in a rack that provides consistent and reliable light control for quantitative aquatic productivity studies. The identical transparent bottles nest in each of five rack positions. The custom design of the rack shields the bottles from light by blocking a fixed percentage of light in 25% increments from 0 to 100%.



The Aquatic Productivity Bottles were completely filled with algae solution and the initial dissolved oxygen (DO) concentrations of the solutions were determined with a DO sensor. The bottles were then placed into the rack and the specially molded, light-varying lid was locked into place over the bottles. After 24 hours of incubation in fluorescent light, the bottles were removed from the rack and the DO concentration was again determined with a DO sensor. Using the initial and final (DO), students calculate Net Primary Productivity and Gross Primary Productivity.





Net Primary Productivity (mg/L) vs. Light Intensity (%): notice that for the bottle in the dark, the Net Productivity is negative.

Includes

Plastic bottles w/lids (5)
Case with slotted lid



Order Information

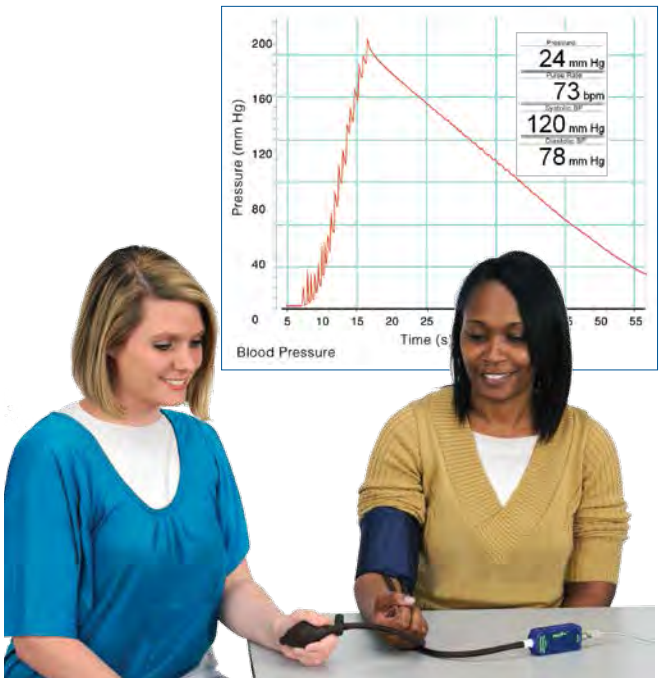
Aquatic Productivity Bottles	ME-6937
Shown in use with:	
Optical Dissolved Oxygen Sensor	PS-2196

Blood Pressure

DIGITAL sensor

PS-2207

With PASCO's Blood Pressure Sensor students easily measure heart rate (bpm) and systolic and diastolic arterial blood pressure (mmHg). Students gain a greater understanding of the physiology of the circulatory system when they also learn about the physiology of blood pressure. The systolic and diastolic pressure provided in the digits display can be used by the student to verify their own determination of blood pressure from the graph.



A student "patient" remains still while another student uses the pump to increase the pressure in the cuff. The students observe the graph as the pressure in the cuff slowly decreases. On the digits display, students observe the patient's heart rate and systolic and diastolic blood pressure.

Experiment ideas

- Determine the effects of exercise on blood pressure and heart rate
- Explore the effects of body position on blood pressure and heart rate
- Compare the blood pressure and heart rate of students in the class

Includes

Blood Pressure Sensor, standard arm cuff*, bladder and pressure release valve.

**Small and large cuffs are also available.*



Order Information

Blood Pressure Sensor (PASPORT)	PS-2207
Recommended:	
Blood Pressure Sensor with Small Cuff	PS-2208
Blood Pressure Sensor with Large Cuff	PS-2209
Replacement Parts:	
Small Cuff	PS-2531
Medium Cuff	PS-2532
Large Cuff	PS-2533

Physiology

EKG

DIGITAL sensor

PS-2111



ANALOG sensor

CI-6539A



The EKG Sensor measures electrical signals produced by the heart. As cardiac muscle depolarization and repolarization occur, the EKG trace graphically illustrates the beating of the heart. The sensor comes with 100 self-adhesive conductive patches that are easily removed from the skin after use.

Typical Applications

- Generate a personal EKG graph
- Compare EKG graphs before and after mild exercise

Specifications

PS-2111 (PASPORT):

EKG Waveform:
- Voltage: 0 to 4.5 mV
- Resolution: 4.5 µV
- Sample Rate: 50 to 200 samples per second (sps)
- Default Sample Rate: 200 samples per second (sps)

Heart Rate (Beats):
- Range: 47 to 250 beats per minute (bpm)
- Resolution: 1 beat per minute (bpm)

CI-6539A (ScienceWorkshop):

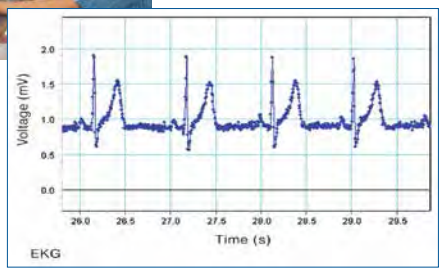
Pin Configuration: 5-pin DIN plug on case

A package of 100 disposable silver/silver chloride electrodes is included.





NOTE: The EKG Sensor has been designed for educational purposes only and is not suitable for medical diagnoses.





Additional EKG Electrode Patches (CI-6620) may be ordered separately.

Order Information

EKG Sensor
- (PASPORT) PS-2111
- (ScienceWorkshop) CI-6539A

EKG Patches (100 each) CI-6620

Exercise Heart Rate

DIGITAL sensor

PS-2129A



The Exercise Heart Rate Sensor measures a student's heart rate before, during, and after physical activity based on electrical signals generated by the cardiac muscle. A belt worn around the ribcage houses a wireless transmitter. The voltage output from the receiver allows PASCO Capstone™ software to produce the heart rate graph.

Typical Applications

- Compare a student's heart rate before, during, and after exercise
- Calculate recovery rate after physical activity
- Determine the effects of mild stimulants (e.g. caffeine)
- Investigate how heart rate changes when a student sits, reclines, stands or moves suddenly

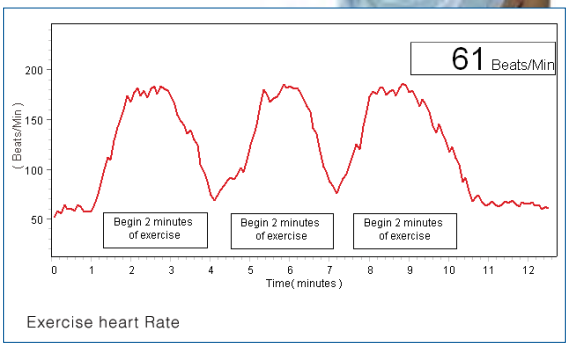
Specifications

Digitally analyzes cardiac signal and determines heart rate

Measures in beats per minute

The electrode belt fits around the ribcage (worn against the skin for best results, but can be worn over a shirt if saline solution is applied under the electrodes) and wirelessly transmits the cardiac signal to the sensor.





Graph shows the heart rate as a student alternates between exercise and resting.

Includes

Exercise Heart Rate Sensor, Transmitter and Belt

Order Information

Exercise Heart Rate Sensor
- (PASPORT) PS-2129A

Replacement Transmitter and Belt PS-2512A

Hand Grip Heart Rate

PS-2186



The Hand Grip Heart Rate Sensor is the easiest way to measure resting and exercise heart rate. Our new design allows students to measure heart rate without the restriction and inconvenience of belts or clips. Extra-long cords allow students to freely increase their physical activity in order to determine exercise heart rate. Simply grip the handles while the sensor measures cardiac muscle contraction in beats per minute.

Typical Applications

- AP® Biology Lab 10: Physiology of the Circulatory System
- Measure and compare resting, exercise, and recovery heart rate to determine physical fitness levels

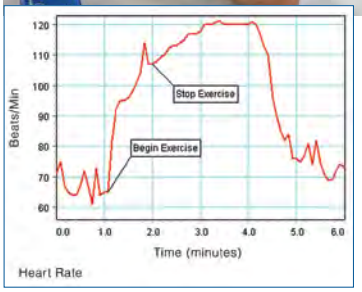
Specifications

Measurement Range:
40-240 beats per minute

Time to acquire heart beat:
8-10 seconds

Typical LED Indicators:
Standby: handgrips not held
Acquire: acquiring heart beat
Beat: flashes with each beat





Order Information

Heart Rate Sensor (PASPORT) PS-2186

Goniometer

PS-2137

- Accurately measures joint movements
- Flexible mounting options



PASCO's Goniometer helps students better understand physics because they use their bodies as the experimental apparatus. The Goniometer can be connected to the knee, hip, or elbow joints to measure angle changes during a variety of movements. Measure the angular position, velocity, and acceleration for the arm or leg. Use with the Xplorer GLX for a compact, easy-to-use human motion lab.

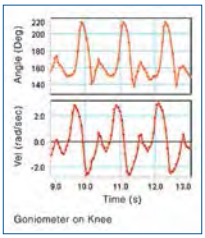
The PS-2137 includes one Angle Sensor (PS-2139) and one Goniometer Probe with Velcro connection kit. To measure the motion of two joints simultaneously, simply purchase another Goniometer Probe separately.

Specifications

Range: 0 to 120°
Accuracy: 2% of measurement
Resolution: 0.25°
Maximum Sample Rate: 500 Hz

Position and velocity of knee joint while running





See page 139 for more information.

Developed in cooperation with Nancy Beverly, Assistant Professor of Physics at Mercy College, Dobbs Ferry, New York.

Order Information

Goniometer Sensor (PASPORT) PS-2137

Recommended:
Additional Goniometer Probe PS-2138
Xplorer GLX ..... PS-2002 p. 18

Angle Sensor

PS-2139



The Angle Sensor measures angle by measuring resistance. It has two ports to accept two Goniometers (PS-2137) or the two probes in the joints of the Human Arm (ME-6807).

Order Information

Angle Sensor (PASPORT) PS-2139

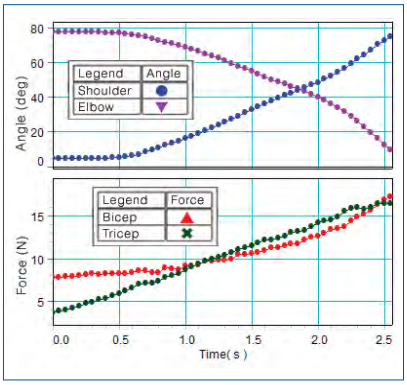
Human Arm Model

PS-2611

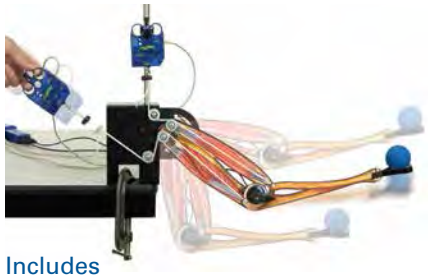


The Human Arm Model simulates the muscles and motion of an actual human arm. To activate the arm motion, students pull on the cord with a Force Sensor. Changes in position are measured at the shoulder and elbow using the two built-in potentiometers plugged into one Angle Sensor (PS-2139), included with PS-2611.

Different arm muscles are activated depending on which pulleys are selected. Static force measurements can also be made to see how the muscle tension changes at various arm positions.



Angles and Forces During Extension: *The upper graph shows the angles of the elbow (violet trace) and the shoulder (blue) as the arm is extended as shown in the picture below. Shown in the lower graph, the bicep tension (red) has little change at first and then rises sharply as the arm reaches out, while the tricep tension (green) rises steadily.*
See page 138 for more information.



Includes

Human Arm Model ME-6807
Angle Sensor PS-2139

Order Information

Human Arm Model (PASPORT) PS-2611

Required for sensor measurement:
PASPORT Force Sensor (2) ..... PS-2104 p. 30

Spirometer

PS-2152



With our Spirometer Sensor students can measure airflow, duration, and lung volume. Disposable mouth pieces available for student safety.

Typical Applications

- Compare a student's airflow before and after exercise
- Investigate the lung volume of athletes vs. non-athletes
- Compare smokers vs. non-smokers
- Conduct respiratory experiments
- Determine total lung capacity

Specifications

Displays volume in liters

Minimal resistance to air flow

Bi-directional air flow

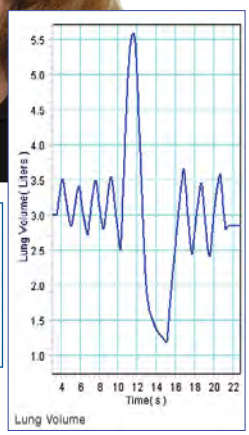
Sample Rate Range: 50 to 100 Hz



Measuring lung capacity.



Replaceable mouthpiece clips



Order Information

Spirometer Sensor (PASPORT) PS-2152

Spirometer Mouth Pieces (10-pack) PS-2522

Breath Rate

PS-2187

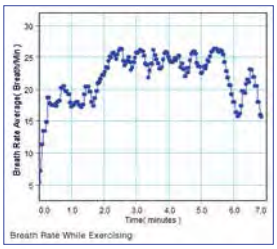
- Works while exercising



The Breath Rate Sensor uses standard disposable dust masks and gives stable output even when exercising. Breath rate is measured by sensing the pressure changes inside the mask. Tubing from the sensor connects to the disposable pressure clips that fasten on the side of the mask.

Two Modes

- One reading every breath
- Running average over last four breaths



Data collected with Xplorer GLX while exercising.



Includes

Sensor with Tubing

Pressure Clips (10)

Masks (10)



Order Information

Breath Rate Sensor (PASPORT) PS-2187

Replacement Clips (10) PS-2568

Replacement Masks (10) PS-2567

Respiration Rate

PS-2133



The Respiration Rate Sensor uses PASCO's Relative Pressure Sensor, along with a Respiration Belt, to measure the change in pressure that occurs as the chest cavity expands and contracts during breathing. The Respiration Belt is wrapped around the lower part of the ribcage at the sternum, and the rubber bladder inside the belt is inflated using the attached squeeze bulb. A second tube connected to the rubber bladder attaches to the Pressure Sensor so that a graph of breath rate can be generated.

Typical Applications

- Conduct comparisons before and after exercise
- Calculate possible correlations between respiration rate and heart rate
- Determine the effects of altitude variation on respiration

Specifications

Maximum Sample Rate: 20 Hz



Order Information

Respiration Rate (PASPORT) PS-2133

Respiration Belt CI-9842

Thermocline

PS-2151

DIGITAL sensor



At last, students can measure temperature as a function of depth in local streams and lakes. PASCO's Thermocline measures depth automatically — no need to read markings on a cable and enter data manually. Weighted housing provides depth measurement stability in fast-flowing streams.

Typical Applications

- Study thermoclines in fresh and salt water environments
- Create depth profiles for streams, small rivers, shorelines, and swimming pools
- Study ocean tides

Specifications

Depth (pressure) -sensing element:

Range: 0 m to 10.5 m

Accuracy: 0.15 m (in fresh water after barometric pressure compensation)

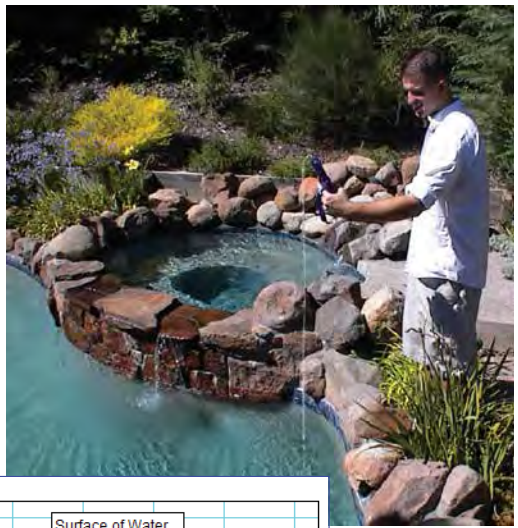
Resolution: 0.03 m

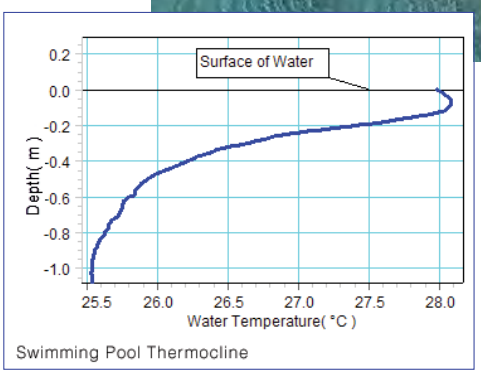
Temperature-sensing element:

Range: 0°C to 100°C

Accuracy: ±1.5°C

Maximum Sample Rate: 10 Hz





The temperature of the water in a swimming pool is measured as a function of depth.

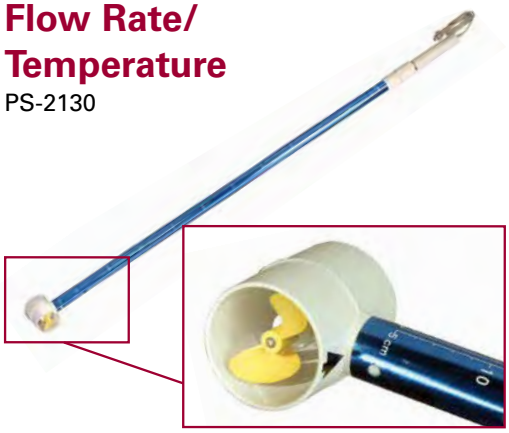
Order Information

Thermocline Sensor (PASPORT) PS-2151

Flow Rate/ Temperature

PS-2130

DIGITAL sensor



PASCO's Flow Rate Sensor allows students to measure the rate of movement and temperature of streams, rivers, and other flowing systems. The propeller is a rugged, single-piece unit encased by protective material — no more losing pieces at the bottom of the stream.

Typical Applications

- Determine sediment transport rate for a stream or other body of water
- Measure and compare flow rate at various locations in a stream
- Compare the characteristics of one stream to another

Specifications

Flow Range: 0 m/s to 3.5 m/s

Temperature Range: -10°C to 50°C

Maximum Length: 1.8 m (6 feet)
Telescoping handle to reach deep levels

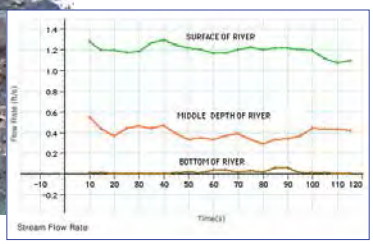
Maximum Sample Rate: 20 Hz

Special Features

Revolutions of a magnet on the submersible propeller are counted and converted to linear flow rate measurements in ft/sec or m/s. Students can use PASCO Capstone™ software to calculate volume discharge rates.

Exclusive built-in temperature sensor conveniently measures temperature at the same point as flow rate.





Graph shows the flow rates at the top (green), middle (orange), and bottom (brown) of a stream.

Order Information

Flow Rate/Temperature Sensor (PASPORT) PS-2130

Salinity

PS-2195

The PASPORT Salinity Sensor works with the 10X Salinity Sensor Probe to measure salinity, conductivity, and temperature. The sensor determines salinity based on electrical conductivity. The sensor has a built in calculation to compensate for the change in conductivity due to temperature change based on the Practical Salinity Scale (PSS).



The Salinity Sensor measures the electric current through a solution between the two platinized platinum electrodes in the Salinity Sensor Probe. The current through the solution is due to the movement of ions, so the higher the concentration of ions in the solution, the higher its conductivity. A voltage (AC) is applied across the two electrodes in the tip of the probe and the measured current is proportional to the conductivity of the solution.

Typical Applications:

- Explore the salinity of local water sources.
- Explore the interrelationship of salinity, temperature, and conductivity.
- Measure the change in the salinity of saltwater as the water evaporates.

Examples of Water Salinity

Fresh water: <0.5 ppt
Brackish water: 0.5 to 30 ppt
Saline water: 30 to 50 ppt
Ocean Water: 35 ppt
Brine: >50 ppt

Specifications

Measurement Ranges:
Conductivity: 1,000 to 100,000 µS
Temperature: 0 to 50°C
Salinity: 1 to 55 ppt ±1% (with calibration)
Sample Rate (maximum): 50 Hz
Temperature Compensation: ±0.5 ppt from 0 to 45°C at 33 ppt
Cell Constant: 10X

Order Information

Salinity Sensor (PASPORT) PS-2195
Recommended:
PASPORT Extension Cable PS-2500

Humidity/Temp/Dew Point

PS-2124A



This PASPORT multisensor is designed for single readings or continuous monitoring of relative and absolute humidity. The sensor also reports temperature, allowing a measurement of dew point, calculated from the humidity measurements and temperature measurements.

Typical Applications

- Conduct weather station experiments
- Check humidity in a terrarium, greenhouse or other enclosure
- Measure dew point

Specifications

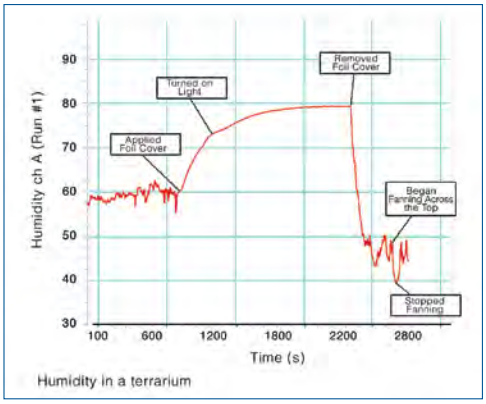
Humidity:
Range: 0 to 100% RH; 0 g/m^3 to 50 g/m^3 AH
Accuracy: ±2% RH; 10% of reading AH

Temperature:
Range: -20°C to +55°C
Accuracy: ±0.5°C

Dew Point:
Range: -50°C to +55°C
Accuracy: ±2°C

Maximum Sample Rate: 10 Hz





Graph shows the humidity in a terrarium, both covered and uncovered.

Order Information

Humidity/Temp/Dew Point Sensor (PASPORT) PS-2124A

EcoZone™ System

ME-6668

- Three EcoChambers, interconnected or stand-alone
- Designed for sensor-based measurements

PASCO's EcoZone System is designed to help students model and understand the complex interactions within, and among, different ecosystems. The three clear acrylic EcoChambers are specially designed to accommodate PASCO sensors, making qualitative and quantitative measurements as easy as observing.

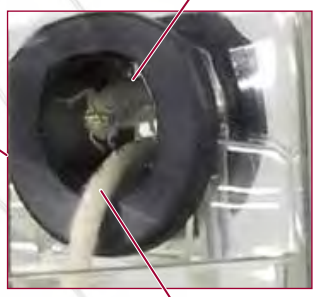
With three interconnected chambers, students can model the interaction between three different ecosystems. Choose the traditional terrestrial, aquatic, and decomposition arrangement or create unique biomes to model and measure. Decouple the system for isolated investigations: how does the availability of light affect the ecosystem? Students can create two identical ecosystems and monitor one in light conditions and one in dark.

Keep the system closed during chemical testing – use the included syringe to extract water. Or inject pollutants into the system and see how the ecosystem responds.





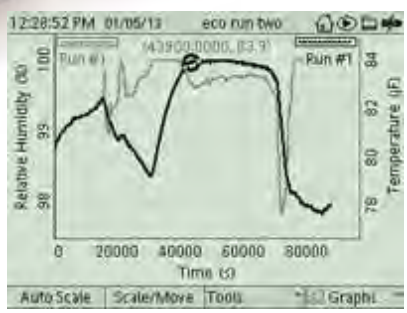
Opening connects the chambers and allows the interaction between the living and non-living components of each unique ecosystem.



The included cord efficiently wicks water between the chambers.

Clean up is easy, and the chambers are durable enough to use again and again. The unique design of the PASCO EcoZone System allows you to use your environmental science probes to actively measure a model ecosystem.*

Decomposition Chamber



Monitor the physical environment!
This graph shows the relationship between the relative humidity and temperature within the terrestrial chamber over a 24 hour period.

Terrestrial Chamber *Aquatic Chamber*



Includes

Three individual EcoChambers with lids

Custom tray for holding EcoChambers in a connected ecosystem

Stoppers and connectors

Cotton wick

Syringe and plastic tubing



*For more information on sensors and probes available for use with the EcoZone System, see **www.pasco.com/ecozone** select Order Information tab.

Order Information

EcoZone System ME-6668

Weather

Weather/Anemometer

PS-2174

DIGITAL sensor

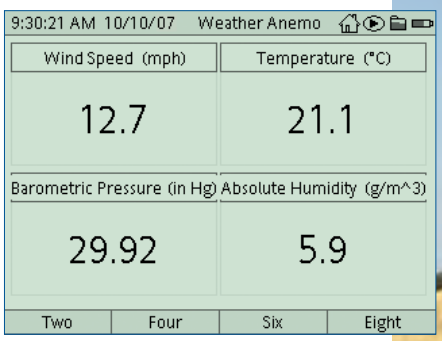


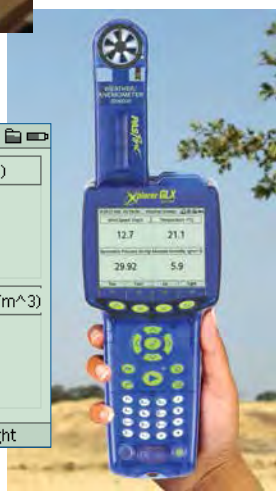
The Weather/Anemometer Sensor measures wind speed and wind chill in addition to temperature, barometric pressure, relative and absolute humidity, and dew point.

Typical Applications

- Measure wind speed in direction of running on a track
- Study wind and pressure changes as a storm approaches
- Collect weather data for weeks inside or outside the classroom







Specifications

Wind Speed: 1 to 65 miles per hour

Barometer: 800 to 1090 hecto Pascals (hPa), 800 to 1090 milli Bars (mBar) and 24 to 34 inches Mercury (in Hg)

Humidity: 0 to 100% RH ±2%, 0g/m 3 to 50 g/m 3 ±10% AH

Temperature: -20°C to 55°C ±0.5°C

Dew Point: -50°C to 55°C ±2%

Maximum Sample Rate: 5 Hz

Order Information

Weather/Anemometer Sensor (PASPORT) PS-2174

Weather

PS-2154A

DIGITAL sensor



PASCO's Weather Sensor allows students to measure temperature, barometric pressure, relative and absolute humidity, and dew point. Whether you're comparing outdoor measurements to indoor, or monitoring an approaching storm, this powerful MultiMeasure Sensor™ does it all.

Typical Applications

- Conduct weather station experiments
- Take one-time readings or collect data over days or weeks, in the classroom or anywhere
- Collect readings at various locations around school
- Study weather phenomena such as thunderstorms, cloud cover, etc.

Specifications

Barometer: 800 to 1090 hecto Pascals (hPa), 800 to 1090 milli Bars (mBar) and 24 to 34 inches Mercury (in Hg)

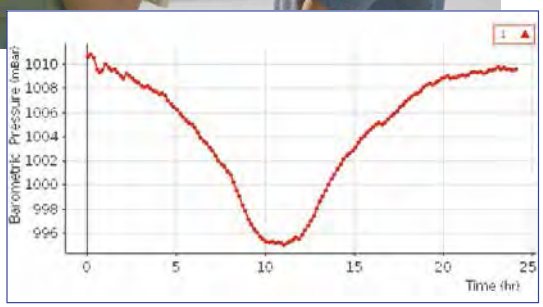
Humidity: 0 to 100% RH ±2%, 0g/m 3 to 50 g/m 3 ±10% AH

Temperature: -20°C to 55°C ±0.5°C

Dew Point: -50°C to 55°C ±2%

Maximum Sample Rate: 5 Hz





Graph shows barometric pressure during a passing storm.

Order Information

Weather Sensor (PASPORT) PS-2154A

Barometer/Low Pressure

PS-2113A



DIGITAL sensor

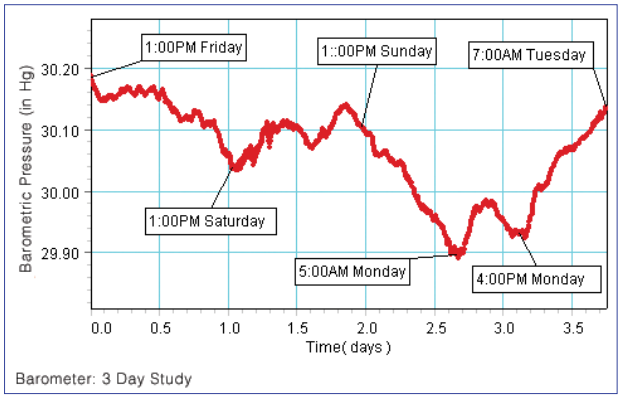
PASCO's Barometer Sensor measures changes in atmospheric pressure over long and short periods of time. The sensor reports measurements in units of in Hg, hPa, or mBar. It can also be used as a Low Pressure Sensor.

Typical Applications

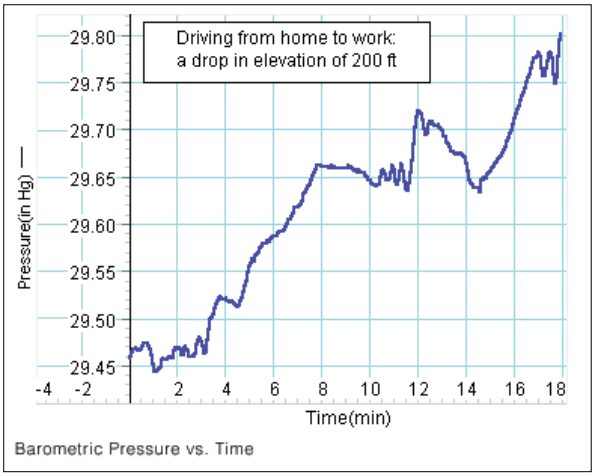
- Conduct weather station experiments
- Measure changes in elevation
- Compare classroom data to local weather reports to predict weather

Specifications

Range: 4.4 in Hg to 34 in Hg
Accuracy: ±0.03 in Hg
Resolution: 0.001 in Hg
Maximum Sample Rate: 20 Hz
Operating Temperature: 0°C to +40°C



Graph shows pressure changes as a storm moves through over a three day period.



Graph shows data for a 200-foot decrease in elevation during a car drive.

Order Information

Barometer Sensor (PASPORT) PS-2113A

Soil Moisture

PS-2163



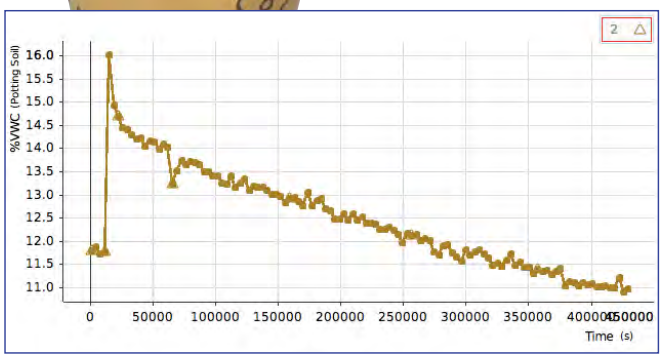
DIGITAL sensor

The Soil Moisture Sensor measures the water content of soil and reports it in percent. It can be used to conduct experiments in environmental science, agricultural science, horticulture, and biology.

Typical Applications

- Measure the loss of soil moisture over time due to evaporation and plant uptake
- Evaluate optimum soil moisture contents for various species of plants
- Monitor soil moisture content to control irrigation in greenhouses





Soil moisture data over time shows evaporation.

Specifications

Sensor Range: 0 to 45% volumetric water content in soil
Sensor Probe Length: 5.5 cm
Sensor Probe Cable Length: 5 m
Accuracy: ±4%
Resolution: 0.1%
Power: 3 mA at 5 V DC
Operating Temperature: -40 to 60°C
Default Sample Rate: 10 samples per second

Order Information

Soil Moisture Sensor (PASPORT) PS-2163

Turbidity

PS-2122



The Turbidity Sensor measures the cloudiness of liquid samples by quantifying the degree to which light passing through the solution is scattered by suspended particles. Calibration is done with the touch of a button in less than a minute. The sensor's black opaque housing assures accuracy of data. The Turbidity Sensor is packaged along with five empty glass cuvettes and a Hach StablCal 100-NTU standard in a sturdy plastic case.

Typical Applications

- Compare the turbidity of water samples from various field locations
- Determine the rate of settling of a sample
- Conduct water quality studies
- Measure the formation of a precipitate

Specifications

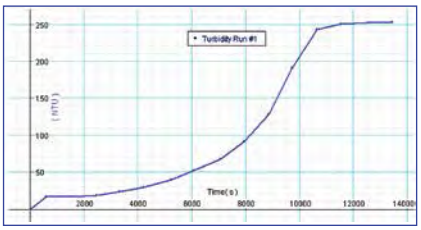
Range: 0 NTU to 400 NTU

Accuracy: 0 to 20 NTU: ±0.2 NTU
20 to 100 NTU: ±0.5 NTU
100 to 400 NTU: ±1.0 NTU

Temperature Range: 5°C to 40°C (recommended)

Maximum Sample Rate: 5 Hz





Over time, turbidity increases in a solution of suspended E. Coli.

Order Information

Turbidity Sensor PS-2122
Replacement Cuvettes/Caps (6 each) PS-2509
100 NTU Cal Standard PS-2511

Conductivity

PS-2116A



The Conductivity Sensor, including amplifier box and 10x electrode, is designed for monitoring conductivity (µS/cm) in aqueous solutions. PASCO's Capstone™ Software can convert data to total dissolved solids (mg/L). Most conductivity sensors use graphite probes, but our conductivity sensors use platinum for greater range and improved accuracy at high and low concentrations. The result is better measurements that lead to better labs. Three ranges, push-button selectable on the sensor, allow it to be used for a wider variety of experiments without requiring recalibration.

- Electrode houses rugged, research-grade conductors that provide superior accuracy over the entire range.
- Replaceable probe reduces maintenance costs.

Typical Applications

- Accurately compare conductivity of different water samples
- Study the effects of chemical flocculants on conductivity
- Conduct environmental studies
- Investigate drinking water purity

Specifications

Range: 0 to 1,000, 0 to 10,000, 0 to 100,000 µS/cm

Accuracy: ±10% of full scale without calibration; ±0.1% after calibration

Resolution: Better than 0.05% of full scale

Repeatability: Better than 0.01% of full scale

Maximum Sample Rate: 20 Hz



Location Number (no units)	Conductivity (µS/cm)
1	141
2	109
3	113
4	122
5	1227
6	93

Checking water quality of collected rain water.

Order Information

Conductivity Sensor PS-2116A

Conductivity Replacement Probe

PS-2571 *(Previously part number 699-06621)*



Order Information

Conductivity Replacement Probe PS-2571

Advanced Water Quality

NEW

PS-2230

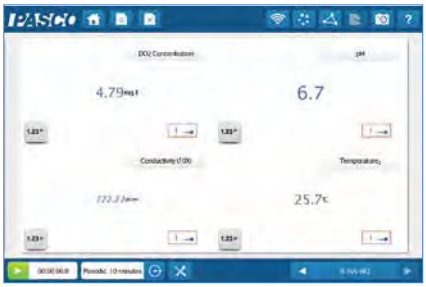


Typical Applications

- Use each probe separately or in any combination you choose
- Ideal for Environmental Science or Biology classrooms
- Simultaneously measure pH, dissolved oxygen, temperature, and conductivity



Use a single sensor to understand an estuary.



Convenience in field measurement – the Advanced Water Quality Sensor captures four important measurements at once: dissolved oxygen, pH, conductivity, and temperature. Shown in use with SPARK Science Learning System (PS-2008A).

Includes

Optical Dissolved Oxygen Probe (mg/L, %), Stainless Steel Temperature Probe, Conductivity 10x Probe, pH Probe, Ambient Barometric Pressure (built into sensor enclosure)

Order Information

Advanced Water Quality Sensor PS-2230

Water Quality Colorimeter

DIGITAL sensor

PS-2179



This PASPORT Water Quality Colorimeter is designed specifically to support chemical analysis of water samples using PASCO's ezSample Snap Vial water quality test kits.

Complete with built-in calibration curves to determine the concentration of ions in the solution for the ions listed on this page. Simple to use in the field and students avoid direct contact with chemicals!



1. Snap tip of ampoule and sample instantly flows into tube.



2. Read concentration using Xplorer GLX.

Specifications

Measurable Ranges:

ezSample Snap Vials (Colorimetric)	
Iron	0 to 7 mg/l
Nitrate	0 to 2 mg/l
Ammonia	0 to 3 mg/l
Phosphate	0 to 8 mg/l
Chlorine	0 to 6 mg/l
ezSample Field Titrators	
Total Hardness	20 to 200 mg/l
CO_2	10 to 100 mg/l
Alkalinity	10 to 100 mg/l
Operating Temperature:	0° to 40°C

Order Information

Water Quality Colorimeter (PASPORT) PS-2179

Available Test Kits:*
(30 tests per kit)

ezSample Snap Vials (Colorimetric)

- Iron EZ-2331
- Nitrate EZ-2333A
- Ammonium EZ-2334
- Phosphate EZ-2337
- Chlorine EZ-2339

ezSample Field Titrators

- Total Hardness EZ-2338
- CO_2 ..... EZ-2341
- Alkalinity EZ-2340

**Special shipping restrictions may apply. Please contact PASCO for more information.*

GPS Position Sensor

DIGITAL sensor

PS-2175

- Correlate GPS coordinates with sensor measurements
- Ability to track under trees



Use PASCO's GPS Position Sensor to collect GPS data simultaneously with other sensor measurements, automatically synching the data to your latitude, longitude, altitude, and velocity.



Students use the Xplorer GLX, GPS Position Sensor and the Weather/Anemometer to make environmental measurements around the perimeter of a park.

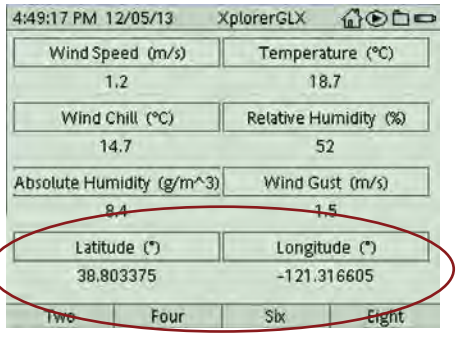


The GPS Position Sensor utilizes satellite triangulation to determine the sensor's position and velocity in outdoor environments. The highly sensitive receiver is able to track satellites even under tree canopies often found along rivers. The sensor provides latitude, longitude, horizontal speed, course over ground, altitude and the number of tracked satellites. LED indicators let the user know if the GPS Position Sensor is currently computing position reports. Data is exported to a mapping program.

Aerial photo and GPS position data, color-coded by number of satellites in fix, from hike in Costa Rica. Notice, even in thick jungle canopy, there is continuous satellite reception.



Display digital readings of position data with your other measurements on the Xplorer GLX, or graph latitude and longitude to track your movement.



Order Information

GPS Position Sensor (PASPORT) PS-2175

Recommended:

Weather Sensor (PASPORT)	PS-2154A	p. 70
PASPORT Sensor Extension Cable	PS-2500	p. 26
Xplorer GLX	PS-2002	p. 19

USB Digital Video Flex®

SE-7235A



- Display and record falling Millikan oil drops
- Digital signal for crisp, clear images
- High-resolution: 1920 x 1080

The high-definition 3.2 Megapixel Digital Video Flex connects directly to a PC or laptop via a fast USB 2.0 connection. The flexible gooseneck and the ball-and-socket head allow the camera to adapt easily to microscopes or to focus on scientific experiments, graphic materials, moving objects, or presenters. A custom CMOS chip and Quick Focus™ 8 mm glass lens enable this Digital Video Flex to capture superior quality images, showing details that would otherwise be missed. The Ken-A-Vision Applied Vision software (supplied) allows easy display and editing of pictures and videos. The lens can be focused from 6 mm to infinity, allowing magnification up to 50x for macro- and micro-photography.

No external power supply is required, as the camera is powered by the computer through the USB connection. The delivery is complete with a 28 mm microscope adapter, Discovery Scope Kit, Applied Vision software, and carrying case. The USB cable is pre-attached to the camera.

Specifications

Light Sensitivity: 20 lux
Sensor: CMOS
Output/Interface: Digital / USB 2.0
Exposure: Software controlled
Output Resolution: HD 1080P
Pixel Count: 1920 x 1080
Real-Time Video: Up to 30 frames per second
Lens: 8 mm HD interchangeable C-mount, glass
Focal Distance: 1⁄4" (6 mm) to infinity
Magnification: 50:1
Eyepiece Adapter: 34.5 mm built-in, and 28 mm
Power Supply: via USB
Cable Length: USB connecting cable, approx. 1.5 m pre-fixed
Gooseneck: 65 cm length
Base: 7" x 7" x 7" / 180 x 180 x 180 mm, polycarbonate
Weight: 10 lbs / 4.55 kg
Height: 30" / approx. 76 cm

Order Information

USB Digital Video Flex SE-7235A

USB Camera Microscope

PS-2343

- Use as web camera
- Optical zoom from 1x to 60x
- Built-in LED lights

See the USB Camera Microscope in use with the Universal Gravitational Constant Experiment (EX-5550) on page 317.

The versatile USB Microscope Camera is ideal for a variety of applications in the science classroom. Its dual-functionality means it can take pictures just like a digital camera, but it can also magnify like a microscope when it's up close to a specimen. It is especially useful when studying things such as crystalline structure. And you can use it to take pictures showing lab setups, such as what materials look like before and after an experiment has been performed.

How It Works

Used with the video and image capture features in PASCO Capstone. Magnification of specimens can be done by adjusting the dial located on the front of the camera.

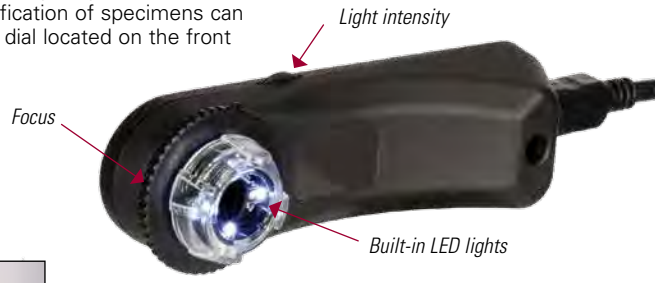
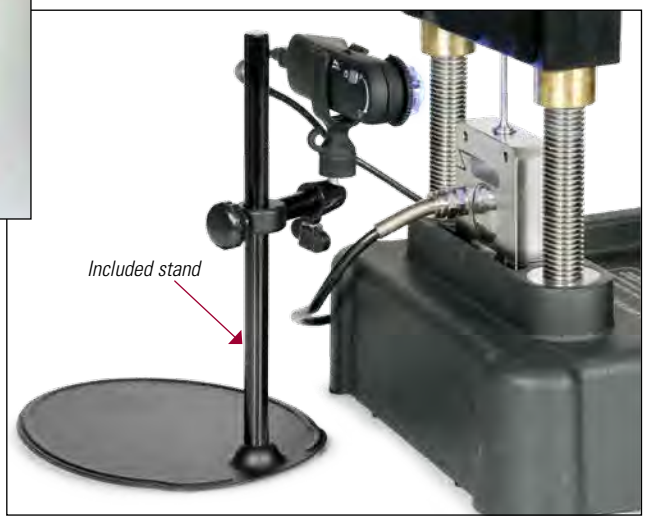
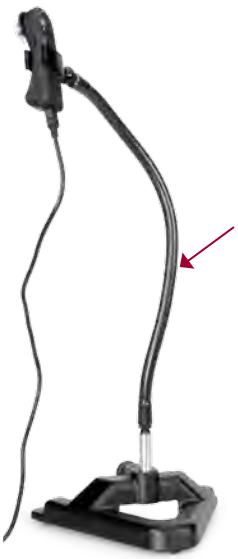




Image of broken steel tensile sample taken with the microscope.

Shown in use with ME-8236 Materials Testing Machine (see page 144). As the tensile sample is being stretched, the force versus time data is graphed in sync with the movie.





Optional Flex Rod (ME-8978A), holds the USB Camera Microscope in place for recording experiments.

Includes

Camera Microscope and stand

Order Information

USB Camera Microscope PS-2343

Suggested Base Supports:

Flex Rod	ME-8978A	p. 171
Small "A" Base	ME-8976	p. 170
Aluminum Clamp	ME-8995	p. 173

Video Capture and Analysis Integrated into PASCO Capstone Software

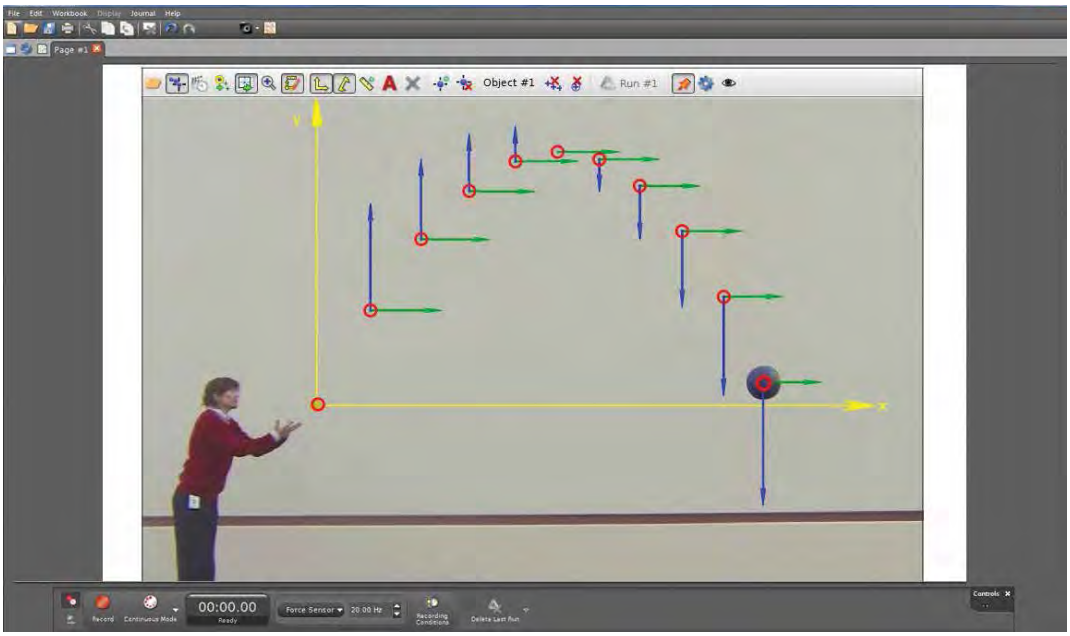
NEW Vectors and Auto-Tracking

- New: Velocity and Acceleration Vectors
- New: Auto-track objects
- Study motion in two dimensions
- Track more than one object
- Make linear and circular measurements

See pages 6-13 for more information about PASCO Capstone.

PASCO capstone™ Software

Use any USB webcam to record a movie or open a movie file and then analyze the x-y motion – all within PASCO Capstone. Even record sensor data along with the movie, synched together automatically in most cases.



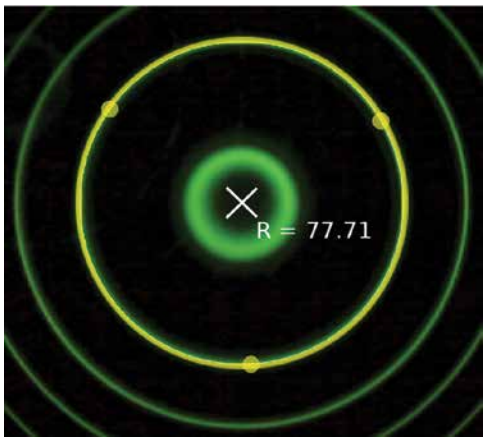
Auto-tracking:

Identify the object you want to track and the program will automatically track it in each frame. It's a real time-saver.

Vectors on a tossed ball:

Position, velocity, and acceleration data is generated in PASCO Capstone when the user clicks on each position of the object. In this experiment, the x- and y- components of the velocity are shown.





Special measurement tools allow you to measure the radius of circles or lengths of objects. Shown is a frame from a video of the Zeeman Effect as the magnetic field is increased.

Video Analysis Features:

- Show velocity and acceleration vectors
- Change to cylindrical coordinates
- Use magnifier to identify the exact center of the object
- Use calibration ruler at any time
- Back up and reposition any point
- Track more than one object
- Generate XY data for position, velocity, and acceleration
- Move the origin of the axes
- Rotate the axes, even after taking data
- Make linear measurements in frames or snapshots
- Measure the radius of circle
- Measure angles
- Create annotations
- Automatic frame-advance after taking a point
- Set the number of frames that are advanced
- Change playback rate

Order Information

PASCO Capstone Software

Single User License	UI-5401
Site License	UI-5400

Version 1.1 upgrade is available free to all current PASCO Capstone owners.

850 Comprehensive Physics System

UI-5800B

NOTE: The 850 Universal Interface (UI-5000) must be purchased separately.

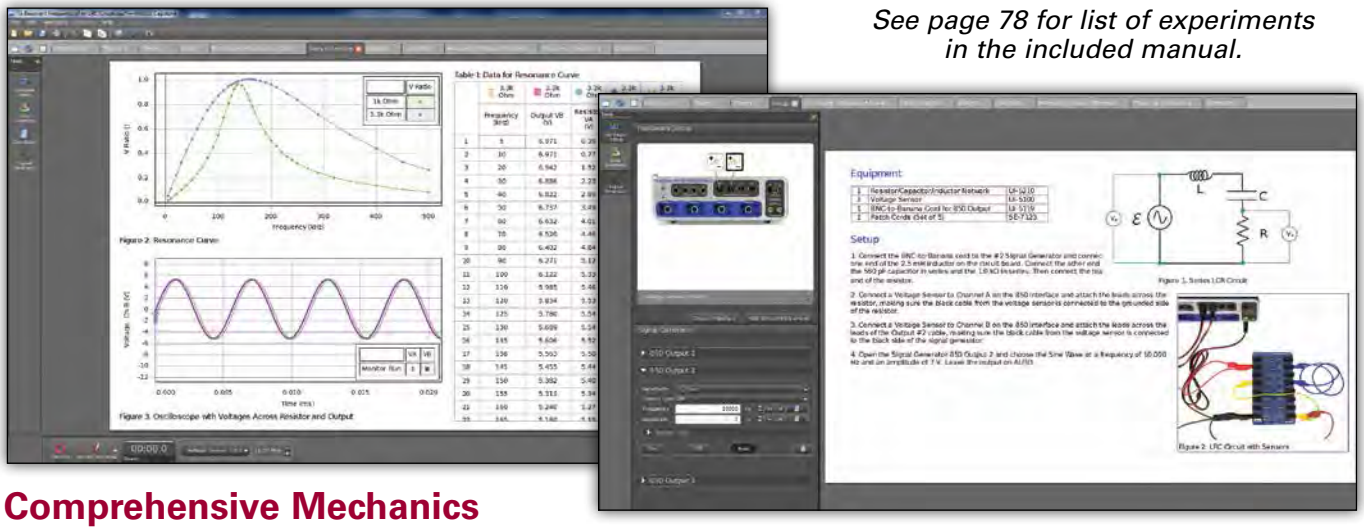
Designed for the 850 Universal Interface and PASCO Capstone Software

The 850 Comprehensive Physics System consists of 83 experiments and all the equipment and sensors needed to perform these experiments. The experiments span the topics of mechanics, waves, optics, thermodynamics, and electromagnetism (See page 78 for a complete list of experiments). The equipment and sensor bundles for the three subject areas are shown on these two pages.

The included experiment manual contains instructions written in Word, a PASCO Capstone electronic workbook, and sample data.

The key to a successful lab is a PASCO Capstone electronic workbook. These workbooks have step-by-step instructions with live embedded displays such as graphs, FFTs, oscilloscopes, and meters. They contain the theory, experiment set-up, procedure, data analysis, and questions designed to get the students to think about their results.

These electronic workbooks can be easily modified by teachers to fit their individual needs.



See page 78 for list of experiments in the included manual.

Comprehensive Mechanics

UI-5801B

(Component of the 850 Comprehensive System UI-5800B)



UI-5801B Includes

Part No.	Description
CI-6545	Force Accessory Bracket
CI-6691	Mini Rotational Accessory
ME-6743	Cart Adapter
ME-6755	Compact Cart Mass (2)
ME-6806	Pi Set
ME-6810	Time-of-Flight Accessory
ME-6821A	Photogate Mounting Bracket
ME-6825A	Mini Projectile Launcher
ME-6828	Magnetic Damping Accessory
ME-6829	Mini Launcher Ballistic Pendulum Accessory
ME-6843	Spring Cart Launcher
ME-6950	PAScar (Set of 2)
ME-6977	Super Fan Cart
ME-8569	Density Set
ME-8574	Discover Friction Accessory
ME-8735	Large Rod Base
ME-8736	Rod, stainless steel, 45 cm
ME-8738	Rod, stainless steel, 90 cm
ME-8933	Smart Timer Picket Fences (2)
ME-8971	Endstops (Set of 2)
ME-8972	Track Feet (Set of 2)
ME-8979	Mass and Hanger Set
ME-8998	Elastic Bumper
ME-8999	Dynamics Track Spring Set (12)
ME-9377A	Picket Fence
ME-9436	Pivot Clamp
ME-9472	Large Table Clamp
ME-9493	1.2 m Dynamics Track
ME-9498A	PASCO Photogate Head (2)
ME-9506	Pendulum Clamp
ME-9507	Multi Clamp (2)
ME-9595	Car Sail
ME-9781	Variable Speed Motorized Cart
ME-9821	Centripetal Force Pendulum
PS-2103A	Motion Sensor (2)
PS-2136A	3-Axis Acceleration/Altimeter
PS-2120	Rotary Motion Sensor
PS-2189	High Resolution Force Sensor (2)
SA-9242	Pulley Mounting Rod
SE-7347	No Bounce Pad
SE-8050	String, spool
UI-5813	Comprehensive 850 Experiment Manual

Order Information

850 Comprehensive Physics System UI-5800B

Required:

850 Universal Interface ..... UI-5000 pp. 14-17

PASCO Capstone™ Software ..... pp. 6-13

Want Mechanics Only?

850 Comprehensive Mechanics UI-5801B

Comprehensive Waves, Optics, and Thermodynamics

UI-5802 *(Component of the 850 Comprehensive System UI-5800B)*

The experiments for this section require some of the components of the 850 Comprehensive Mechanics UI-5801B



UI-5802 Includes

Part No.	Description
CI-6506B	Sound Sensor
ET-8499	ET Calorimeter
OS-8453	High-Precision Diffraction Slits
OS-8458	Green Laser
OS-8495	Color Mixer Accessory Kit
OS-8496	Color mixer
OS-8515C	Basic Optics System
OS-8525A	Red Laser
OS-8533A	Polarization Analyzer
OS-8535	Linear Translator
OS-8494	Adj focal length lens
PS-2107	Absolute Pressure
PS-2143	Quad Temp
PS-2176	High Sensitivity Light Sensor
SE-7345	Resonance Box Set
SE-9750	Red Patch cords
TD-8570	Radiation Cans
TD-8595	Absolute Zero Apparatus
TD-8596A	Ideal Gas Law Apparatus
WA-9495	Economy Resonance Tube
WA-9857	String Vibrator
WA-9900	Open Speaker

See page 78 for manual.

Comprehensive Electromagnetism

UI-5803 *(Component of the 850 Comprehensive System UI-5800B)*



UI-5803 Includes

Part No.	Description
EM-8620	Bar Magnets (pair)
EM-8652	Zero Gauss Chamber
EM-8656	AC/DC Electronics Laboratory
ES-9080B	Electrostatics System
PK-9023	Field Mapper Kit
PS-2184	Current Probes (2)
PS-2162	Mag Field Sensor 2-axis

Part No.	Description
SE-7123	Short patch cords
SE-8680	Plotting Compasses
SF-8619	Dip Needle
UI-5100	Voltage Sensors (4)
UI-5119	BNC Funct. Gen Cables
UI-5210	Circuit board

The experiments for this section require some of the components of the 850 Comprehensive Mechanics UI-5801B

Comprehensive 850 Physics System (UI-5800B) Includes

- Comprehensive Mechanics UI-5801B
- Comprehensive Waves, Optics, and Thermodynamics UI-5802
- Comprehensive Electromagnetism UI-5803

See page 78 for list of experiments in the included manual.

Order Information

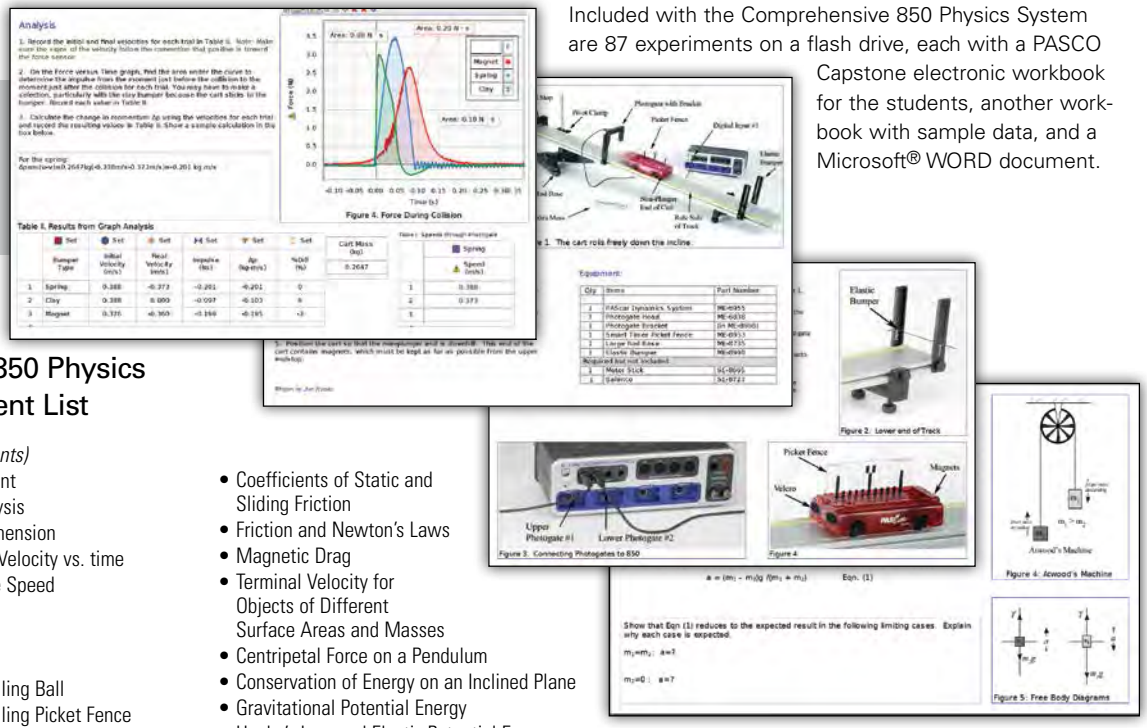
850 Comprehensive Physics System	UI-5800B	
Required:		
850 Universal Interface	UI-5000	pp. 14-17
PASCO Capstone™ Software		pp. 6-13
Also Available Separately:		
850 Comprehensive Mechanics	UI-5801B	
850 Comprehensive Waves, Optics, and Thermodynamics	UI-5802	
850 Comprehensive Electromagnetism	UI-5803	
850 Comprehensive Physics System Manual	UI-5813	

Systems: 850 Comprehensive Physics System

Comprehensive 850 Physics System Experiment Manual

UI-5813

See pages 76-77 for the equipment bundles needed for these experiments



Included with the Comprehensive 850 Physics System are 87 experiments on a flash drive, each with a PASCO Capstone electronic workbook for the students, another workbook with sample data, and a Microsoft® WORD document.

Comprehensive 850 Physics System Experiment List

Mechanics *(49 Experiments)*

- Introduction to Measurement
- Uncertainty and Error Analysis
- Relative Motion in One Dimension
- Match Graph-Position and Velocity vs. time
- Instantaneous and Average Speed
- Position and Velocity
- Velocity and Acceleration
- Equations of Motion
- Acceleration of a Freely Falling Ball
- Acceleration of a Freely Falling Picket Fence
- Acceleration: on an Incline
- Projectile Motion
- Projectile Motion – Against a Wall
- Newton's First Law – No Net Force
- Newton's Second Law
- Force and Acceleration
- Inertia and Newton's Second Law
- Newton's Third Law
- External Forces and Newton's Third Law
- Atwood's Machine
- Acceleration up an Inclined Plane
- Static Equilibrium
- Coefficients of Static and Sliding Friction
- Friction and Newton's Laws
- Magnetic Drag
- Terminal Velocity for Objects of Different Surface Areas and Masses
- Centripetal Force on a Pendulum
- Conservation of Energy on an Inclined Plane
- Gravitational Potential Energy
- Hooke's Law and Elastic Potential Energy
- Conservation of Energy for a Simple Pendulum
- Work-Energy Theorem
- Conservation of Momentum in Collisions
- Impulse and Change in Momentum
- Ballistic Pendulum
- Newton's Second Law for Rotation
- Rotational Inertia
- Rotational Kinetic Energy
- Conservation of Angular Momentum
- Simple Harmonic Motion – Mass on a Spring
- Oscillations of Cart and Springs
- Oscillation Equations of Motion
- Driven Harmonic Motion – Mass on a Spring
- Physical Pendulum
- Period of a Large Amplitude Pendulum
- Variable-g Pendulum
- Physical Pendulum Minimum Period
- Archimedes' Principle - Buoyant Force

Waves, Optics, and Thermodynamics *(22 Experiments)*

- Heat and Temperature
- Transfer of Energy by Radiation
- Specific Heat
- Electrical Equivalent of Heat
- Boyle's Law: P and V of a Gas at Constant T
- Absolute Zero
- Behavior and Characteristics of Sound Waves
- Standing Waves on a String
- Resonant Modes of Sound in a Tube
- Speed of Sound in Air
- Superposition of Sound Waves
- Interference of Sound Waves
- Shadow and Color in Light
- Object and Image Distances for a Thin Lens
- Reflection and Refraction
- Focal Length of a Concave Mirror
- Optical Instruments: Telescope and Microscope
- Variation of Light Intensity
- Light Intensity versus Distance
- Polarization: Verify Malus' Law
- Brewster's Angle
- Diffraction of Light

Electromagnetism *(16 Experiments)*

- Electrostatic Charges
- Electric Field Mapping
- Ohm's Law
- Series/Parallel Circuits
- Kirchhoff's Laws: Resistors in Series and Parallel
- Capacitance
- RC Circuit
- Resonant Frequency of an LRC Circuit
- General Properties of Diodes
- Build a Rectifier
- Transistor 1 – The NPN Transistor as a Digital Switch
- Transistor 2 – Measure the Current Gain
- Earth's Magnetic Field
- Magnetic Field Mapping
- Induction – Magnet Through a Coil
- Magnetic Field in a Current-Carrying Coil

This manual is included in both the 850 Comprehensive Physics System UI-5800 and the 850 Comprehensive Mechanics System UI-5801.

Order Information

Comprehensive 850 Physics System Experiment Manual (Flash Drive) UI-5813

Word™ files, PASCO Capstone files, and graphics are supplied on a flash drive.

850 Mechanics System (Includes 850 Universal Interface)

UI-5820

- Integrates probeware and physics equipment
- Includes 850 Universal Interface
- Perform a wide variety of mechanics experiments

When used together, PASCO's probeware and physics apparatus can help students learn the major concepts of mechanics more effectively. The Mechanics 850 System includes the 850 and equipment required to perform a wide variety of mechanics experiments.

The new manual consists of 10 PASCO Capstone electronic workbooks with complete experiments that take full advantage of the components of this system. Sample data files are included.



Impulse Experiment
Measure the force as a function of time as the cart hits the spring and also measure the change in momentum using the photogate.

Ten Experiments Included in Manual (UI-5821)

Title	Purpose	Sensors Used
Acceleration Down an Incline	Discover how the acceleration of an object down an incline depends on the angle of incline. Measure the acceleration due to gravity.	Photogate with picket fence
Newton's Second Law	Verify Newton's Second Law by varying the applied force and the mass.	Motion Sensor
Kinetic Friction I	Measure the kinetic coefficient of friction.	Motion Sensor
Kinetic Friction II	Study how the coefficient of kinetic friction depends on the velocity, acceleration, surface area, and weight of the object.	Photogate with pulley
Impulse and Momentum	Measure the impact force of a cart and compare the impulse to its change in momentum.	Force Sensor/ Photogate
Conservation of Momentum in Explosions	Verify that momentum is conserved for two carts pushing off from each other.	Two photogates with picket fences
Conservation of Momentum in Inelastic Collisions	Verify that momentum is conserved in inelastic collisions and that kinetic energy is not conserved.	Two photogates with picket fences
Conservation of Momentum in Elastic Collisions	Verify that momentum is conserved in elastic collisions.	Two photogates with picket fences
Conservation of Energy	Show spring potential change into kinetic energy.	Motion Sensor/ Photogate with picket fence
Simple Harmonic Motion	Measure the period of oscillation of a spring and mass system and compare it to the theoretical value. Evaluate the effect of changing the mass and spring constants.	Photogate and flag



UI-5820 Includes

1.	UI-5000	850 Universal Interface	p. 14
2.	PS-2189	High Resolution Force Sensor	p. 30
3.	PS-2103A	Motion Sensor	p. 27
4.	ME-9471A	Photogates and Fences	p. 40
5.	ME-8574	Discover Friction Accessory	p. 101
6.	ME-9429B	1.2 m Classic Dynamics System	p. 88
7.	CI-6545	Force Accessory Bracket	p. 98
8.	ME-8979	Mass and Hanger Set	p. 181
9.	ME-9491	Fan Accessory	p. 97
10.	UI-5821	Lab Manual (not shown)	

Order Information

850 Mechanics System UI-5820

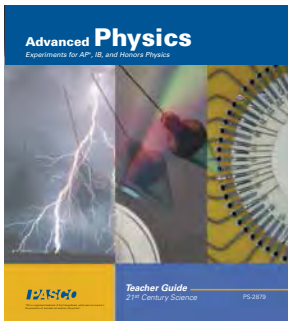
Required:

PASCO Capstone™ Software ..... pp. 6-13

Bundles: High School Probeware Bundles

Advanced AP® Physics Lab Manual for High School

PS-2879C



- Includes 31 Advanced Physics labs inspired by AP®* Physics exam content.
- Each lab is available in three levels of inquiry-based delivery.
- Each lab activity includes analysis, synthesis, and multiple-choice question forms, emulating those standardized assessments often seen on AP Physics exams.

See www.pasco.com/products/curriculum for a list of experiments.

Advanced Physics Standard Sensor Bundle

PS-2932B



Includes

Freefall Adapter (ME-9207B)
Photogate Head (1) (ME-9498A)
Smart Gate (1) (PS-2180)
Motion Sensor (PS-2103A)
Magnetic Field Sensor (PS-2112)
Barometer/Low Pressure Sensor (PS-2113A)
Voltage-Current Sensor (PS-2115)
Rotary Motion Sensor (PS-2120)
Absolute Pressure/Temp Sensor (PS-2146)
Stainless Steel Temperature Probe (PS-2153)
High-Sensitivity Light Sensor (PS-2176)
High-Resolution Force Sensor (PS-2189)
Extension Cable (PS-2500)
Perform All 31 Lab Activities with this bundle.

Required equipment (additional)

Many of the Advanced Physics lab activities require the combination of PASPORT sensors (listed above) with PASCO's signature Physics apparatus and equipment. For a full list of required equipment and a breakdown of specific lab activity requirements, see www.pasco.com/equip

Order Information

Advanced Physics Teacher Guide PS-2879C
Order one guide per classroom.

Advanced Physics Standard Sensor Bundle PS-2932B
Order one bundle per lab group (3-4 students).

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AP* and Advanced High School Physics Equipment Bundle

PS-2944



Includes all the lab equipment to perform 31 lab activities in the Advanced AP* Physics Lab Manual (PS-2871C), shown at left.

Includes

Mechanics
Mini Rotational Accessory CI-6691
Photogate Mounting Bracket ME-6821A
Mini Projectile Launcher ME-6825A
PAStrack Curved Track ME-6841
PAStrack Dynamics System ME-6961
Discover Friction Accessory ME-8574
Water Reservoir ME-8594
Photogate Pendulum Set ME-8752
Discover Collision Bracket ME-8973A
Super Pulley with Clamp ME-9448B
Pendulum Clamp ME-9506
Cart Picket Fence ME-9804
Photogate Bracket ME-9806
Discover Centripetal Force Kit ME-9837
Discover Density Set SE-9719A

Thermodynamics
Specific Heat Set SE-6849
Steam Generator TD-8556A
Hot Plate SE-8830
Calorimeter Cups (Foam) TD-8825A
Computer-based Thermal Expansion TD-8579A

Optics and Waves
Dynamics Track Optics System OS-8471A
Sensor-based Diffraction System OS-8455A
Ray Table OS-8465
Concave Mirror Accessory OS-8532
Snakey Spring SE-7331
Tuning Fork Set (8) SE-7342

Electricity and Magnetism
AC/DC Electronics Laboratory EM-8656
Electric Field Mapper PK-9023
Primary and Secondary Coil Set SE-8653
DC Power Supply SE-8828

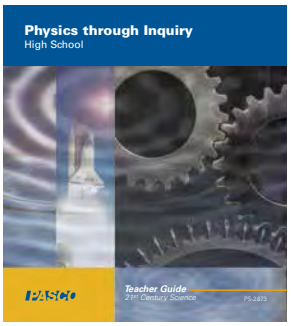
Supplies
Stopwatch ME-1234
Carbon Paper SE-8693
Balance SE-8707
Calipers SE-8710
Meter Stick 4-scale SE-8695
Patch Cords SE-9750
Alligator Clip Adapters (4) SE-9756
1000 mL Beaker, mass sets, string, rods, clamps, and stands

Order Information

AP* and Advanced High School Physics Equipment Bundle PS-2944

Physics through Inquiry Manual for High School

PS-2873C



- This standards-based STEM-focused guide has been designed by educators.
- Includes 38 standards-based Physics lab activities.
- Core topic areas include: mechanics, electricity and magnetism, optics, and thermodynamics.

See www.pasco.com/products/curriculum for a list of experiments.

Starter Bundle

Physics Starter Sensor Bundle

PS-2923



Includes

Motion (Qty 1) (PS-2103A)
Force (Qty) (PS-2104)
Voltage Current (PS-2115)
Magnetic Field (PS-2112)
Perform 23 of 38 Lab Activities with this bundle.

Standard Bundle

Physics Standard Sensor Bundle

PS-2931B



Includes

Motion (Qty 2) (PS-2103A)
Force (Qty 2) (PS-2104)
Voltage Current (PS-2115)
Magnetic Field (PS-2112)
Absolute Pressure Temperature (PS-2146)
Stainless Steel Temperature (PS-2153)
Light (PS-2106A)
Sound Level (PS-2109)
Charge (PS-2132)
Photogate Head (Qty 2) (ME-9498A)
Digital Adapter (PS-2159)
Time-of-Flight Accessory (ME-6810)
Perform All 38 Lab Activities with this bundle.

Order Information

Physics through Inquiry Teacher Guide PS-2873C
Order one guide per classroom.
Physics Starter Sensor Bundle PS-2923
Physics Standard Sensor Bundle PS-2931B
Order one bundle per lab group (3-4 students).

Inquiry-Based Physics Equipment Bundle

PS-2945



Includes all the lab equipment to perform 38 lab activities in the Physics through Inquiry Manual (PS-2873C), shown at left.

Includes

Mechanics
Mini Launcher ME-6825A
PAStrack Dynamics System ME-6961
Discover Friction Accessory ME-8574
Photogate Pendulum Set ME-8752
Discover Collision Bracket ME-8973A
Angle Indicator ME-9495A
Pendulum Clamp ME-9506
Variable Speed Motorized Cart (2) ME-9781
Discover Centripetal Force Kit ME-9837
Overflow Cup SE-8568

Thermodynamics
Steam Generator TD-8556A
Absolute Zero Apparatus TD-8595
Calorimetry Cups (set of 6) TD-8825A

Electricity and Magnetism
Alnico Bar Magnets (2-pk) EM-8620
Charge/Discharge Circuit EM-8678A
Neodymium Magnet EM-9980A
Faraday Ice Pail ES-9042A
Charge Producers ES-9057C
Bar Magnets (2-pk) SE-8687
Series/Parallel battery holders (10-pk) SE-8799
Student Power Supply SE-8828
200-Turn Coil SF-8609
400-Turn Coil SF-8610
800-Turn Coil SF-8611
Electrostatics Materials Kit SF-9068

Light and Sound
Basic Optics Light Source OS-8470
Dynamics Track Optics Kit OS-8472
Polarizer Set OS-8473
Basic Optics Diode Laser OS-8525A
Aperture Bracket OS-8534A
Sine Wave Generator WA-9867
Open Speaker WA-9900

Supplies
Cart Adapter Accessory ME-6743
Photogate Mounting Bracket ME-6821A
Carbon Paper SE-8693
Digital Calipers SE-8710
Plumb Bob SE-8721
Hooked Mass Set SE-8759
Meter Stick 4-scale SE-8695
Hot Plate SE-8830
Patch Cord (set of 5 red) SE-9750
Patch Cord (set of 5 black) SE-9751
Stopwatch ME-1234
Glassware, batteries, string, clamps, rods and stands

Order Information

Inquiry-Based Physics Equipment Bundle PS-2945

Lab Manual for AP Physics

Advanced Physics through Inquiry 1 Teacher Guide

PS-2848

- Advanced-level labs suitable for AP® classes*

Prepare your students for inquiry investigations in the physics lab. Each lab is presented three ways:

- Structured
- Guided Inquiry
- Student designed

You decide which level of inquiry is appropriate for each lab.

Covers the new standards for College Board Advanced Placement Physics 1.

- Every lab is based on the College Board Learning Objectives.
- Data Analysis and Assessment Questions are designed to prepare students for the AP® Physics 1 exam.
- The teacher guide emulates strategies that are used in free response questions.

Teacher Resources

- Pre-lab discussion and questions
- Procedural overview
- Teacher tips
- Sample data
- Assessment and Synthesis questions

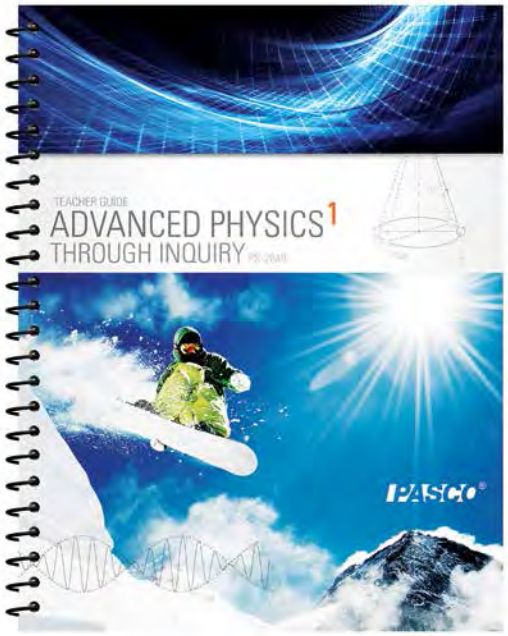
Instruction videos are included.

- Short videos guide students through use of equipment
- Host videos on your school computers
- Link to videos from anywhere with included QR codes
- Videos support a flipped classroom model



Try It!

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Advanced Physics 1 Labs:

Graphical Analysis: Motion

Newton's Second Law

Atwood's Machine

Coefficients of Friction

Two-Dimensional Motion: Projectile

Conservation of Mechanical Energy

Work and Kinetic Energy

Conservation of Momentum

Momentum and Impulse

Rotational Dynamics

Rotational Statics

Periodic Motion: Mass and Spring

Simple Pendulum

Resonance and Standing Waves

DC Circuits

Includes:

Printed manual and electronic files with PDF of the full teacher edition and an editable MS Word version of student handouts. Manual contains detailed teacher version complete with guided inquiry lab activities, suggested answers, and much more.

Order Information

Advanced Physics through Inquiry 1 Teacher Guide PS-2848

Advanced Physics I Starter Bundle

NEW

PS-2815



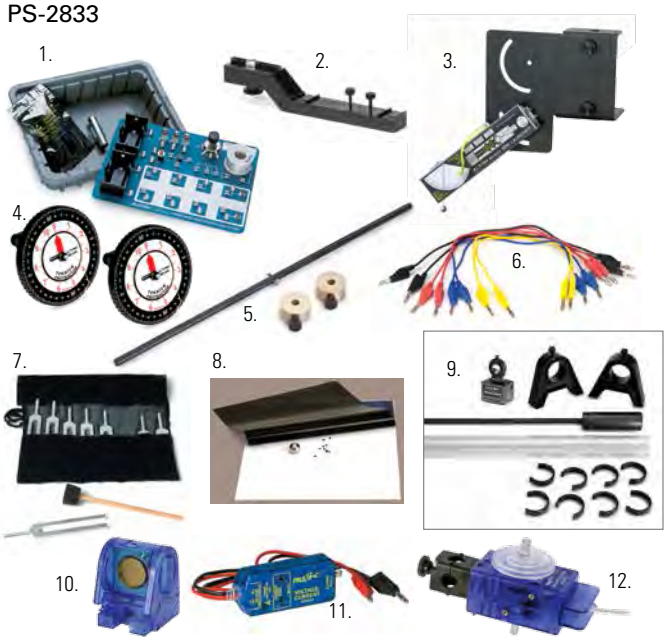
	Part #	Equipment	Qty
1.	ME-6950	PAScar (Set of 2)	1
2.	ME-8574	Discover Friction Accessory	1
3.	ME-8752	Photogate Pendulum Set	1
4.	ME-8971	Dynamics Track End Stop (2 pack)	1
5.	ME-6960	PAStrack	1
6.	ME-8973A	Discover Collision Bracket	1
7.	ME-8979	Mass and Hanger Set	1
8.	ME-9433	Super Pulley Kit	1
9.	ME-9495A	Angle Indicator	1
10.	ME-9804	Cart Picket Fences (2 Pack) -- IDS	1
11.	ME-9806	Photogate Brackets (2 Pack) -- IDS	1
12.	ME-9836	Pivot Clamp -- IDS	1
13.	ME-9866	Demonstration Spring Set	1
14.	ME-9506	Pendulum Clamp	1
15.	ME-6756	Cart Mass	3
16.	ME-6755	Compact Cart Mass	2
17.	PS-2103A	PASPORT Motion Sensor	1
18.	PS-2180	Smart Gate	1
19.	PS-2189	PASPORT High Resolution Force Sensor	1

Order Information

Advanced Physics 1 Starter Bundle PS-2815

Advanced Physics I Expansion Bundle

PS-2833



	Part #	Equipment	Qty
1.	EM-8656	AC/DC Electronics Lab Kit	1
2.	ME-6821A	Photogate Mounting Bracket	1
3.	ME-6825A	Projectile Launcher (mini)	1
4.	ME-6855	Tension Protractor	2
5.	ME-8969	Pendulum Accessory	1
6.	SE-7123	4-mm Banana Plug Patch Cord Set	1
7.	SE-7342	Tuning Fork Set	1
8.	SE-8693	Carbon Paper (100 Sheets)	1
9.	WA-9606	Resonance Air Column	1
10.	PS-2103A	PASPORT Motion Sensor	1
11.	PS-2115	PASPORT Voltage Current sensor	1
12.	PS-2120	PASPORT Rotary Motion Sensor	1

Order Information

Advanced Physics 1 Expansion Bundle PS-2833

Bundles: Xplorer GLX® Standard Bundle

Physics Standard Bundle with the Xplorer GLX:

CA-6789A Includes Xplorer GLX, sensors and equipment

- Includes comprehensive lab manual
- Appropriate for conceptual and general physics labs

The Standard bundle provides complete coverage for the 35 labs in *Physics with the Xplorer GLX* Lab Manual. This bundle allows students to probe deeper into topic areas. Additional equipment and probes allow more advanced students to quantitatively study projectile motion, thermal radiation, impulse/momentum, and light. Computers are not required for students to collect, analyze, and even print their data.



CA-6789A Includes

1.	PS-2002	Xplorer GLX
2.	PS-2103A	PASPORT Motion Sensor (2)
3.	PS-2104	PASPORT Force Sensor (2)
4.	ME-9472	Large Table Clamp
5.	SE-8028A	Constant Speed Buggy
6.	ME-8970	Equal Length Springs
7.	ME-9837	Discover Centripetal Force
8.	SE-7343	Adjustable Tuning Fork
9.	TD-8557A	Basic Calorimetry Set
10.	EM-8624A	CASTLE Kit
11.	CI-6545	Accessory Bracket w/ Bumpers
12.	EM-8620	Bar Magnets Alnico
13.	ME-6743	Cart Adapter Accessory
14.	ME-6800	Projectile Launcher (Short-Range)
15.	ME-6810	Time-of-Flight Accessory
16.	ME-6821A	Photogate Mounting Bracket
17.	ME-6950	PAScar (Set of 2)
	ME-8971	Endstops (Set of 2)
	ME-8972	Track Feet (Set of 2)
	ME-9436	Pivot Clamp
	ME-9493	1.2 m Dynamics Track
18.	ME-8574	Discover Friction Accessory
19.	ME-9448B	Super Pulley with Clamp
20.	ME-9491	Fan Accessory
21.	ME-9495A	Angle Indicator
22.	ME-9498A	Photogate Head (2)
23.	OS-8471A	Dynamics Track Optics Kit
24.	OS-9477A	Polarizer Demonstrator (2)
25.	PI-6602	Four "D" Batteries
26.	PI-8117	Phone Jack Extender Cable
27.	PS-2106A	Light Sensor
28.	PS-2115	Voltage/Current Sensor
29.	PS-2159	Digital Adapter
30.	PS-2500	PASPORT Extension Cable
31.	SA-9242	Pulley Mounting Rod
32.	SE-7347	No-Bounce Pad
33.	SE-8568	Overflow Can
34.	SE-8759	Hooked Mass Set
35.	ME-9506	Pendulum Clamp
36.	SE-9445	Three Finger Clamp
37.	SE-9756	Alligator Clip Adapters
38.	SF-8609	200 Turn Coil
39.	SF-8610	400 Turn Coil
40.	TD-8570A	Radiation Cans
41.	ME-9355	Large Base and Support Rod
42.	ME-8741	Stainless Steel Rod (120 cm long)
43.	ME-9507	Multi Clamp
44.	ME-8998	Elastic Bumpers

Order Information

Physics Standard Bundle with the Xplorer GLX CA-6789A

Physics with the Xplorer GLX Lab Manual (included in CI-6789A) PS-2826

Physics Economy Bundle with the Xplorer GLX:

CA-6788A

Includes Xplorer GLX, sensors and equipment

- Includes comprehensive lab manual
- Appropriate for conceptual and general physics labs

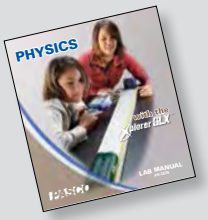
The Economy bundle provides tremendous value to the physics teacher. This investment will enable you to do 25 labs covering topics from the first day of school through Spring. Mechanics, sound, electricity, magnetism, thermodynamics, and optics, it's all here. *Physics with the Xplorer GLX Lab Manual* is at the core of this bundle. You are ready to go without the worry of needing computers.



Includes

1. ME-6951 GOcar
2. ME-6960 PAStrack
3. OS-8470 Basic Optics Light Source
4. OS-8465 Ray Table
5. SE-7581 Lens Set
6. OS-8516A Ray Optics Kit
7. PS-2002 Xplorer GLX
8. PS-2103A PASPORT Motion Sensor
9. PS-2104 PASPORT Force Sensor
10. SE-8028 Constant Speed Buggy
11. SE-7343 Adjustable Tuning Fork
12. ME-8970 Equal Length Springs
13. ME-9837 Discover Centripetal Force
14. TD-8557A Basic Calorimetry Set
15. EM-8624A CASTLE Kit

Free Lab Manual



Physics with the Xplorer GLX Lab Manual (PS-2826)

Order this bundle — we send a free lab manual with your shipment!

Order Information

Physics Economy Bundle with the Xplorer GLX CA-6788A

Physics with the Xplorer GLX Lab Manual (included in CI-6789A) PS-2826

Perform these experiments with the included *Physics with the Xplorer GLX* lab manual

These bundles are specifically designed to enable you to do the experiments in the *Physics with the Xplorer GLX* Lab Manual (PS-2826). However, we do assume that your lab has some basic equipment such as rods and stands. For a complete list of equipment required but not supplied in this bundle, please visit www.pasco.com/equip.

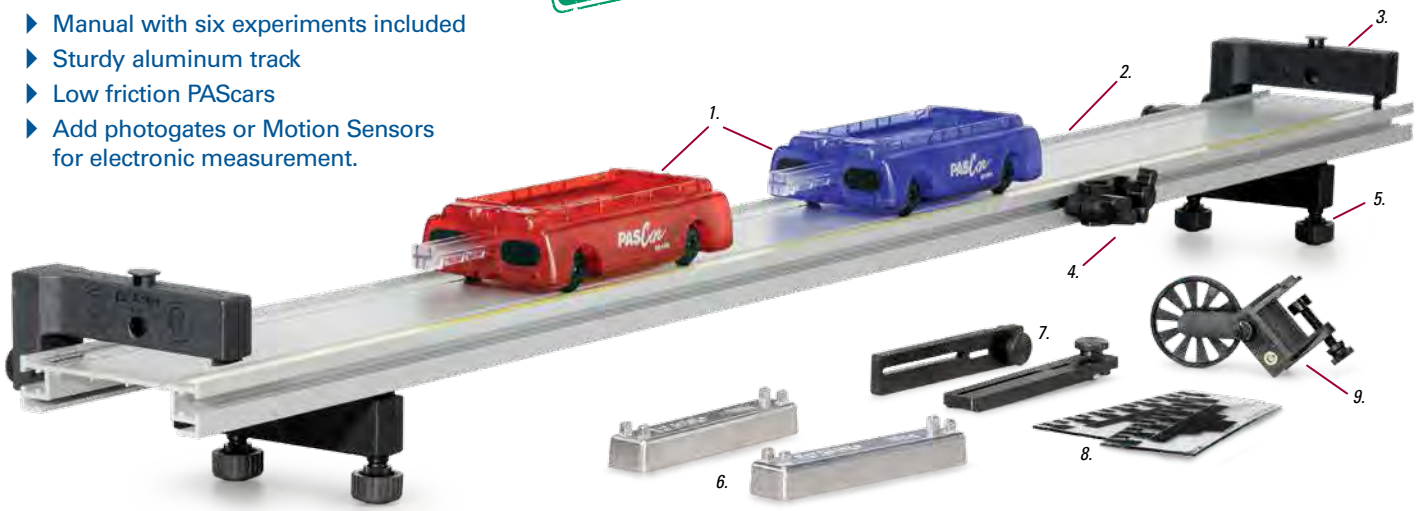
Physics Economy Bundle CA-6788A	Physics Lab Bundle CA-6789A *(See p. 84)*	
X	X	Position–Match Graph
	X	Relative Motion–Frames of Reference
X	X	Velocity of a Motorized Cart
X	X	Acceleration on an Inclined Track
X	X	Acceleration Due to Gravity
	X	Newton's First Law–No Net Force
X	X	Newton's Second Law–Constant Force
X	X	Newton's Second Law–Constant Mass
X	X	Newton's Third Law–Tug-of-War
	X	Forces in Equilibrium–A Lab Practical
	X	Static and Kinetic Friction
X	X	Hooke's Law of Elasticity
X	X	Simple Harmonic Motion–Mass on a Spring
X	X	Simple Harmonic Motion–Pendulum
	X	Momentum in Collisions
X	X	Impulse and Change in Momentum
	X	Safety Bumper Design Competition
X	X	Explore Gravitational Potential Energy
X	X	Conserve Energy
X	X	Work and Energy
	X	Projectile Motion–Initial Speed and Time of Flight
X	X	Centripetal Force, Constant Radius and Mass
X	X	Centripetal Force, Constant Radius and Force
X	X	Centripetal Force, Constant Mass and Force
	X	Ohm's Law: Current, Voltage, Resistance
X	X	Voltage in a Series Circuit
X	X	Voltage in a Parallel Circuit
	X	Current in a Series Circuit
	X	Current in a Parallel Circuit
X	X	Time Constant of a Resistor–Capacitor Circuit
	X	Electromagnetic Induction–Magnet and Coil
X	X	Sound Wave Properties
X	X	Interference–Beat Frequency
X	X	Archimedes' Principle–Buoyant Force
X	X	Transfer of Energy
X	X	Specific Heat of an Unknown Metal
X	X	Latent Heat of Vaporization
X	X	Latent Heat of Fusion
	X	Inverse Square Law–Light Intensity versus Distance
	X	Polarization

PAScar Dynamics System

ME-6955A

TEACHER FAVORITE

- Manual with six experiments included
- Sturdy aluminum track
- Low friction PAScars
- Add photogates or Motion Sensors for electronic measurement.



PAScar 1.2 m Dynamics System Components

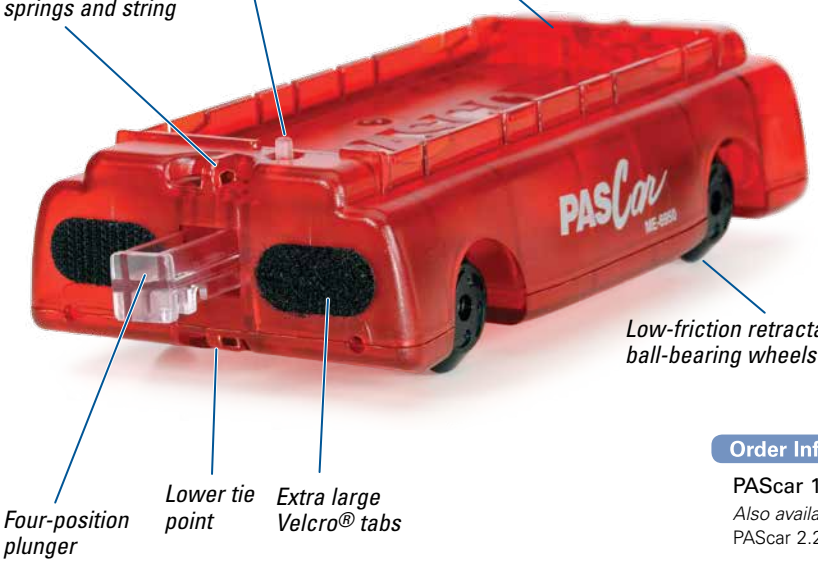
1. PAScar (set of 2) (ME-6950)	6. 250 gram Mass (2) (ME-6756)
2. 1.2 m Track (ME-9493)	7. Photogate Brackets (2) (ME-9806)
3. Adjustable Endstop (2) (ME-8971)	8. Cart Picket Fences (2) (ME-9804)
4. Rod Clamp (ME-9836)	9. Super Pulley with Clamp (ME-9448B)
5. Adjustable Feet (2) (ME-8972)	10. Experiment Manual (not shown)

Experiments Included

1. Acceleration down an Incline
2. Conservation of Momentum in Explosions
3. Conservation of Momentum in Inelastic Collisions
4. Conservation of Momentum in Elastic Collisions
5. Conservation of Energy*
6. Simple Harmonic Oscillation*

**Experiments 5 and 6 require a spring set (ME-8999).*

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.



System features the amazing PAScars

- Multiple attachment points for sensors and accessories
- Easy to use, lightweight, four-position plunger
- Magnets for elastic collisions
- Velcro® for completely inelastic collisions

Order Information

PAScar 1.2 m Dynamics System ME-6955A

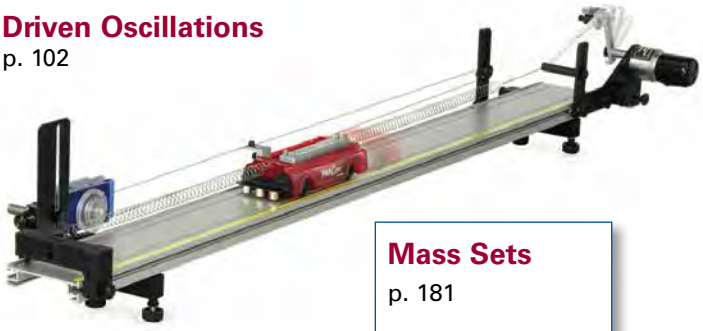
Also available in 2.2 m length:

PAScar 2.2 m Dynamics System ME-6956A

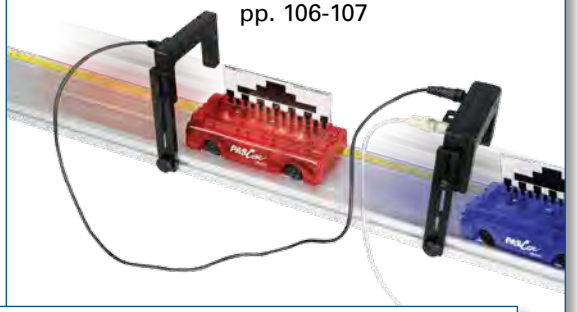
Looking for classic metal cart systems? See page 88.

Expand your Dynamics Track system with these exciting accessories

Driven Oscillations
p. 102



Photogates
pp. 106-107



Mass Sets
p. 181



Fan Carts, Motor Driven Carts
p. 97



Dynamics Track Optics
p. 269



Motion Sensor
p. 103



Force and Collisions
p. 98



Visual Accelerometer
p. 94



Ballistic Cart
p. 95



Supplies: Springs, string and replacement parts
pp. 104-105



Check out pages 88 to 90 for more Dynamics Track Systems!

Friction and Drag
p. 100-101



Mechanics: Dynamics Systems with Metal Tracks

Classic Dynamics Systems

1.2 m Track
ME-9429C

2.2 m Track
ME-9452B



TEACHER FAVORITE

- High quality aluminum track
- Classic metal carts
- Springs, friction block, pulley, angle indicator

These systems include extra equipment for doing additional experiments such as oscillations, friction, Hooke's Law, spring potential energy, and conservation of energy. The Spring Cart Launcher component provides an economical way to launch carts in a repeatable fashion and do energy experiments. Three different strength springs are provided with the Spring Cart Launcher.

Classic Dynamics System Components

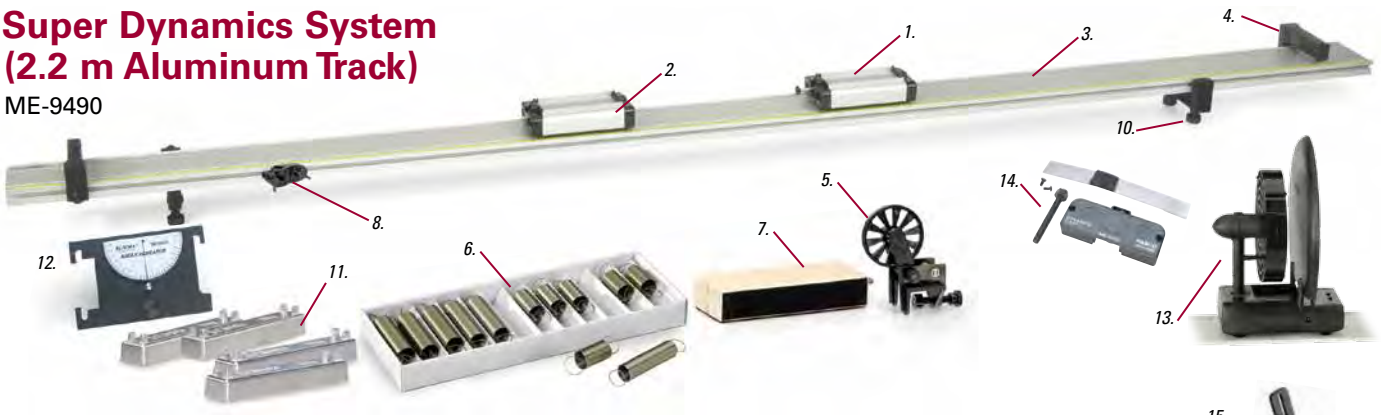
1. Plunger Cart ME-9430	7. Friction Block ME-9807
2. Collision Cart ME-9454	8. Rod Clamp ME-9836
3. Track	9. Spring Cart Launcher ME-6843
4. Adjustable Endstop (2) ME-8971	10. Adjustable Feet (2) ME-8972
5. Super Pulley with Clamp ME-9448A	11. 250 gram Mass (4) ME-6756
6. Spring Set ME-8999	12. Angle Indicator ME-9495
Includes Experiment Manual (not shown)	

Order Information

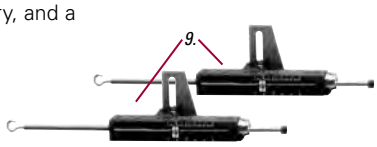
1.2 m Classic Dynamics System ME-9429C
2.2 m Classic Dynamics System ME-9452B

Super Dynamics System (2.2 m Aluminum Track)

ME-9490







The Super Dynamics System provides an even wider range of accessories for a more advanced study of linear dynamics, including a Fan Cart, Friction Accessory, and a Mechanical Oscillator Driver for harmonic motion and resonance studies.
(Note: DC power supply is necessary for operation of the driver.)

Super Dynamics System Components

1. Plunger Cart ME-9430	9. Cart Launcher (2) ME-9488
2. Collision Cart ME-9454	10. Adjustable Feet (2) ME-8972
3. Track ME-9779	11. 250 gram Mass (4) ME-6756
4. Adjustable Endstop (2) ME-8971	12. Angle Indicator ME-9495
5. Super Pulley with Clamp ME-9448A	13. Fan Cart ME-6977
6. Spring Set ME-8999	14. Friction Accessory ME-9457
7. Friction Block ME-9807	15. Mechanical Oscillator Driver ME-8750
8. Rod Clamp ME-9836	Includes Experiment Manual (not shown)

Order Information

2.2 m Super Dynamics System ME-9490
Recommended:
Base and Support Rod ..... ME-9355 p. 171
Mass and Hanger Set ..... ME-8979 p. 181
DC Power Supply ..... SE-9720A p. 232

PAScar Expanded Dynamics Systems

1.2 m Track
ME-9431A

2.2 m Track
ME-9432A

TEACHER FAVORITE



PAScar Expanded Dynamics System Components

1. PAScar (set of 2) ME-6950	8. Spring Cart Launcher ME-6843
2. Track	9. Adjustable Feet (2) ME-8972
3. Adjustable Endstop (2) ME-8971	10. 250 gram Mass (2) ME-6756
4. Super Pulley with Clamp ME-9448A	11. Angle Indicator ME-9495
5. Spring Set ME-8999	12. Photogate Brackets (2) (ME-9806)
6. Friction Block ME-9807	13. Cart Picket Fences (2) (ME-9804)
7. Rod Clamp ME-9836	Includes Experiment Manual (not shown)

- High quality aluminum track
- Colorful PAScars
- Springs, friction block, pulley, angle indicator

These systems include extra equipment for doing additional experiments such as oscillations, friction, Hooke's Law, spring potential energy, and conservation of energy. The Spring Cart Launcher component provides an economical way to launch carts in a repeatable fashion and do energy experiments. Three different strength springs are provided with the Spring Cart Launcher.

Order Information

1.2 m PAScar Expanded Dynamics System ME-9431A

2.2 m PAScar Expanded Dynamics System ME-9432A

Aluminum Starter Tracks



1.2 and 2.2 meter Aluminum Tracks

Have 1.2 m length tracks and want to change to 2.2 m?

These aluminum tracks are available in 1.2 m and 2.2 m lengths.

Order Information

1.2 m Aluminum Starter Track ME-9493

2.2 m Aluminum Starter Track ME-9779

PAScar Systems without Carts

Includes

Aluminum Track
Pivot Clamp
End Stops (2)
Track Feet (2)
Manual



Order Information

PAScar System 1.2 m (without carts) ME-6953

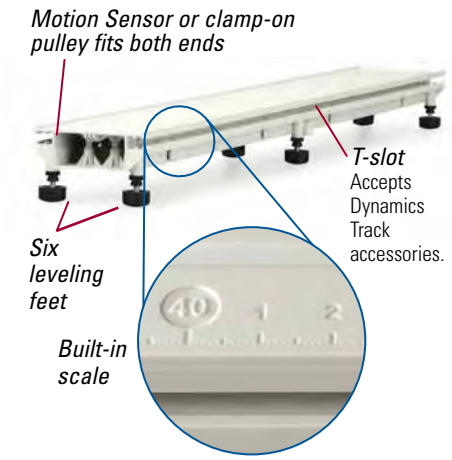
PAScar System 2.2 m (without carts) ME-6954

PAStrack

ME-6960

- 1 m length dynamics track
- Two-piece molded construction
- Accepts dynamics track accessories

Two-piece track construction for easy storage. Snap-on connector clip holds sections straight and rigid. Use the second clip (included) to connect multiple tracks! The track ends are designed to accept the Motion Sensor and Clamp-on Pulley, and the side T-slots accept Dynamic Track accessories, such as photogate brackets and end stops. Track includes six built-in leveling feet.





Includes

Two Piece Track
Connector Clip (2)
Leveling Feet (6)



Order Information

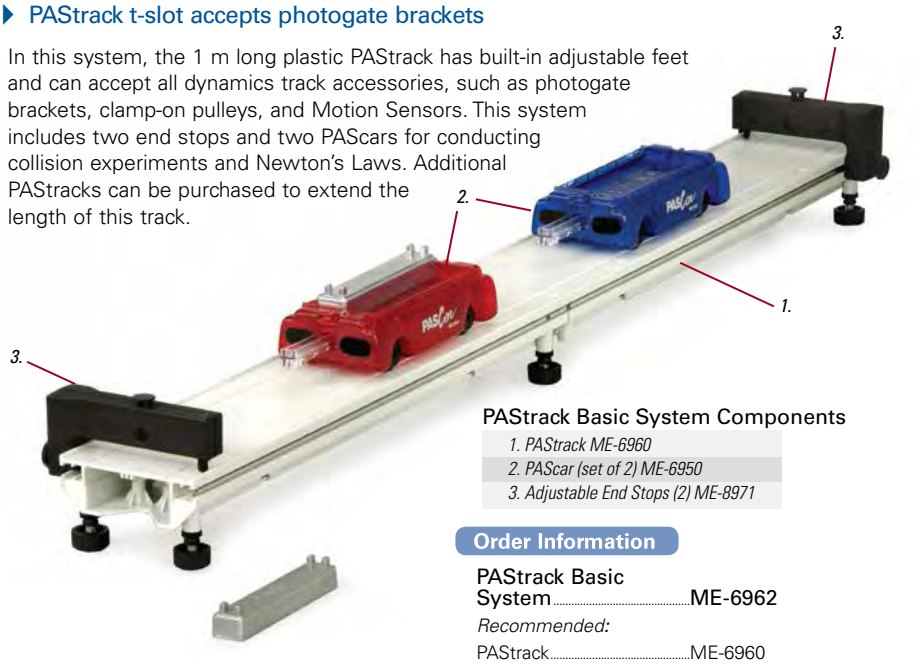
PAStrack ME-6960

PAStrack Basic System

ME-6962

- Most economical system
- Two-piece PAStrack for easy storage
- PAStrack t-slot accepts photogate brackets

In this system, the 1 m long plastic PAStrack has built-in adjustable feet and can accept all dynamics track accessories, such as photogate brackets, clamp-on pulleys, and Motion Sensors. This system includes two end stops and two PAScars for conducting collision experiments and Newton's Laws. Additional PAStracks can be purchased to extend the length of this track.



PAStrack Basic System Components

1. PAStrack ME-6960
2. PAScar (set of 2) ME-6950
3. Adjustable End Stops (2) ME-8971

Order Information

PAStrack Basic System ME-6962
Recommended:
PAStrack ME-6960

PAStrack Dynamics System

ME-6961

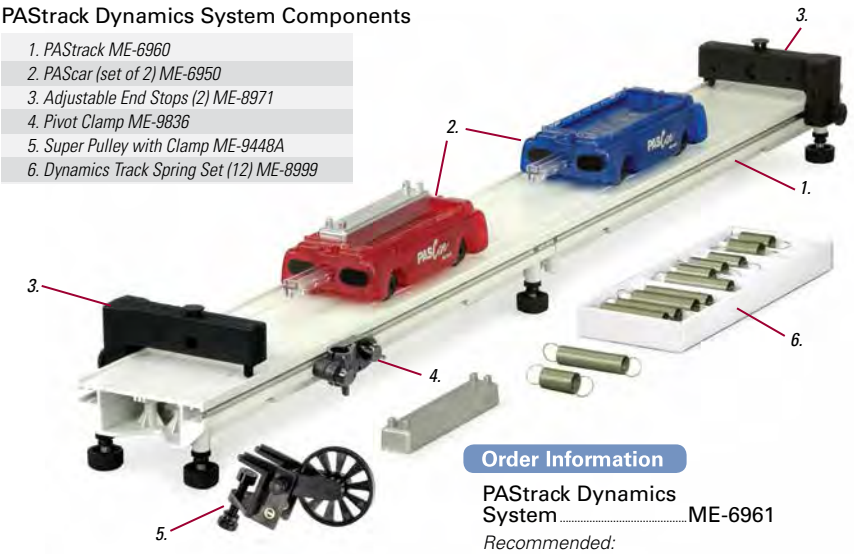
TEACHER FAVORITE

- Multiple uses
- Two-piece PAStrack for easy storage

With this one system, study collisions, Newton's Laws, oscillations, Hooke's Law, velocity, and acceleration. Hang weights over the included clamp-on pulley to accelerate carts or stretch the springs attached to the cart. Additional PAStracks can be purchased to extend the length of this track.

PAStrack Dynamics System Components

1. PAStrack ME-6960
2. PAScar (set of 2) ME-6950
3. Adjustable End Stops (2) ME-8971
4. Pivot Clamp ME-9836
5. Super Pulley with Clamp ME-9448A
6. Dynamics Track Spring Set (12) ME-8999



Order Information

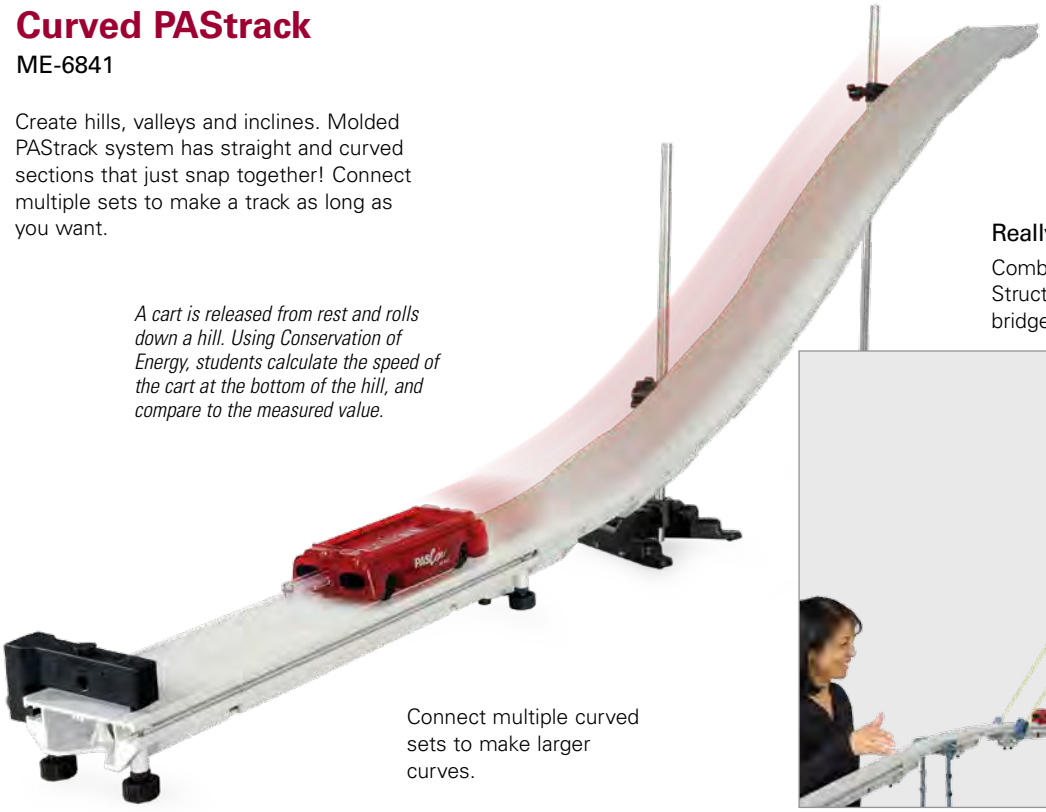
PAStrack Dynamics System ME-6961
Recommended:
PAStrack ME-6960

Curved PAStrack

ME-6841

Create hills, valleys and inclines. Molded PAStrack system has straight and curved sections that just snap together! Connect multiple sets to make a track as long as you want.

A cart is released from rest and rolls down a hill. Using Conservation of Energy, students calculate the speed of the cart at the bottom of the hill, and compare to the measured value.



Connect multiple curved sets to make larger curves.

Really cool! Really big!

Combine your PAStrack with PASCO's Structures System to make really BIG bridges! *See page 134-135.*



Includes

Concave-up Curved Piece
Concave-down Curved Piece
Connector Clip (2)



Order Information

Curved PAStrack	ME-6841	
Shown in use with:		
PAStrack Basic System	ME-6962	p. 90

See page 170-171 for Base and Support Rods.

PAStrack Wheel Set

ME-6964

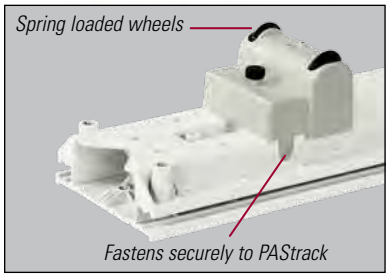
GREAT DEMO

- Add wheels to your PAStrack!
- Demonstrate center of mass and relative motion



Relative Motion

As the Motorized Cart moves forward, the track with wheels moves backwards. Perfect for studying relative motion and center of mass. Shown in use with the Motorized Cart ME-9781 and additional sections of the PAStrack ME-6960.



Includes

Wheel set (2)



Order Information

PAStrack Wheel Set	ME-6964	
Shown in use with:		
PAStrack Basic System	ME-6962	p. 90
Curved PAStrack	ME-6841	
PAStrack	ME-6960	p. 90
Motorized Cart	ME-9781	p. 96

Inclined Plane Dynamics Set

ME-6966

- One set of equipment yields multiple experiments
- Use as an inclined plane or as a straight track
- Designed to allow sensors to be added

At the heart of this Dynamics Set is the Inclined Plane Accessory (ME-6965), a plastic hinge (with an angle scale) that enables the two halves of a PAStrack (ME-6960) to be configured as an inclined plane. There is even a rubber band bumper at the lower end of the incline to keep things from sliding off the bottom of the incline. The advantage of using a PAStrack is that it accepts all the accessories that fit a regular dynamics track, such as photogate brackets and Motion Sensors. It has the added advantage that the PAStrack can be used on its own as a one-meter straight dynamics track.



The inclined plane dynamics set can be used in a variety of ways:

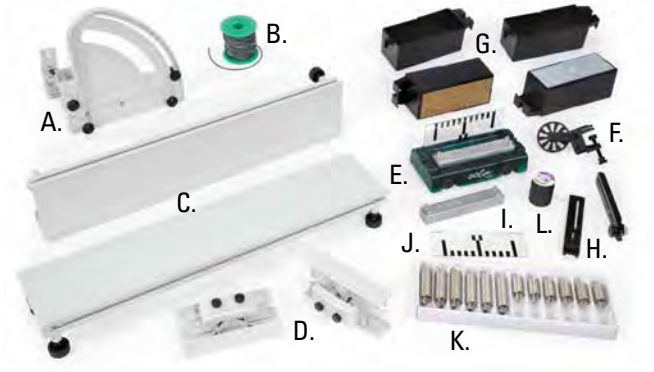
– If you want a nearly frictionless experiment, use the included GOcar.
– To explore friction, use the four friction trays that have different surfaces and can change mass by putting masses in the trays.
– Accelerate the car by hanging a weight over the clamp-on pulley and attach a photogate using the photogate bracket so the pulley blocks the photogate.
– Use Hooke's Law to determine the spring constants of the 12 springs.
– Connect the springs to the cart and make the cart oscillate on the incline, finding the period of oscillation for different springs and different masses.

ME-6966 included equipment

A. PAStrack Inclined Plane Accessory	ME-6965
B. Rubber Cord, 1.5 mm square, 30 m	ME-8986
C. PAStrack, 1 meter	ME-6960
D. PAStrack Connectors (2)	
E. GOcar	ME-6951
F. Super Pulley with Clamp	ME-9448A
G. Discover Friction Accessory	ME-8574
H. Photogate Brackets (2)	ME-9806
I. PAScar Masses (2)	ME-6756
J. Picket Fence - Smart Timer (2)	ME-8933
K. Dynamics Track Spring Set	ME-8999
L. Nylon Thread	
Experiment Manual	

The included manual includes five complete experiments:

1. Oscillations on an Inclined Plane
2. Acceleration Down an Incline
3. Springs in Series and Parallel
4. Friction and the Inclined Plane
5. Newton's Second Law on an Inclined Plane



Order Information

Inclined Plane Dynamics Set ME-6966

Recommended:

Mass and Hanger Set	ME-8979	p. 181
Photogate Head	ME-9498A	p. 39
Motion Sensor	PS-2103A or CI-6742A	p. 27
Stopwatch	ME-1234	p. 182
Force Sensor	PS-2104 or CI-6746	p. 30

PAStrack Inclined Plane

ME-6967

The PAStrack Inclined Plane includes the Inclined Plane Accessory (ME-6965) and the PAStrack (ME-6960).



Order Information

PAStrack Inclined Plane ME-6967

Inclined Plane Accessory

ME-6965

The Inclined Plane Accessory includes the hinge with angle scale and the rubber cord for the rubber bumper. A PAStrack is required to make a complete inclined plane.





Order Information

Inclined Plane Accessory ME-6965

Required:

PAStrack ME-6960

PASCO Dynamics Carts

PAScar (set of 2)

ME-6950

Each 250 gram polycarbonate plastic cart includes both a spring plunger, magnets and Velcro tabs for collision studies. The PAScars come in sets of two, red and blue, and are compatible with all PASCO Dynamics Tracks and accessories.

Polycarbonate Body
Total mass: 250 g



Order Information

PAScar (set of 2)	ME-6950	
Replacement Supplies:		
Replacement Axles (4 pack)	ME-6957	p. 104
PAScar Mass	ME-6756	p. 104

Classic Carts

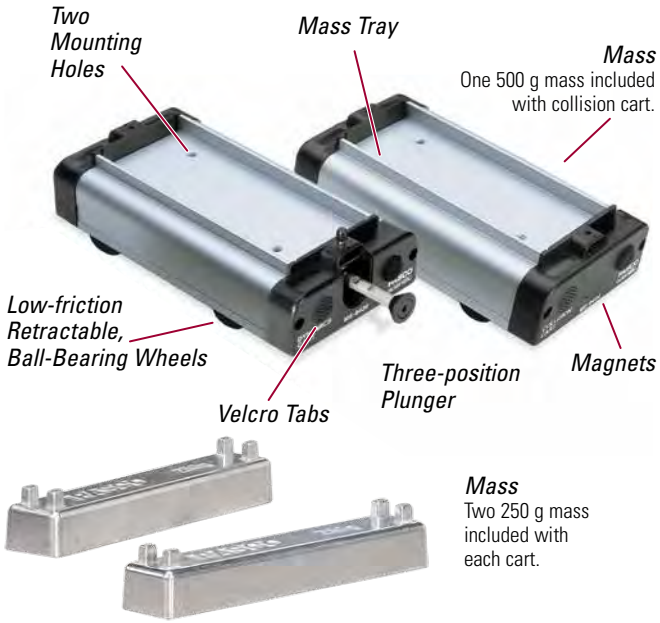
Plunger Cart

ME-9430

Collision Cart

ME-9454

These are the standard carts in thousands of physics labs around the world. With an aluminum body, high-impact ABS plastic end caps, and a 500 g mass, they make dynamics experiments quick to set up and very quantitative. The Classic Carts are compatible with all PASCO Dynamics Tracks and accessories.



Order Information

Plunger Cart	ME-9430	
Collision Cart	ME-9454	
Replacement Supplies:		
Replacement Axles (4 pack)	ME-6957	p. 104
Classic Cart Mass	ME-6757	p. 104

GOcar

ME-6951



The GOcar is the low-cost alternative to the PAScar. It's the same molded, plastic body without the plunger, magnets or Velcro tabs. A low-friction car with spring-loaded wheels to prevent damage from drops. Mass is approximately 220 g.

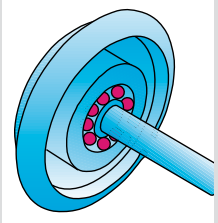
Order Information

GOcar	ME-6951	
Recommended:		
PAStrack	ME-6960	p. 90
PAScar, GOcar Accessories	ME-6952	p. 100
Spring Cart Launcher	ME-6843	p. 99
PAScar Mass	ME-6756	p. 104

PASCO Carts share two important features:

Low friction

Ball-bearing, knife-edge wheels mean that student data will more closely match theory.



Spring-loaded suspension

Wheels retract into the body, so they are protected from drops or "skateboarding."



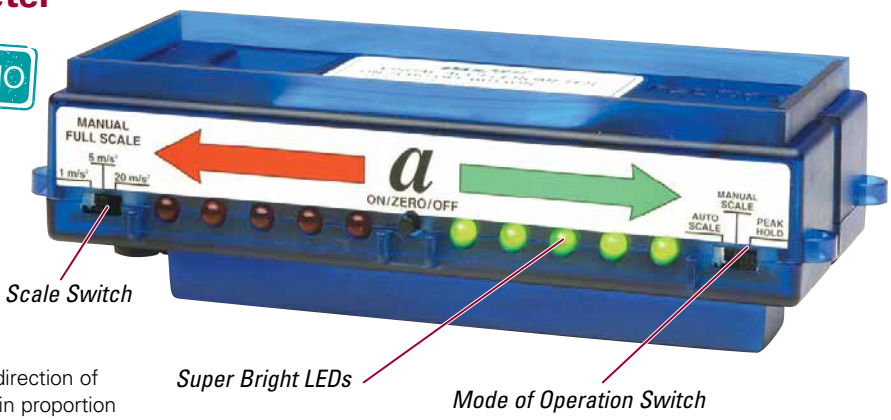
Students can even step on a PASCO Dynamics Cart without damaging it.

PASPORT Visual Accelerometer

PS-2128

GREAT DEMO

- Clearly demonstrates the difference between velocity and acceleration
- Shows both direction and magnitude of acceleration
- Acts as a PASPORT Sensor when connected to a computer *(See page 36)*



How It Works

The Visual Accelerometer shows the magnitude and direction of acceleration in one dimension. Five green LEDs light in proportion to the acceleration to the right and five red LEDs light in proportion to the acceleration to the left. Because the Visual Accelerometer is mounted on the accelerating object, students see the acceleration without having to look away at a computer.



Push a cart up the incline and let it go back down. Students will expect the direction of the acceleration to change, depending on whether the cart is going up or down the incline. They are surprised that the red lights stay lit in the same direction.



The Visual Accelerometer can be used with the Fan Accessory (ME-9491) for constant acceleration experiments. The Time Pulse Accessory (ME-9496) allows the fan to turn on and off hands-free.

Features

Super Bright LEDs: Strong visual clues to both the magnitude and direction of the acceleration.

Portable: Clearly shows magnitude and direction of acceleration with no cord attached.

Auto-Scale: The auto-scale feature makes any acceleration between 0.2 and 20 m/s^2 a full-scale reading.

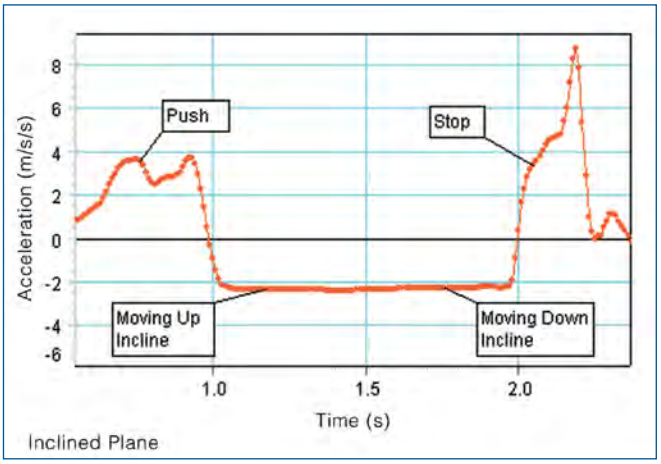
Peak-Hold Mode: Freezes the lighted LEDs at the maximum acceleration so it can be viewed after the object stops.

Specifications

Three Manual Scales: 1 m/s^2, 5 m/s^2, 20 m/s^2 full scale

Requires three AA batteries for stand-alone operation (included)

Auto-off after three hours



When connected to a computer, the Visual Accelerometer measures the acceleration as the cart is pushed by hand. The direction and magnitude of the acceleration is constant as the cart goes up and then goes down the incline.

Includes

Visual Accelerometer

Plastic M5 screws for attachment to a Dynamics Cart (2)

PASPORT Sensor Cable



Order Information

PASPORT Visual Accelerometer PS-2128

Recommended:

Visual Accelerometer Accessory Kit ..... PS-2516 p. 36

Ballistic Cart Accessory

ME-9486

- Works every time
- Non-contact release
- Adjustable barrel

GREAT DEMO

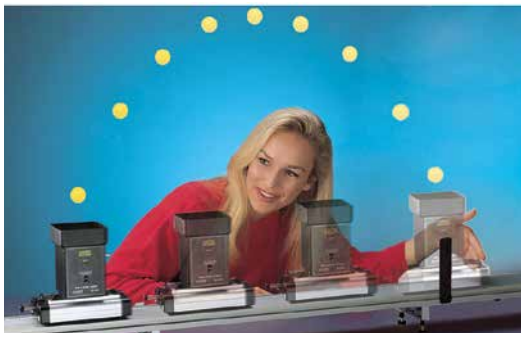


PASCO's Ballistic Cart Accessory helps beginning physics students grasp the independence of vertical and horizontal motion.

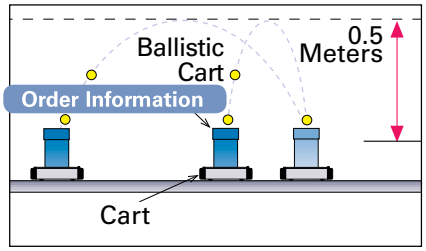
How It Works

Mounted on a dynamics cart or motorized cart moving at constant velocity, the Ballistic Cart Accessory launches a ball vertically, continues down the track, and then catches the ball as it falls—every time. Offers an exciting introductory demonstration to projectile motion.

Compatible with PASCO Classic Carts, PAScars and GOcars.



Ballistic Cart Accessory attaches to a dynamics cart and projects a ball as it travels along a track.



At slow or fast speeds, the results are the same.

Features

Photogate Ball Release: PASCO's optical release does not affect cart motion or ball flight path, no matter what the speed of the cart.

Alignable Barrel: The barrel has X and Y adjustments so perfect vertical projections can be produced every time, even on non-level surfaces.

Constant Velocity: Mounts on the low-friction PASCO Dynamics Cart so horizontal velocity remains constant.

Strong Compression Spring: Fires a colored nylon ball 0.5 meters or higher—impressive for demonstration purposes.

Includes

Ballistic Launcher
Trigger Bracket
Plastic Balls (2)
9V Battery

Order Information

Ballistic Cart Accessory ME-9486

Required:

Dynamics System ..... p. 88-90

Recommended:

Variable Speed Motorized Cart ..... ME-9781 p. 96

Cart Launcher ..... ME-9488 p. 99

Drop Rod Accessory for Ballistic Cart

ME-9487

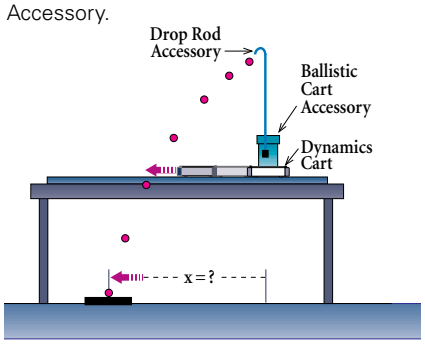


How It Works

The Drop Rod mounts on the side of the Ballistic Cart Accessory. A magnetic nylon ball attaches to the top of the rod and is released when the photogate on the cart is triggered. The rod can be mounted to drop the ball into the cart or rotated 180° so the ball will drop to the floor. Students can calculate where the ball will hit the floor under the following conditions:

1. Constant velocity
2. Constant acceleration
3. On an inclined track

All these experiments are possible with the Ballistic Cart and the Drop Rod Accessory.



Dropping the ball to the floor offers several challenging quantitative experiments.

Typical Experiments

1. Shoot and Catch
2. Tunnel
3. Accelerating Cart*
4. Inclined Plane*
5. Drop Ball**
6. Bombing Run**

**Can be performed with or without the Drop Rod.*
***Requires Drop Rod.*

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Includes

Ball and Rod

Order Information

Drop Rod Accessory ME-9487

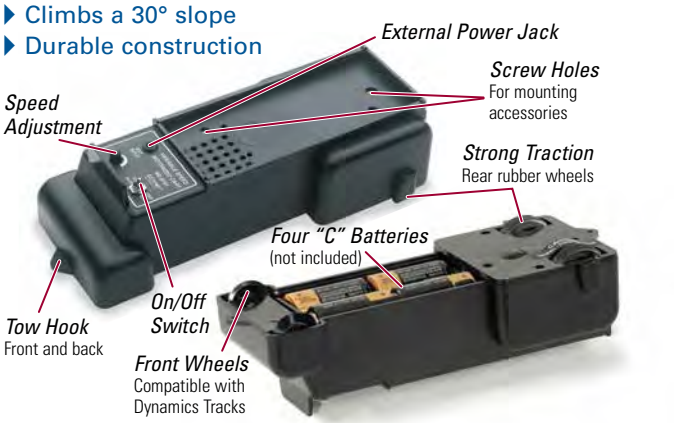
Required:

Ballistic Cart Accessory ME-9486

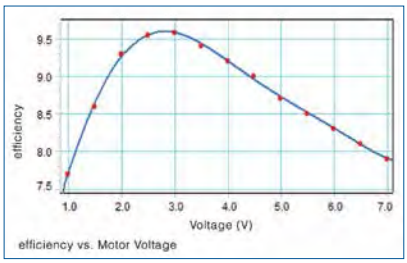
Motorized Cart

ME-9781

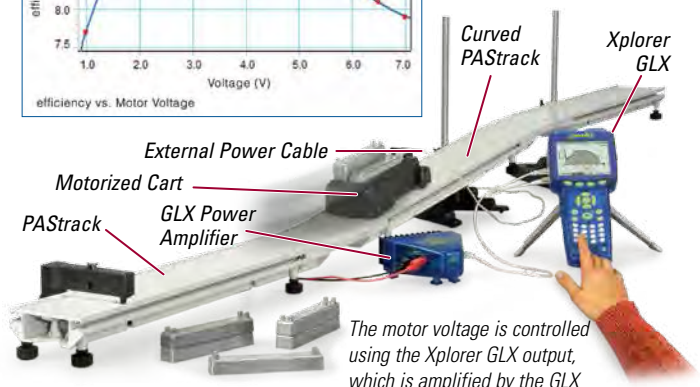
- Battery powered/adjustable speeds
- External power jack
- Climbs a 30° slope
- Durable construction



The tank-like molded casing and a rugged internal gear mechanism are built for the harshest student environment. Runs on four "C" batteries and has variable speed adjustment knob. External power input accepts phone plug cable (included) to power the car using a DC power supply, or a programmable power supply such as the GLX Power Amplifier (shown in use below).



This graph shows effect of increasing motor voltage on the efficiency.



The motor voltage is controlled using the Xplorer GLX output, which is amplified by the GLX Power Amplifier.

Includes

Motorized cart

Cable for connecting to external power supply

Specifications

Adjustable Speed: ≈ 8-25 cm/s
Battery Power: Four "C" (not included)
External Power Input Jack
Battery Life (Alkaline): Six hours

Order Information

Motorized Cart	ME-9781	
PAStrack	ME-6960	p. 90
Curved PAStrack	ME-6841	p. 91
Xplorer GLX	PS-2002	p. 19
GLX Power Amplifier	PS-2006	p. 20
250 g Mass	ME-6756	p. 104
Base and Support Rods	Various	p. 171
"C" Batteries (4 pack)	PI-6603	p. 216

Super Fan Cart

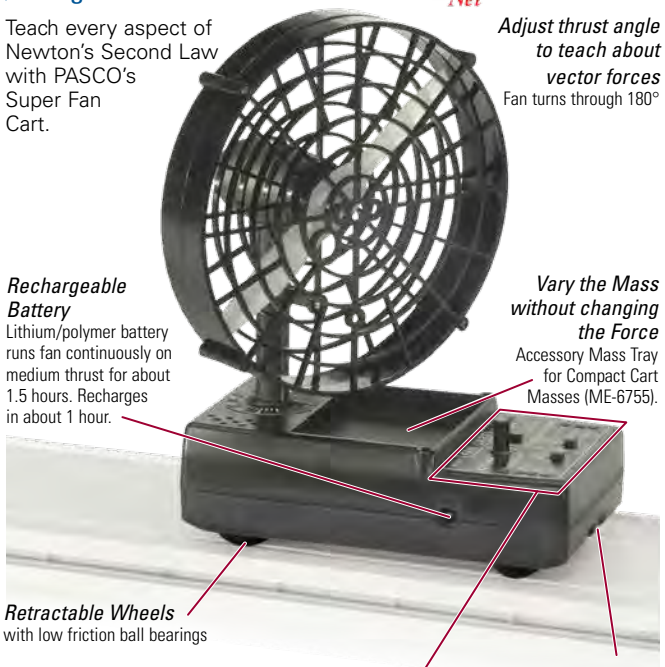
ME-6977

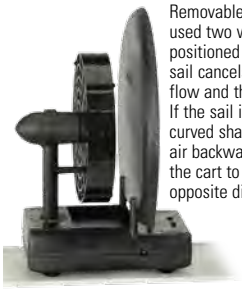
GREAT DEMO

$\vec{F}_{Net} = m\vec{a}$

- Constant force
- Rechargeable
- Programmable

Teach every aspect of Newton's Second Law with PASCO's Super Fan Cart.





The Net Force Is Zero
Removable sail can be used two ways: When positioned as shown, the sail cancels the forward air flow and there is no thrust. If the sail is reversed, its curved shape reflects the air backwards, causing the cart to move in the opposite direction.



Pulse Duration
Program fan to be pulsed on for specific time to demonstrate acceleration only occurs when a force is applied. Includes time delay and auto-repeat option.

Specifications

Fan Cart Mass: Approximately 0.3 kg
Sail Mass: Approximately 0.1 kg
Regulated Power Supply: Lithium/polymer battery (7.2 volts, 1.25 amp-hour)
Run-time: Runs approximately 1.5 hr on medium thrust
Recharge Time: One hour typical
Thrust Settings: Approximately 0.04 N on Low, 0.15 N on Medium, and 0.22 N on High
Thrust, Variable: Approximately 0.01 N to 0.23 N

Order Information

Super Fan Cart	ME-6977	
Includes: Fan cart, sail and charger		
Recommended:		
PAStrack	ME-6960	p. 90
Compact Cart Mass	ME-6755	p. 104
Motion Sensor	PS-2103A	p. 27
USB Link	PS-2100A	p. 21

Fan Accessory

ME-9491

TEACHER FAVORITE

The Fan Accessory gives any PASCO cart self-propulsion capability and includes a safety guard to protect student fingers. Simply snap the accessory onto the top of a cart, flip the switch, and observe the constant acceleration motion. The speed can be varied by removing one or more batteries and replacing with included slugs.



Cart not included

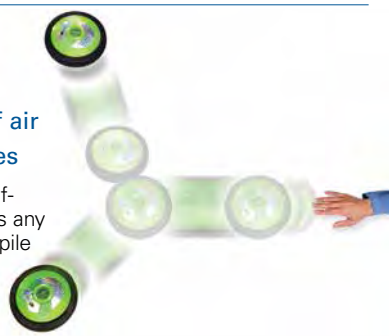
Order Information

Fan Accessory	ME-9491	
Recommended:		
Four "AA" Cell Alkaline Batteries	PI-6601	p. 216
Dynamics Carts		p. 93
Dynamics Track (1.2 or 2.2 m)		p. 88-89
Time Pulse Accessory	ME-9496	

Hover Puck

SE-7335B

- Hovers on a cushion of air
- Ideal for inertia activities



The Hover Puck glides on a self-generated cushion of air across any smooth surface, including low-pile carpet. The rubber bumper provides protection for the puck and other objects during collisions. Each puck includes four "AA" batteries.

Includes

Hover Puck

Four "AA" Batteries



(Appearance may vary)

Specifications

Diameter: 18.5 cm

Height: 6.0 cm

Order Information

Hover Puck	SE-7335B	
Recommended:		
PASPORT Motion Sensor	PS-2103A	p. 27
ScienceWorkshop Motion Sensor II	CI-6742A	p. 27

Hover Puck Launcher

SE-7389

Use this sturdy launcher to propel the Hover Puck with repeatable velocities. The launcher includes large rubber bands that can be placed at two different positions to vary the launch velocity.



Includes

Launch Pad

Large Rubber Bands (30)

Order Information

Hover Puck Launcher	SE-7389

Time Pulse Accessory

ME-9496



Time Pulse Accessory mounted on Fan Accessory

When plugged into the Fan Accessory or the Variable-speed Motorized Cart, the Time Pulse Accessory allows students to apply a repeatable impulse for constant acceleration and constant velocity experiments.

The Start button, with a 2-second delay feature, engages the motor of the Fan Accessory or the Variable-speed Cart for 1, 2 or 4 seconds, or for an adjustable pulse of 1-7 seconds.

The Time Pulse Accessory includes two replaceable lithium batteries that last up to five years.

Order Information

Time Pulse Accessory	ME-9496

Multi Fan Bracket

ME-6616



The Multi Fan Bracket fastens onto any PASCO cart and holds up to three of the Fan Accessories. The fans can be clipped on in either direction.

Includes

Bracket

Mounting Screws



Order Information

Multi Fan Bracket	ME-6616

Constant Speed Buggy

SE-8028A



Turn on the Constant Speed Buggy and watch it go. When it reaches a wall, it flips over and changes directions. This low-cost solution features flashing lights and a sporty appearance. Requires two "C" batteries that are not included. Actual product may vary from picture.

⚠ WARNING
CHOKING HAZARD
Small parts. Not for children under 3 years.

Order Information

Constant Speed Buggy	SE-8028A

Force Accessory Bracket

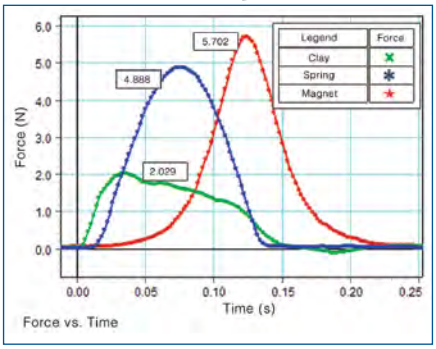
CI-6545

LAB ESSENTIALS

The Force Accessory Bracket with Bumpers mounts the Economy Force Sensor or Force Sensor directly to a Dynamics Track. Includes five collision attachments for the Force Sensor and conveniently stores each attachment on the bracket itself.

Using any of these attachments, the bracket serves as an excellent support or target for collision studies using the Force Sensor.





Force vs. time data for a clay, spring and magnet.

Includes

Spring Bumpers (2)
(different spring constants)

Magnetic Bumper (1)

Rubber Bumper (1)

Clay Cup for Inelastic Collisions (1)
(clay included)

#0 Phillips Head Screwdriver
(to attach to Force Sensor)



Note the bumper springs and various mounting options.

Order Information

Force Accessory Bracket CI-6545

Bumper Accessory Set

ME-9884



This set of bumpers can be used with any PASCO Force Sensor to perform both elastic and inelastic collisions. The standard hook for each Force Sensor can be easily removed and replaced with any of these bumpers. Use a spring and a cup for elastic collisions. Combine two cups with clay to explore inelastic collisions.

Includes

Stiff Spring

Light Spring

Empty Cup (2)

Modeling Clay



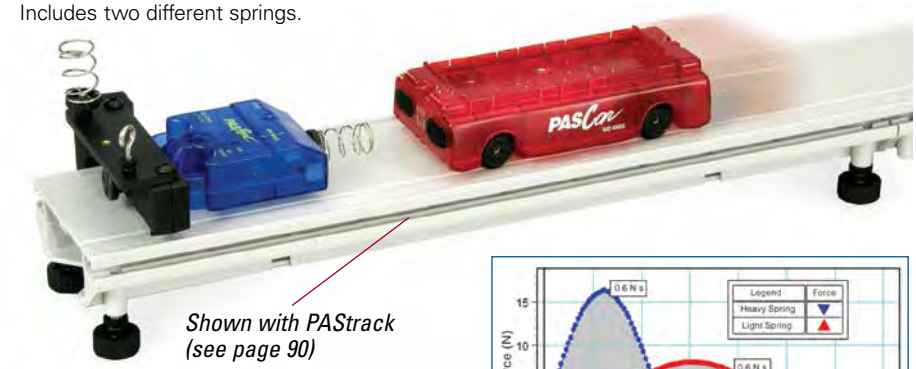
Order Information

Bumper Accessory Kit ME-9884

Discover Collision Bracket

ME-8973A

The Collision Bracket fastens to the T-slot of a Dynamics Track, and securely holds the Force Sensor for measuring collisions with a Cart. Includes two different springs.



Shown with PAStrack (see page 90)

Includes

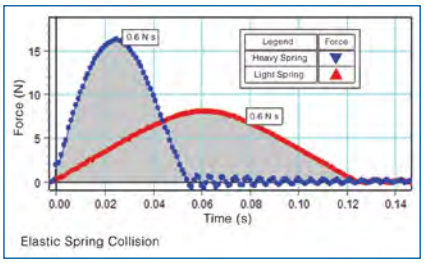
Two Springs

Bracket



Order Information

Discover Collision Bracket ME-8973A



The cart collides with the Force Sensor at the same initial speed for both of the springs. The area under the Force vs. Time graph is the change in momentum (impulse) of the cart and is the same for both collisions.

Magnetic Bumper Set

ME-9885A



This set of magnetic bumpers can be used with any PASCO Force Sensor to perform elastic collisions without any contact. The bumpers screw directly into the beam of the sensor. They can also be used with the Force Accessory Bracket.

Includes

Magnetic Bumper (2)



Order Information

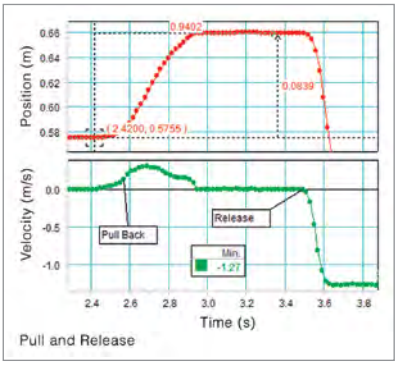
Magnetic Bumper Set ME-9885A

Spring Cart Launcher

ME-6843

- Affordable cart launcher
- Hooke's Law
- Spring potential energy





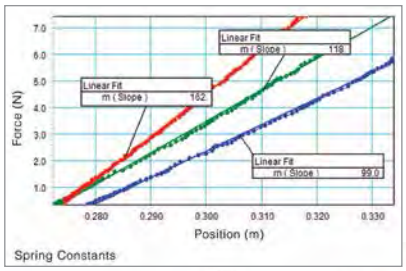
The spring potential energy is converted to kinetic energy. The Spring Cart Launcher rides in the cart, so nearly all the energy from the spring is transferred to the cart. The position of the cart (top) and the velocity of the cart (bottom) are measured using the Motion Sensor.

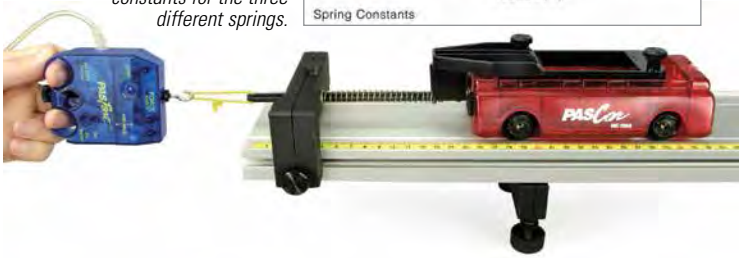
The Spring Cart Launcher provides an economical way to launch carts in a repeatable fashion. It can be used for Hooke's Law, collisions, and for Conservation of Energy.

The Spring Cart Launcher fits into the bed of a Dynamics Cart, PAScar, or GOcar.

To launch the cart, the plunger is pulled through the hole in the new endstop, compressing the spring, and then released. To add repeatability, a second endstop can be used with the supplied pin to hold the plunger at a specified compression position. Three different strength springs are provided with the Spring Cart Launcher. Use with or without probeware.

To perform the Hooke's Law experiment, the Spring Cart Launcher plunger is pulled with a Force Sensor (PS-2104), compressing the spring, while the displacement of the cart is measured with a Motion Sensor (PS-2103A). The slopes of the graphs of Force versus Position give the spring constants for the three different springs.







Includes

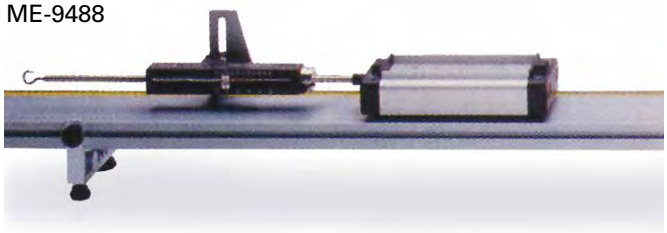
Spring Cart Launcher
Trigger Pin
Three Different Strength Springs

Order Information

Spring Cart Launcher	ME-6843	
Required:		
Dynamics Track System	See pages 88-90	
Recommended:		
End Stops (2)	ME-8971	p. 105
Replacement Springs (Three different strength springs, two each)	ME-6847	
Compact Cart Mass	ME-6755	p. 104

Cart Launcher

ME-9488



The Cart Launcher launches PASCO Dynamics Carts with repeatability that is impossible to achieve by hand. The force of the launcher is fully adjustable, and the built-in scale permits force calibration. Mounts to PASCO Dynamics Tracks.



Includes

Cart Launcher with Trigger Release
Dynamics Track Mount

Features

Repeatability: Launch carts with the same force each time. Data will be consistent and accurate.

Variable Launch Speed: Vary spring compression to vary the speed.

Compatible with Dynamics Cart Accessories: Use with the Ballistic Cart or Fan Cart.

Calibration—
Mount the launcher vertically and hang masses from the hook to calibrate the spring. Use the built-in scale as a reference. At maximum spring compression, the launcher produces a 30 N force.



Order Information

Cart Launcher	ME-9488

Magnetic Damping Accessory

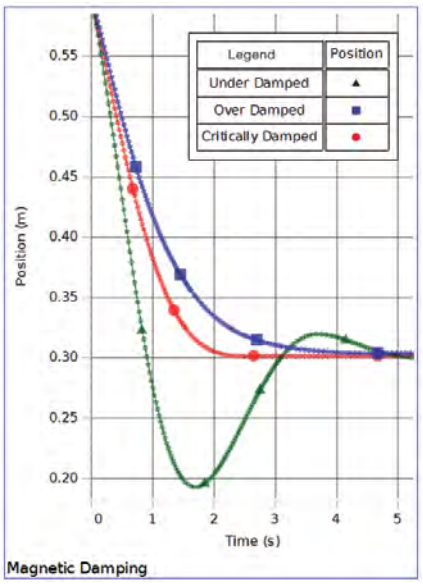
ME-6828



Magnetic Damping
The steel bracket of the Magnetic Damping Accessory slides up and down to adjust the amount of damping.

The Magnetic Damping Accessory induces eddy currents in the aluminum track, causing friction that is proportional to the velocity of the cart.

Over-damped, Under-damped, Critically-damped



The green line shows a system that is under-damped. The cart is over-damped (blue line) when the magnets are very close to the track. When the cart is critically damped (red line), it reaches its equilibrium position in the minimum amount of time.

Includes

Bracket
Magnets
Keeper



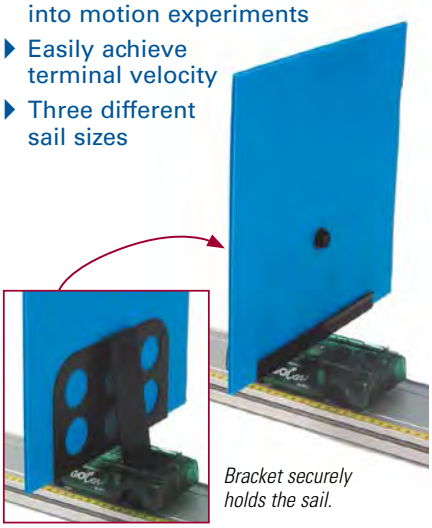
Order Information

Magnetic Damping Accessory ME-6828
Equipment shown:
PAScar Dynamics System (1.2 m) ME-6955A
Dynamics Track Spring Set ME-8999
Motion Sensor PS-2103A

Car Sail

ME-9595

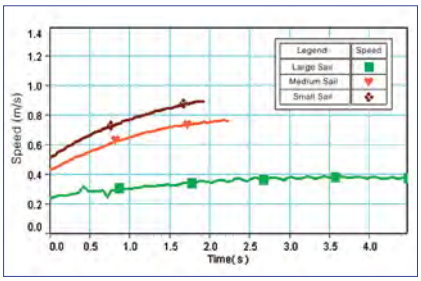
- Introduce air resistance into motion experiments
- Easily achieve terminal velocity
- Three different sail sizes



Bracket securely holds the sail.

The Car Sail allows students to study the effects of air resistance on PASCO carts. Simply attach the bracket to the mass tray of the cart and attach any of the three included sails. Using the various sails, the relationship between surface area and terminal velocity can be studied. Students can also create their own sails and attach them to the bracket.

Terminal velocity is related to both the surface area and the mass of an object in motion. Students should compare the motion of the cart without a sail to its motion with the sails. As the surface area of the sail increases, the cart will more closely approach a terminal velocity.



Comparison of cart velocity as it moves down the track with various sails attached.

Includes

Sail Bracket
Screws for Cart and Sail Mounting
Sails: 3600 cm², 1800 cm², and 900 cm²

Order Information

Car Sail ME-9595

PAScar/GOcar Accessories

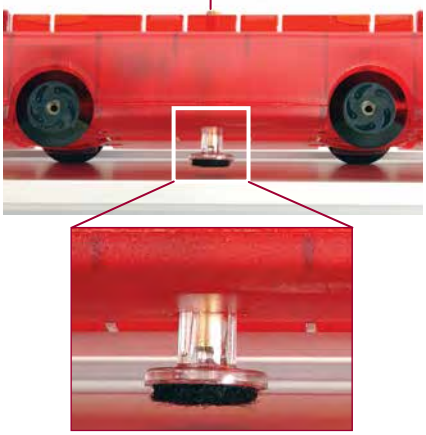
ME-6952

Extend the utility of the PAScar and GOcar.



The Magnetic Bumper attaches to the Velcro® end of the PAScar for a chain of elastic collisions. The bumper can also be attached to the GOcar so it can undergo elastic collisions with a PAScar.

Adjustment Screw



The Friction Pad is installed through a threaded hole in the middle of the cart. Students can rotate the pad to either increase or decrease the induced friction.

Includes

Friction Pad
Magnetic Bumper



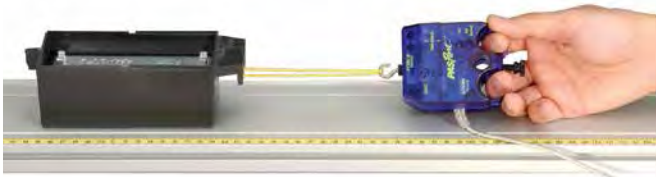


Order Information

PAScar/GOcar Accessories ME-6952

Discover Friction Accessory

ME-8574



PASCO's Discover Friction Accessory is unlike any other friction set. The trays are designed to work effectively with PASCO carts and sensors. Using the four trays, students can discover such concepts as coefficient of friction, static friction, kinetic friction and the sliding friction equations. The two trays with identical plastic surfaces can be hooked together to explore the relationship between surface area and sliding frictional forces.



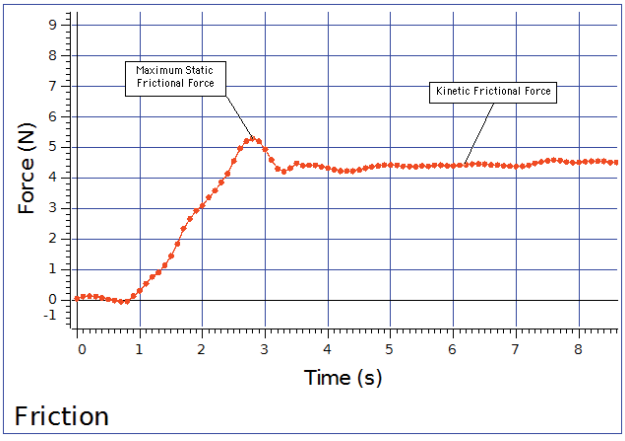
Motorized Cart can also be used to pull the loaded friction tray from rest to a constant velocity.

Features

Easy Storage: Friction trays are stackable

Versatile: Students discover key friction concepts

Compatible: Can be used with PASCO carts, masses, and Force Sensors



The peak of the graph represents the maximum static frictional force. Once the friction tray begins to move, the kinetic frictional force is evident on the graph.

Includes

Friction Tray - Felt

Friction Tray - Cork

Friction Tray - Plastic (2)



Order Information

Discover Friction Accessory ME-8574

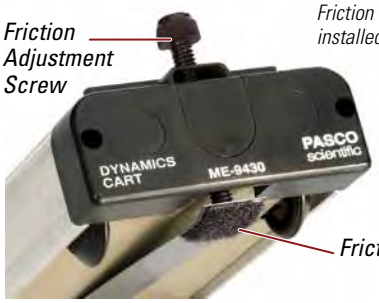
Recommended:

PAScar Mass	ME-6756	p. 104
PAScars (set of 2)	ME-6950	p. 93
GOcar	ME-6951	p. 93
Variable Speed Motorized Cart	ME-9781	p. 96
Force Sensor	See pages 30-31	
Dynamics System	See pages 88-90	

Friction Cart Accessory

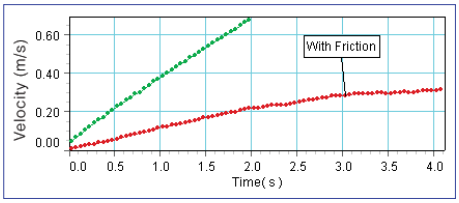
ME-9457

The Friction Cart Accessory mounts to either a Plunger (ME-9430) or Collision Cart (ME-9454) by replacing the cart's end cap. All parts and mounting hardware are included.



Friction Cart Accessory installed on a Dynamics Cart.

The Friction Cart Accessory allows the friction of either a Plunger or a Collision Cart to be varied over a wide range of values.



Graph shows velocity of a cart on an incline, both with and without friction.

Includes

Friction Adjustment Screw

Friction Pad

Mounting Hardware

Replacement End Cap



Order Information

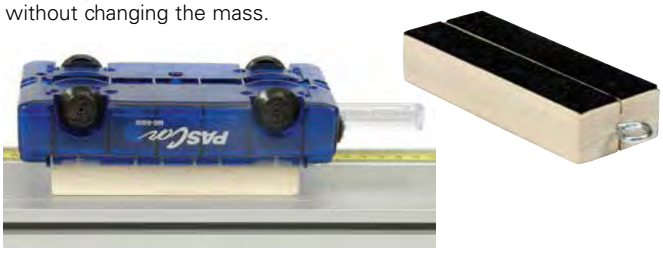
Friction Cart Accessory ME-9457

Friction Block

ME-9807

- Two Types of Material
- Vary Surface Area by Using It Flat or Up On Its Side
- Hook for Attaching a String to Pull It
- Slot for a Picket Fence or Flag for Photogate Timing

The wooden Friction Block has felt on two sides, so the frictional coefficients for felt or wood can be measured. It also fits into the dynamics cart tray so the cart can run on its wheels, or it can be turned upside down to run on the Friction Block, without changing the mass.



Features

Dimensions:
13 cm x 5 cm x 1.7 cm

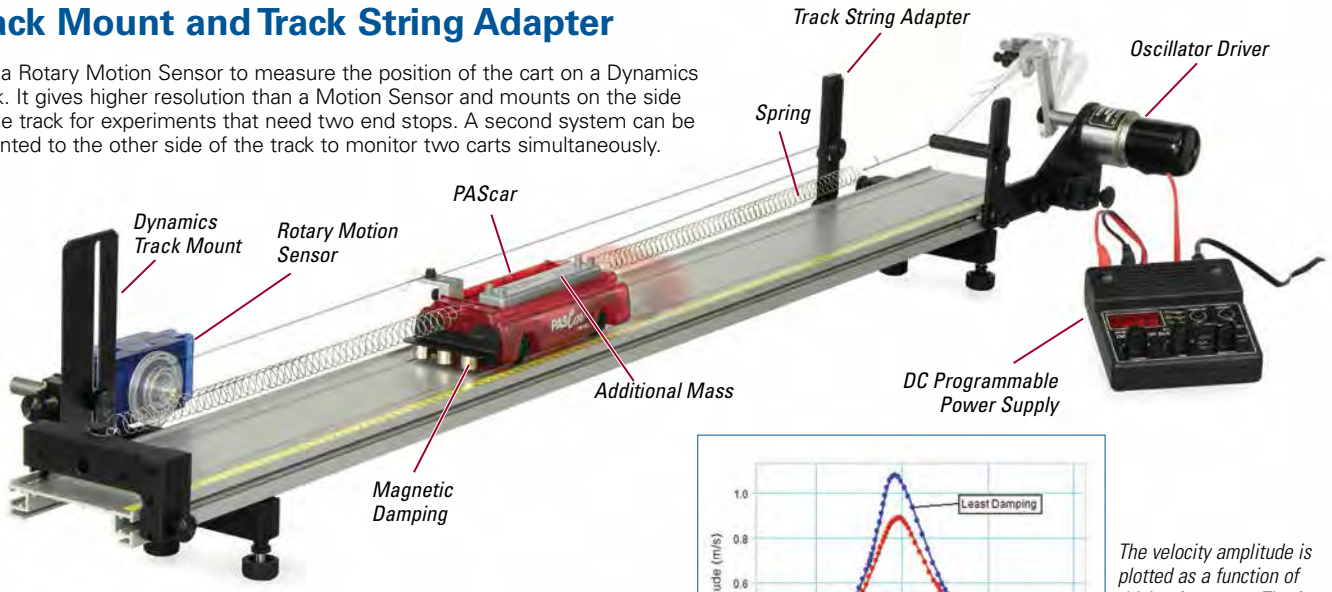
Approximate Mass: 110 g

Order Information

Friction Block ME-9807

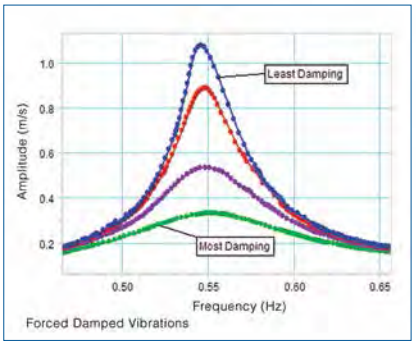
Rotary Motion Sensor with Dynamics Track Mount and Track String Adapter

Use a Rotary Motion Sensor to measure the position of the cart on a Dynamics Track. It gives higher resolution than a Motion Sensor and mounts on the side of the track for experiments that need two end stops. A second system can be mounted to the other side of the track to monitor two carts simultaneously.



Equipment Shown

1.2 m PAScar Dynamics System	ME-6955A	
Dynamics Track Spring Set	ME-8999	p. 104
Magnetic Damping Accessory	ME-6828	p. 100
DC Programmable Power Supply	PI-9880	p. 231



The velocity amplitude is plotted as a function of driving frequency. The four resonance curves show the effect of varying the strength of the magnetic damping.

Dynamics Track Mount

CI-6692



The Dynamics Track Mount (CI-6692) is for mounting the Rotary Motion Sensor to the Dynamics Track, allowing it to act as a high resolution, bi-directional Smart Pulley.

Includes

Bracket



Order Information

Dynamics Track Mount CI-6692

Rotary Motion Sensor for use with:

ScienceWorkshop	CI-6538	p. 28
PASPORT	PS-2120A	p. 28

Mechanical Oscillator/Driver

ME-8750



The Mechanical Oscillator/Driver delivers repeatable, low-frequency, high-force sinusoidal motion for harmonic motion experiments. Shown with the PAScar Dynamics System (ME-6956), and also works with the Classic Dynamics Systems.

Features

Sinusoidal Drive:
12 VDC motor
(frequency: 0.3-3 Hz, current: 0-0.3 A).

Adjustable Amplitude: Up to 12 cm.

Order Information

Mechanical Oscillator/Driver ME-8750

Track String Adapter (RMS/IDS Kit)

ME-6569



When used in conjunction with the Dynamics Track Mount (CI-6692), this unit allows a Rotary Motion Sensor to continuously monitor the Dynamics Cart position. A loop of string wraps around the Rotary Motion Sensor pulley and the ball-bearing pulley, and then it attaches to the cart via a special clip (included).

Includes

Bracket with Pulley

Cart String Clip

Thread



Order Information

Track String Adapter (RMS/IDS Kit) ME-6569

Motion Sensors

PS-2103A PASPORT
CI-6742A *ScienceWorkshop*

- 360° rotating head
- False target rejection circuitry
- Bi-directional measurements of position, velocity and acceleration

PASCO's ultrasonic Motion Sensors clip directly to Dynamics Tracks, and their unique "Narrow Beam" technology provides cleaner data.



The Motion Sensor can be mounted directly to the Dynamics Carts or PAScars for relative motion studies.

Motion Sensor clips to Dynamics Track.

Order Information

ScienceWorkshop Motion Sensor II	CI-6742A	p. 27
PASPORT Motion Sensor	PS-2103A	p. 27
Required to mount on PASCO Carts:		
Cart Adapter Accessory	ME-6743	

Cart Adapter Accessory

ME-6743



The Cart Adapter Accessory allows the Motion Sensor II and many other sensors to be mounted to a Dynamics Cart or a PAScar.



Mounting a Motion Sensor on a cart is ideal for the study of relative motion. The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Includes

Two M5 thumb screws to attach to cart

1/4"-20 screw at center



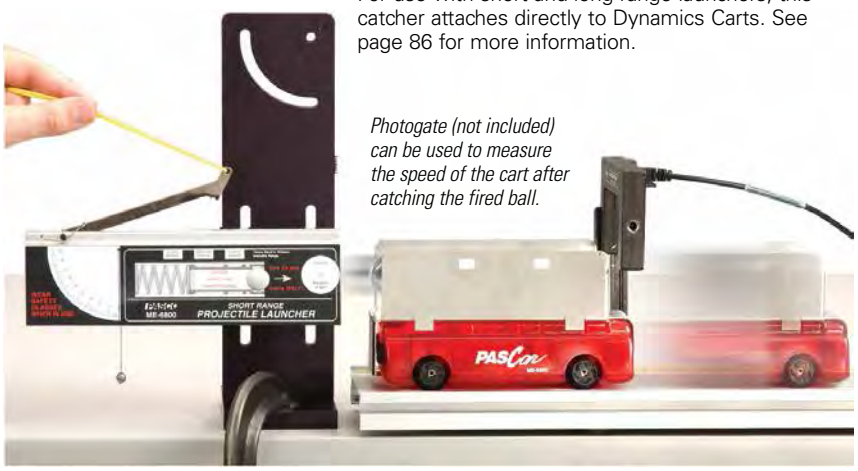
Order Information

Cart Adapter Accessory	ME-6743

Projectile Catcher Accessory

ME-6815

For use with short and long range launchers, this catcher attaches directly to Dynamics Carts. See page 86 for more information.



Photogate (not included) can be used to measure the speed of the cart after catching the fired ball.

Includes

Projectile Catcher (170 g)
String holder plate and clamp
2.5 cm steel balls (2) (67 g each)
Spool of string
Velcro strips (not shown)
Instruction manual and experiment guide

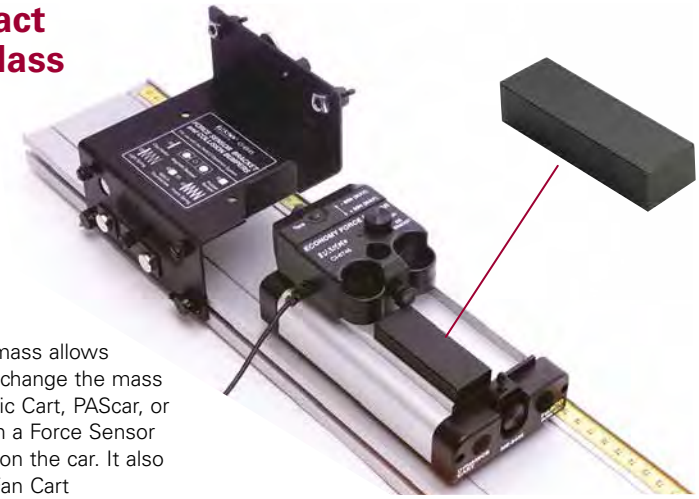


Order Information

Projectile Catcher Accessory	ME-6815

Compact Cart Mass

ME-6755



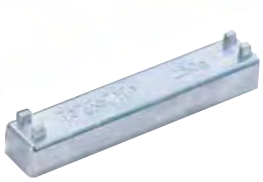
This 250 g mass allows students to change the mass of the Classic Cart, PAScar, or GOcar when a Force Sensor is mounted on the car. It also fits on the Fan Cart (ME-9485).

Order Information

Compact Cart Mass ME-6755

PAScar Mass

ME-6756



This 250 gram mass fits in any Dynamics Cart, the Motorized Cart (ME-9781), or the Discover Friction Accessory (ME-8574).

Order Information

PAScar Mass ME-6756

Cart Replacement Axles (4 pack)

ME-6957



Although the ball bearings are designed for many years of use, the bearings can become damaged from dirt and other contaminants. The wheels and axles of the PAScar can be easily replaced by removing the lower section of the car and placing the new wheels in the chassis. A perfect tune-up for a PAScar or GOcar! The wheels of the Classic Carts can also be replaced with the same set of wheels. Contact PASCO's technical support for further assistance.

Order Information

Cart Replacement Axles (4 pack) ME-6957

Braided Physics String

SE-8050



- 30-lb. test

This braided Dacron® string is tough, resists stretching, and won't unravel. Withstands up to 133 Newtons of force (equivalent to 13.6 kg). Each roll provides 320 meters of string.

Order Information

Braided Physics String SE-8050

Spring Set

ME-9803B



Includes eight identical springs: 8 cm long, 3.4 N/M spring constant.

Order Information

Spring Set (8) ME-9803B

Dynamics Track Spring Set

ME-8999



Includes 12 springs (1.6 cm diameter) with approximate spring constants of:

3.4 N/m (3 short and 3 long springs)
6.8 N/m (3 short and 3 long springs)

Order Information

Dynamics Track Spring Set (12) ME-8999

Super Pulley with Clamp

ME-9448B



Shown with PAStrack

Pulley clamps on the end of any Dynamics Track. Its height is fully adjustable to match height of string attached to a dynamics cart.

Order Information

Super Pulley with Clamp ME-9448B

Rubber Cord (30 meters)

ME-8986



For Elastic Bumper (ME-8998). Also fits Air Track Bumpers

Order Information

Rubber Cord (Spool of 30 m) ME-8986

Pivot Clamp

ME-9836



Pivot Clamp fastens to the T-slot of a Dynamics Track and accepts 1/2" rod.

Order Information

Pivot Clamp ME-9836

Adjustable Feet (2)

ME-8972



Order Information

Adjustable Feet (2) ME-8972

End Stops (2)

ME-8971



Order Information

End Stops (2) ME-8971

Angle Indicator

ME-9495A

The Angle Indicator fastens to the T-slot of a dynamics track. Hanging plumb-bob indicates angle to 1/2°.



Order Information

Angle Indicator ME-9495A

Recommended:
Projectile Launcher Plumb Bobs (24 pack) ME-9868

Dynamics Systems Spares Kit

ME-9823

The Spares Kit contains many of the small parts that can get lost after classroom use. All parts are organized in a convenient case for easy storage.

Includes

Cart Bumper Magnets (2)
Velcro Hoop and Loop Bumpers (4)
Dynamics Track Feet Screws (4)
1/4"-20 x 9/16" Tee Thumb Screws (4)
1/4"-20 x 9/16" Round Thumb Screws (6)
1/4"-20 x 3/8" Round Thumb Screws (6)
1/4"-20 x 7/32" Square Nuts (20)
1/4"-20 Nylon Thumb Nuts (6)
6-32 x 3/8" Nylon Thumb Screw (6)
M5 x 0.8 x 20 mm Nylon Thumb Screw (4)
1/4"-20 x 3/8" Set Screws (4)
Bumper Squares (8)
Round Rubber Bumpers (4)



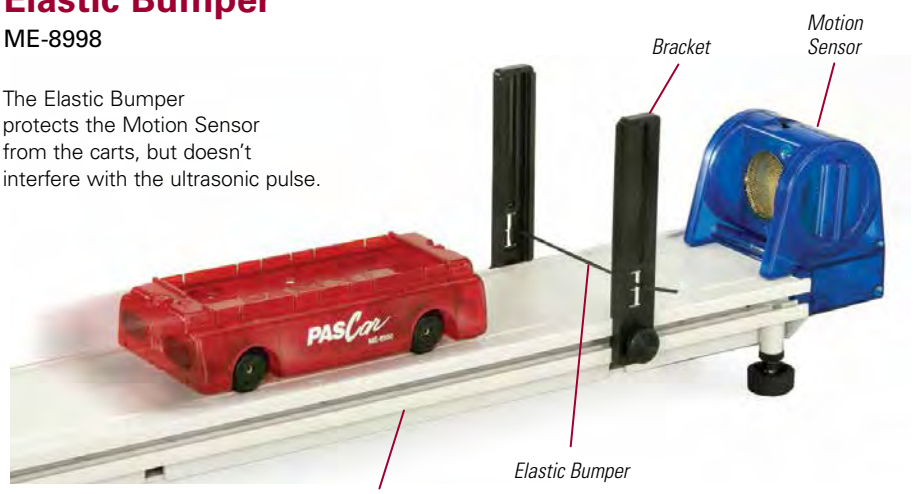
Order Information

Dynamics Systems Spares Kit ME-9823

Elastic Bumper

ME-8998

The Elastic Bumper protects the Motion Sensor from the carts, but doesn't interfere with the ultrasonic pulse.



Includes

Two pairs of brackets
10 meters of elastic material



Order Information

Elastic Bumper ME-8998

Smart Gate

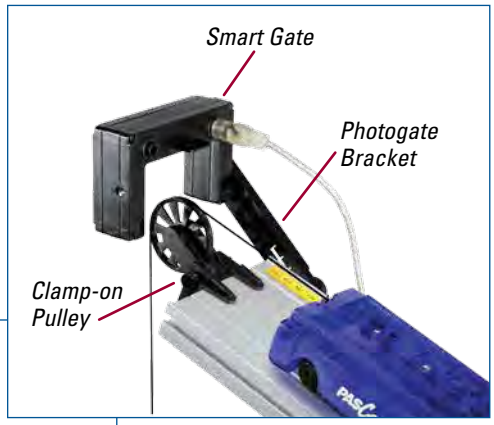
PS-2180

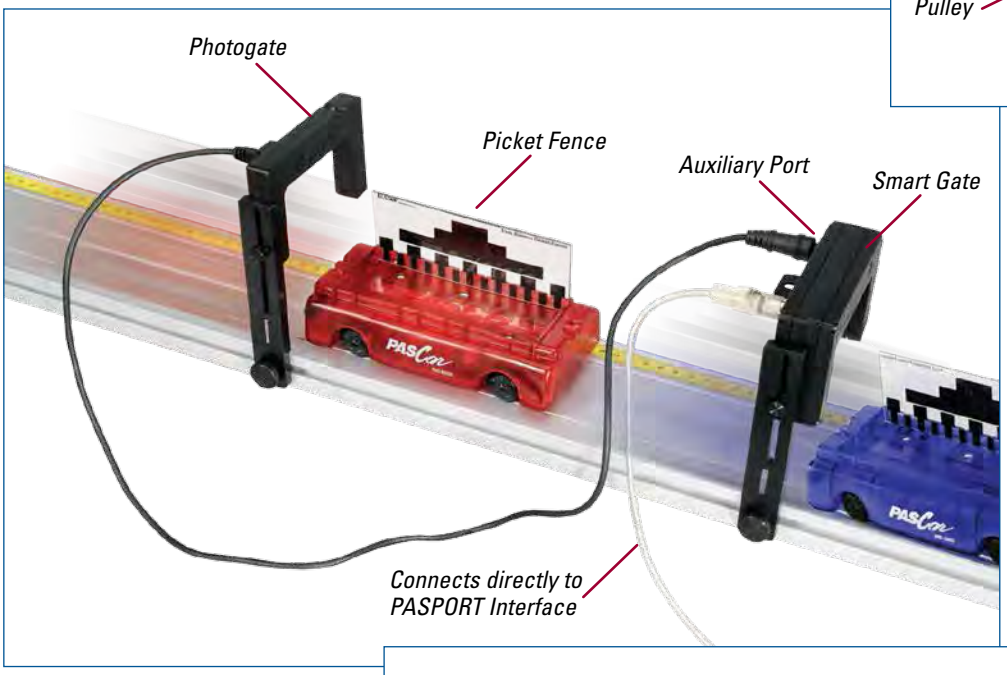
NEW

The Smart Gate connects directly to any PASPORT interface, and has an auxiliary port to daisy chain to an additional Photogate. Can be used with cart picket fence, clamp on super pulley, and flexible Photogate Tape.

Smart Pulley

Use the Smart Gate and Photogate bracket with the Clamp-on Super Pulley to create a "smart pulley"





Double Infrared Beams

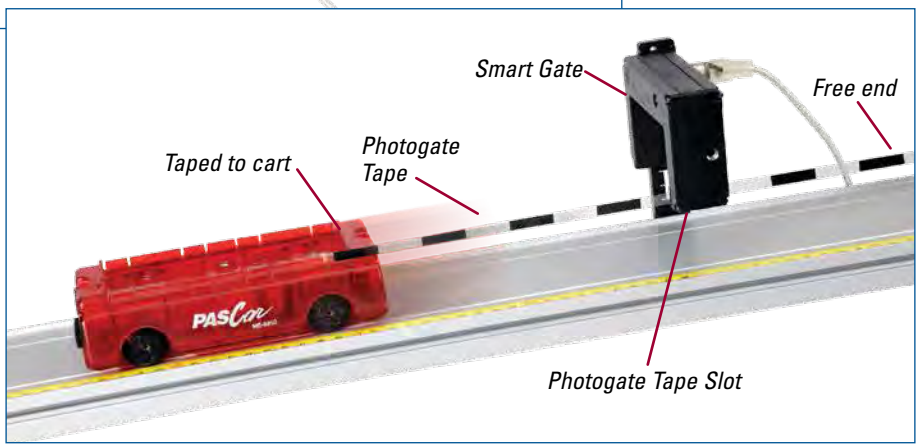
Using the double beam of the Smart Gate, the speed of the cart can be determined accurately using the front edge of a single flag.

Auxiliary Port

A second photogate is connected to the Smart Gate Auxiliary Port so only one PASPORT port is required for two photogates.

Photogate Tape Slot

The Smart Gate has a special slot through which the Photogate Tape can be threaded. This creates an excellent way of measuring the speed of the cart the full distance of the track as the cart accelerates down the inclined track.



Includes

Smart Gate
PASPORT Cable



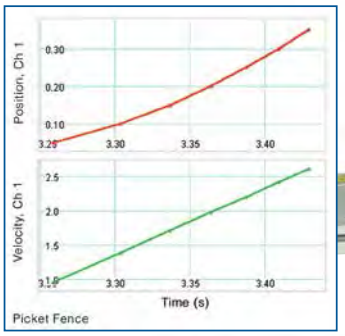
Order Information

Smart Gate	PS-2180	
Recommended:		
Photogate Head	ME-9498A	p. 39
Photogate Tape (30 m)	ME-6663	p. 40
High Resolution Photogate Tape	ME-6666	p. 40
Photogate Brackets (2)	ME-9806	p. 107
Cart Picket Fences (2)	ME-9804	
Super Pulley with Clamp	ME-9448B	p. 174

Photogates and Fences

ME-9471A

When used with the computer for data recording, display, and analysis, the photogate/pulley timing system can provide a wide range of time, speed, and velocity measurements. The photogates mount to the dynamics track using the provided brackets. The picket fences provided mount directly to the dynamics carts.





Position and velocity graphs are obtained using a Picket Fence and Photogate.



Includes

Photogate Heads (2)

Photogate Brackets (2)

Picket Fences (2)

Super Pulley with attachment screw (attaches Super Pulley to Photogate)

Pulley Mounting Rod

Order Information

Photogates and Fences	**ME-9471A**	
Individual Components:		
Photogate Head	ME-9498A	p. 39
Photogate Brackets (2)	ME-9806	
Cart Picket Fences (2)	ME-9804	
Super Pulley	ME-9450A	p. 174
Pulley Mounting Rod	SA-9242	p. 133
Required for use with PASPORT Interfaces:		
Digital Adapter	PS-2159	p. 41

Cart Picket Fences (set of 2)

ME-9804



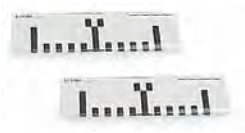
Order Information

Cart Picket Fences (set of 2) ME-9804

Smart Timer Picket Fences (set of 2)

ME-8933

See Smart Timer on pages 120-121.



Order Information

Smart Timer Picket Fences (set of 2) ME-8933

Photogate Brackets

ME-9806

- Attaches Photogates to PASCO Dynamics Tracks
- Easily Adjust Photogate Height



(Photogate not included.)

The Photogate Bracket allows the Photogate Head to be attached directly to PASCO dynamics tracks. This eliminates the need for separate photogate stands and allows the photogate height to be easily adjusted relative to the track. Includes two Photogate Brackets.

Order Information

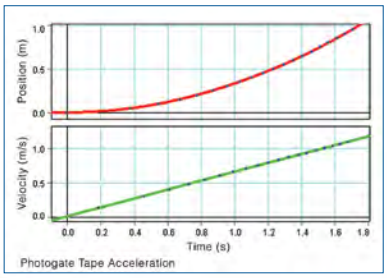
Photogate Brackets (2) ME-9806

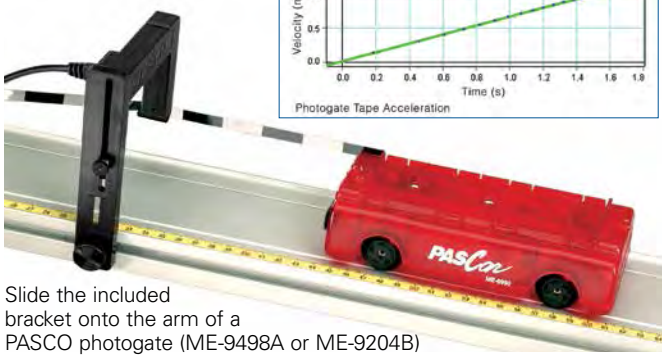
Photogate Tape Set

ME-6664

Flexible Mylar® picket fence tape can be cut to any length. Tape guide slides onto the arm of PASCO photogates to more accurately measure the motion of a cart.

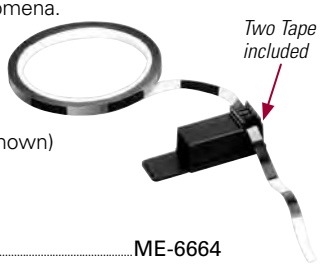
Photogate tape can be used as a picket fence "string" to continuously measure the motion of the cart.





Slide the included bracket onto the arm of a PASCO photogate (ME-9498A or ME-9204B) and slide the photogate tape through the slot to measure position, velocity, and acceleration. The band spacing on the tape is 5 cm from edge to edge, which is identical to the Large Picket Fence (ME-9377A).

The High Resolution Photogate Tape, available separately, has a distance of 1 cm between edges for more data points during high velocity or acceleration phenomena.



Includes

Photogate Tape (30 m)

Photogate Tape Guide (2)

Double-Adhesive Tape (not shown)

Velcro Strips (not shown)

Order Information

Photogate Tape Set	**ME-6664**	
High Resolution Photogate Tape	**ME-6666**	
Photogate Tape (30 m)	**ME-6663**	
Required:		
Photogate Head	ME-9498A	p. 39
or Accessory Photogate	ME-9204B	p. 39

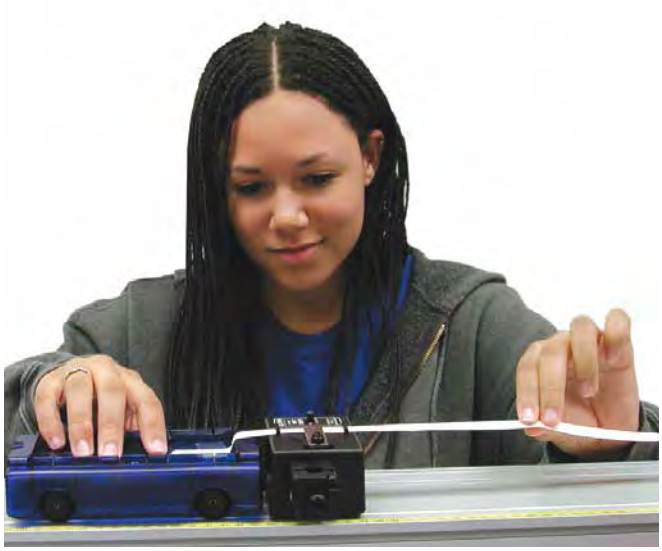
Measurement Devices for Dynamics Systems

Tape Timer

ME-9283



This traditional paper tape method clearly illustrates the relationship between displacement and time. The tape produces many data points so students can plot displacement, velocity and acceleration graphs. See page 118 for additional details.



Use a Tape Timer, Dynamics Cart and Track to calculate acceleration down an inclined plane.

Order Information

Tape Timer ME-9283
Includes one roll of paper, 10 carbon paper discs, battery and manual.
Replacement Supplies:
Tape Timer Supplies ..... ME-9284 p. 118
Includes five rolls of paper (each 150 m) and 10 carbon paper discs.

PASCO Stopwatch

ME-1234

TEACHER FAVORITE



- Durable
- Simple to use
- No alarm
- Uses one AA battery (included)
- Memory: Stores up to nine event times

See page 182 for more details.

Order Information

PASCO Stopwatch ME-1234
Also Available:
PASCO Stopwatch (10 pack) ..... ME-1235 p. 182

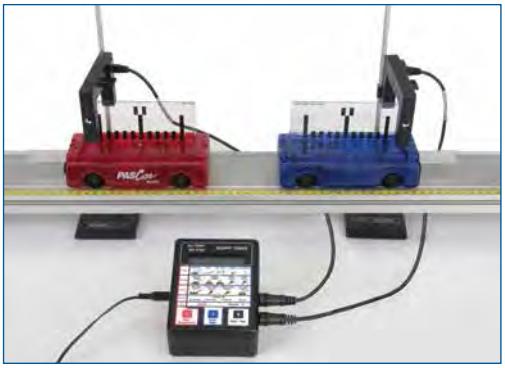
Smart Timer

ME-8930

LAB ESSENTIALS



With the use of the picket fence or photogate/pulley, the Smart Timer measures time, speed and acceleration. A single Smart Timer with two photogates (as shown below) can measure initial and final speeds of two carts in a conservation of momentum experiment. See pages 118-119 for additional details.



Speed before and after collision—In Speed: *Collision mode, use two carts and two photogates with a single Smart Timer to measure initial and final speeds of both carts.*

Order Information

Smart Timer ME-8930
Includes two fences, 9 VAC adapter and manual.
Additional Equipment:
Accessory Photogate ..... ME-9204B p. 39
Photogate & Fences-IDS ..... ME-9471A p. 40

Photogate Timer

ME-9215B



Ideal for quick setup and accurate measurements of velocity. Two "Memory Timers" (ME-9215B) make all the velocity measurements necessary for a conservation of momentum experiment. See page 120 for additional details.

Order Information

Photogate Timer ME-9215B
Recommended:
Accessory Photogate ..... ME-9204B p. 39

The PASCO Air Track

PASCO 2.0 m Air Track

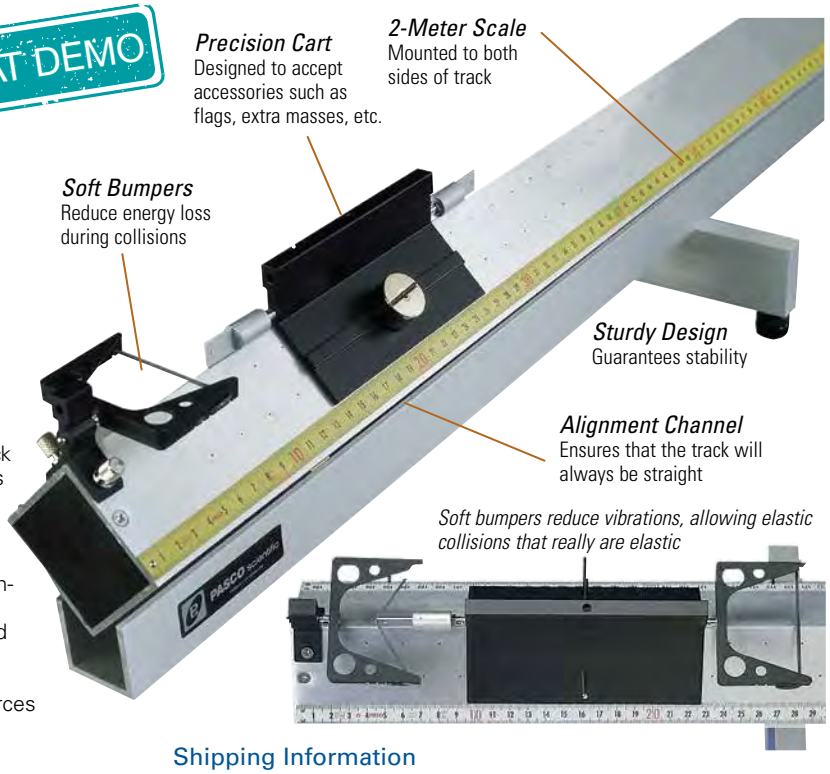
SF-9214

GREAT DEMO

Variable Output Air Supply

SF-9216

- Nearly frictionless linear motion
- Two meters long
- Complete accessories included



It's simple physics—a moving object will continue forever at a constant velocity unless it's acted on by an external force. To the physicist, Newton's First Law is second nature. Yet it's still fascinating to watch an air track glider moving endlessly back and forth on an air track. It's even more fascinating for students, who are often seeing this simplest form of motion for the first time.

An air track glider provides the raw material for highly accurate investigations into the laws of motion. Add a timing system and investigate uniform motion, average and instantaneous velocities, uniform acceleration, elastic and inelastic collisions, impulse and change in momentum, conservation of momentum, conservation of energy and more. The data is precise and unambiguous. Frictional forces are negligible.

Compared to other air tracks, the PASCO Air Track is:

- Longer: The 2-meter length provides more room for experimenting, yet it still fits on a standard lab table.
- Straighter: Guaranteed straight to within 0.04 mm over its entire 2-meter length. If the Air Track should ever become misaligned, return it to PASCO and we will realign it for free.
- Tougher: The track is a large, square aluminum extrusion with 3 mm thick walls further strengthened by a supporting U-channel. This construction preserves straightness and allows for accurate realignment.
- Quieter: PASCO's Air Supply is exceptionally quiet. The air flow can be adjusted precisely for each experiment. Too little air causes friction; too much air causes energy loss due to glider "flutter."
- Complete: The PASCO Air Track comes with a complete set of accessories:
  - Two 170-gram gliders with soft bumpers. Glider collisions with hard bumpers can cause glider vibration, resulting in significant energy loss. Soft rubber band bumpers eliminate vibration and allow students to control the force and duration of each collision by varying the band tension.
  - Air Track Accessory Kit (all items shown on page 110)
  - Mounting hardware (two single-leg screws, two double-leg screws, one 4 mm wrench, one 5 mm wrench)
  - One single leg
  - One double leg with adjustable feet
  - Two fixed-end stops

Shipping Information

Track:
Size: 2.2 m (85") length x 17 cm (7") diameter
Weight: 12.7 kg (28 lb)

Accessories:
Size: 28 x 21 x 16 cm (11 x 8 x 6 in.)
Weight: 4.5 kg (10 lb)

Note: Air Supply needed for Air Track

Specifications

Length: 2.0 m (working distance 1.9 m)

Straight: ±0.04 mm

Construction: Extruded aluminum square (3 mm wall thickness) on a U-channel support with seven alignment screws

Air Holes: 382 holes of 1 mm diameter; 2 cm spacing; 4 cm diameter air inlet

Base: Three-point with bilateral leveling screws

Millimeter Scales: 2 meters long on each side

Includes

Gliders (2):13 cm long; 170 g; with rubber band bumpers

Glider Flags (2): 100 mm

Glider Masses (4): 50 g

Inelastic Collision Kit (1): Needle with wax-filled receptacle

Constant Acceleration Kit: Ball-bearing pulley, glider hook, mass hanger (2 g) and five acceleration masses: two 1 g; one 2 g; one 5 g; one 10 g

Storage Tray

Order Information

2.0 m Air Track	SF-9214
Required:	
Variable Output Air Supply	SF-9216
Suggested:	
Replacement Parts	see pages 110-111

GREAT DEMO



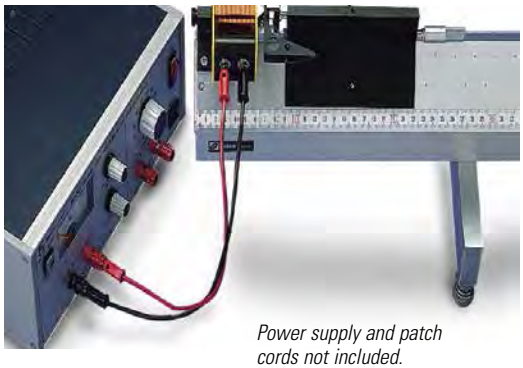
PASCO Air Track SF-9214: *Available separately (add a timing system) or in a complete Photogate Timer system that includes everything required for an Air Track lab.*

Electric Launcher–Air Track

SF-9296

Launch a glider repeatedly with the same impulse and velocity each time. Or use two launchers to launch both gliders in a collision experiment. Each launcher kit includes the iron core, coil and armature.

Note: This launcher is designed for use only on the PASCO Air Track.



Power supply and patch cords not included.

Order Information

Electric Launcher – Air Track	SF-9296	
Required:		
Banana Plug Cord-Black (5-pack)	SE-9751	p. 214
Triple Output-Power Supply	SE-8587	p. 232
or equivalent supply providing 2 A at 5 VDC		

Coupled Harmonic Oscillators–Air Track

SF-9297

Investigate coupled harmonic motion on the PASCO Air Track. Kit includes three gliders, 12 connecting plugs, six 50-gram masses, six springs and an adjustable end stop. With the two gliders that come with the PASCO Air Track, students can experiment with up to five gliders in coupled harmonic motion.



Coupled Harmonic Oscillators mounted on the PASCO Air Track

Note: Add the Mechanical Wave Driver and a Function Generator and students can drive the coupled oscillators at fixed and measurable frequencies. See the Waves section for more information.

Order Information

Coupled Harmonic Oscillators – Air Track	SF-9297	
Recommended:		
Mechanical Wave Driver	SF-9324	p. 244
Function Generator	PI-8127	p. 236

Air Track Accessory Kit

SF-9295



A set of accessories (SF-9295) comes with every PASCO Air Track. All that's needed is a timing system. The set may be ordered separately.

Order Information

Accessory Kit– Air Track	SF-9295
Recommended:	
Glider Kit-Air Track	SF-9224
Air Supply Hose (2 m)-Air Track	SF-9298
T-Adapter and Hose-Air Track	SF-9217
Riser Block Kit	ME-9239

Variable Output Air Supply

SF-9216



The PASCO Air Supply is exceptionally quiet. Its variable output lets students match the air flow to the experiment.

A 2-meter hose is included. By adding the T-Adapter and Hose (SF-9217), the Air Supply can operate two PASCO Air Tracks at the same time.

Note: This Air Supply produces 36 cfm at 0.122 psi for use with the Precision Air Track SF-9214. If used with another track, the total area of the air flow holes must be ≥2.6 cm2, or the supply may overheat.

Order Information

Variable Output Air Supply	SF-9216

Rubber Cord (30 meters)

ME-8986



For Elastic Bumper (ME-8998)

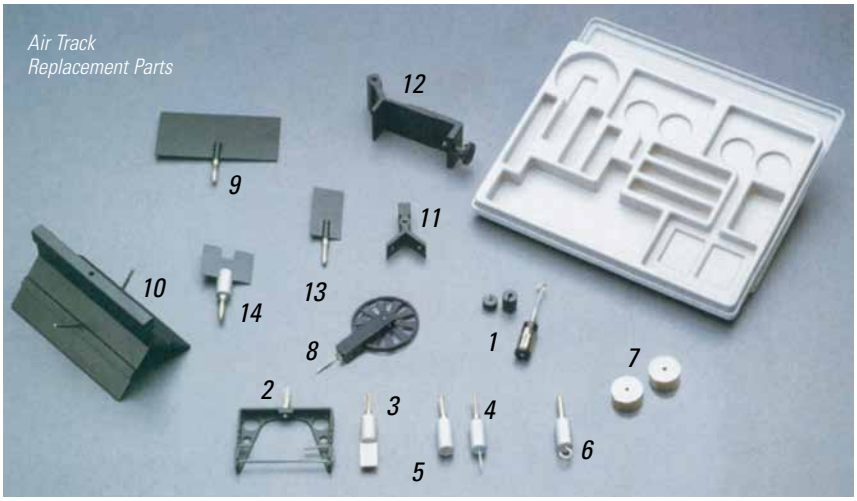
Also fits Air Track Bumpers

Order Information

Rubber Cord (30 m spool)	ME-8986

Optional Accessories and Replacement Parts

The Air Track includes accessories for standard air track experiments, from simple acceleration to elastic and inelastic collisions. To add more advanced experiments, a variety of additional accessories are available.

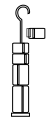


Air Track Accessories

(included in the SF-9295 Kit)

(Each item may be ordered separately. The number in parentheses indicates how many of each item is included in the Accessory Kit.)

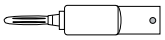
1. *Mass/Hanger Set-Air Track (1)*
   SF-6300



2. *Bumper with Holder-Air Track (3)*
   SF-6301



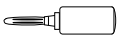
3. *Bumper Set-Air Track (2)*
   SF-6302



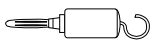
4. *Inelastic Collision Needle-Air Track (1)*
   SF-6303



5. *Wax Receptacle (1)*
   SF-6304



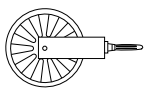
6. *Glider Hook (1)*
   SF-6305



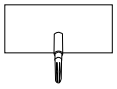
7. *Glider Mass (4)*
   SF-6307



8. *Ball Bearing Pulley-Air Track (1)*
   SF-6308



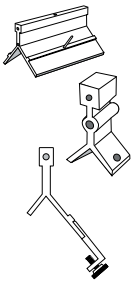
9. *100 mm Flag (2)*
   SF-6310



(not included in the SF-9295 Kit)

(Must be ordered separately.)

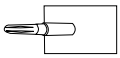
10. *Glider-Air Track*
    SF-6306



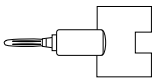
11. *Fixed End Stop-Air Track*
    SF-6313

12. *Adjustable End Stop-Air Track*
    SF-6309

13. *25 mm Glider Flag*
    SF-6311



14. *U-shaped Glider Flag*
    SF-6312



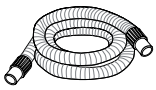
15. *Glider Kit-Air Track*
    (see photo at right)
    SF-9224
    (Includes one glider, two 50 g masses, bumper with holder, and bumper blade.)



15. Additional Glider Kit SF-9224

(The following three items are not pictured above and not included in the kit.)

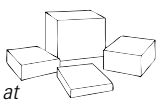
16. *Air Supply Hose (2 m)-Air Track*
    SF-9298



17. *T-Adapter and Hose-Air Track*
    SF-9217
    (Allows two air tracks to be operated from one air supply.)



18. *Riser Block Kit*
    ME-9239
    (Includes four aluminum blocks of 0.25, 0.50, 1.00 and 2.00 cm to tilt Air Track at repeatable angles.)



Hovercraft

ME-9838

- Students experience Newton's Laws
- Durable nylon skirt
- Rubber bumper
- Optional cordless air supply



Air source not Included

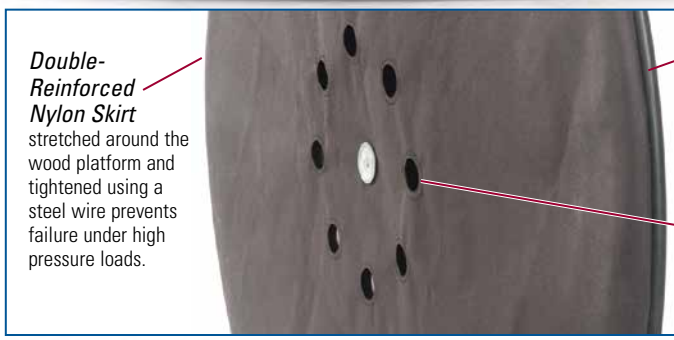
Our Hovercraft follows the classic design, with a rugged nylon skirt attached around a 1.2 m wood platform. Students can easily ride on the Hovercraft to experience first-hand the kinematics of frictionless motion.

How It Works

The nylon skirt is stretched around the wood platform and tightened using a steel wire. The center of the skirt is attached to the bottom of the wood platform. A custom rubber bumper is placed around the circumference of the wood platform. The bumper helps secure the skirt and also provides a soft cushion around the edge of the Hovercraft. A high-volume air source is used to force air through the platform and into the skirt. After sitting on the platform, the air source is turned on and the skirt inflates. Small holes in the skirt allow the air to escape, while providing the higher pressure needed to lift the rider. A built-in level helps students center their weight on the Hovercraft.

An optional Cordless Air Source (SE-8806) is also available (below). In addition, most leaf blowers provide enough air flow to support the Hovercraft.

The PASCO Hovercraft is capable of supporting up to 300 lbs and comes completely assembled.



Includes

Wood platform (1.2 m diameter, 1.9 cm thick)
Nylon skirt with mounting hardware
Rubber bumper
Liquid level
Connection hose for air source



Order Information

Hovercraft	ME-9838
Required:	
Cordless Air Source	SE-8806

Cordless Air Source

SE-8806



Includes

Rechargeable Battery
Charging Adapter

Note: 220 V version **not** available.

Order Information

Cordless Air Source	SE-8806

Hovercraft Kit

ME-9878



The Hovercraft Kit includes everything to build the Hovercraft, except the wood platform. Cordless Air Source is available separately.

Order Information

Hovercraft Kit	ME-9878
Required:	
Cordless Air Source	SE-8806
Round Wood Platform (1.2 m dia., 1.9 cm thick)	

Amusement Park Physics Kit

ME-9426A

- Extend your lab into the "real world"
- Complete kit for 15 students
- Developed in conjunction with AAPT*

They might lose their notes. They might even lose their nerve. But in one day at an amusement park, students will also gain a real "gut-level" appreciation for Newton's Laws. Using this kit, students don't observe a dynamics cart. They *are* the dynamics cart.

The PASCO Amusement Park Physics Kit is the only kit that is:

- Approved by the safety officers of major amusement parks across the USA.
- Student-tested in amusement parks by hundreds of schools.
- Teacher-tested in hundreds of Amusement Park Physics Workshops.
- Made with a metal coil spring for the Vertical Accelerometer (far more accurate than the commonly used rubber band).
- Supporting physics education (for each set sold, $2.50 is donated to the AAPT).

** American Association of Physics Teachers*



Students experience the thrill of scientific investigation.

Photo courtesy of Paramount's Great America.

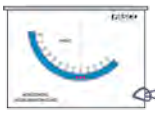


The Vertical Accelerometer: The stretch of the spring measures the vertical acceleration in "g's."

Includes

Brass Hanging Weights (19)
Springs* k = 3 N/m (16)
Plastic Tubing (2.5 m)
Plastic Tubes, 30 cm long (16)
Plastic Tube End Caps (32)
Bumper Stickers (16)
Horizontal Accelerometer Cards (16)
Push Pins (5)
No. 3 Paper Clips (17)
Cotton String
Metal Balls (60)
Straws (16)
Wire Ties
Vinyl Tape
Rubber Bands #117 (32)
Rubber Bands #19 (6)
Plastic Storage Bags (16)
Instruction Manual

**Additional accelerometer springs may be purchased separately. See order information below.*



The Horizontal Accelerometer: The angle to which the BBs rise measures the horizontal acceleration. This accelerometer doubles as a sextant to measure distances by triangulation.

Order Information

Amusement Park Physics Kit (15 pack) ME-9426A

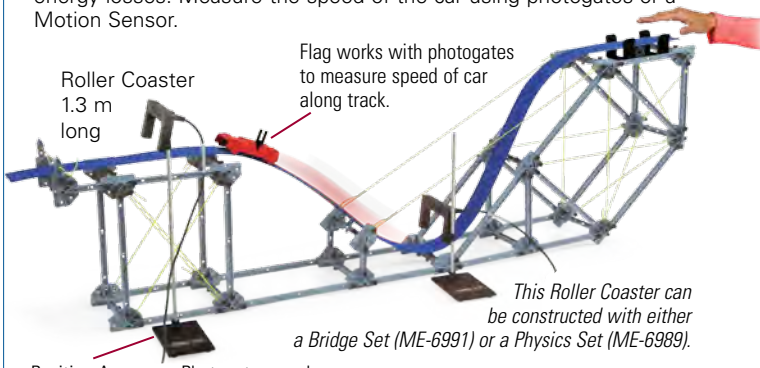
Recommended:

Additional Accelerometer Springs (15 pack) ME-8734

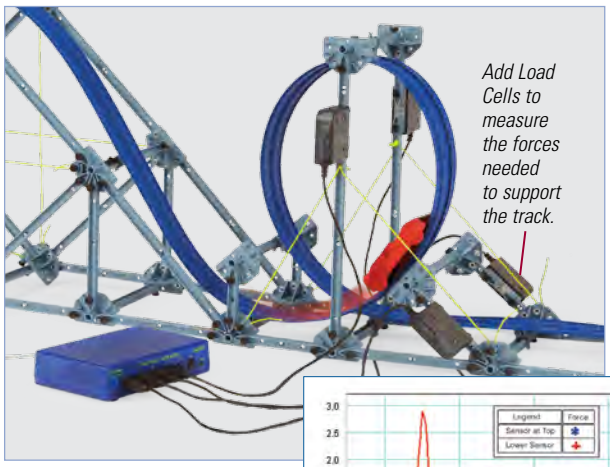
Scissors, pliers, masking tape, clear plastic tape

Design your own roller coaster with PASCO's Structures System

PASCO's Structures System allows students to design and build their own roller coaster for detailed studies of conservation of energy and centripetal force. The flexible track is perfect for building hills, valleys and even a loop! Car with low friction, ball-bearing wheels minimizes energy losses. Measure the speed of the car using photogates or a Motion Sensor.



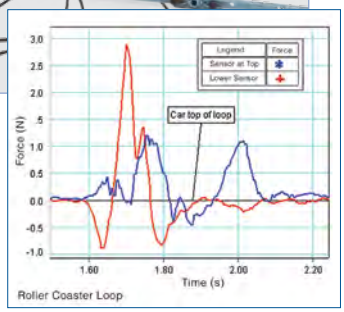
This Roller Coaster can be constructed with either a Bridge Set (ME-6991) or a Physics Set (ME-6989).



Add Load Cells to measure the forces needed to support the track.

Add a loop to your roller coaster

Investigate the effect of changing the size and shape.



Graph shows support forces exerted on the track as the car goes up and over the loop.



Large Roller Coaster
2.3 m long

Constructed using the Large Structures Set (ME-7003).

Order Information

Bridge Set	ME-6991	p. 134
Large Structures Set	ME-7003	p. 135
Shown in use with:		
Load Cell & Amplifier Set	PS-2199	p. 34
Accessory Photogate	ME-9204B	p. 39

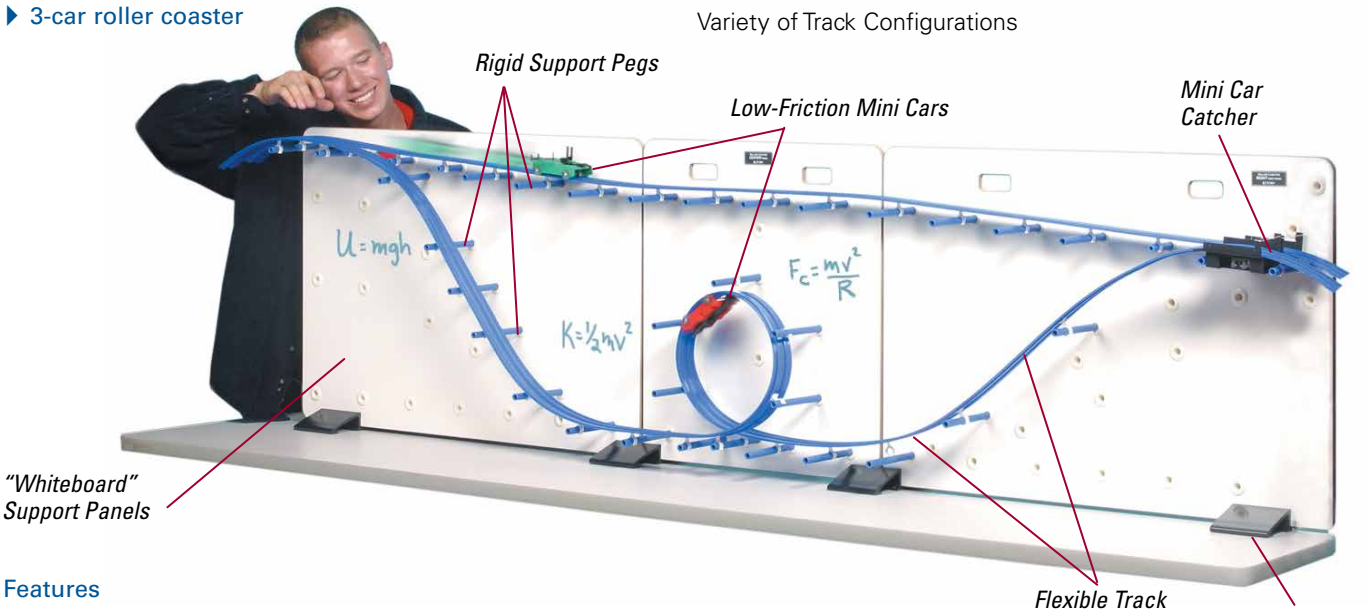
Roller Coaster Complete System

ME-9812

- Quantitative studies of Energy Conservation
- Easy to change track configurations
- 3-car roller coaster

GREAT DEMO

Variety of Track Configurations



Features

Support Panels: Have a variety of track configuration holes predrilled for easy student assembly. Feature a dry-erase surface so calculations can be performed at the point of interest on the track.

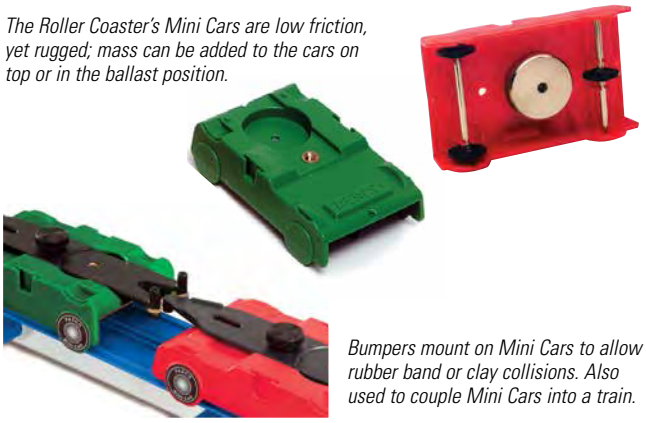
Mini Cars: Feature low-friction ball bearings and ABS construction to withstand repeated impacts. One red, one yellow, and one green Mini Car included. Each car includes a slot for a supplied photogate flag, cup/mass holder, and cup. The body of the car extends just far enough below the wheels to protect them, if the car leaves the track.

Ballast Mass: Can be added to mass tray of Mini Car or hidden under Mini Car to increase the energy without changing the car's outward appearance.

Flexible Track: Guides carts on their path, yet is flexible enough to form loops and hills, or can be rolled out flat on a table. Easily attaches to the support pegs using the twist-on track clips. Long pegs allow two tracks side-by-side for comparison.

Probeware Compatible: Threaded support pegs and Mini Car photogate flags allow photogates to be used at many positions around the track to measure velocity and acceleration.

The Roller Coaster's Mini Cars are low friction, yet rugged; mass can be added to the cars on top or in the ballast position.



Bumpers mount on Mini Cars to allow rubber band or clay collisions. Also used to couple Mini Cars into a train.



Includes

Support panel (3 sections)
Support feet (4)
Flexible track (9.1 meters)
Mini Cars (3)
Support pegs for track (43)
Photogate support pegs (4)
Track clips (50)
Mini Car catcher (2)
Mini Car starter bracket (2)
Mini Car collision accessory (3)
Mini Car photogate flags (3)
Water cup (3)
Mini Car ballast mass (3)
Photogate brackets (4)
Track couplers (2)

Order Information

Complete Roller Coaster	ME-9812	
Recommended:		
Photogate Head	ME-9498A	p. 39
Photogate Bracket (2)	ME-9806	p. 107
Smart Timer	ME-8930	p. 118
or Computer Interface		p. 14-23

Roller Coaster Applications:



Conservation of Energy: Release the Mini Car and measure its velocity and height at several points along the track. Use these values to calculate total energy of the Mini Car. Frictional losses are less than 5%.

Constant Acceleration: Several straight inclined sections can be used to measure and demonstrate constantly accelerated motion.

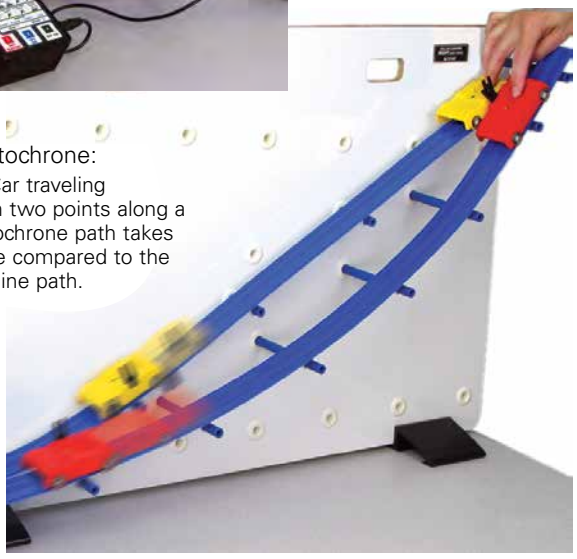
Centripetal Acceleration: Use either the circular loop or clothoid loop to measure the maximum and minimum accelerations experienced by the Mini Car.

Projectile Motion/Conservation of Energy: Use the initial height of the Mini Car to determine its speed as it flies off the end of the track. Using this speed and height above the ground when it leaves the track, predict where the Mini Car will land.



Multi-car Train:
Mini Cars can be coupled to form a train and the velocity of each car can be measured with a photogate and a Smart Timer. The velocities are not the same.

Brachistochrone:
A Mini Car traveling between two points along a brachistochrone path takes less time compared to the straight line path.



Basic System

ME-9811



Includes

Flexible track (9.1 meters)
Mini Cars (3)
Mini Car collision accessory (3)
Mini Car photogate flags (3)
Track Clips (50)

Order Information

Basic Roller Coaster ME-9811

Roller Coaster Spares Kit

ME-9815



Includes

Long track pegs (23)
Short track pegs (2)
Photogate support pegs (2)
Track clips (25)
Mini Car photogate flags (3)
Ballast mass screws (3)
Mini Car mass post (3)

Order Information

Roller Coaster Spares Kit ME-9815

Mini Car Set

ME-9813



Includes

Mini Cars (3)
Decals
Elastic Bumpers (3)
Flags (3)
Rubberbands

Order Information

Mini Car Set ME-9813
Mini Cars sold separately:
Red Mini Car ME-9834
Green Mini Car ME-9839
Yellow Mini Car ME-9840

Roller Coaster Track (9.1 m)

ME-9814



Longer replacement roll of flexible plastic track for use with the Bridge Set (ME-6991), Physics Structures Set (ME-6989), Large Structures Set (ME-7003), and Roadbed Spares (ME-6995).

Order Information

Roller Coaster Track (9.1 meters) ME-9814

Mini Car Starter Bracket

ME-9856



Order Information

Mini Car Starter Bracket ME-9856

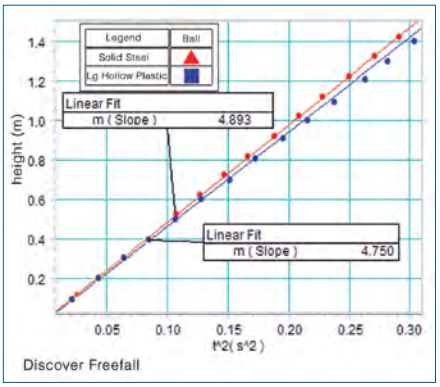
Discover Freefall System

ME-9889

- Determine g
- Investigate air resistance dependence on mass, volume, cross-sectional area

PASCO's Discover Freefall System can be used to drop almost any small object by attaching a small steel washer with a small adhesive pad (both are included in the system). Using an electric switch, timing is started automatically, just as the object is dropped. And the Time-of-Flight Pad stops timing when the object strikes it.

Students can investigate the effect of air resistance on acceleration. In addition, students can drop objects of the same size but different mass to study how object mass affects terminal velocity during freefall. The drop box has a magnetic mount for attaching to metal frames in ceilings.



When the switch is pressed, the ball is dropped and the time of fall is measured for various balls. The graph shows height vs time-squared data for the 1 inch steel ball and the large hollow plastic ball. The slope of the line (equal to 1/2 g) gives an acceleration for the steel ball of 9.79 m/s^2. Note that the acceleration of the large hollow ball is considerably smaller, and that its data is not linear.

Shown in use with rods and clamps sold on pages 170-173. The Drop Box also has built-in magnets to fasten directly to the ceiling.

LAB ESSENTIALS



This redesigned system can also accept the Target Accessory, ME-6854, to perform the shoot-the-target demonstration. See page 124.





Any small object can be dropped with the Discover Freefall System by attaching a washer to the object with an adhesive pad (both included).



The Discover Freefall System also works with the 850, PASPORT or any ScienceWorkshop Interface. Shown here using an Xplorer GLX with a Digital Adapter.

Includes

Drop box
Control cable
Control box
AC adapter
Time-of-Flight receptor pad
Timer Switch
Release washers (10)
Release labels for attaching washers to object (50)
Small nylon ball
Large plastic ball
Golf ball
Hollow golf ball
1" steel ball
5/8" steel ball

Order Information

Discover Freefall System	ME-9889	
Required:		
Smart Timer	ME-8930	p. 118
850 or ScienceWorkshop Interface		p. 14-17, 23
or PASPORT Interface		p. 18-21
with Digital Adapter	PS-2159	p. 41
Recommended:		
Freefall Balls Accessory	ME-9890	p. 176
Rods and Clamps		p. 170-173

Coin and Feather Tube

SE-9788



The "Coin and Feather" experiment is one of the best ways to dispel the "lighter objects fall more slowly" myth.

When the air inside the 75 cm tube is at atmospheric pressure, the feather (in this case a very visible piece of styrofoam) falls significantly more slowly than the coin. The syringe vacuum pump (included) will bring the air inside the tube down to about 7% of atmospheric pressure, making the feather and the coin appear to drop at the same rate.

The Coin and Feather Tube includes a 3.8 cm diameter clear plastic tube with end caps, coin and "feather" (styrofoam), and syringe vacuum pump.

Order Information

Coin and Feather Tube SE-9788

Freefall Timer Adapter

ME-9207B

How It Works

A steel ball is clamped into a spring-loaded release mechanism. At the instant the ball is released, the electronic timer automatically starts. The timer stops when the ball hits the receptor pad. With the accurate, high resolution timing and automatic start and stop, results are precise and repeatable.



Includes

Ball release mechanism with stereo phone plug and receptor pad

Four steel balls (1.9 cm, 1.6 cm diameter)

Maximum distance of fall is 2 m.



Freefall Timer Adapter shown in use with the Smart Timer. The Smart Timer records the elapsed time from when the ball is dropped until the ball hits the receptor pad.

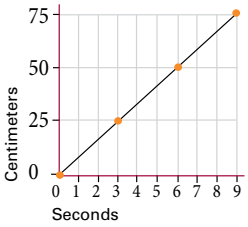
Order Information

Freefall Timer Adapter	ME-9207B	
Required:		
Large Table Clamp	ME-9472	p. 173
Multi Clamp	ME-9507	p. 172
Rod (90 cm long)	ME-8738	p. 170
Photogate Timer	ME-9215B	p. 120
or Smart Timer	ME-8930	p. 118
or 850 or ScienceWorkshop Interface		p. 14-17
or PASPORT Interface		p. 18-21
with Digital Adapter	PS-2159	p. 41

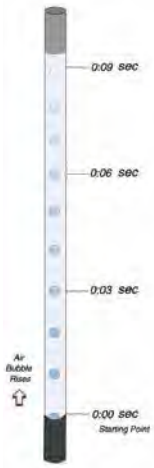
Constant Velocity Tubes (6)

SE-9076





By monitoring the bubble's position, students can plot a position versus time graph. Slower tubes will have lower slopes.



Constant Velocity Tubes effectively introduce the relationship between graphs and motion. Students can use a meterstick and a stopwatch to plot the position of the bubble as a function of time as it moves up the tube. Each tube has an obstruction that serves as the initial position for the bubble. The slope and vertical intercept from the graph yield the equation of motion.

Constant Velocity Tubes include six tubes with varying viscosities and initial starting points.

Order Information

Constant Velocity Tubes (6) SE-9076

Constant Velocity Tubes (4)

Includes both a bubble and a metal ball!

SE-9072

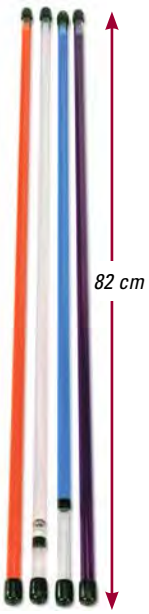
This set is unusual because it includes a tube with both a bubble, a plastic ball and a metal ball, giving the students the added twist of having an object with a negative velocity and thus a negative slope on the graph. Students can predict where the ball and the bubble will meet.





Constant Velocity Tubes effectively introduce the relationship between graphs and motion. Students can use a meterstick and a stopwatch to plot the position of the bubble as a function of time as it moves up the tube. Each tube has an obstruction that serves as the initial position for the bubble. The slope and vertical intercept from the graph yield the equation of motion.

This set includes three tubes with varying viscosities and initial starting points plus one tube with both a bubble and two balls. The red one and the colorless one have the same viscosity.



Order Information

Constant Velocity Tubes (4)	SE-9072	
Required:		
Meter Stick (6 pack)	SE-8827	
PASCO Stopwatch	ME-1234	

Tape Timer

ME-9283

- Crystal-controlled
- Two frequencies (10 Hz and 40 Hz)
- Easy-to-read dots

Features

Two crystal-controlled, calibrated frequencies: (10 Hz and 40 Hz), accurate to 0.1%. The 40-Hz frequency is ideal for freefall experiments. The slower 10-Hz frequency is best for most dynamics track experiments.

Includes an internal 9-V battery, or use an optional external 9-V AC adapter/power supply: A single battery can last for up to a year's worth of normal experiments.

Low mass, small-pin printing head: Driven by short millisecond pulses, produces sharp, round dots without smearing.

Plain paper: Print on 12.5 mm (1/2 inch) wide, plain paper supplied in 150-meter (500 feet) rolls.

Carbon paper discs: Used for printing. The adjustable disc holder allows the printing point to be adjusted, giving a long life to the discs.

Rod clamp: Allows the Tape Timer to be mounted on a standard lab stand rod so that the paper path is either parallel or perpendicular to the rod. Rod sizes between 13 mm (1/2 inch) and 9 mm (3/8 inch) are accommodated.



Use a Tape Timer, Dynamics Cart and Track to calculate acceleration down an inclined plane.



Includes

One roll of paper, 10 carbon paper discs, battery and manual (not shown).

Order Information

Tape Timer ME-9283

Recommended:

9-V AC Adapter 120 V/500 mA 540-007

Tape Timer Supplies ME-9284

Includes five rolls of paper (each 150 m) and 10 carbon paper discs.

Smart Timer

ME-8930

- Portable timer for photogates and smart pulleys
- Measures time, speed and acceleration
- Counter for G-M Tubes
- Crystal-controlled 0.01% accuracy

TEACHER FAVORITE

Measure Time:

- One Gate: Returns time from leading edge to leading edge
- Fence: Returns 10 time values
- Two Gates: Returns time between two gates
- Pendulum: Measures pendulum period
- Stopwatch: Returns time between pressing Start/Stop button

Measure Speed:

- One Gate: Single object speed using picket fence
- Collision: Initial and final speeds for one or two carts
- Pulley: Angular speed

Measure Acceleration:

- One Gate: Direct measurement of acceleration using picket fence
- Linear Pulley: Acceleration of string
- Angular Pulley
- Two Gates: Object's average acceleration between two photogates

Measure Counts:

- Three timing intervals
- Manual mode counts until Stop is pressed
- Up to 5,000 counts/second
- Up to 9,999,999 total counts

2-line, 16-character Alphanumeric LCD
Top Line: Measurement Description; Bottom Line: Numerical Values



It's as easy as 1-2-3.

1. Measurement
Press this button to select the quantity to be measured: "Time," "Speed," "Accel," "Count" or "Test" will appear on the display.

2. Mode
Press this button to select the type of experimental setup. Each mode is shown in words on the display.

3. Start/Stop
Press Start. The Smart Timer "beeps," and waits for an event to occur. After the event, the Smart Timer displays a result.

Two Photogate Ports



Durable Positive-click Buttons



The Most Versatile Stand-Alone Timer Available

The ME-8930 Smart Timer works with all PASCO timing devices

- Accessory Photogate
- Photogate/Pulley System
- Time-of-Flight Accessory
- Freefall Adapter
- Laser Switch
- G-M Tube

Features

Works with Two Photogates

More than just a Timer: Measures speed and acceleration as well as time.

Quick Setup: Turn on the switch, plug in the photogates, and it's ready to use.

Portability or Plug-in: The battery-operated (four "AA"s) Smart Timer can be used outside the classroom away from power outlets. It can also be operated on the 9 VAC adapter (included).

Calculation Lock-out Switch: A switch inside the battery compartment disables the speed and acceleration modes. Timing modes are unaffected, and students are required to do their own calculations.

Specifications

Resolution: 100 µs

Accuracy: 0.01 % of full range of the measured time

Display: 2-line, 16-character, alphanumeric LCD

Inputs: Two 1/4" stereo phone jacks on side panel—TTL compatible

Power Requirements: Four "AA" batteries (not included) or AC adapter (9 VDC, 500 mA) included

Typical Experiments

1. Acceleration Due to Gravity*
2. Newton's Second Law*
3. Conservation of Momentum in Collisions*
4. Rotational Inertia of a Disk & Ring*
5. Acceleration Down an Incline
6. Simple Harmonic Oscillator
7. Oscillations on an Incline
8. Springs in Series and Parallel
9. Projectile Motion Using Photogates
10. Time-of-Flight and Initial Velocity
11. Determining the Acceleration Due to Gravity
12. Counting Radiation with the G-M Tube

*Experiments require accessories listed on pages 39 and 41.

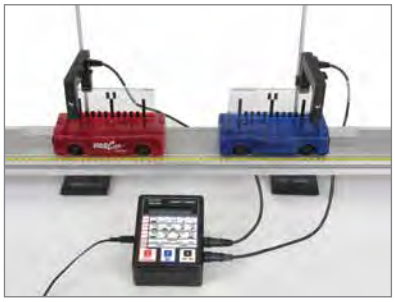
To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

A variety of modes and measurements

The microprocessor-based PASCO Smart Timer is the most versatile way to make time, speed, acceleration and count measurements.



Speed of projectile— In Time: Two Gates mode, determine the speed of a ball fired by a Projectile Launcher through two photogates.



Speed before and after collision— In Speed: Collision mode, use two carts and two photogates with a single Smart Timer to measure initial and final speeds of both carts.



Rotary motion— In Acceleration: Linear Pulley mode, the Smart Timer measures the acceleration of the string over the Smart Pulley.

Smart Timer (ME-8930) Includes

Smart Timer — 9 VAC Adapter
Picket Fences (2) — Lab Manual

Order Information

Smart Timer	**ME-8930**	
Recommended:		
Accessory Photogate	ME-9204B	p. 39
Smart Timer Fences (2)	ME-8933	
Freefall Adapter	ME-9207B	p. 117
Laser Switch	ME-9259A	p. 39
Photogate/Pulley System	ME-6838A	p. 133
Time-of-Flight Accessory	ME-6810	p. 41
G-M Tube/Power Supply	SN-7927A	p. 41
Phone Jack Extender Cord	PI-8117	p. 41



Speed of object through one gate— In Time: One Gate mode, timing begins when the photogate beam is first blocked and continues until the beam is blocked again. Use the fence supplied with the Smart Timer.

Smart Timer Photogate System

ME-8932

Comes with a full set of accessories for timing experiments. Attach the photogate to the Super Pulley to produce a "Smart Pulley."



Smart Timer Photogate System (ME-8932) Includes

1. Smart Timer
2. Accessory Photogate (2)
3. Super Pulley
4. Picket Fences (2)

9 VAC Adapter and Lab Manual (not shown)

Order Information

Smart Timer Photogate System	**ME-8932**

Digital Photogate Timer System

ME-9403A

- High accuracy and resolution
- Four timing modes: gate, pulse, pendulum and manual stopwatch
- Built-in memory

PASCO digital photogates are used in thousands of physics labs throughout the world. They are rugged and simple to operate.



0.1 ms Resolution

Memory
Record two times in rapid succession. The photogate will remember the first and the total of the two times.

Four Timing Modes

Features

Built-in Photogate: Timer serves as the base

0.1 ms Resolution and 0.05% Accuracy

Memory Function: Allows two measurements in rapid succession, such as pre- and post-collision velocities

Easy Setup: Turn it on and begin taking measurements

Portability or plug-in: Use four "C" cells (not included) or 9 V AC adapter (included)

The Photogate Timers work with the following:

Accessory Photogate

Time-of-Flight Accessory

Freefall Timer

Laser Switch



Precision Photogates
PASCO photogates are highly accurate timing devices. Each photogate has a high output, narrow angle infrared emitter and a narrow angle detector. The photogate signals:
– have a spatial resolution error of less than 1 mm
– have a rise time of less than 10 µs
– are unaffected by normal ambient light

Accessory Photogate
Can be purchased separately.

ME-9215B Photogate Timer with Memory

Digital Photogate Timer System
Includes both the Photogate Timer and the Accessory Photogate.

Specifications

Modes: Gate, pulse, pendulum, manual stopwatch

Resolution: 0.1 ms (max time 19.9999 s)

Accuracy: 0.05% of full range of the measured time ± 1 digit

Display: 5-1/2 digit, 10 mm high LCD

Memory: Preserves displayed time while new time is measured

Photogate: 6.5 cm wide; fully adjustable swivel mount; LED trigger indicator; fall time <10 ns; spacial resolution <1 mm

Inputs: Accessory Photogates, or TTL-compatible signals; one photogate jack and a 9-V AC adapter jack (or four "C" size batteries) on back panel



Shown with the Freefall Timer Adapter ME-9207B.

Order Information

Digital Photogate Timer System	ME-9403A
Photogate Timer with Memory	ME-9215B
Accessory Photogate	ME-9204B
Four "C" Cell Batteries	PI-6603

Short-Range Launcher

ME-6800

Long-Range Launcher

ME-6801

▶ Accurate ▶ Durable



Add optional Smart Gate to measure launch velocity.



Unique Sights

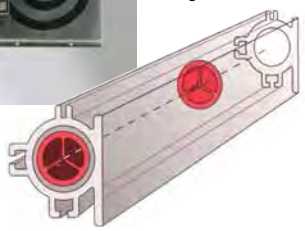
Shoot-the-Target

The "gun" is aimed directly at the target. Although the target "drops" the moment the projectile is fired, the ball still hits the target since the ball falls with the same acceleration.

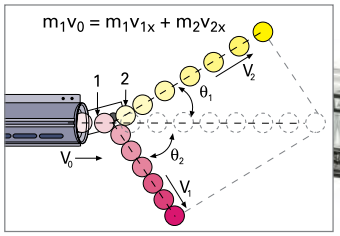


GREAT DEMO

Two bore sights simplify aiming the launcher.



2-D Collisions





The 2-D Collision Accessory (included with all PASCO launchers) allows the study of ***Conservation of Momentum*** *in two dimensions. Use the points of impact with the floor of each of the two balls to determine relative velocities and angles.*

Specifications

Ranges: (ME-6800) 1.2, 3, 5 m, (ME-6801) 2.5, 5, 8 m
Launch Angles: 0 to +90°
Launcher Length: 21 cm

Features

Fixed Firing Height at Any Launch Angle:
Firing height of ball is same for any launch angle.

Unique Piston Design: Minimizes projectile spin to ensure repeatability of impact position.

Includes

Launcher with Base, Projectile Balls, Loading Rod, Safety Glasses, 2-D Collision Accessory and Manual

Order Information

Projectile Launcher (Short-Range)	ME-6800	
Projectile Launcher (Long-Range)	ME-6801	
Shown in use with:		
Shoot-The-Target System	ME-6853	p. 124
Photogate Mounting Bracket	ME-6821A	p. 128
Smart Gate	PS-2180	p. 106
Recommended:		
Projectile Catcher Accessory	ME-6815	p. 127
Time-of-Flight Accessory	ME-6810	p. 128
Large C-Clamp (6 pack)	SE-7285	p. 173
Plumb Bobs (10 pack)	SE-8728	p. 178

Launcher Spares Kit

ME-6802

- Loading Rod (2)
- 2-D Collision Accessory (2)
- Plastic Balls (10 pack)
- Sights (5 pack)
- Angle Indicator Plumb Bobs (24 pack)
- Thumbscrew to attach launcher to base (10)



Order Information

Launcher Spares Kit ME-6802

Projectile Launcher Smart Gate System

NEW

ME-6798

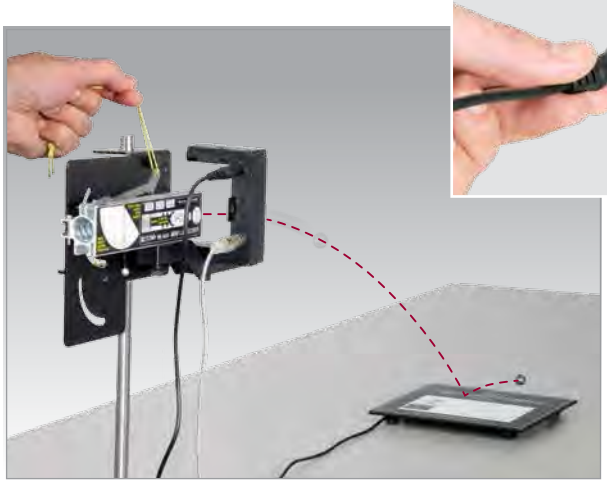
- Vary height.
- Vary angle.
- Vary launch speed.
- Measure accurately with Smart Gate.

With this combination, your students can study projectile motion and measure the initial speed with one economical Smart Gate since it has two photogate beams built in. The Mini Launcher and Smart Gate make the setup simple: Just clamp the launcher to the table and slide the Smart Gate on. All the components needed are included, even the rod and clamp.

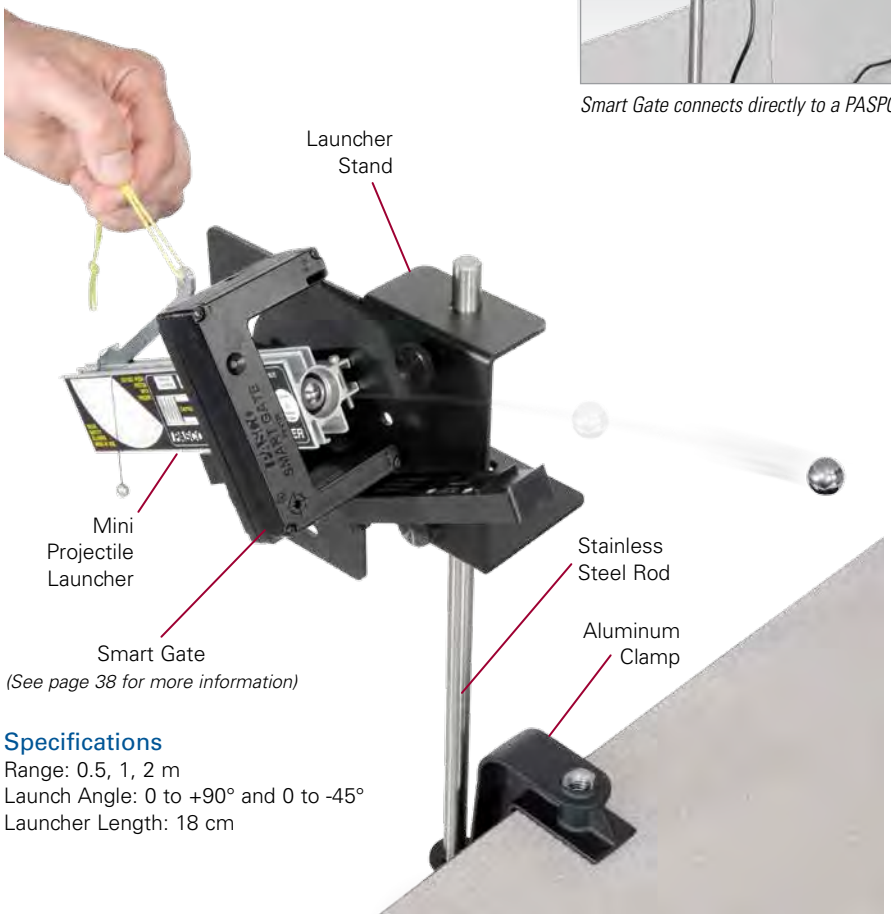
Add optional Time-of-Flight



Daisy-chain Time-of-Flight to Smart Gate



Smart Gate connects directly to a PASPORT interface.



(See page 38 for more information)

Specifications

Range: 0.5, 1, 2 m
Launch Angle: 0 to +90° and 0 to -45°
Launcher Length: 18 cm

Includes

Smart Gate with mounting bracket
Launcher with Mounting Stand
Steel balls (2) with loading rod
2-D collision Accessory
Aluminum Table Clamp
45 cm Stainless Steel Rod



Order Information

Projectile Launcher Smart Gate System ME-6798

Shown in use with:
Time-of-Flight Accessory ..... ME-6810 p. 128

Required:
PASPORT Interface

Projectile Launcher Plumb Bobs (24 pack)

ME-9868

Use this kit to make 24 plumb bobs to replace lost or broken parts from any of PASCO's projectile launchers.



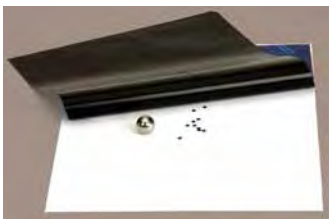
Order Information

Projectile Launcher Plumb Bobs (24 pack) ME-9868

Carbon Paper (100 sheets)

SE-8693

For marking the position of the ball.



Order Information

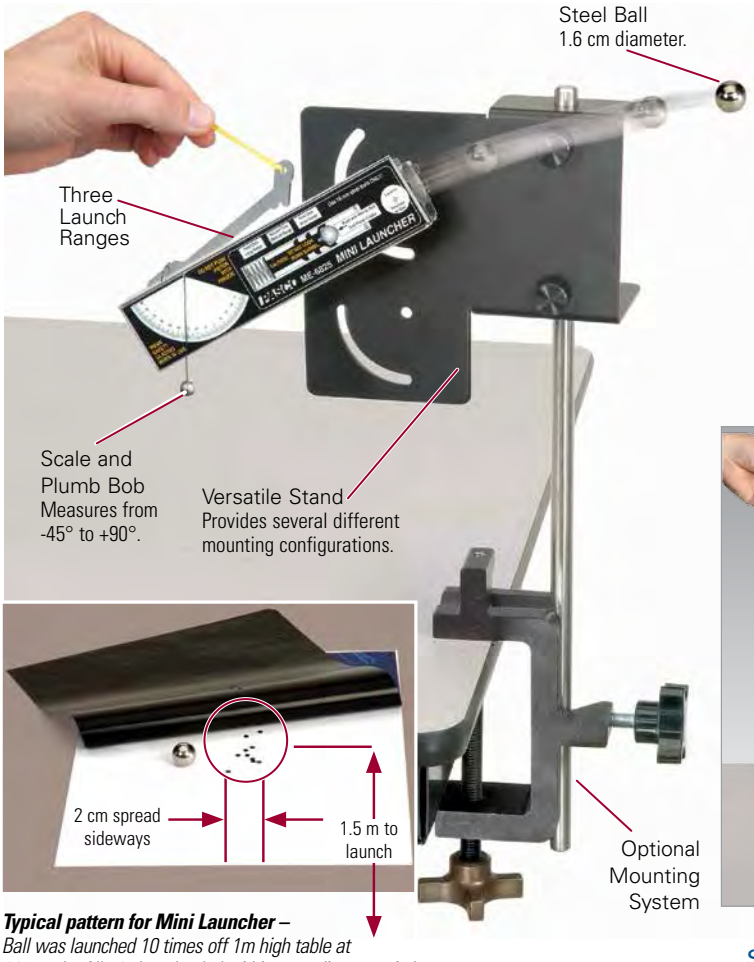
Carbon Paper (100 sheets) SE-8693

Mini Launcher

ME-6825A

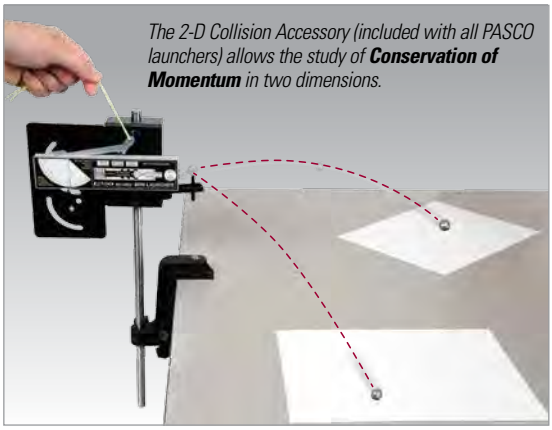
TEACHER FAVORITE

- Ideal for tabletop projectile experiments
- Fires at downward angles
- Low cost

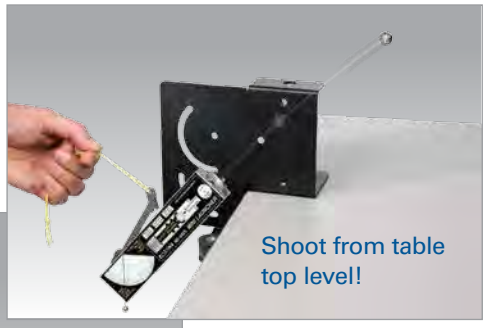


Typical pattern for Mini Launcher –
Ball was launched 10 times off 1m high table at 30° angle. All 10 shots landed within 5 cm diameter circle.

2-D Collision



*The 2-D Collision Accessory (included with all PASCO launchers) allows the study of **Conservation of Momentum** in two dimensions.*





Unique stand design allows ball to be launched from tabletop height. The ball lands on the table at the same height from which it was launched.

Magnetic Piston holds ball in place for launching at downward angles.

Specifications

Range: 0.5, 1, 2 m
Launch Angle: 0 to +90° and 0 to -45°
Launcher Length: 18 cm

Includes

Launcher Base	Loading Rod	2-D Collision Accessory
Projectile Balls	Safety Glasses	Manual

Order Information

Mini Launcher	ME-6825A	
Recommended:		
Photogate Mounting Bracket	ME-6821A	p. 128
Smart Gate	PS-2180	p. 106
Time-of-Flight Accessory	ME-6810	p. 128
Clamps		p. 173
Steel Rod	ME-8736	p. 170
Plumb Bobs (10)	SE-8728	p. 178
Carbon Paper (100 Sheets)	SE-8693	p. 122
Metric Measuring Tape	SE-8712A	p. 176

Mini Launcher Spares Kit

ME-6824

Loading Rod (10)
2-D Collision Accessory (2)
Steel Balls (10 pack)
Angle Indicator
Plumb Bobs (24 pack)
Thumbscrew to attach launcher to base (10)



Order Information

Mini Launcher Spares Kit	ME-6824

Shoot-the-Target

ME-6853

- Demonstrate independence of *x*- and *y*-motion
- For use with all launchers

A unique electromagnet design provides quick release of the target. The projectile hits the target, proving that the projectile accelerates downward at the same rate as the target.



The "gun" is aimed directly at the target. Although the target "drops" the moment the projectile is fired, the ball still hits the target since the ball falls with the same acceleration.

Includes

Drop Box & Control Box
Control Cable
High Impact Plastic Target (75 cm x 20 cm) ME-6852
Photogate Head & Bracket
AC Adapter (9 VDC, 500 mA)



Order Information

Shoot-the-Target System	ME-6853	
Recommended:		
Short-Range Launcher	ME-6800	p. 121
Long-Range Launcher	ME-6801	p. 121
Mini Launcher	ME-6825A	p. 123

Shoot-the-Target Accessory

ME-6854

- Use with Discover Freefall System

This accessory allows the Shoot-the-Target experiment to be performed with the ME-9889 Discover Freefall System.



Includes

High Impact Plastic Target (75 cm x 20 cm)
Photogate Head & Bracket

Order Information

Shoot-the-Target Accessory	ME-6854	
Required:		
Discover Freefall System	ME-9889	p. 116

Discover Freefall Accessory

ME-9893

This accessory allows the Drop and Control box from the ME-6853 Shoot-the-Target to perform all the experiments in the ME-9889 Discover Freefall System. See page 116.

Includes

Time-of-Flight receptor pad
Timer Switch
Release washers (10)
Release labels for attaching washers to object (50)
Small nylon ball
Large plastic ball
Golf ball
Hollow golf ball
1" steel ball
5/8" steel ball



Order Information

Discover Freefall Accessory	ME-9893
Required:	
Shoot-the-Target	ME-6853

Laser Sight

OS-8527A

- For use with short and long range launchers

Makes the Shoot-the-Target experiment even easier with more impact for students. The sight mounts on the back of the Projectile Launcher. Students can clearly see that the Launcher is aimed at the target. Includes AC Adapter (9 VDC, 500 mA).



Order Information

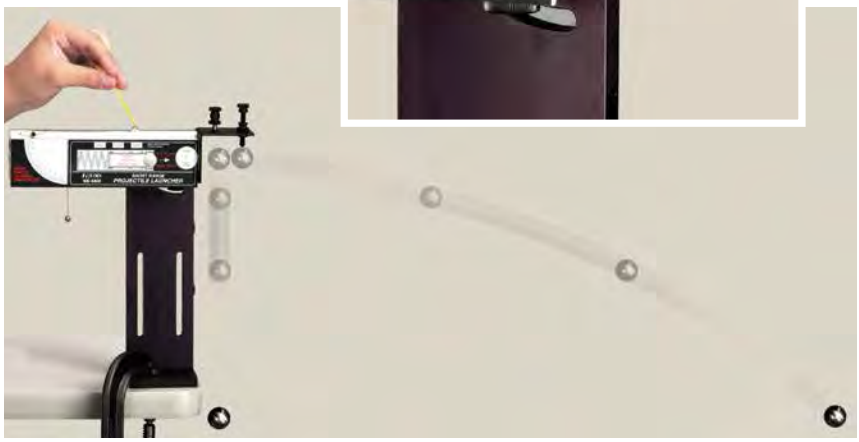
Laser Sight Accessory	OS-8527A

Drop Shoot Accessory

ME-9859

- Simultaneously drops one ball and launches a second ball horizontally
- Prove the independence of *x*- and *y*-motion
- Mounts on PASCO projectile launchers (short- and long-range)





The Drop Shoot Accessory is an easy-to-use tool that helps students better understand the independence between the horizontal and vertical motion of a projectile. Connect the accessory to either the short or long range projectile launchers, hang one ball from the magnet and fire away. The fired ball strikes the hanging ball, causing one ball to shoot horizontally at the same instant the other ball falls straight down. Both balls hit the ground at the same time, regardless of the fired projectile's muzzle velocity, provided the Projectile Launcher is level. This device also provides an interesting demonstration of Conservation of Momentum in collisions.

When the (included) hollow steel ball is used, the two balls are both fired horizontally at two different speeds. A Photogate and Time-of-Flight Accessory can also be used to directly measure time of flight.

Includes

Drop Shoot Bracket
2.5 cm Steel Balls (2)
2.5 cm Hollow Steel Ball
Mounting Hardware
Loading Rod



Order Information

Drop Shoot Accessory	ME-9859	
Required:		
Short-Range Projectile Launcher	ME-6800	p. 121
Long-Range Projectile Launcher	ME-6801	p. 121

Mini Drop Shoot Accessory

ME-6827

- Compatible with the Mini Launcher



This accessory is used with the Mini Launcher (ME-6825) to demonstrate the independence of x- and y-motion. The operation is similar to the Drop Shoot Accessory (ME-9859) shown above but it uses the smaller solid steel balls which fit the Mini Launcher. A photogate fits on the Mini Drop Shoot Accessory and can be used with a Time-of-Flight Accessory to measure the time of flight of each ball.

Includes

Drop Shoot Bracket
1.6 cm Solid Steel Balls (2)
Mounting Hardware
Loading Rod



Order Information

Mini Drop Shoot Accessory	ME-6827	
Required:		
Mini Launcher	ME-6825A	p. 123

Vertical Acceleration Demonstrator

SF-9339



One ball is dropped as the other is launched horizontally. Both balls hit the floor at the same time, demonstrating that vertical acceleration is independent of horizontal velocity. The Vertical Acceleration Demonstrator includes two steel balls, the launcher with a receptacle for storing the balls and instructions.

Order Information

Vertical Acceleration Demonstrator	SF-9339

Ballistic Pendulum

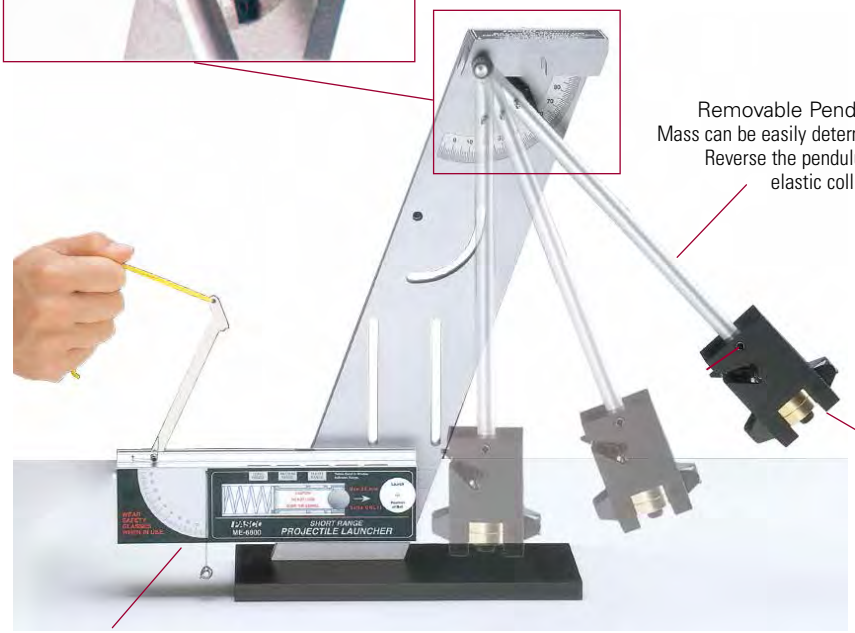
ME-6830

- Extremely accurate— ±2.5% of predicted values
- Both elastic and inelastic experiments
- Projectile launcher experiments



TEACHER FAVORITE

Unique Angle Measurement Design
Easily measures pendulum angle to 0.5°.
Low friction gives repeatable results.



Removable Pendulum
Mass can be easily determined. Reverse the pendulum for elastic collisions.

Projectile Catcher
Securely captures ball.

Projectile Launcher
Durable with three repeatable launch settings.



Add Masses
Two 50 g masses (included) can be added to change the pendulum mass and rotational inertia.

This classic physics experiment combines the laws of Conservation of Momentum and Conservation of Energy to determine the muzzle velocity of the projectile. Only simple mass and distance measurements are required to make this determination.

How It Works

A projectile is fired into a pendulum, causing it to rise.

Using the projectile mass, the pendulum mass, and the rise in pendulum height, students can calculate the gravitational potential energy of the system.

Since the potential energy is equal to the pendulum's kinetic energy at the lowest point, students can calculate the speed of the pendulum at impact.

Applying the Law of Conservation of Momentum, the projectile's speed is easily calculated.



Mount the launcher on the other side of the base and perform the full range of projectile launcher experiments.

Already own a PASCO Projectile Launcher?

The base and pendulum assembly can be purchased separately.

See Ballistic Pendulum (No Launcher) in the order block for more information.

PASCO's Ballistic Pendulum— A New Approach

The PASCO Ballistic Pendulum has the following unique features:

Repeatable: The three velocity settings on the Projectile Launcher produce consistent velocities.

Accuracy: The 0-80° angle measurement scale resolves to 1/2°, leading to experimental results within 2.5% of predicted values.

Removable Pendulum: Remove the pendulum to determine its mass and center of mass. It can swing freely so students can determine its rotational inertia. Mount the pendulum backwards so the ball bounces away for elastic collision experiments.

Vary Ball and Pendulum Mass:
Two 50 g masses can be added to the pendulum, and two steel and two plastic balls are included.

Projectile Launcher: Mount the Projectile Launcher on the other side of the base, and students have access to all the accessories that come with the Projectile Launcher ME-6800 (see following page).

Includes

Ballistic Pendulum and Base
Projectile Launcher
2.5 cm Plastic Balls (2)
2.5 cm Steel Balls (2)
Masses (2)
2-D Collision Accessory
Safety Glasses (2 pairs)
Operations and Experiment Manual



Order Information

Ballistic Pendulum	**ME-6830**	
Ballistic Pendulum (No Launcher)	**ME-6831**	
Recommended:		
Spherical Mass Set	ME-8968	p. 177
Shoot-the-Target	ME-6853	p. 124
Time-of-Flight	ME-6810	p. 41
Large C Clamp (6 pack)	SE-7285	p. 173

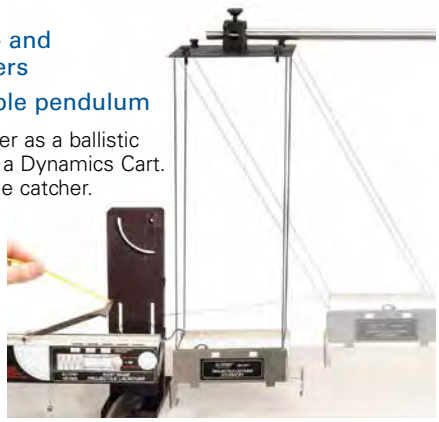
Projectile Catchers Make Ballistic Pendula That Won't Rotate

Projectile Catcher Accessory

ME-6815

- For use with short- and long-range launchers
- Can treat as a simple pendulum

Use the Projectile Catcher as a ballistic pendulum or attach it to a Dynamics Cart. Fire the steel ball into the catcher. Measure the maximum catcher height to determine the potential energy of the catcher and ball. From the conservation of momentum and energy laws, determine the ball's initial velocity.



Thread passes through Velcro™ strips on the back of the launcher stand to measure the resulting motion of the catcher.



Photogates can be used to measure the speed of the cart after catching the fired ball.

Includes

Projectile Catcher (170 g)
String holder plate and clamp
2.5 cm steel balls (2) (67 g each)
Spool of string
Velcro strips (not shown)
Instruction manual and experiment guide



Order Information

Projectile Catcher Accessory	ME-6815	
Recommended:		
Right Angle Clamp	SE-9444	p. 172
Large Table Clamp	ME-9472	p. 173
90 cm Steel Rod	ME-8738	p. 170
45 cm Steel Rod	ME-8736	p. 170

Mini Catcher Accessory

ME-6814

- For use with the Tabletop Mini Launcher

Students can perform a classic ballistic pendulum experiment by measuring the height of the Mini Catcher's swing.

Includes

Projectile Catcher (25 g)
String Holder Plate and Clamp
1.6 cm Steel Balls (2) (16 g each)
String and Velcro
Instruction Manual and Experiment Guide



Order Information

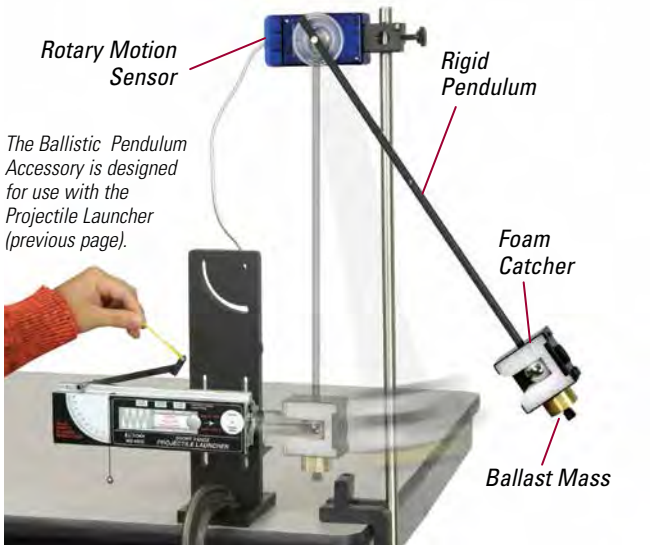
Mini Catcher Accessory	ME-6814

Ballistic Pendulum Accessories

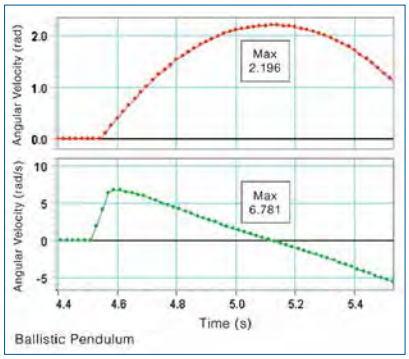
Ballistic Pendulum Accessory ME-9892
Mini Launcher Ballistic Pendulum Accessory ME-6829

- Accessory to the Rotary Motion Sensor
- Both elastic and inelastic experiments
- Low cost

The Ballistic Pendulum Accessories use a Rotary Motion Sensor to measure the speed of the catcher assembly immediately after the collision, as well as the maximum height to which the pendulum swings. The Rotary Motion Sensor can also be used to measure the rotational inertia of the pendulum, for detailed study of the collision using conservation of angular momentum.



The Ballistic Pendulum Accessory is designed for use with the Projectile Launcher (previous page).



Rotary Motion Sensor (required for use) allows measurement of instantaneous velocity of catcher immediately after collision, as well as total angle of rotation of the pendulum arm.

Includes

Pendulum Arm with Catcher
Ballast Mass
Steel Ball



Order Information

Ballistic Pendulum Accessory	ME-9892
Mini Launcher Ballistic Pendulum Accessory (Not Shown)	ME-6829

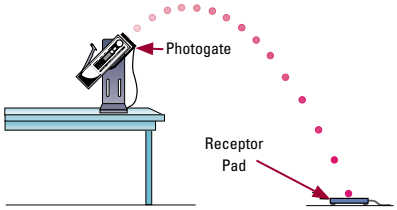
Time-of-Flight Accessory

ME-6810

▸ For use with all PASCO launchers



When the projectile is launched, the photogate mounted on the launcher starts timing. When the projectile hits the receptor pad on the Time-of-Flight Accessory, an electric signal is sent to stop timing.



Includes

Time-of-Flight Accessory

Instruction Manual and Experiment Guide

Order Information

Time-of-Flight Accessory ME-6810

Photogate Mounting Bracket

ME-6821A



Mount one or two photogates on any Projectile Launcher. Compatible with Photogate Heads below.



Order Information

Photogate Mounting Bracket ME-6821A

Photogate Head ..... ME-9498A p. 39

Accessory Photogate ..... ME-9204B p. 39

Small Steel Balls (10 pack)

ME-9872



These 1.6 cm diameter steel balls are used with the Mini Launcher (ME-6825).

⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Order Information

Small Steel Balls (10 pack) ME-9872

Steel Balls (4 pack)

ME-9864



⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

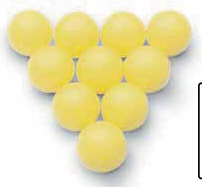
Purchase this 4 pack of 2.5 cm diameter balls for use with PASCO Short or Long-Range Projectile Launchers (ME-6800 or ME-6801).

Order Information

Steel Balls (4 pack) ME-9864

Plastic Balls

ME-6822



⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Extra brightly colored balls are available for the Projectile Launcher. Diameter is 2.5 cm (1 in.).

Order Information

Plastic Balls (10 pack) ME-6822

Spherical Mass Set

ME-8968



⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

This set includes four balls with a diameter of 2.5 cm each, but features various masses, including a hollow steel ball, solid steel ball, plastic ball and aluminum ball.

Order Information

Spherical Mass Set ME-8968

Projectile Launcher Sights (5 pack)

ME-9865



Purchase this 5 pack of aiming sights as a replacement for the Short-Range or Long-Range Projectile Launchers.

Order Information

Projectile Launcher Sights (5 pack) ME-9865

Projectile Launcher Plumb Bobs (24 pack)

ME-9868



Use this kit to make 24 tin plumb bobs to replace lost or broken parts from any of PASCO's projectile launchers.

Order Information

Projectile Launcher Plumb Bobs (24 pack) ME-9868

Plumb Bobs (10 pack)

SE-8728



Plumb Bobs (10 pack) SE-8728

Carbon Paper (100 sheets)

SE-8693



For marking the position of the ball.

Order Information

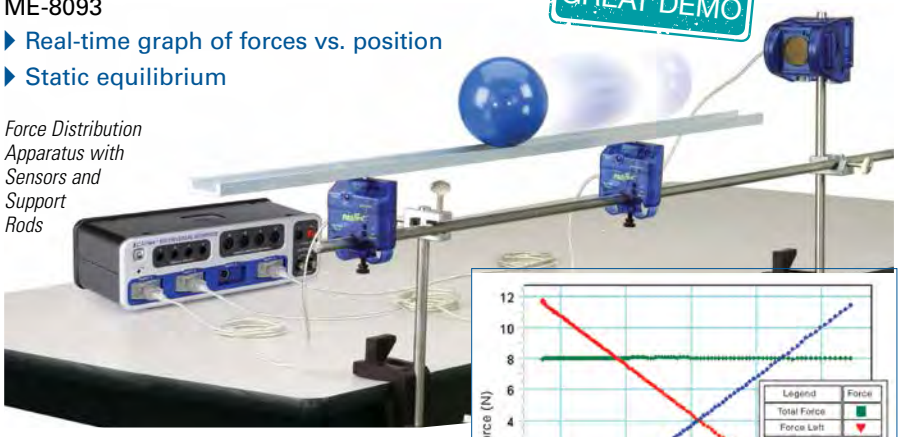
Carbon Paper (100 sheets) SE-8693

Force Distribution System

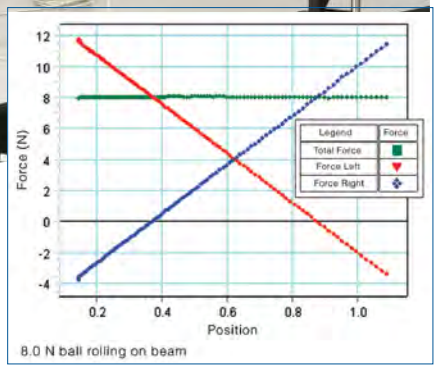
ME-8093

- Real-time graph of forces vs. position
- Static equilibrium

GREAT DEMO



Force Distribution Apparatus with Sensors and Support Rods



The Force Distribution System allows students to measure the vertical forces on a beam as a ball rolls along the beam. The position of the ball is tracked with a Motion Sensor.

Force vs. Position of the ball for each support force and the total force using PASCO Capstone™ Software.

Includes

Beam (1m long) with Attachment Screws for the Force Sensors
Ball (10 cm diameter, 810 g mass)
Large Table Clamp (2) (ME-9472)
45 cm Long Rod (ME-8736)
90 cm Long Rod (ME-8738)
120 cm Long Rod (ME-8741
Multi-Clamp (2) (SE-9442)

Order Information

Force Distribution System	ME-8093	
Required for use with PASPORT:		
Force Sensor (2) DIGITAL sensor	PS-2104	p. 30
Motion Sensor DIGITAL sensor	PS-2103A	p. 27
Required for use with ScienceWorkshop:		
Force Sensor (2) ANALOG sensor	CI-6746	p. 30
Motion Sensor ANALOG sensor	CI-6742A	p. 27
Force Distribution Apparatus (Ball and Track only)	ME-8092	

CLEMSON EXPERT

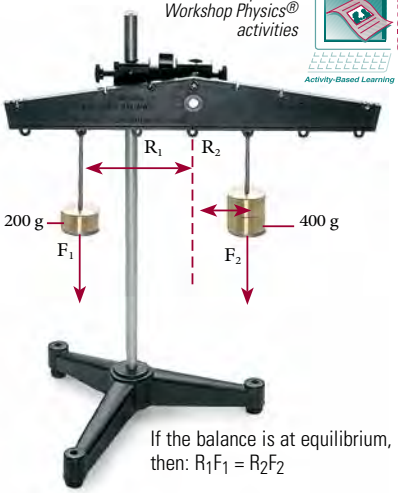
Developed in cooperation with Professor Matt Ohland at Clemson University.

Equal Arm Balance

ME-8949

Developed for Workshop Physics® activities

WORKSHOP PHYSICS Activity-Based Learning



If the balance is at equilibrium, then: $R_1F_1 = R_2F_2$

With 200 and 400 g masses placed as shown above, the balance remains in equilibrium.

The Equal Arm Balance was specially designed to simplify the study of torques. This balance has a ball-bearing pivot.

Includes

Balance Arm with Ball-Bearing Pivot



Specifications

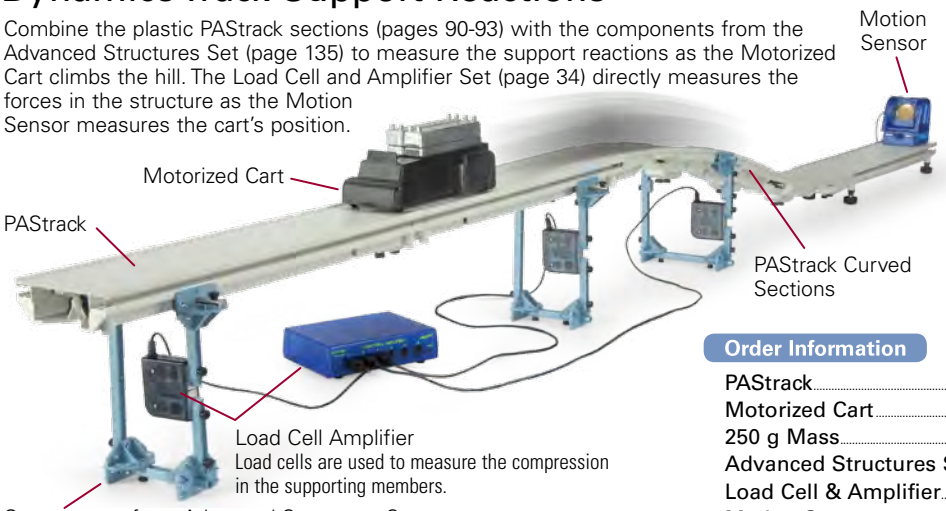
Total length: 34 cm
Maximum weight exerted on balance arm: 1 kg or 10 N

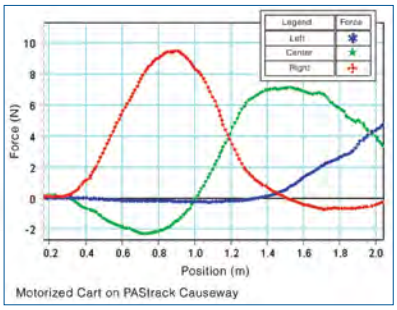
Order Information

Equal Arm Balance	ME-8949	
Required:		
Drilled Mass and Hanger Set	ME-8979	p. 181
or Ohaus Hooked Mass Set	SE-8705	p. 180

Dynamics Track Support Reactions

Combine the plastic PAStrack sections (pages 90-93) with the components from the Advanced Structures Set (page 135) to measure the support reactions as the Motorized Cart climbs the hill. The Load Cell and Amplifier Set (page 34) directly measures the forces in the structure as the Motion Sensor measures the cart's position.





Force vs. Position of the cart for each of the support forces as the Motorized Cart climbs the hill.

Order Information

PAStrack	ME-6960	p. 90
Motorized Cart	ME-9781	p. 96
250 g Mass	ME-6756	p. 104
Advanced Structures Set	ME-6992B	p. 134
Load Cell & Amplifier	PS-2199	p. 34
Motion Sensor	PS-2103A	p. 27

Force Table

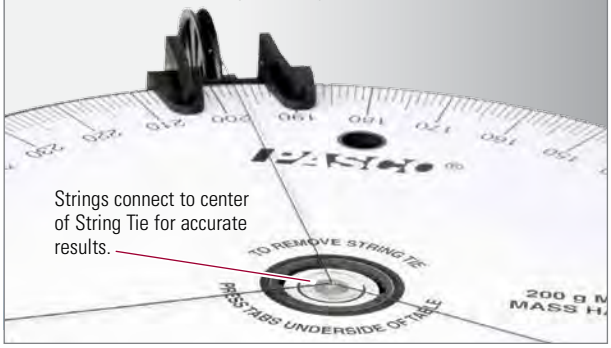
ME-9447B

- High accuracy
- Easy, compact storage
- Inexpensive!

LAB ESSENTIALS

String tie

String Tie is captured to make set-up of hanging masses easy, but it freely floats over bulls-eye pattern to clearly show even small changes in equilibrium.



Adjustable height

The swivel feature of the pulleys can virtually eliminate parallax for more precise angle measurements.



Built-in Scale
Measure angles quickly and accurately.



Compact, Easy Storage



Mass and Hanger
(sold separately)

Change the mass by 1/2 gram or an angle by 1/2 degree and see an immediate change in the equilibrium.



Improved leg storage

The screw-in legs snap under the table for easy storage.

Improved stacking

Stacked tables are keyed together to eliminate slipping. Now you can store all your Force Tables in one convenient stack!



Includes

25 cm diameter table with detachable legs, three adjustable Super Pulleys with Clamps, and a spool of thread.



Mass and Hanger Set is sold separately.

Order Information

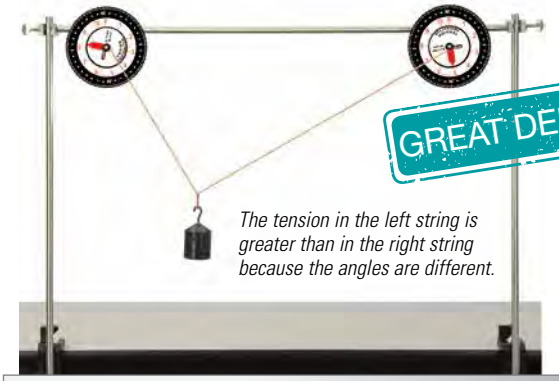
Force Table	ME-9447B	
Required:		
Mass and Hanger Set	ME-8979	p. 181
Additional Pulleys:		
Super Pulley with Clamp	ME-9448B	p. 174

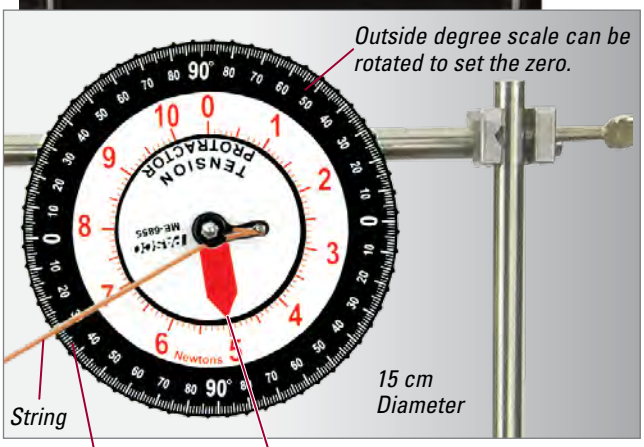
Tension Protractor

ME-6855

- Measure tension and angle with one device
- Large scale for viewing demonstrations
- Zero-adjust for torsion spring scale
- Built-in rod clamp

The Tension Protractor is a spring scale and a protractor integrated into one device. Perfect for static equilibrium experiments, the rotary dial indicates the tension in the string and the angle is read where the string passes over the degree scale on the outer ring. Since the Tension Protractor is supported on a rod, it has an advantage over other spring scales, which tend to weigh down the string, changing the angle.





Specifications

Force Range: 0 N to 10 N
Smallest Force Division: 0.1 N
Force Accuracy: ±4% of Reading
Angle Range: -90° to +90°
Smallest Angle Division: 1°
Diameter: 15 cm



Includes

One Tension Protractor

Order Information

Tension Protractor	ME-6855	
Recommended:		
Large Table Clamp	ME-9472	p. 173
90 cm Long Rod	ME-8738	p. 170
Multi Clamp	ME-9507	p. 172
Hooked Mass Set	SE-8759	p. 181

Pulley Demonstration System

SE-8685

- Demonstrate the mechanical advantage of single or combination pulleys
- Complete stand-alone pulley apparatus
- Simple setup



Features

Stable Base: Easily attach two threaded 81 cm rods to the sturdy base. Includes an eye-hook and capstan to demonstrate an entire pulley system.

Comprehensive: Contains everything needed to effectively display the usefulness of pulleys, including slotted masses and mass hangers.

Several Pulley Types: Reveal the benefits of single pulleys and those of tandem pulleys, quadruple pulleys, and even the four-step pulley. Combine several of them for an efficient pulley system.

Set up a double pulley and a single pulley, each with a 200 g mass. Pull the string of each from the same vertical height down to the base simultaneously. Observe that the mass of the single pulley moves twice as high as the double pulley with twice the force.

Includes

20 cm x 81 cm base with eye-hook and capstan
Threaded 81 cm rods (2)
Clamps (2)
Horizontal rod
Hook collars (8)
90° clamp
Single pulleys (2)
Triple-tandem pulleys (2)
Quadruple pulleys (2)
Four-step pulley (1)
Slotted masses (13)
Mass hangers (6)



Order Information

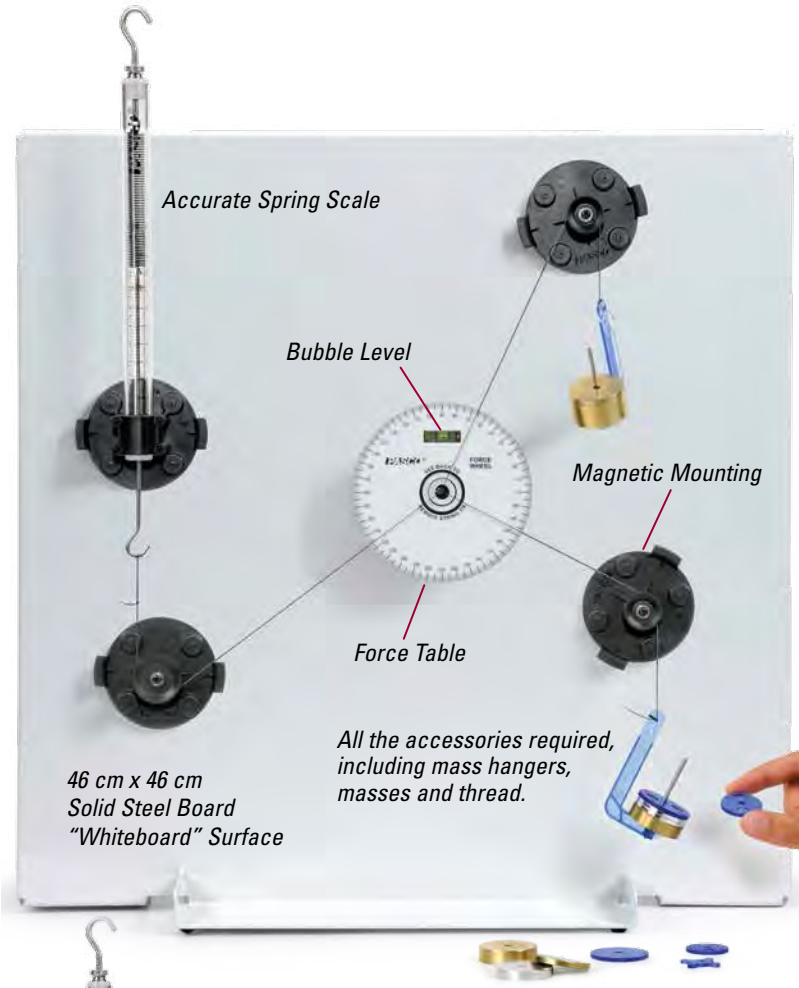
Pulley Demonstration System	SE-8685

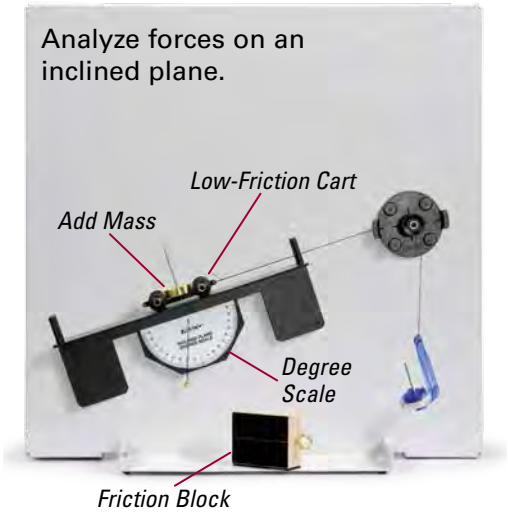
Statics System

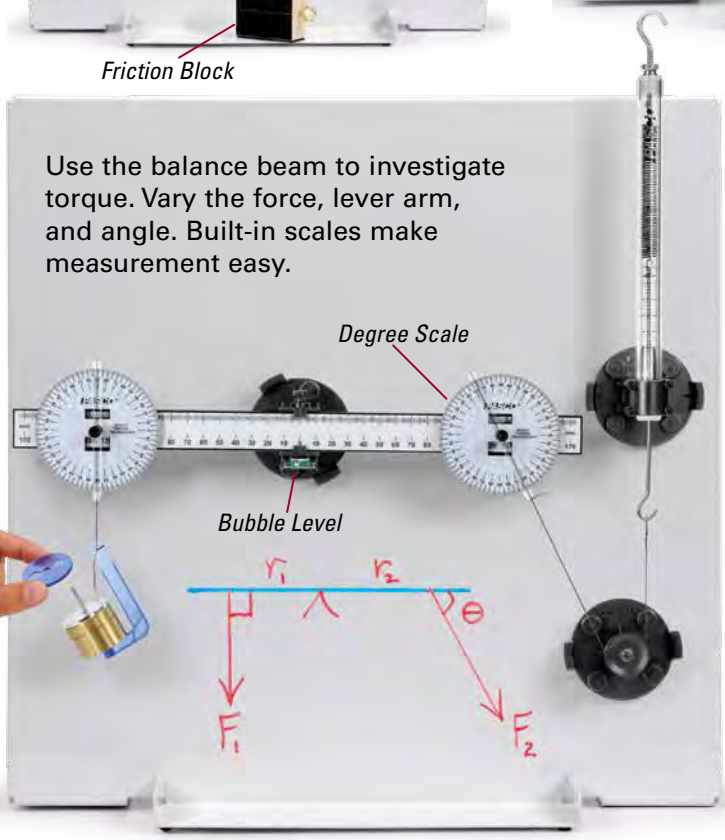
ME-9502

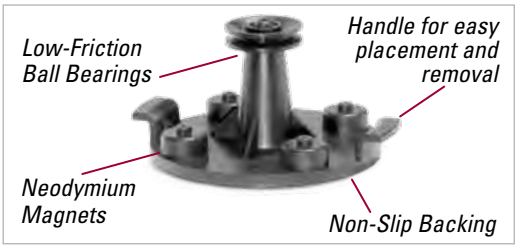
- Everything required for 15 experiments
- Comprehensive — from vector addition to simple machines
- Easy Setup — magnetic mounting

A versatile lab system for demonstrating the basic concepts of vector forces, torques, center of mass, simple machines, and more. The ME-9503 Statics Board (sold separately) doubles the width and is perfect for demonstrations.









Easy Storage

Store magnetic components on back of experiment board.



Includes

Experiment Board, Components, Mass Set and Comprehensive Manual.

Order Information

Statics System	ME-9502
Additional Equipment:	
Statics Board	ME-9503
Spring Scale	ME-9824A
Statics Spares Package	ME-9504

The PASCO Super Pulley

Super Pulley

ME-9450A

- 20 N max load
- Nearly frictionless
- Durable

TEACHER FAVORITE



The PASCO Super Pulley is the standard in physics labs. Its low-friction design produces excellent results. The precision spacing of the 10 spokes makes it ideal for photogate monitoring with PASCO's computer interfaces and photogate systems.

Features

Low Friction: Dual precision ball-bearings (not cone bearings) keep friction to a bare minimum, support heavier loads, and minimize wear.

Lightweight: The sheave is only 5.5 grams, so pulley inertia is negligible in most applications.

Precision Dimensions: The 10 spokes are accurately spaced, and the inside and outside diameters are machined to precise dimensions. This means accurate results and graphs.

Order Information

Super Pulley ME-9450A

Pulley Mounting Rod

SA-9242



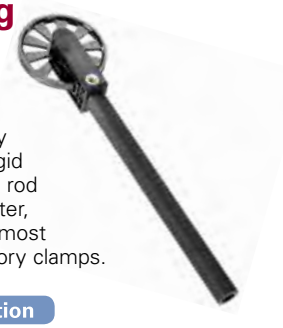
This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Clamp.

Order Information

Pulley Mounting Rod (rod only) SA-9242

Super Pulley with Mounting Rod

ME-9499



This Super Pulley mounted on a rigid plastic mounting rod (12.7 mm diameter, 14 cm long) fits most standard laboratory clamps.

Order Information

Pulley with Mounting Rod ME-9499

Mounting Rods (10 pack)

ME-9483



These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) screw into a Super Pulley.

Order Information

Mounting Rods (10 pack) ME-9483

Super Pulley with Clamp

ME-9448B



Upgrade your force table and inclined plane experiments. The Super Pulley with its integral clamp makes setup and alignment easy. The pulley height is fully adjustable, so you can skim the top of a force table for parallax-free readings. Yet you can keep the force parallel to the track on an inclined plane, as shown in the photo below. Fits tables up to 2.0 cm (13/16 in.) thick.



Order Information

Super Pulley with Clamp ME-9448B

Photogate/ Pulley System

ME-6838A



The Super Pulley attaches directly to the Photogate Head, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments. See page 39.

Order Information

Photogate/Pulley System ME-6838A

Atwood's Machine

SA-9241



Two Super Pulleys mounted on a 6.4 cm long rod produce a classic, low-friction introduction to Newton's Second Law. The instruction sheet fully describes both the experiment and the theory.



Includes

Two Pulleys and Connecting Rod

Order Information

Atwood's Machine SA-9241

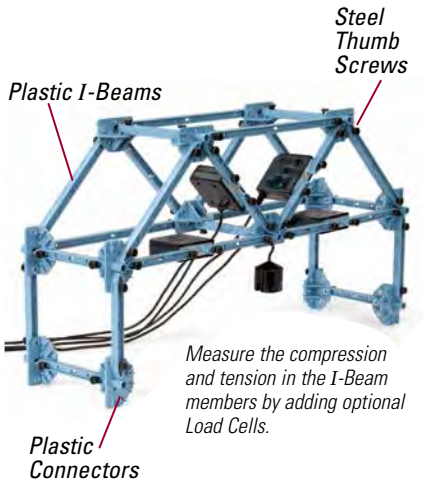
PASCO Structures System

Truss Set

ME-6990

- Teach the basics of trusses
- Demonstrate the properties of I-beams

Use the Truss Set to build a variety of structures to investigate the principles of trusses. The ABS plastic I-Beams fasten securely together using the provided connectors and thumb screws. Load cells can be inserted anywhere into the design by replacing one beam at a time. Students can load the truss by hanging weights.



Measure the compression and tension in the I-Beam members by adding optional Load Cells.





Construction is easy:
I-Beams fit into the connectors and are secured with thumb screws. Thumb screws are also slotted so a screwdriver can be used.

Includes

One package each of Truss Set Members and Truss Set Screws

(See page 137 for details)

Order Information

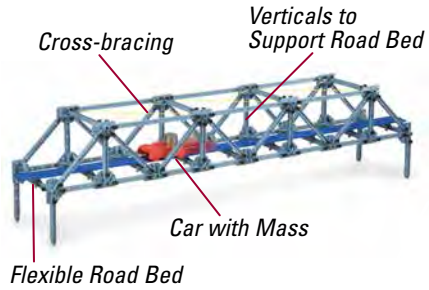
Truss Set ME-6990
Recommended:
Load Cell & Amplifier Set (includes four Load Cells) ..... PS-2199 p. 34

Bridge Set

ME-6991

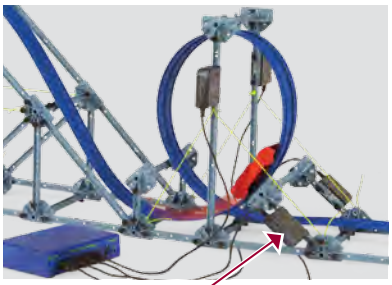
- Study the principles of bridge construction
- Road bed and car add realism to bridges
- Add load cells to see dynamic oading as car traverses bridge

Warren with Verticals
1.5 m long



Special cord locks allow tensioning of cord (cables) for cross-bracing. A flexible plastic road bed clips to the cross-beams and, using load cells, the tension and compression of each element can be displayed in real time.

Design your own roller coaster!



Add Load Cells to measure the forces needed to support the track as the car goes up and over the loop. See pages 114-115 for more roller coasters.

Includes

Two packages each of Truss Set Members and Truss Set Screws
One package each of Roadbed Spares and Cord Lock Spares

(See page 137 for details)

Order Information

Bridge Set ME-6991
Recommended:
Load Cell & Amplifier Set (includes four Load Cells) ..... PS-2199 p. 34

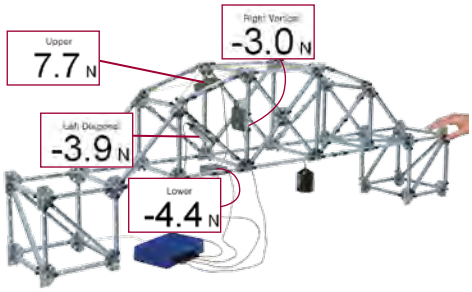
Advanced Structures Set

ME-6992B

- Build bridges, cranes, catapults, and cars

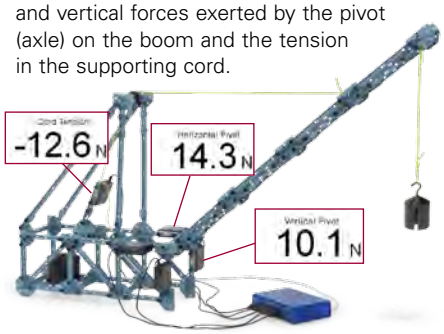
The Advanced Structures Set includes more components to build a larger variety of structures. Axles and pulleys allow construction of cranes, cars, and even a working catapult!

Camelback Truss Bridge
1.4m long



Add Load Cells to measure forces anywhere in the structure.

Forces on a Boom
Vary all parameters including length and angle of the boom. Directly measure the horizontal and vertical forces exerted by the pivot (axle) on the boom and the tension in the supporting cord.



Support structure uses 1/2 kg masses from the Large Slotted Mass Set for counter balance.

Includes

Three packages of Truss Set Members
Four packages of Truss Set Screws
One package each of Flexible I-Beams, Cord Lock Spares, Axle Spares, Round Connector Spares, Angle Connector Spares, Flat Beams, Structures Rod Clamps, and Force Platform Structures Bracket

(See page 137 for details)

Order Information

Advanced Structures Set ME-6992B
Shown in use with:
Load Cell & Amplifier Set (includes four Load Cells) PS-2199
Hooked Mass Set SE-87599
Large Slotted Mass Set ME-7566

Large Structures Set

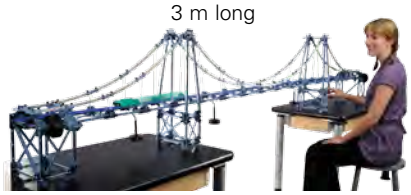
ME-7003

The Large Structures Set includes all the components contained in the Advanced Structures Set (ME-6992B) plus additional parts to build even bigger structures. It also includes the Mini Cars with plastic track to build roller coasters and to add realistic roadbeds to your bridges.



Student uses the Hydraulic/Pneumatic Structures System (ME-6984) to adjust the crane.

Suspension Bridge
3 m long



Includes

Six packages of Truss Set Screws
Three packages of Truss Set Members
Two packages of Connector Spares
One package each of #6 I-Beam Spares, Flexible I-Beams, Cord Lock Spares, Axle Spares, Round Connector Spares, Angle Connector Spares, Flat Beams, Structures Rod Clamps, Mini Car Track Spares, Force Platform Structures Bracket, and one each Green Car, Yellow Car, 9.1 m Track, and Starter Bracket

(See page 137 for details)

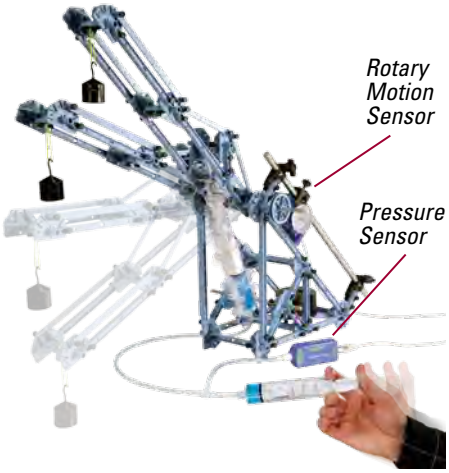
Order Information

Large Structures Set	**ME-7003**	
Shown in use with:		
Hydraulic/Pneumatic Structures	ME-6984	
Load Cell & Amplifier Set (includes four Load Cells)	PS-2199	p. 34
Slotted Mass Set	ME-7589	p. 181

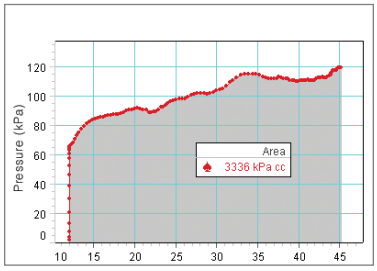
Hydraulic and Pneumatic Structures

ME-6984

Add a hydraulic/pneumatic ram to make your structures move and do work. Not only will students see the cranes and jacks in action, they can directly measure the pressure and volume to calculate how much work was done.



The weight is lifted using a syringe of water to fill the master cylinder. An Absolute Pressure Sensor measures the pressure and a Rotary Motion Sensor records the movement of the piston.



Pressure and volume are recorded as the weight is lifted, and the work done is the area under the curve.



Includes

Master Cylinder
Pressure Sensor "T"
Check Valves and Tubing
Syringes (10, 20, 60 ml)
Drive Belt for Rotary Motion Sensor (Not shown)

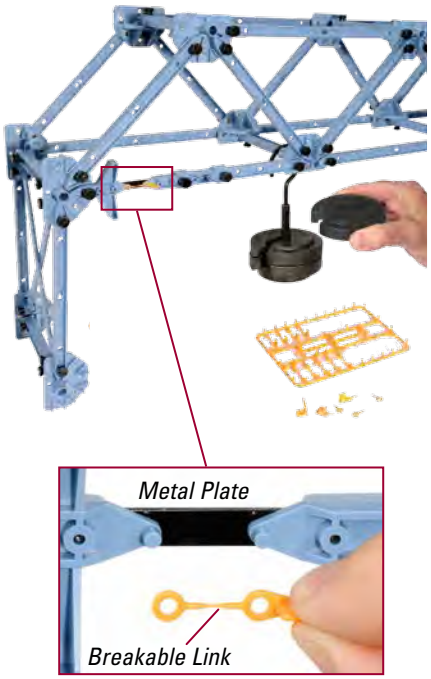
Order Information

Hydraulic/Pneumatic Structures	**ME-6984**	
Advanced Structures Set	ME-6992B	p. 134
Steel Rod (45 cm)	ME-8736	p. 170
Absolute Pressure Sensor	PS-2107	p. 43
Rotary Motion Sensor	PS-2120A	p. 28

Destructible Bridge Members

ME-7004

Investigate structural failure by inserting a breakable link into the structure. The Destructible Bridge Fixture has a fail-safe mechanism, so the bridge will not catastrophically collapse.



The black metal plate of the Destructible Bridge Fixture allows the Breakable Link to stretch and fail but keeps the bridge from falling down completely. A broken link can be easily replaced with a new one by simply sliding it onto the posts.



Includes

Destructible Bridge Fixtures (2)
Breakable Links
(100 each of two different strengths)

Order Information

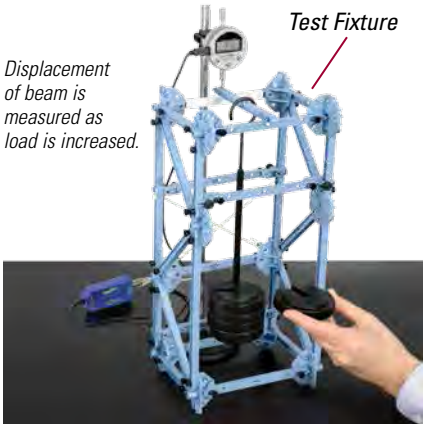
Destructible Bridge Members	**ME-7004**	
Advanced Structures Set	ME-6992B	p. 134
Load Cell & Amplifier Set	PS-2199	p. 34
Displacement Sensor	PS-2204	p. 35
Large Slotted Mass 2 kg Set	ME-7589	p. 181
Destructible Bridge Members Spares	ME-7005	

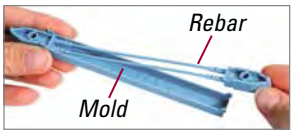
Cast Beam Structures Set

ME-7009

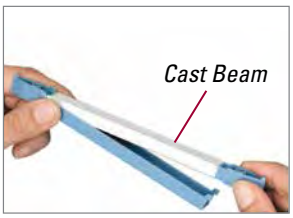
- Both the tension fixture and the test fixture can be built concurrently with this set.

Make your own cast beams that represent pre-stressed concrete beams. These beams are cast with a mixture of sand and plaster of Paris (not included). The rebar is made of the same plastic used for the I-beams. Students can explore how the strength of the beam is affected by the amount of tension put on the rebar and the mixture of sand and plaster of Paris.





Step 1: The rebar with connecting ends snaps into the plastic mold.



Step 2: Pour a mixture of sand and plaster of Paris into the mold. After it dries, it is easy to remove the cast beam from the flexible plastic mold.

Includes

One package each of Truss Set Members, Cast Beam Spares Set, Cord Lock Spares, Axle Spares, Round Connector Spares, and Angle Connector Spares and two packages of Truss Set Screws. *(See next page for details)*

Order Information

Cast Beam Structures Set ME-7009

Also shown:

Displacement Sensor ..... PS-2204 p. 35
Cast Beam Spares (Includes 30 rebar members, 10 cast beam molds with connectors) ME-6983
Large Slotted Mass Set ..... ME-7566 p. 181
Small Round Base (set of two) ..... ME-8974A p. 170
60 cm Threaded Rod ..... ME-8977 p. 170

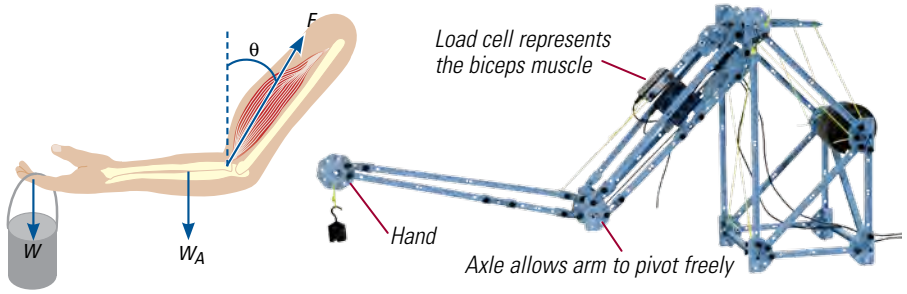
Human Structures Set

ME-7001

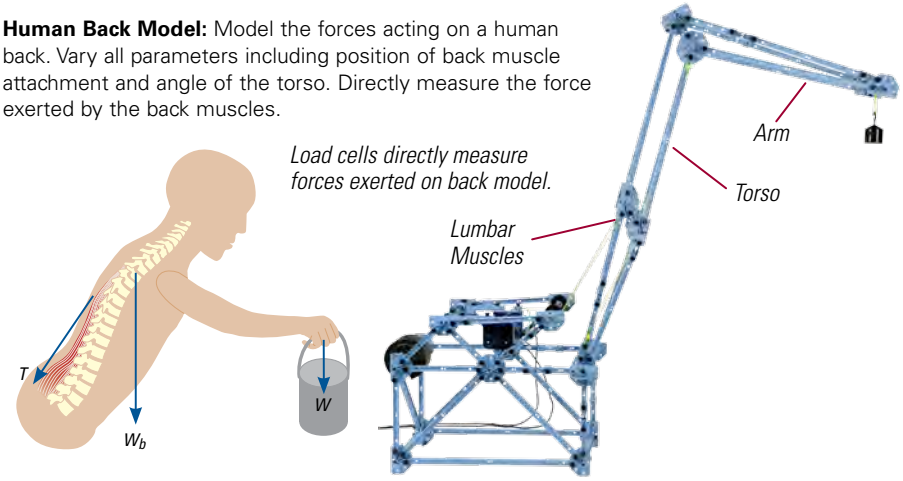
- Build models that represent real life examples.
- Construct all three models concurrently with this set.
- Bring homework problems to life!

Human Arm Model: Students build a realistic arm model and directly measure the forces exerted by the biceps muscle (tension in supporting cord). Vary the lengthand angle of upper and lower arm, as well as the point of attachment of the muscle.

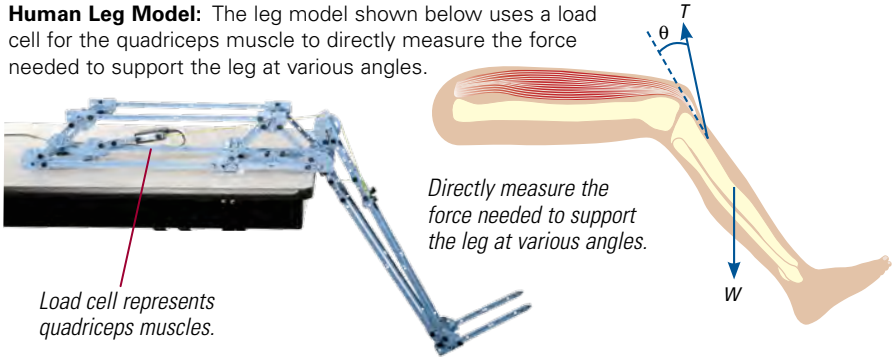
Support Structure allows the angle of the upper arm to be easily adjusted.



Human Back Model: Model the forces acting on a human back. Vary all parameters including position of back muscle attachment and angle of the torso. Directly measure the force exerted by the back muscles.



Human Leg Model: The leg model shown below uses a load cell for the quadriceps muscle to directly measure the force needed to support the leg at various angles.



Includes

Five packages of Truss Set Screws
Two packages of Truss Set Members
Two packages of Connector Spares
One package each of #6 I-Beam Spares, Cord Lock Spares, Axle Spares, Round Connector Spares, Angle Connector Spares, roll of rubber cord.

Order Information

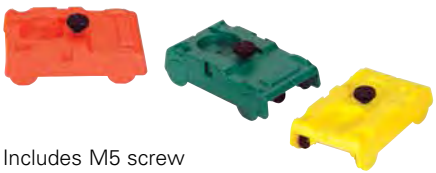
Human Structures Set ME-7001

Shown in use with:

Load Cell & Amplifier Set (includes four load cells) ..... PS-2199 p. 34
Hooked Mass Set ..... SE-8759 p. 181
Large Slotted Mass Set ..... ME-7566 p. 181

Mini Car

Red Mini Car ME-9834
Green Mini Car ME-9839
Yellow Mini Car ME-9840



Includes M5 screw

Order Information

Red Mini Car	ME-9834
Green Mini Car	ME-9839
Yellow Mini Car	ME-9840

Mini Car Track Spares

ME-6974



Includes two gates, two track couplers and one bag (24) of roadbed clips.

Order Information

Mini Car Track Spares	ME-6974

Mini Car Collision Spares

ME-6973



Includes two gates, one each of ballast mass, track coupler, bag (24) of roadbed clips, thread, clay and rubber bands.

Order Information

Mini Car Collision Spares	ME-6973

Axle Spares

ME-6998A

Includes drive wheel with rubber tire (4), pulleys with "O" rings (12 each), axles (two each of three lengths), spacers (12) and collets (24).



Order Information

Axle Spares	ME-6998A

Roadbed Spares

ME-6995



Includes flexible roadbed (3 m), roadbed clips (24), car with flag, extra mass, mini car starting bracket, and track couples (2).

Order Information

Roadbed Spares	ME-6995
Sold Separately:	
Roller Coaster Track (9.1 m)	ME-9814
Mini Car Starter Bracket	ME-9856

Force Platform Structures Bracket

ME-6988A

Includes two brackets and four screws.

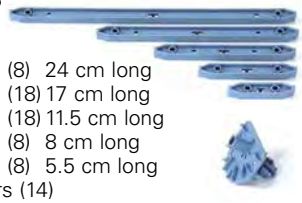


Order Information

Force Platform Structures Bracket	ME-6988A

Truss Set Members

ME-6993



Includes
I-beam #5 (8) 24 cm long
I-beam #4 (18) 17 cm long
I-beam #3 (18) 11.5 cm long
I-beam #2 (8) 8 cm long
I-beam #1 (8) 5.5 cm long
Connectors (14)

Order Information

Truss Set Members	ME-6993

Truss Set Screws

ME-6994



Includes 75 screws. All components in the Structures System use this same 6-32 thumb screw.

Truss Set Screws	ME-6994

Structures Rod Clamps

ME-6986



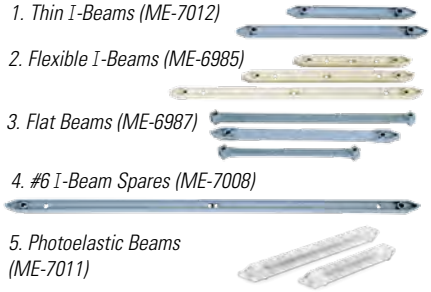
Connects structure members to 1/2"rod. Includes a set of two.

Order Information

Structures Rod Clamps (2)	ME-6986

Beams

1. *Thin I-Beams (ME-7012)*
2. *Flexible I-Beams (ME-6985)*
3. *Flat Beams (ME-6987)*
4. *#6 I-Beam Spares (ME-7008)*
5. *Photoelastic Beams (ME-7011)*



1. *Includes Thin I-beam #4 (24) 17 cm long, Thin I-beam #3 (24) 11.5 cm long.*
2. *Includes Flex I-beam #5 (10) 24 cm long, Flex I-beam #4 (18) 17 cm long, and Flex I-beam #3 (18) 11.5 cm long.*
3. *Includes 16 each 2x3 beams 12 cm long, F4 beams 17 cm long, and 3x4 beams 19 cm long.*
4. *Includes 24 of the #6 I-beams, 35 cm long.*
5. *Includes Clear, Polycarbonate Thin I-beams #4 (24) 17 cm long, and #3 (24) 11.5 cm long.*

Order Information

Thin I-Beams	ME-7012
Flexible I-Beams	ME-6985
Flat Beams	ME-6987
#6 I-Beam Spares	ME-7008
Photoelastic Beams	ME-7011

Connectors

1. *Connector Spares (ME-7002)*
2. *Angle Connector Spares (ME-6999A)*
3. *Round Connector Spares (ME-6997)*



1. *Set of 14 connectors used to join truss members.*
2. *Includes sliding connectors (12), angle connectors (24), and straight connectors (24).*
3. *Includes round connectors (6), flat connectors (6), and six bolts with nuts.*

Order Information

Connector Spares	ME-7002
Angle Connector Spares	ME-6999A
Round Connector Spares	ME-6997

Cord Lock Spares

ME-6996

Includes 32 cord-tensioning clips and a spool of yellow cord.



Order Information

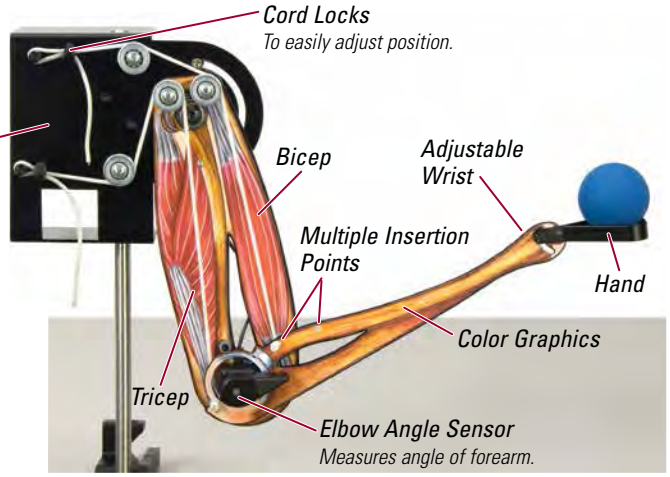
Cord Lock Spares	ME-6996
Yellow Cord (2 pack)	ME-9876

Human Arm Model

PS-2611 with Angle Sensor
ME-6807A without Angle Sensor

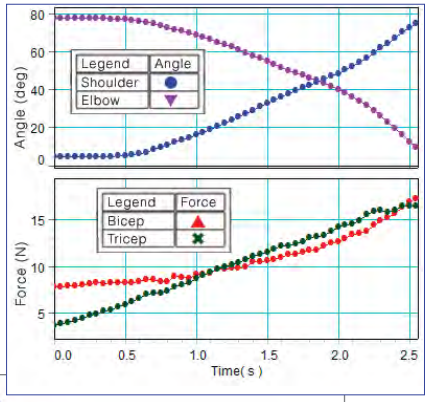
GREAT DEMO

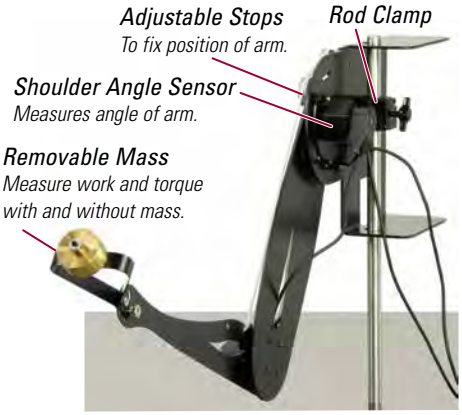
- Working model of the human arm
- Associate tricep/bicep muscle action with arm motion
- Measure torque resulting from lifting weights
- Actually throws a ball



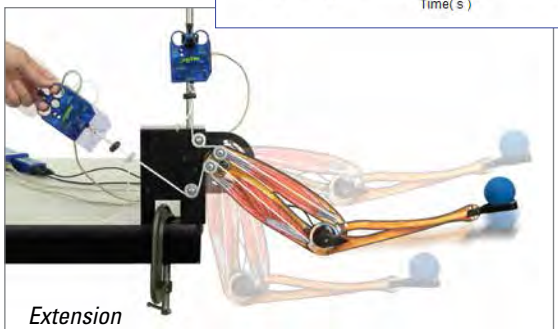
The Human Arm Model simulates the muscles and motion of an actual human arm. To activate the arm motion, students pull on the cord with a Force Sensor. Changes in position are measured at the shoulder and elbow using the two built-in potentiometers plugged into one Angle Sensor (PS-2139), included with PS-2611. From this information, the torque applied when lifting an object can be determined. Also, students can evaluate the work done by the arm in throwing a ball and the resulting kinetic energy delivered to the ball.

The Arm can perform many types of motion such as extending and lifting an object, curling, or throwing a ball overhand. Different arm muscles are activated depending on which pulleys are selected. Static force measurements can also be made to see how the muscle tension changes at various arm positions.

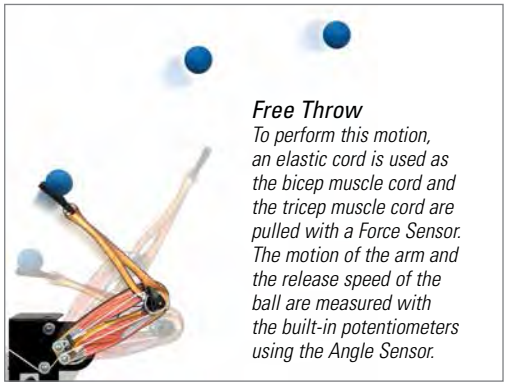




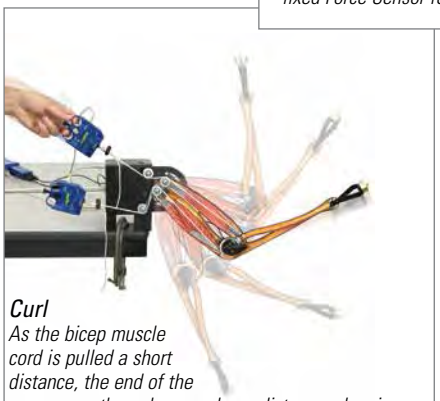
Angles and Forces During Extension:
The upper graph shows the angles of the elbow (violet trace) and the shoulder (blue) as the arm is extended as shown in the picture at right. Shown in the lower graph, the bicep tension (red) has little change at first and then rises sharply as the arm reaches out, while the tricep tension (green) rises steadily.



Extension
As the tricep muscle cord is pulled with a Force Sensor, another fixed Force Sensor records the tension in the bicep muscle cord.



Free Throw
To perform this motion, an elastic cord is used as the bicep muscle cord and the tricep muscle cord are pulled with a Force Sensor. The motion of the arm and the release speed of the ball are measured with the built-in potentiometers using the Angle Sensor.



Curl
As the bicep muscle cord is pulled a short distance, the end of the arm moves through a very large distance, showing the mechanical advantage of the arm. The load at the end of the arm can be varied.



PS-2611 Includes

Arm
Angle Sensor
Removable Mass
Cord & Cord Locks
Mounting Bracket with Rod
Force Sensor Mounting Rod
Rubber Ball

Order Information

Human Arm Model PS-2611
Human Arm Model without Angle Sensor ME-6807A

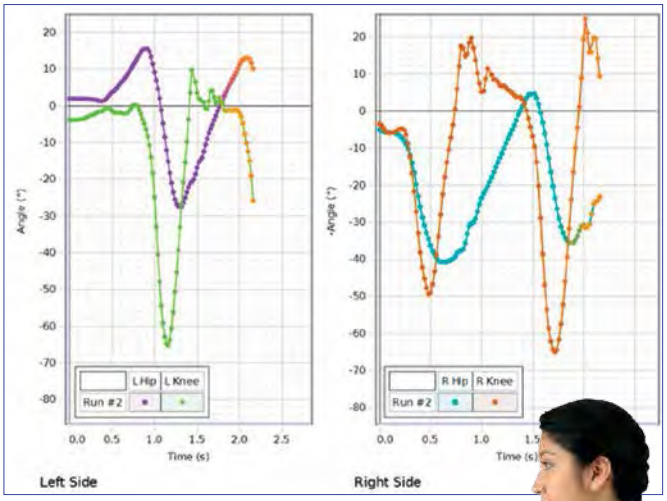
Required:
"C" Clamp or Large Table Clamp ..... p. 173
Required for sensor measurement:
PASPORT Force Sensor (2) ..... PS-2104 p. 30
850 Universal Interface ..... pp. 14-17
Angle Sensor (for use w/ ME-6807A) ..... PS-2139 p. 65

Goniometer

PS-2137

- Accurately measures joint movements
- Flexible mounting options for hip, knee, and elbow

The SPARKlink® Air Interface is used here with two Angle Sensors, part of the PS-2137 Goniometer System. The data is sent via Bluetooth to a desktop computer, and displayed live with the video being recorded by a web cam.



Data shows position of both left and right knee and hip joints during walking.

Capture data remotely!

The SPARKlink Air Interface records the sensor data, and sends it to the computer via Bluetooth.





Goniometer Probes

The probes are fastened in place using the blue Velcro® straps, and can be positioned to measure the motion of the knee, hip, or elbow.

Specifications

Range: 0 to 340°
Accuracy: ±1° (calibrated), ±3° (uncalibrated)
Resolution: 0.1°

Includes

Goniometer Probe, Angle Sensor, and Velcro Straps



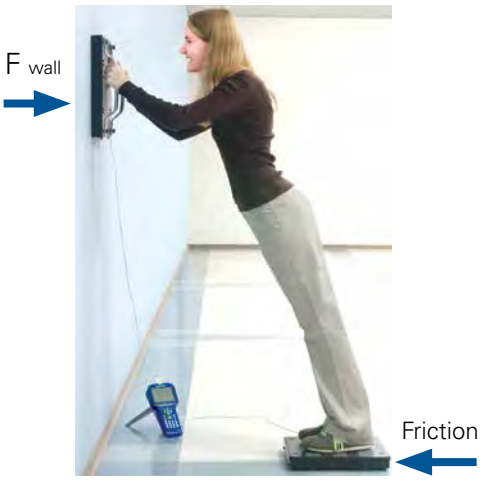
Order Information

Goniometer Sensor	PS-2137	
Recommended:		
SPARKlink® Air	PS-2011	p. 22
Additional Velcro Straps	PS-2547	
Additional Goniometer Probe	PS-2138	p. 65
Field Bag	PS-2549	

Forces on the Human Body

- Measure forces on human body
- 1-axis and 2-axis force platforms
- Precise and fast

Explore the forces exerted on the human body in everyday situations, sports, and large-scale physics experiments. The Force Platforms are designed to measure large forces, such as the weight of a person.



By standing on a 2-Axis Force Platform while pushing against the wall with a 1-Axis Force Platform, a real-life statics problem can be analyzed.



Confirm Newton's Third Law by pushing on a Force Platform using two sets of handles (available separately). Handles bolt onto the Force Platform (1 axis or 2-axis). Can be mounted on either side or both sides.

Developed in cooperation with Nancy Beverly, Assistant Professor of Physics at Mercy College, Dobbs Ferry, New York.

Order Information

2-Axis Force Platform (PASPORT)	PS-2142	p. 33
Force Platform (PASPORT)	PS-2141	p. 33
Recommended:		
Handle Set	PS-2548	p. 33

Super-Flex I-Beam

ME-8987

- Demonstrate the difference in stiffness between the two directions of bending
- Show that I-beams twist easily
- Show torsion and buckling
- Grid shows deformation



GREAT DEMO

This Super-Flex I-Beam is made of plastic so it can be visibly bent by hand. It shows the basic reasons for using this cross-section in construction. It is four times as stiff in the upright orientation as it is sideways.



Grid on top and side clearly show deformation.



Demonstrate lack of torsional strength.

Includes

Super-Flex I-Beam (24 inches long, 2 inches tall)
Instructions



Order Information

Super-Flex I-Beam ME-8987

Structures #6 I-Beam

ME-7008

These 35 cm long plastic I-beams are part of the PASCO Structures System.
See pages 139-140.





Show difference in stiffness between the two directions of bending.

Includes

24 of the #6 I-Beams

Order Information

Structures #6 I-Beam ME-7008
Shown in use with:
Hooked Mass Set ..... SE-8759 p. 181
Aluminum Table Clamp ..... ME-8995 p. 173

Structures Flexible I-Beam

ME-6985

Use these flexible I-Beams to make a bridge that dramatically demonstrates how a bridge fails and yet the beams return to their original shape when the load is removed.



Dramatically demonstrate structural failure

Includes

Flexible I-Beam #5, 24 cm long (10)
Flexible I-Beam #4, 17 cm long (18)
Flexible I-Beam #3, 11.5 cm long (18)

Order Information

Structures Flexible I-Beam ME-6985
Shown in use with:
Truss Set ..... ME-6990 p. 134

Matter Model

ME-9825A



The atoms of the Matter Model are brightly colored spheres specifically designed to allow students to better understand the structure of matter. The bonds between the atoms are modeled by springs, so that when forces are applied, the atoms can move in response.

The atoms can be configured into many patterns depending on the concepts to be investigated. Each atom can be opened and closed using two snaps. The inside of each atom has a slot where students can place one of the included nuts. In this way, the mass of the atoms can be changed. In addition, the springs can be easily connected to or removed from the atom using the six quick connects. A hole extends through each atom, allowing several to be placed on the included brass rod for wave and pressure activities.



Demonstrate the normal force response as a material is compressed.

Includes

Atoms (4.5 g each) (40)

Heavy springs (spring constant 350 N/m) (60)

Light springs (spring constant 70 N/m) (60)

Long springs (60)

Nuts (for increasing the atom mass) (30)

One brass rod (for longitudinal waves) (90 cm long)



The Matter Model is shipped in component pieces, ready for assembly.

Order Information

Matter Model ME-9825A

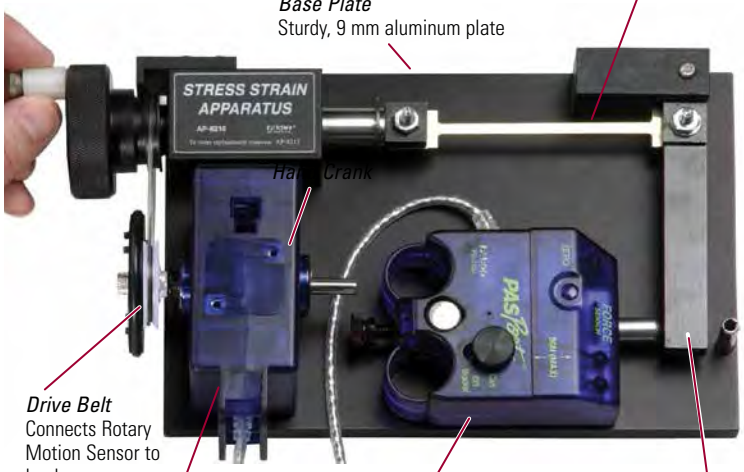
Tensile Tester

- Compact and inexpensive
- Plot stress vs. strain in real-time
- Determine Young's Modulus

Test Sample
Available in different materials and thicknesses. Easily changed with just screws.



Base Plate
Sturdy, 9 mm aluminum plate

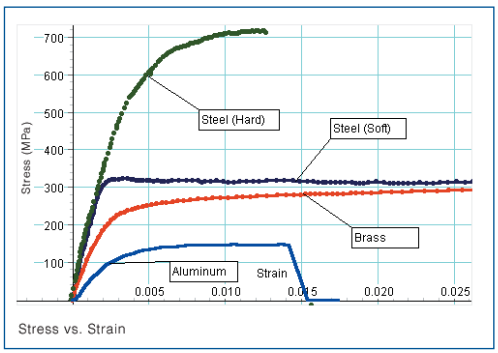


Drive Belt
Connects Rotary Motion Sensor to lead screw.

Rotary Motion Sensor
Optical Encoder
Resolves changes in sample length to 0.063 mm.

Force Sensor Strain Gauge
Provides a continuous measurement of the force applied to the sample.

Force Lever Arm
The 5 to 1 arm allows the Force Sensor to measure up to 250 Newtons.



Stress vs. Strain

These are the characteristic curves for four different test coupons.

AP-8214A includes

Base unit with micrometer head, sample holder, force lever arm, storage box (not shown), and ten each of nine types of coupons.

Plastic Test Coupons



Metal Test Coupons *Stress/Strain Unit*

Order Information

Materials Stress-Strain Apparatus (without sensors) AP-8214A

Materials Stress-Strain Apparatus (includes ScienceWorkshop sensors) AP-8216A

Materials Stress-Strain Apparatus (includes PASPORT sensors) AP-8213B

Replacement Supplies:

Replacement Metal Test Coupons Full Set (50 coupons) AP-8223

Replacement Plastic Test Coupons Full Set (40 coupons) AP-8222

Replacement Test Coupons Full Set (90 coupons) AP-8217A

Comprehensive Materials Testing System

ME-8244

NEW

- Compression and tensile testing
- Column buckling
- Three and Four-point bending
- Shear testing
- Stress lines with photoelasticity

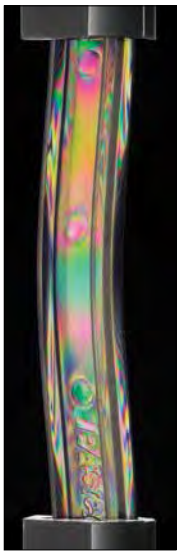
System includes everything needed to study material testing; Testing Machine with attachments, test samples, and computer software. PASCO Capstone Workbooks include set-up instructions, theory, and detailed analysis questions.



Perform Three-point and Four-point bending. See p. 145.



Shown performing tensile test of brass sample.



Visualize the stress lines as the clear photoelastic beam is compressed and buckles. See p. 144.



Shown here performing a compression test on one of the included polyethylene test samples. See p. 144.

More information on pages 143-145

Comprehensive Materials Testing System Includes:

Materials Testing Machine

Storage Base

Tensile Samples (10 of each): Aluminum, Brass, Annealed Steel, Steel, Acrylic, and Polyethylene

Bending Accessory

Four-point Bending Load Anvil

Photoelasticity Accessory (with photoelastic beams)

Shear Accessory (with Shear Samples)

Structures Beam Fixture

Thin Beams

Cast Spares

Compression Accessory (with Compression Samples)

Flat Coupon Fixture

Plastic Flat Coupons

Metal Flat Coupons

Clevis Grip

10-32 Adapter

USB Link

PASCO Capstone Software Single User License



Order Information

Comprehensive Materials Testing System.....ME-8244

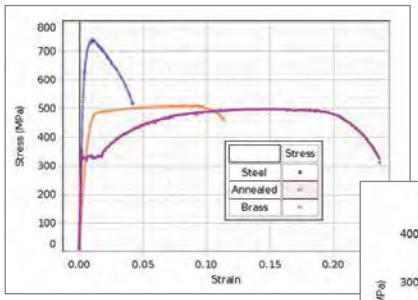
Materials Testing Machine

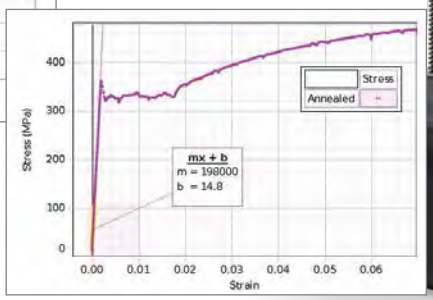
ME-8236

- 7100 N max load
- Hand-cranked so students can feel samples break
- Inexpensive samples make it possible for each student to experience it first-hand

Measure force and displacement for various materials as they are stretched, compressed, sheared, or bent. Investigate material properties including Young's Modulus, Tensile Strength, Yield Strength, Ductility and Modulus of Resilience.

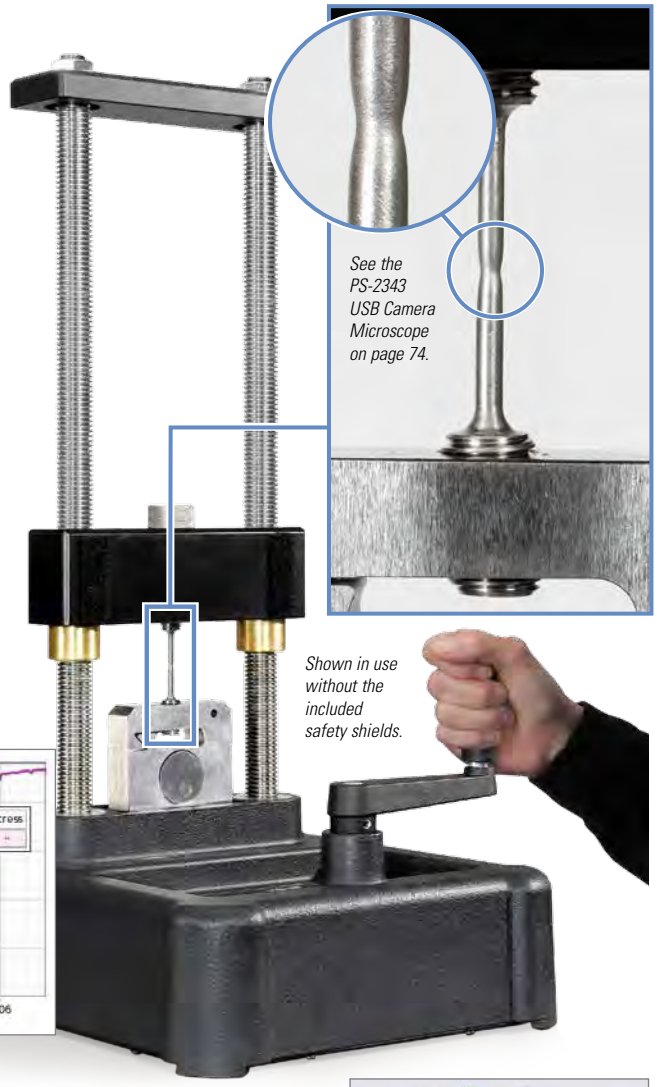
The Materials Testing Machine measures force with a 7100 N load cell and displacement with an optical encoder. It runs on PASCO Capstone software which has a built-in compliance calibration wizard and has all the tools to record and display stress vs. strain, apply linear fits to find Young's Modulus, and to record and play back webcam movies of the breaking samples, synced to the data. See page 74.





Tensile stress versus strain is plotted in PASCO Capstone software for steel, annealed steel, and brass.

For annealed steel, a linear fit is applied to find Young's Modulus.



See the PS-2343 USB Camera Microscope on page 74.

Shown in use without the included safety shields.

Specifications

Load cell capacity: 7100 N (1600 lbs)
Machine weight: 20 lbs (9 kg)
Footprint: 24 wide x 25 depth x 51 cm height
Lead screw length: 38 cm
Sturdy base: cast aluminum
Mounting holes: for bolting to table



Tensile Samples (set of 10 each)
Shown using tensile sample from Steel Set (ME-8243).



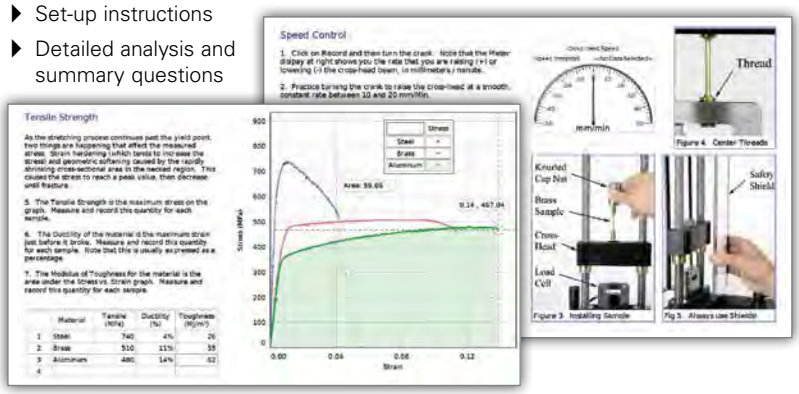
ME-8236 Includes

Machine, compliance calibration rod, and safety shields (requires Capstone software)

Workbooks include all instructions needed to perform the experiment:

- Introduction and theory
- Set-up instructions
- Detailed analysis and summary questions

Download FREE www.pasco.com/MaterialsTester



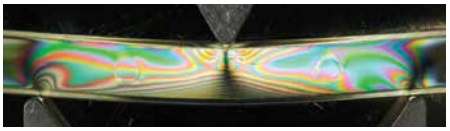
Order Information

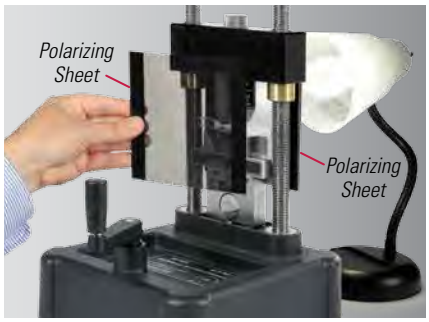
Materials Testing Machine	ME-8236
Tensile Samples:	
Tensile Sample Aluminum (10)	ME-8231
Tensile Sample Brass (10)	ME-8232
Tensile Sample Annealed Steel (10)	ME-8233
Tensile Sample Steel (10)	ME-8243
Tensile Sample Acrylic (10)	ME-8234
Tensile Sample Polyethylene (10)	ME-8235
PASCO Capstone Software	pp. 6-13

Photoelasticity Accessory

ME-8241

See stress lines by bending a clear, colorless photoelastic I-beam between two polarizing sheets. As the beam is bent, areas of greater stress show up as patterns of colored lines.





Photoelasticity Accessory consists of two crossed polarizing sheets which are placed in front of and behind the clear beam. When illuminated from behind by a bright white light, fringes due to the stress lines become visible.

Lamp not included



Includes

Two polarizing sheets, 5 3/8" x 5 3/8" x 1/8" and one Photoelastic I-Beams Set (ME-7011)

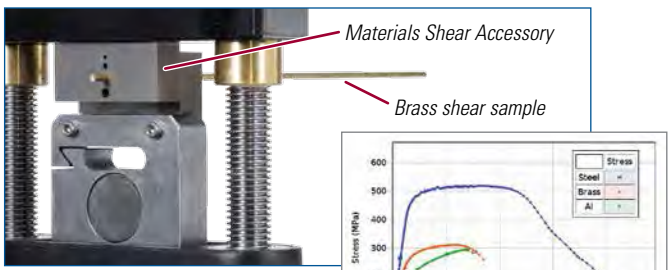
Order Information

Photoelasticity Accessory	ME-8241	
Photoelastic I-beams Set	ME-7011	p. 137
Shown in use with:		
Bending Accessory	ME-8237	

Materials Shear Accessory

ME-8239

Perform shear tests for a variety of wires. Accessory accepts diameters of 1/16", 3/32", 1/8," and 5/32". The Shear Accessory includes the ME-8240 Shear Samples, three each of 1/8" diameter, 12" long, aluminum, brass and mild steel.



Shown shearing a brass wire..

The graph shows shearing of steel, brass, and aluminum rods, all having an 1/8" diameter. The shear strength of each material is measured.





Includes

Shearing Block and Shear Samples (ME-8240), 3 each of three types of wire.

Order Information

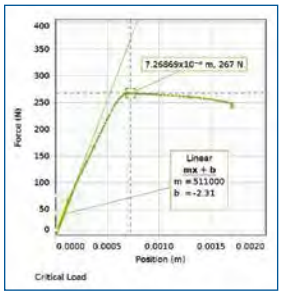
Materials Shear Accessory	ME-8239	
Replacement Supplies:		
Shear Samples (Set of 9)	ME-8240	

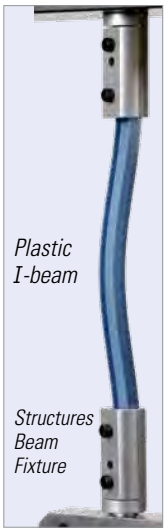
Structures Beam Fixture

ME-8242

The Structures Beam Fixture allows any of the I-beams from PASCO's Structures System to be stretched or compressed in the Materials Testing Machine.

Find the critical load that causes the beam to buckle.





Includes

Two clamps.

Order Information

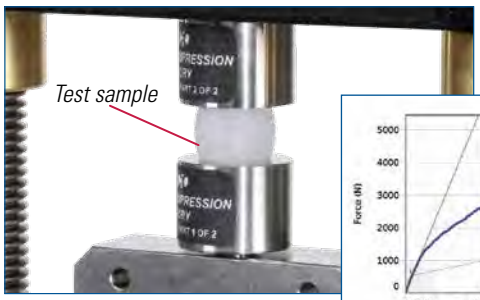
Structures Beam Fixture	ME-8242

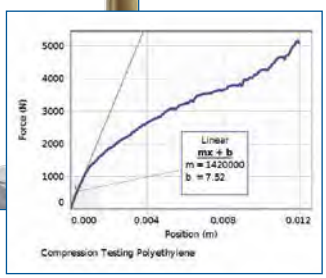
Compression Accessory

NEW

ME-8247

This one-inch diameter platform provides a sturdy base to investigate compression of a variety of materials. It is shown here in a compression test on one of the included polyethylene test samples.







"Before and after" photo of compression sample.





Includes

The platform and 20 polyethylene cylinders (ME-8248), 1.3 cm dia. x 2 cm long.

Order Information

Compression Accessory	ME-8247
Replacement Supplies:	
Compression Samples (20)	ME-8248

System Storage Base

NEW

ME-8229

The plastic base is made of High Density Polyethylene (HDPE). Includes base and mounting hardware.



Order Information

System Storage Base	ME-8229

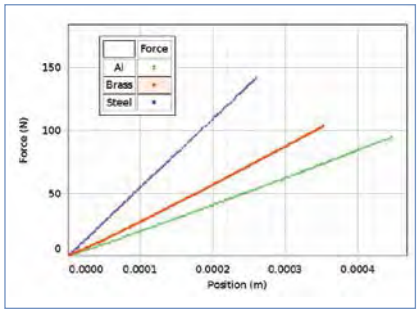
Bending Accessory

ME-8237

Perform three-point bending tests of various materials, including beams from the PASCO Structures System. Support anvils have adjustable separation up to 10 cm.



A Three-Point Bend test is performed on a brass rod from the ME-8240 Shear Samples. The support anvils have adjustable separation up to 10 cm.



This Force vs. Position graph shows three-point bending for aluminum, brass, and steel samples, all with the same anvil spacing. From this graph, the flexural elastic modulus for each material is measured.

Four-Point Bending Accessory

NEW

ME-8249

Add the optional Four-Point Bending Accessory to the ME-8237 to perform both three-point and four-point bending.

Perform a Four-Point Bend Test on the Cast Beams from the PASCO Structures System. Quantities measured include the Flexural Elastic Modulus and the Modulus of Rupture for the material.





ME-8237 Includes

Base with adjustable support anvil and load anvil.



ME-8249 Includes

A two-point fixture which, when added to the Bending Accessory, allows four-point bending.

Order Information

Bending Accessory ME-8237
Four-point Bending Accessory ME-8249

Shown in use with:

Shear Samples (set of 9) ME-8240
Thin I-Beams ME-7012
Cast Beams Spares ME-6983
(includes 30 rebar members, 10 cast beam molds)

Flat Coupon Fixture

ME-8238

Test any flat material, such as paper, foil, or plastic. Shown using the Flat Plastic Test Coupons (AP-8222).



Includes

Two clamps and wrench



Order Information

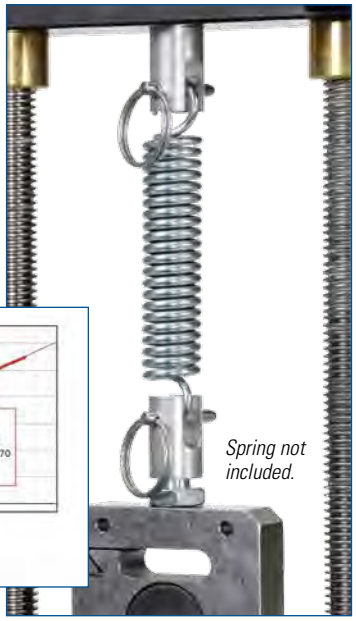
Flat Coupon Fixture ME-8238
Plastic Test Coupons (40 coupons) ..... AP-8222 p. 141
Metal Test Coupons (50 coupons) ..... AP-8223 p. 141

Clevis Grip

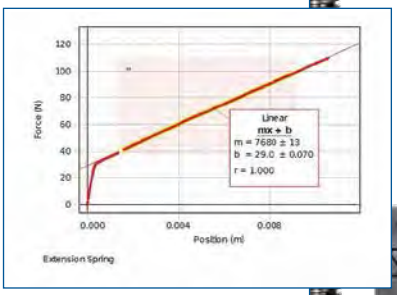
NEW

ME-8245

This generic pin and clevis adapter allows the user to tensile test a wide variety of samples with hooked ends or through-holes. It is shown here testing an extension spring (not included).



Spring not included.





Includes

Clevis adapter and pin.
Pin diameter is 0.187 in.
Max width of sample is .300 in

Order Information

Clevis Grip ME-8245

10-32 Adapter

NEW

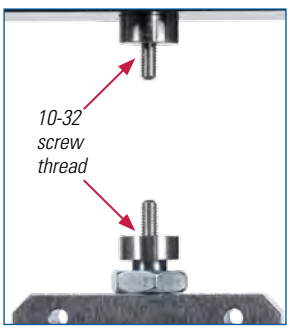
ME-8246

Allows use of grips and attachments from other vendors that require a 10-32 male thread.



Includes

Upper and lower adapters.



Order Information

10-32 Adapter ME-8246

Demonstration Wave Spring

WA-7334



The Demonstration Wave Spring is ideal for illustrating mechanical wave properties such as frequency, wavelength, and interference. Because it's not as stiff as the Snakey (below), the Demonstration Wave Spring provides a different medium in which to study waves. Two hooks on either end allow students to stretch this spring to a length of 8 meters.

It has a diameter of 2.3 cm and an unstretched length of 80 cm.



Clear standing wave patterns can easily be created.

Order Information

Demonstration Wave Spring	WA-7334

Snakey

SE-7331



The extra-long metal spring is ideal for the study of mechanical waves. The Snakey has an unstretched length of 2 meters. Pull the convenient end loops more than 10 meters apart to demonstrate transverse, longitudinal, and standing waves.

Order Information

Snakey	SE-7331

Double-Length Slinky

SE-8760



The Slinky® is an excellent tool for demonstrating transverse and longitudinal wave phenomena. This Double-Length Slinky is twice as long as a traditional Slinky, allowing students to create well-defined wave pulses and standing wave patterns. The tension in the Slinky is very low, causing wave pulses to travel slowly throughout its length.

Order Information

Double-Length Slinky	SE-8760

Dynamics Track Spring Set

ME-8999



Includes 12 springs (1.6 cm diameter) with approximate spring constants of:

3.4 N/m (3 short and 3 long springs)

6.8 N/m (3 short and 3 long springs)

Order Information

Dynamics Track Spring Set (12)	ME-8999

Longitudinal Wave Spring

WA-9401



This spring has a 1.6 cm diameter and is 13.5 cm long. The approximate spring constant is 0.85 N/m.

Order Information

Longitudinal Wave Spring	WA-9401

Demonstration Spring Set

ME-9866



This set includes four large springs for the demonstration of Hooke's Law or Conservation of Energy. Each spring is constructed of rugged spring steel with large loops for hanging from a pendulum clamp or stretching with hanging masses. Spring constants range from 4 N/m to 14 N/m. Spring lengths vary between 11 cm and 22 cm.



Order Information

Demonstration Spring Set	ME-9866
Recommended:	
Pendulum Clamp	ME-9506
Hooked Mass Set	SE-8759 p. 181

Pendulum Clamp

ME-9506





Hang up to three springs or pendula. Suspension points are 54 mm apart.

See page 172 for more information.

Order Information

Pendulum Clamp	ME-9506

Equal-Length Spring Set

ME-8970

TEACHER FAVORITE

The five color-coded equal-length springs in this set have different spring constants:
25 N/m, 30 N/m, 35 N/m, 40 N/m, 50 N/m (± 5%)



The five color-coded springs stretch different amounts when a 1 kg mass is hung from each spring.

These springs appear to be the same except for their colors. But, when equal masses are hung on them, each stretches a different amount. These extension springs are made of steel and are closed, requiring a slight initial force to separate the coils. The unstretched length of each spring is 30 cm and the approximate diameter is 1.4 cm.

These springs are supplied with a white storage box with cardboard separators to keep the springs from touching each other.



Includes

White storage box
Five (color-coded) springs
30 cm long

Order Information

Equal-Length Spring Set	ME-8970	
Recommended:		
Pendulum Clamp	ME-9506	p. 146
Hooked Mass Set	SE-8759	p. 181

Series/Parallel Spring Set

ME-6842

The set of six springs consists of two each of three different spring constants. These springs are 15 cm long, half the length of the Equal-Length Spring Set, making it possible to combine two series short springs in parallel with one long spring.

Shown below in use with the Parallel Spring Bracket and the Hooked Mass Set.



Specifications

The six color-coded springs, two of each color, have different spring constants:
10 N/m, 20 N/m, 40 N/m (±5%)



Includes

White storage box
Six (color-coded) springs 15 cm long

Order Information

Series/Parallel Spring Set	ME-6842	
Recommended:		
Hooked Mass Set	SE-8759	p. 181

Multi-Length Spring Set

ME-6848



Equal spring constants

Springs have an approximate diameter of 1.5 cm with a spring constant of 40 N/m. Lengths are 13 cm, 19 cm, 24 cm, and 29 cm.

The four springs in this set appear to have the same diameter and wire material, but are actually designed to have the same spring constant even though they have different lengths. It makes a perfect companion to the Equal-Length Spring Set and the Series/Parallel Spring Set, both shown on this page.

Order Information

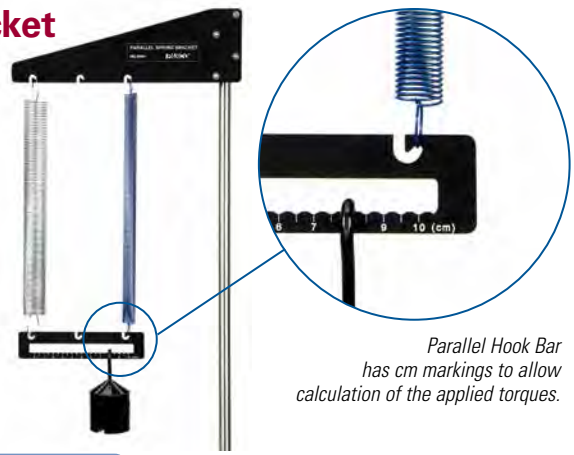
Multi-Length Spring Set	ME-6848

Parallel Spring Bracket

ME-6844

This unique bracket allows springs of different spring constants to be hung in series and parallel. The masses can be hung in an offset position to compensate for the stronger spring.

Set-up includes the use of the Demonstration Spring Set on page 146. Note the cm markings (see inset) on the Parallel Hook Bar. By calculating the applied torques, the relative forces from the two springs can be investigated.



Parallel Hook Bar has cm markings to allow calculation of the applied torques.

Includes

Suspension bracket
Parallel hook bar



Order Information

Parallel Springs Bracket	ME-6844	
Recommended:		
Equal-Length Spring Set	ME-8970	
Series/Parallel Spring Set	ME-6842	
Hooked Mass Set	SE-8759	p. 181

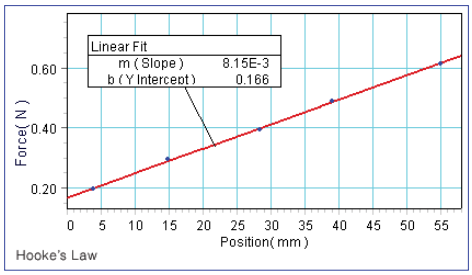
Hooke's Law Set

ME-9827

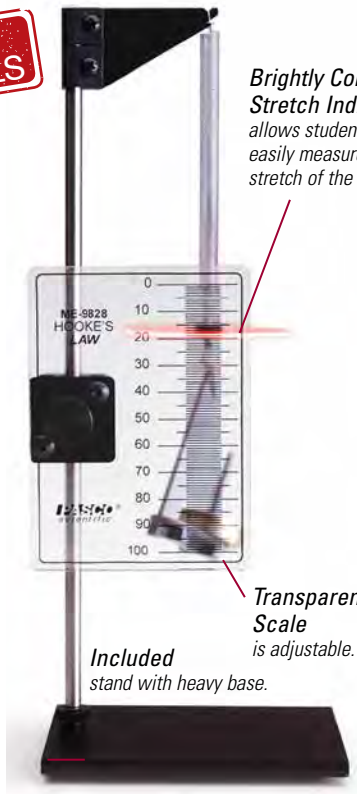
LAB ESSENTIALS

- Brightly colored stretch indicator
- Transparent measuring scale
- Compatible with PASCO mass sets

The Hooke's Law Set allows students to investigate the relationship between the force applied to a spring and the amount of stretch on the spring. This rugged set features a heavy base to allow the stretching of springs without toppling the unit. The transparent scale can be moved vertically to align zero with the brightly colored stretch indicator.



As a force is applied to the spring by placing mass on the hanger, the spring stretches. Students can graph the applied force vs. spring stretch. The slope of this graph is the spring constant of the spring. The vertical intercept shows the initial force needed to begin stretching the spring.



Brightly Colored Stretch Indicator *allows students to easily measure the stretch of the spring.*

Transparent Scale *is adjustable.*

Included *stand with heavy base.*



Includes

Stand with heavy base

Transparent scale with mm resolution

Horizontal support for spring

Brightly colored stretch indicator

Three springs with identical diameter and length, but different spring constants

Three of each spring included, for a total of nine springs: spring constants are 5 N/m, 8 N/m, 70 N/m.

Order Information

Hooke's Law Set ME-9827

Recommended:

Mass and Hanger Set ..... ME-8979 p. 181

Hooke's Law Spring Set

SE-8749



Includes three springs with the same diameter and length, but different spring constants. Three of each type of spring are included, and the springs fit nicely on PASCO mass hangers. All springs are 55 mm long and 7 mm in diameter. Spring constants are 5 N/m, 8 N/m and 70 N/m.

Order Information

Hooke's Law Spring Set SE-8749

Light Duty Spring Set

ME-9835



The Light Duty Spring Set consists of four springs having a spring constant of 1 N/m and four springs having a spring constant of 2 N/m. The springs are 8 mm in diameter. The 1 N/m springs have a closed coil length of 6.5 cm and stretch without deforming to about 90 cm. The 2 N/m springs have a closed coil length of 5.5 cm and stretch without deforming to about 60 cm.

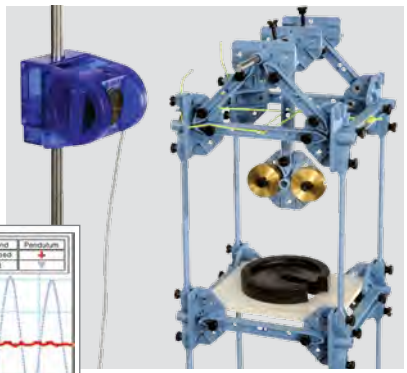
Order Information

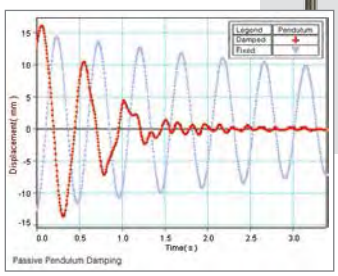
Light Duty Spring Set ME-9835

Measure passive damping with a Motion Sensor

This building frame is built with an Advanced Structures Set using the Flat Members. A pendulum with drag caused by strings is suspended from the top of the building. The Motion Sensor is positioned to record the oscillation of the building.

See page 246 for more examples using the Shaking Tower.





The gray graph (in PASCO Capstone™ Software) shows the oscillation without the pendulum. The red graph shows the damping caused when the pendulum is allowed to oscillate.

Order Information

Advanced Structures Set ..... ME-6992B p. 134

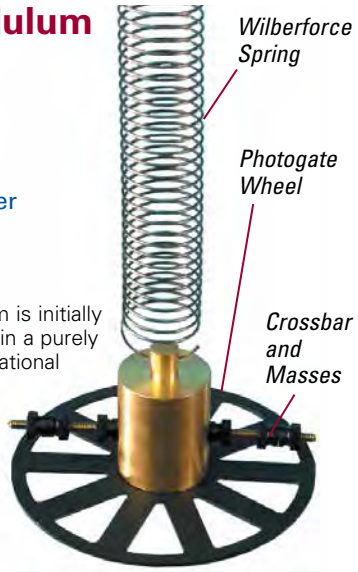
Motion Sensor ..... PS-2103A p. 27

Large Slotted Mass Set ..... ME-7566 p. 181

Wilberforce Pendulum

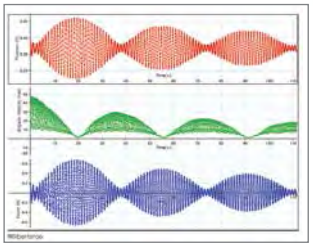
ME-8091

- Use as a Traditional Wilberforce to show coupled oscillations
- Accommodates computer measurements



How It Works

When the Wilberforce Pendulum is initially displaced vertically, it oscillates in a purely up-and-down motion. The translational oscillation gradually transfers to a purely torsional mode and then back to the translational mode. The translational and torsional periods must be the same. This is accomplished by adjusting the position of the masses on the crossbar.



The height is measured by using a Motion Sensor; the angular velocity by using a Laser Switch and Photogate Wheel; and the force using a Force Sensor.

The vertical position, velocity, and acceleration of the Wilberforce Pendulum are measured with a Motion Sensor (p. 27) placed below the pendulum. A laser (p. 283) and a Laser Switch (p. 39) measure the angular speed in the torsional mode as the spokes of the wheel break the laser beam. A Force Sensor (p. 31) attached to the end of the spring measures the spring force as the pendulum oscillates.

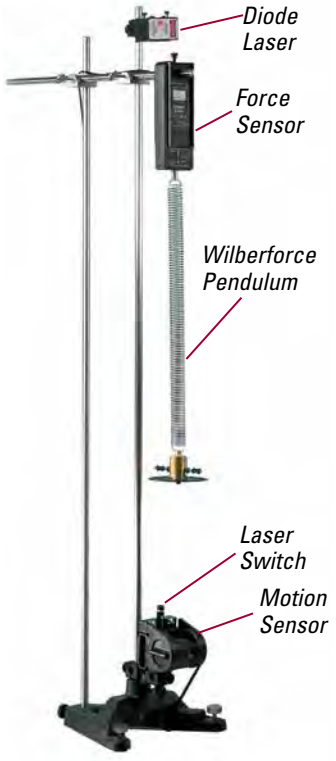
Includes

Spring and Mass

Force Sensor attachment

Rod Clamp

Photogate Wheel





Order Information

Wilberforce Pendulum ME-8091

Shown in use with:

Motion Sensor	CI-6742A	p. 27
Force Sensor	CI-6537	p. 31
Large Rod Base	ME-8735	p. 170
120 cm Steel Rods (2)	ME-8741	p. 170
45 cm Steel Rod	ME-8736	p. 170
Multi Clamps (2)	ME-9507	p. 172

Inertial Balance

SE-8683



Measure the period of this Inertial Balance to find the mass of objects. The balance, three cylindrical 200 g masses, and a C-clamp are included. Establish the spring constant of the balance with any combination of the three masses that fit into convenient slots. Or place one mass in at a time to observe the changing periods. Once calibrated, unknown masses may be measured.

Order Information

Inertial Balance SE-8683

Photogate Pendulum Set

ME-8752

- Great for classic pendulum experiments



The Photogate Pendulum Set is a unique set of four pendula that have the same shape and size, but different masses. Due to their cylindrical shape, these pendula are ideal for use in timing experiments with the photogate. One pendulum each of brass, plastic, wood, and aluminum is included.



Cylindrical shape allows easy calculation of the speed of the pendulum using the time it blocks the photogate. Photogate not included.

Typical Applications

- Determine relationship between period and mass
- Determine relationship between period and amplitude
- Determine relationship between period and length

Order Information

Photogate Pendulum Set ME-8752

Pendulum Clamp

ME-9506



Hang up to three springs or pendula. Suspension points are 54 mm apart.

See page 172 for more information.

Order Information

Pendulum Clamp ME-9506

PASCO's Complete Rotational System

ME-8950A

LAB ESSENTIALS

- Most versatile rotational system available
- Stable, 4 kg cast iron base
- Dual, low-friction ball-bearings

The unit features a cast iron base, dual ball-bearings and stainless steel shaft. The moments of inertia are large enough to be sensed by the student when rotating the system by hand. Computer monitoring of angular velocity and a motorized drive are also possible.

PASCO's Complete Rotational System provides a range of experiments in centripetal force, angular momentum, and rotational motion. A unique set of accessories makes it an ideal tool for experiments in torques, friction, magnetic levitation, and Faraday's Law.



The Complete Rotational System includes

1. Rotating aluminum platform with 4 kg cast iron base, dual ball-bearings, stainless steel shaft, three-step pulley, two rectangular sliding 300 g masses, and 50 cm track where a number of accessories may be mounted.
2. The Rotational Inertia Accessory with a 25.4 cm diameter, 1.50 kg disk (which may be rotated on two axes), a 12.7 cm diameter, 1.42 kg ring and Super Pulley with support rod and adapter.
3. The Centripetal Force Accessory with spring support and radius indicator, mass support, three masses, and Super Pulley with Clamp.

Included Experiments

1. Rotational Inertia of Disk and Ring - Two Axes
2. Centripetal Force
3. Rotational Inertia of Off-Axis Disk (fixed and rotating)
4. Conservation of Angular Momentum, Using a Point Mass

Experiments not shown:

5. Rotational Inertia of a Point Mass
6. Conservation of Angular Momentum, Projectile Version
7. Conservation of Angular Momentum, Using Disk and Ring

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

It is easy to use a computer to monitor rotational motion with the PASCO Rotational System.



The ME-9498A Photogate Head mounts directly to the rotating platform base and measures angular velocity, but not direction. See page 39.

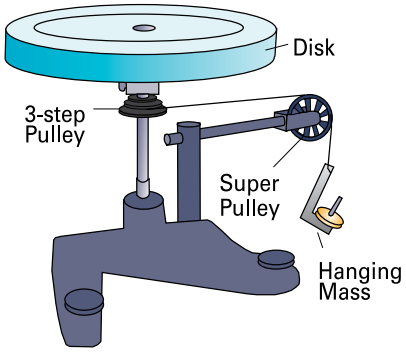
The CI-6538 and PS-2120 Rotary Motion Sensor mounts to the base with an "A" Adapter and measures both angular velocity and direction. See page 28.



1 Rotational Inertia of a disk and ring— 2 axes

"Center" axis

With the disk mounted on the top of the vertical shaft, a torque is applied by a hanging mass. From the mass, the radius, and angular acceleration, the rotational inertia of the disk can be determined.



Radial axis

The disk can also be mounted on edge to decrease the rotational inertia by half.

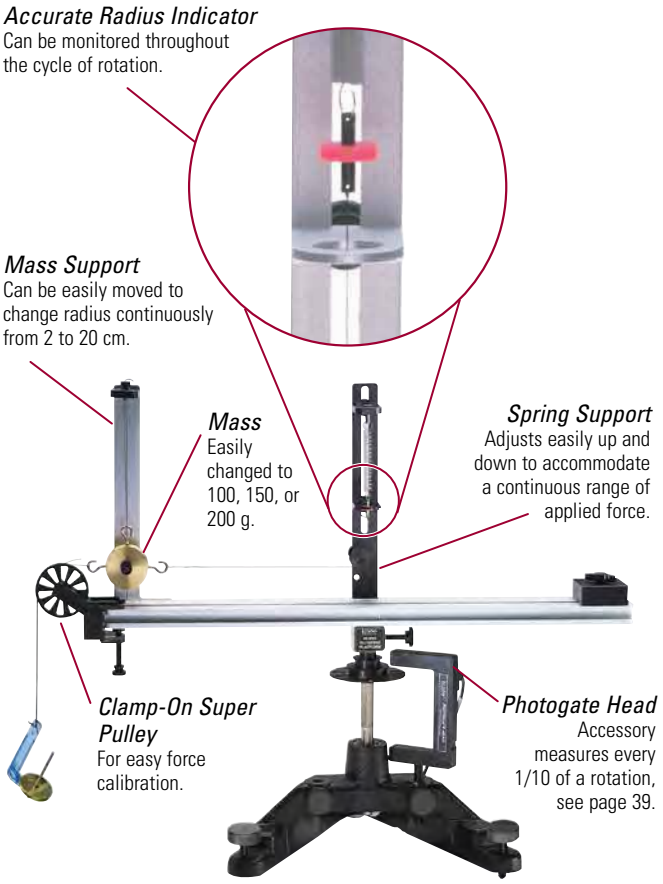


Order Information

Complete Rotational System	ME-8950A	
Required:		
Mass and Hanger Set	ME-8979	p. 181
Recommended:		
Photogate Head	ME-9498A	p. 39
"A"-base Rotational Adapter	CI-6690	p. 153
Required for use with ScienceWorkshop:		
Rotary Motion Sensor	CI-6538	p. 28
Required for use with PASPORT:		
Rotary Motion Sensor	PS-2120A	p. 28

2 Centripetal Force

Centripetal force may be thoroughly investigated by varying both the mass and radius. The unique radius indicator allows students to continuously monitor the equilibrium position.



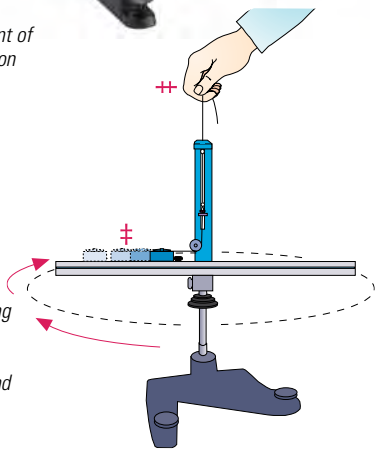
3 Rotational inertia of off-axis disk

The rotational inertia adapter allows students to mount the disk anywhere along the platform. A bearing mounted on one side of the disk allows it to act either as a rigid mass or as a mass free to rotate around its point of attachment as the platform turns on the vertical shaft.



4 Conservation of Angular Momentum

Students can predict what will happen when a point mass rotating at a specific radius is pulled into a smaller radius. The rotational inertia of the mass at the inner and outer radii can be calculated and the results verified.



Rotational System Components and Accessories

Pages 152-154

Rotating Platform and Rotational Inertia Accessory

p. 152



Centripetal Force Accessory

p. 152



Rotational Motor Drive

p. 153



Rotational Acceleration Tank

p. 153



"A"-base Rotational Adapter

p. 153

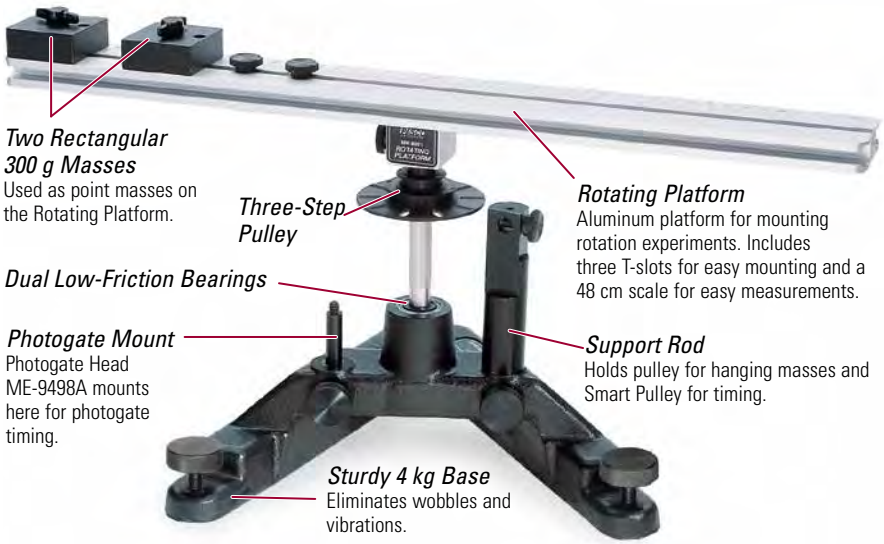


Computer-based Centripetal Force

p. 154



Rotating Platform ME-8951



A Versatile Base

The stable base and precision bearings of the Rotating Platform provide the foundation of PASCO's Rotational System. Serves as an excellent base for general rotation experiments.

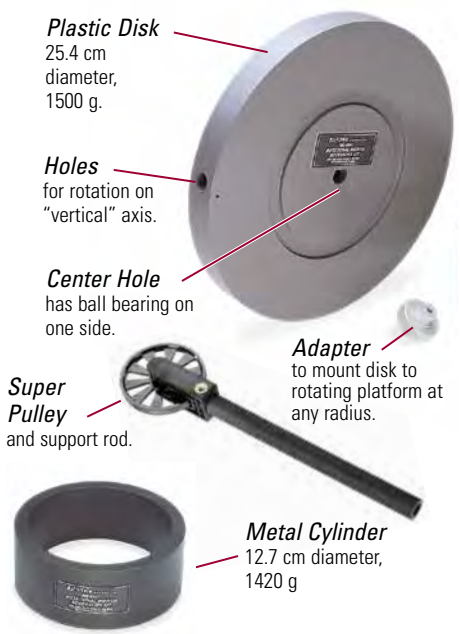
Order Information

Rotating Platform	ME-8951	
Recommended:		
Rotational Inertia Accessory	ME-8953	
Centripetal Force Accessory	ME-8952	
Rotational Acceleration Tank	ME-8957	p. 153
Rotational Motor Drive	ME-8955	p. 153
Replacement Supplies:		
Photogate Mounting Rod	ME-8965	

Rotational Inertia Accessory

ME-8953

A disk and a ring permit several experiments in rotational inertia. The disk may be rotated about several axes. When used in conjunction with the adapter, experiments using the parallel-axis theorem may be performed by moving the disk off from the center of rotation. The ball-bearing on one side of the disk permits it to rotate freely for some experiments, while a "D" hole on the other side prevents rotation about the disk axis.



Includes

Heavy-Grade Plastic Disk
(25.4 cm diameter, 1500 g)
Metal Ring
(12.7 cm outside diameter, 1420 g)
Disk Adapter
Super Pulley and Support Rod

Order Information

Rotational Inertia Accessory	ME-8953

Centripetal Force Accessory

ME-8952

With traditional centripetal units, the ability to change the variables is either impossible or limited. The PASCO Centripetal Force Accessory is designed to make changing the mass, radius, or force quick and easy.



Features

Vary Parameters Independently: Change the centripetal force, mass, and radius independently of each other.

Change Variables Over a Wide Range: Radius can be varied continuously from 2 to 20 cm, and the rotating mass can be 100, 150, or 200 g.

Observe the Radius Indicator Throughout the Cycle: PASCO's design has the indicator at the center of rotation, allowing continuous observation throughout the rotation cycle, which results in more accurate measurements.



Includes

1. Spring Support and Radius Indicator Assembly
2. Mass Support
3. Masses (100 g and two 50 g)
4. Super Pulley with Clamp

Order Information

Centripetal Force Accessory	ME-8952

Rotational Motor Drive

ME-8955



Easily change the gear ratio of the motor drive by moving the drive belt to one of the three possible pulley steps.



The Motor Drive is used with the Rotational Platform to power continuous rotational motion demonstrations. Use this motor to drive the Rotational Acceleration Tank at a constant speed. Power the Motor Drive with a ramp function using the DC Power Supply (p. 231) to smoothly increase the angular speed of the Centripetal Force Accessory. The motor requires a 12 V DC power supply or a function generator.

Specifications

Motor: 12 V maximum, 0.2 A minimum
Base Spindle Speed Range: 10 to 600 rpm
Three-Step Pulley

Includes

Motor
3-Step Pulley
Drive Belt



Order Information

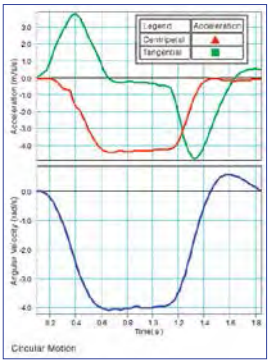
Rotational Motor Drive ME-8955
Required:
Rotating Platform ..... ME-8951 p. 152
850 Universal Interface p. 14-17
Function Generator ..... PI-8127 p. 236
or
DC Power Supply ..... PI-9880 p. 231

"A"-base Rotational Adapter

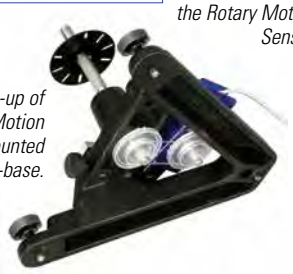
CI-6690



The "A"-base Adapter allows students to mount a Rotary Motion Sensor to obtain high resolution data. One revolution of the vertical shaft corresponds to one revolution of the Rotary Motion Sensor, giving 4000 data points per revolution for the Rotary Motion Sensor.



The platform is quickly rotated (from rest) and then brought to a stop. Both the tangential and centripetal acceleration is measured (using the 2-Axis Acceleration Sensor), while the platform's angular velocity is measured by the Rotary Motion Sensor.



Close-up of Rotary Motion Sensor mounted on "A"-base.

Includes

Rotary Motion Sensor Mounting Post
O-Ring Drive Belt
Three-Step Pulley
Pulley Mounting Screw



Order Information

"A"-base Rotational Adapter CI-6690
Required:
Rotating Platform ..... ME-8951 p. 152
Rotary Motion Sensor
ScienceWorkshop ..... CI-6538 p. 28
Rotary Motion Sensor
PASPORT ..... PS-2120A p. 28

Rotational Acceleration Tank

GREAT DEMO

ME-8957



Rotational Acceleration Tank mounted on Rotating Platform and rotated by hand.

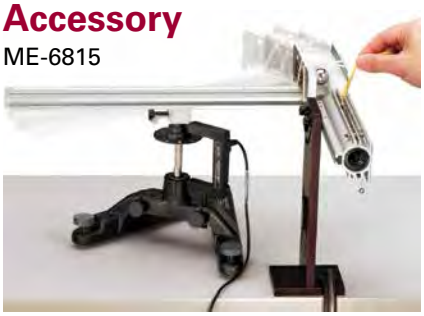
The Rotational Acceleration Tank demonstrates a centrifuge when used on the Rotational Platform. From the shape of the liquid in the tank, students can better understand rotational motion and its relationship to centripetal force.

The tank can also be placed on a table, and light rays from a laser can then be passed through the tank to demonstrate refraction and Snell's Law. Inside dimensions: 43 cm x 20 cm x 2.9 cm.

Rotational Acceleration Tank ME-8957
Recommended:
Rotating Platform ..... ME-8951 p. 152
Rotational Motor Drive ME-8955

Projectile Catcher Accessory

ME-6815



Use the rotating platform with the Short Range Projectile Launcher to investigate Conservation of Angular Momentum. Use Photogates to measure the launch speed of the steel ball and the resulting rotational speed of the rotating platform.

Order Information

Projectile Catcher Accessory ME-6815
Recommended:
Rotating Platform ..... ME-8951 p. 152
Projectile Launcher (Short Range) ..... ME-6800 p. 121

Centripetal Force Apparatus

ME-8088

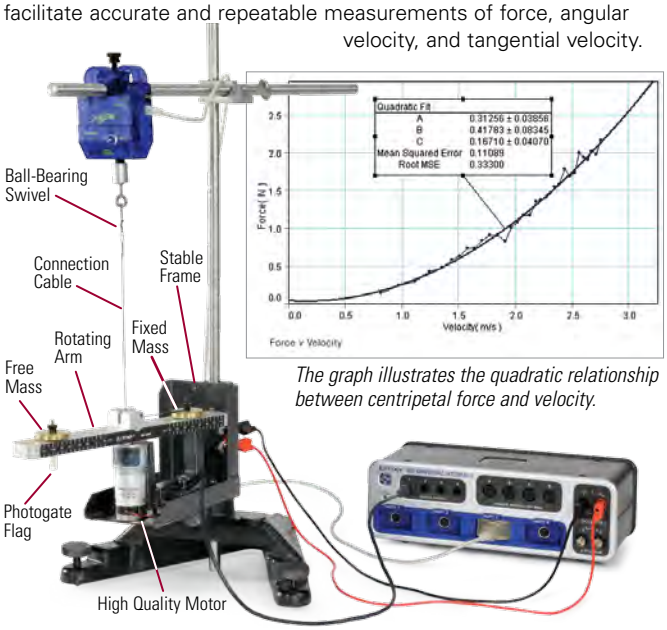
- Empirically determine centripetal force
- Easy to set up
- Repeatable results

Features

Stable Frame: The metal frame can be easily attached to a ring stand using the included clamp. The frame may also be attached to a tabletop with a large table clamp.

High Quality Motor: Will withstand years of student use.

Computer-based Measurements: The Force Sensor and photogate facilitate accurate and repeatable measurements of force, angular velocity, and tangential velocity.



The graph illustrates the quadratic relationship between centripetal force and velocity.

How It Works

The rotating arm features a groove with two captured masses along its length. One of the masses is free to move along the length of the groove. The free mass is connected to a small cable that runs under a pulley in the center of the arm and up to a Force Sensor. A ball-bearing swivel is used to ensure the cable does not tangle as the arm rotates. The other mass is placed the same distance from the center as the free mass, thereby balancing the arm.
A flag attached to the bottom of the fixed mass passes through the photogate once per revolution, allowing a calculation to be made of the angular and tangential velocity of the mass.

Includes

Frame with Mounted 12 VDC Electric Motor
Connecting Cable
Ball-Bearing Swivel
Connecting Hardware for Photogate
Mass Holder for Free Mass
Mass Holder for Fixed Mass
5 g Mass (2)
10 g Mass (2)
20 g Mass (2)



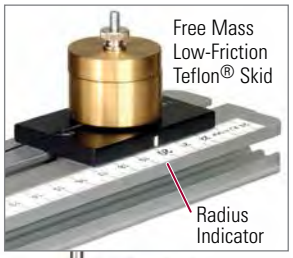
Order Information

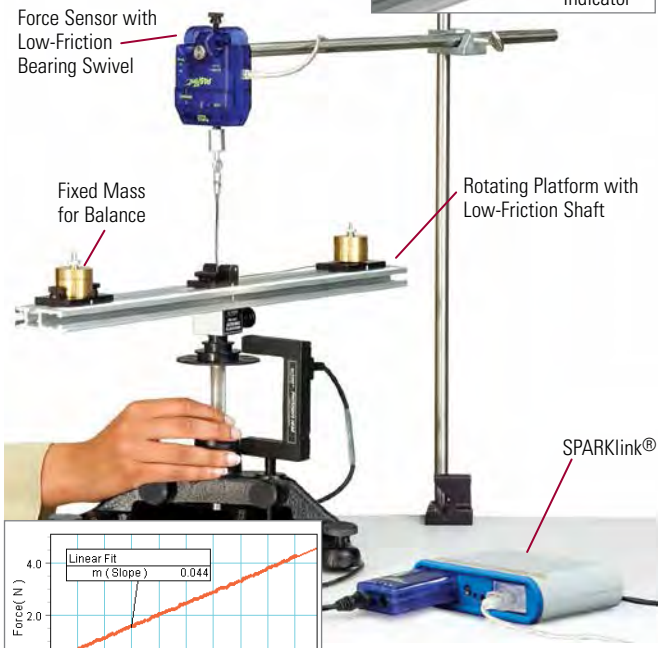
Centripetal Force Apparatus	ME-8088	
Required:		
Force Sensor		pp. 30-31
Photogate Head		p. 39
Triple Output Power Supply	SE-8587	p. 234
Large Rod Base	ME-8735	p. 170
45 cm Steel Rod	ME-8736	p. 170
120 cm Steel Rod	ME-8741	p. 170
Multi Clamp	ME-9507	p. 172

Computer-Based Centripetal Force Accessory

ME-8089

- For use with the Rotating Platform





The slope of the Force vs. Angular Velocity squared graph is the free mass times the radius.

How It Works

The free mass on a low-friction sled is connected to a small cable that runs under a pulley in the center of the arm and up to a Force Sensor. A ball-bearing swivel is used to ensure that the cable does not tangle as it rotates with the arm. The three-step pulley on the Rotational Platform is used with a Photogate to measure the speed of the platform. This allows a calculation to be made of the angular velocity of the mass throughout its revolution.

Includes

Pulley with Mounting Block
Connecting Cable with Ball-Bearing Swivel
Mass Holders (2)
50 g Mass (4)
100 g Mass (2)



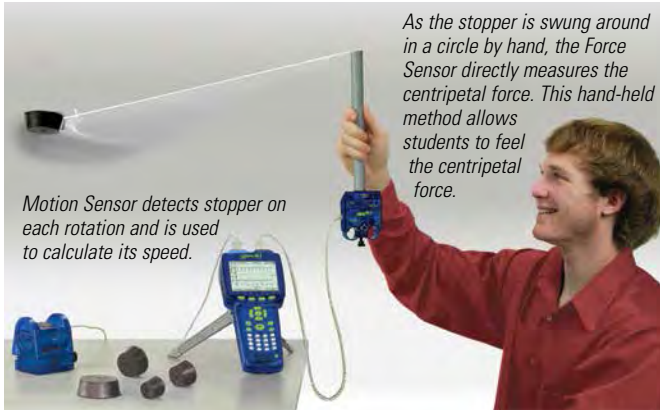
Order Information

Computer-Based Centripetal Force Accessory	ME-8089	
Required:		
Force Sensor		pp. 30-31
Photogate Head		p. 39
Rotating Platform	ME-8951	p. 152
Large Table Clamp	ME-9472	p. 173
45 cm Steel Rod	ME-8736	p. 170
120 cm Steel Rod	ME-8741	p. 170
Multi Clamp	ME-9507	p. 172

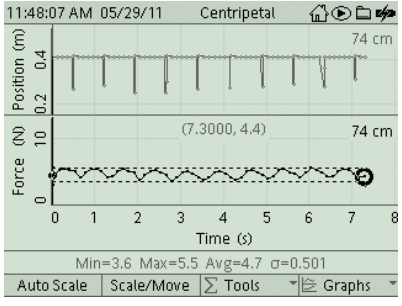
Hand-Held Centripetal Force

Discover Centripetal Force Kit

ME-9837



Use the traditional method with hanging masses, or use with a Force Sensor to continuously measure the centripetal force. Adding sensors to this classic experiment creates a dynamic, quantitative lab that your students will never forget!



The Position vs. Time data (upper graph) gives the period of rotation and is used along with the radius of rotation to determine the calculated value of the centripetal force.

The Force data (lower graph) shows variations in the applied centripetal force as the student swings the stopper around in a circle. The average force for this run (4.7 N) agrees with the calculated value to within 2%.



Classic approach

Designed around the classic PSSC experiment. The rubber stopper moves in a circular path as the other end of the string is connected to a hanging mass. The student uses a stopwatch to time the period of one revolution.

Includes

Rubber Stoppers
(sizes 6, 8, 10, 11.5, and 13)
Plastic Ties (10)
Yellow String (73 meters)
Hollow Tubes (2)



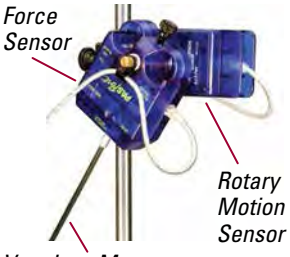
Order Information

Discover Centripetal Force Kit	ME-9837	
Shown in use with:		
Xplorer GLX	PS-2002	p. 19
Force Sensor	PS-2104	p. 30
Motion Sensor	PS-2103A	p. 27
Required for Classic Approach:		
Hooked Mass Set	SE-8759	p. 181
Stopwatch	ME-1234	p. 182

Centripetal Force Pendulum

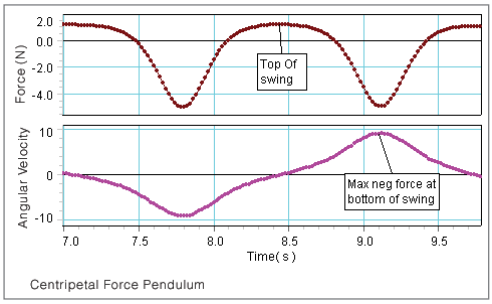
ME-9821

- Quantitative force vs. velocity data
- Repeatable results
- Vary pendulum length and mass





When used with Force and Rotary Motion Sensors, the Centripetal Force Pendulum allows students to collect accurate circular motion data.



The Centripetal Force Pendulum is used to produce graphs of force and angular velocity versus time. Note that the force changes direction at the top of the swing for large amplitudes.

The Centripetal Force Pendulum attaches to a Force Sensor and allows students to directly measure the forces involved in circular motion. By attaching the Force Sensor/pendulum combination to the Rotary Motion Sensor, the relationship between force, mass, and velocity in a circular path can be investigated.

Includes

Graphite Pendulum Rod with Threaded Connector
Sliding Mass (100 g)
Mount with Cord Clip



Order Information

Centripetal Force Pendulum	ME-9821	
Required:		
Large Rod Base	ME-8735	p. 170
45 cm Steel Rod	ME-8736	p. 170
90 cm Steel Rod	ME-8738	p. 170
Multi Clamp	ME-9507	p. 172
Also required for use with ScienceWorkshop:		
Rotary Motion Sensor	CI-6538	p. 28
Economy Force Sensor	CI-6746	p. 30
Also required for use with PASPORT:		
Rotary Motion Sensor	PS-2120A	p. 28
Force Sensor	PS-2104	p. 30

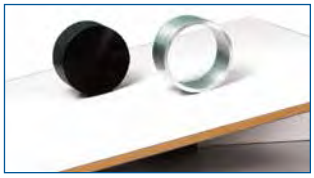
Rotational Inertia Set

ME-9774

GREAT DEMO



Release two different sized objects simultaneously.



How It Works

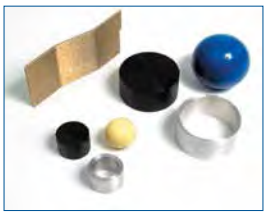
Compare rotational inertias of objects with different shapes and sizes. Students learn that the speed of an object rolling down the ramp is not affected by its mass or radius. The shape or distribution of the mass determines the outcome. The sphere will reach the bottom first, followed by the disk. The ring will be last.

Includes

10 cm outer diameter set
- Solid Sphere (810 g)
- Ring (Aluminum, 230 g)
- Disk (Plastic, 370 g)

5 cm outer diameter set
- Solid Sphere (110 g)
- Ring (Aluminum, 90 g)
- Disk (Plastic, 70 g)

Release Mechanism



Order Information

Rotational Inertia Set ME-9774

Spherical Mass Set

ME-8968



This set includes four balls with a diameter of 25 mm each, but featuring various masses and rotational inertias.

Typical Applications

- Race the hollow steel ball and solid aluminum ball down an incline. They have about the same mass, but the solid aluminum ball has a much larger acceleration down the ramp.
- Fire the yellow plastic, solid steel, and hollow steel balls from a PASCO Short- or Long-Range Projectile Launcher.

Includes

Solid Yellow Nylon Ball (10 grams)
Solid Steel Ball (66 grams)
Hollow Steel Ball (21 grams)
Solid Aluminum Ball (24 grams)
(release mechanism not included)



Order Information

Spherical Mass Set ME-8968

Rotational Inertia Wands

ME-9847

LAB ESSENTIALS

The red and blue wands have the same mass but the red wand is easier to rotate because the red wand has less rotational inertia.

These two wands have the same mass and the same dimensions and yet the red wand is easier to rotate. This is because the red wand has two metal slugs near its center, while the blue wand has two similar metal slugs at its ends. This demonstrates that rotational inertia depends on the distribution of the mass.

These sturdy plastic wands have small holes near the center and at the ends to enable students to see where the metal is located in each wand. So that what initially seems a mystery can be explained to the students by allowing them to examine the wands more closely.



To demonstrate the difference in rotational inertia of the two rods, ask two students to grab the center of a wand and instruct them to rotate the wand back-and-forth as rapidly as they can. No matter how strong the student with the blue wand is, he or she is not able to rotate it as fast as the student with the red wand.

Specifications

Length: 1 m
Diameter: 4 cm
Ratio of Blue Rotational Inertia to Red: Approx. 6

Includes

One Red Wand
One Blue Wand



Order Information

Rotational Inertia Wands ME-9847

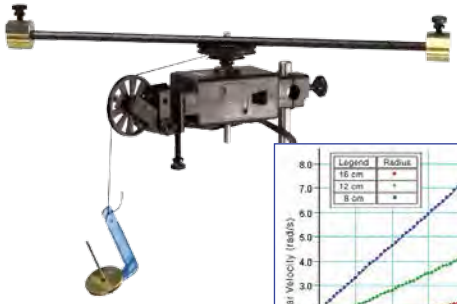
Mini Rotational Accessory

CI-6691

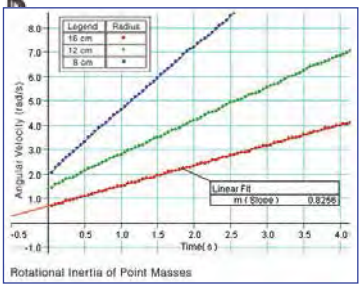
Add the Mini-Rotational Accessory to the Rotary Motion Sensor to study the oscillations of a pendulum, the rotational inertia of an aluminum disk, a steel ring and a metal rod, as well as the conservation of momentum during a rotational collision. The clamp-on Super Pulley allows students to apply a torque by hanging a mass over the pulley.



Finding the rotational inertia of the aluminum disk and ring.

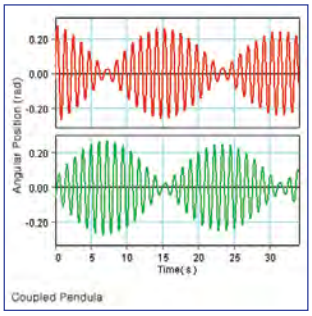


Finding the rotational inertia of point masses using the graph of angular velocity vs. time.



Coupled Pendula

Couple two pendula with a rubber band and plot the position vs. time for each pendulum. The result is a vivid example of energy transfer between the pendula.





Pendulum Accessory

ME-8969

The pendulum rod and masses can be purchased separately.

Includes

38 cm Pendulum Rod (27 g)
75 gram Mass (2)



Order Information

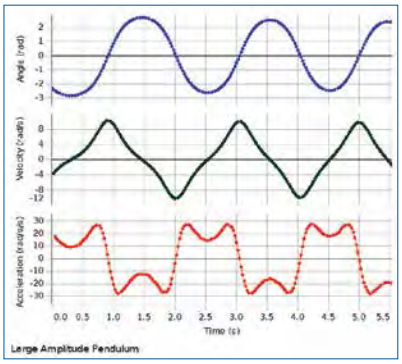
Pendulum Accessory ME-8969

Large Amplitude Pendulum

See page 323 for complete experiment.

By placing one mass on each end of the tube, the pendulum will oscillate slowly. Students will have time to view the motion of the pendulum, while also watching the real-time graph of displacement, velocity, and acceleration versus time. The period can be measured as a function of the amplitude of the pendulum and compared to theory.





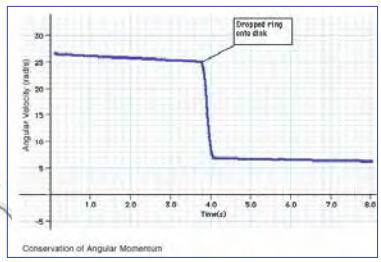
The displacement, velocity, and acceleration for large amplitude are plotted versus time to show the difference from the sinusoidal motion of low amplitude oscillations.

Conservation of Angular Momentum

See page 322 for complete experiment.

To demonstrate conservation of angular momentum, a non-rotating ring is dropped onto a rotating disk. The angular velocity of the disk is recorded in real-time, and students can easily determine the angular velocities of the disk just before and after the ring is dropped. Combining these velocities with the rotational inertia of the disk and ring, students can confirm that angular momentum is conserved.





The angular speed of the disk decreases when the ring is dropped onto the spinning disk.

Includes

Rotating Disk (9.5 cm diameter, 120 g)
Large Ring Mass (7.6 cm o.d., 5.4 cm i.d., 465 g)
38 cm Pendulum Rod (27 g)
75 gram Mass (2)
Clamp-On Super Pulley



Order Information

Mini Rotational Accessory CI-6691

Physical Pendulum Set

ME-9833

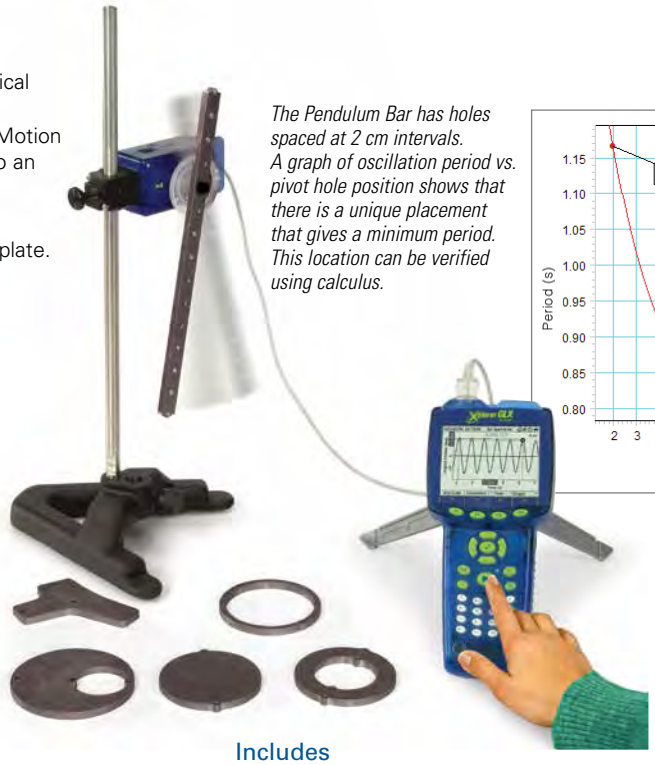
This set of six objects is perfect for studying Physical Pendula, Moments of Inertia, and the Parallel Axis Theorem. Each piece fastens directly to a Rotary Motion Sensor to measure the objects acceleration due to an applied torque, or the period when the pendulum freely oscillates.

Each piece is made from 1/4 inch thick aluminum plate.

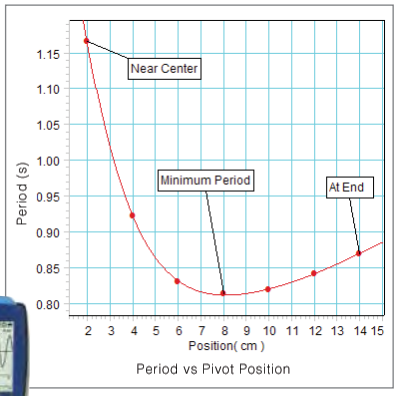
Apply a known torque and measure the angular acceleration to calculate the moment of inertia of the object. Multiple holes in the plate allow investigation of the Parallel Axis Theorem.

Center hole is at center of mass.





The Pendulum Bar has holes spaced at 2 cm intervals. A graph of oscillation period vs. pivot hole position shows that there is a unique placement that gives a minimum period. This location can be verified using calculus.





Unique design allows pivot exactly at the edge. Measure the period of the thick ring oscillating at either the inner or outer radius.



Includes

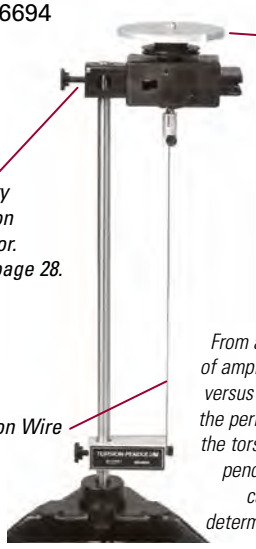
Solid Disk, Thick Ring, Thin Ring, Offset Hole, Pendulum Bar, Irregular Shape, and, six mounting screws

Order Information

Physical Pendulum Set	ME-9833	
Shown in use with:		
Xplorer GLX	PS-2002	p. 19
Rotary Motion Sensor	PS-2120A	p. 28
Base and Support Rods		p. 171
Super Pulley with Clamp	ME-9448B	p. 174
Mass and Hanger Set	ME-8979	p. 181

Torsion Pendulum Accessory

ME-6694



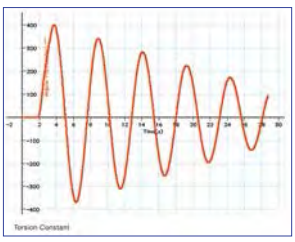
Aluminum Disk from CI-6691 Rotational Accessory

Rotary Motion Sensor. See page 28.

Torsion Wire



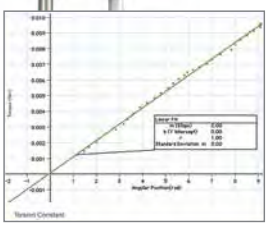
From a plot of amplitude versus time, the period of the torsional pendulum can be determined.





A Force Sensor is used to pull on a string wrapped around the pulley, creating a real-time plot of torque versus angular displacement.





The slope of the resulting straight line is the torsional spring constant.

Includes

One Set of Torsional Wires

Two Clamps; one to attach the wire to a 12.5 mm (1/2 in.) diameter rod and one to attach to a Rotary Motion Sensor.

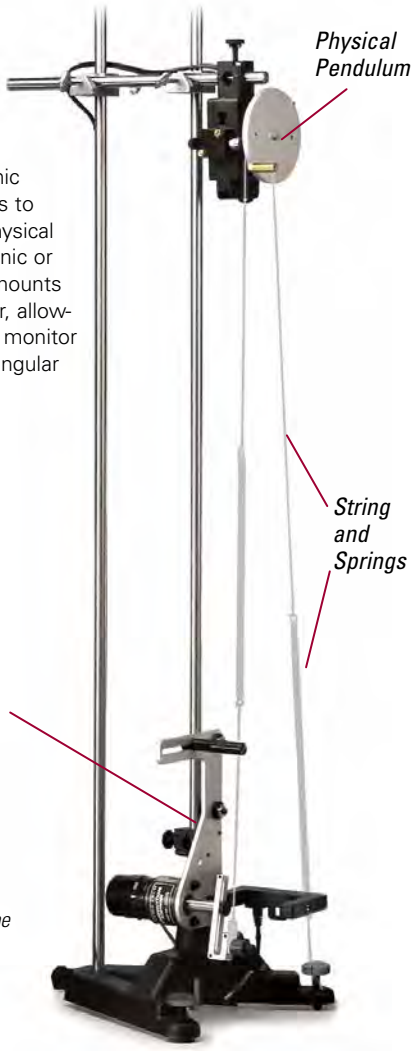
Order Information

Torsion Pendulum Accessory	ME-6694	
Shown in use with:		
Rotary Motion Sensor	CI-6538	p. 28
Base and Support Rods		p. 171

Chaos/Driven Harmonic Accessory

CI-6689A

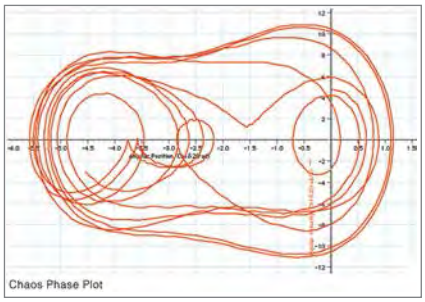
The Chaos/Driven Harmonic Accessory allows students to study the behavior of a physical pendulum in either harmonic or chaotic motion. The disk mounts to a Rotary Motion Sensor, allowing PASCO Capstone™ to monitor and plot the pendulum's angular position and velocity.



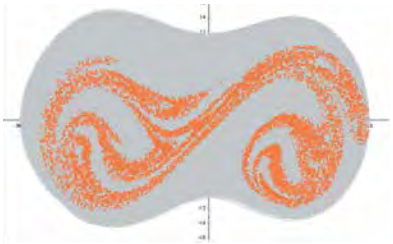
A sinusoidal force is applied to the disk and spring system in the Chaos/Driven Harmonic Motion experiments.

Chaotic Motion

Chaotic oscillations of the physical pendulum are produced by adjusting the magnetic damping, driver amplitude, and driver frequency.



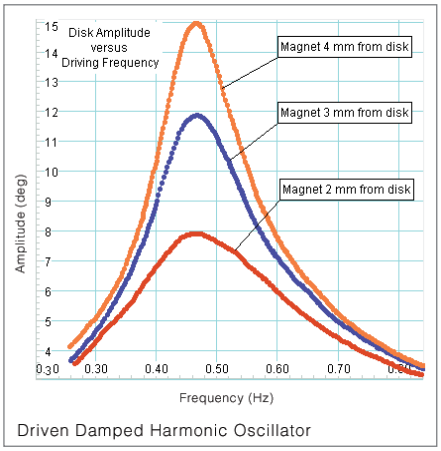
This phase plot (angular velocity vs. displacement) shows chaotic movement of the disk.



This Poincaré plot shows the pendulum's velocity versus position only once per period of the driving force. The gray background is the phase plot.

Driven Harmonic Motion

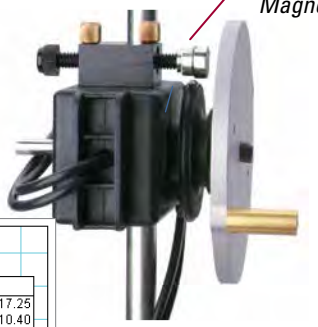
As a 10 cm aluminum disk is driven by a mechanical oscillator, two Rotary Motion Sensors simultaneously monitor the position of the disk and driver. The bidirectional sensors resolve to 1°, so the computer can easily display amplitude, frequency, and phase.



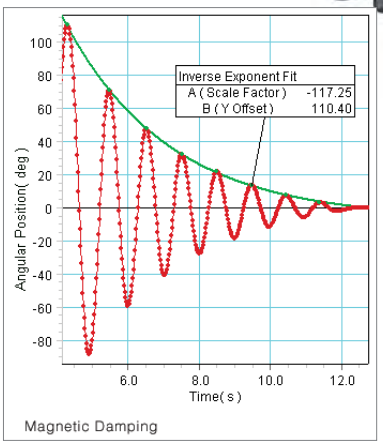
Angular velocity vs. frequency graph shows effects of magnetic damping on amplitude of resonance peak.

Damped Pendulum

The Rotary Motion Sensor graphically monitors the damped oscillations of an aluminum disk. A movable magnet allows students to change the strength of magnetic damping.



A turn of the screw moves the magnet away from or closer to the physical pendulum.



Includes

Rotating Disk (9.5 cm diameter, 120 g)
Eccentric Mass (15 g)
Springs
Adjustable Magnet for Damping



Order Information

Chaos/Driven Harmonic Accessory CI-6689A

For more information, see Driven Damped Harmonic Oscillator Experiment EX-5522A on page 326 and Chaos Experiment EX-5523A on page 327.

Bicycle Gyroscope

ME-6837

- Solid 1/2" steel shaft
- Cushioned hand-grips
- Precision ball-bearings for low friction
- Non-marking rubber tire

The newly redesigned Bicycle Gyroscope is perfect for getting your students engaged in understanding rotational motion. Unlike other bicycle gyroscopes, the PASCO model is extremely rugged for years of use, but also lightweight at just 6 lbs. Cushioned hand-grips, a pull-cord with handle, and an included suspension cord (for demonstrating precession) make it simple and easy to use.



Precision ball-bearings result in extremely low-friction for both the Bicycle Gyroscope and the Rotating Chair.



The Bicycle Gyroscope with the Rotating Chair gives you a perfect demonstration of the conservation of angular momentum.



Use the included pull-cord with handle to spin up the wheel.



This 2.8 kg (6 lb.) Bicycle Gyroscope has a solid 12.7 mm (½") steel shaft with cushioned hand-grips.

Attach cord (included) to hole in handle to demonstrate precession.

Includes

Bicycle Gyroscope

Two Cords with Handles



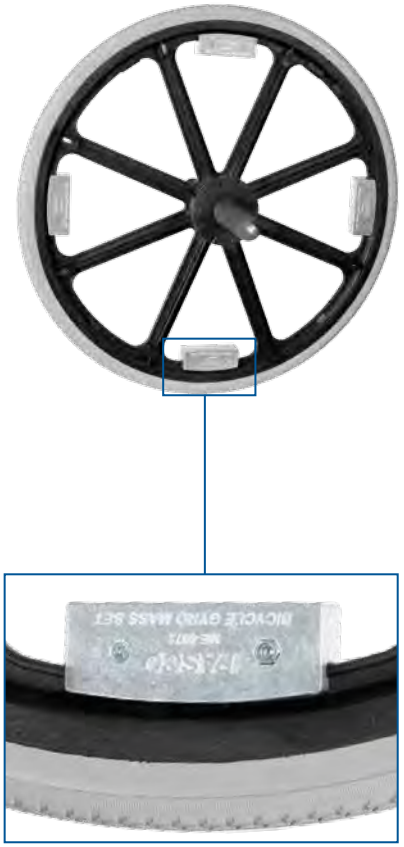
Order Information

Bicycle Gyroscope	ME-6837
Shown in use with:	
Rotating Chair	ME-6856

Bicycle Gyroscope Mass Set

ME-6972

Adding all four of the masses adds 1.6 kg to the wheel's (approximate) 2.8 kg mass and increases its rotational inertia by over 60%.



Mass securely clamps to the wheel rim using included screws.

Includes

Four 400 g masses



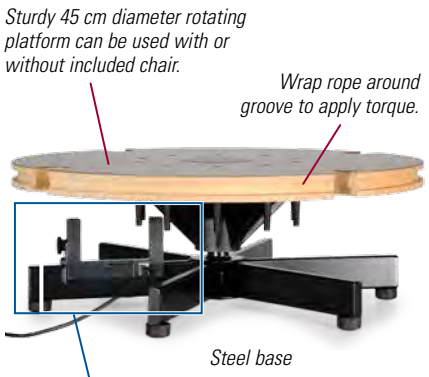
Order Information

Bicycle Gyroscope Mass Set	ME-6972
Required:	
Bicycle Gyroscope	ME-6837

Rotating Chair

ME-6856

Rugged design and incredibly low friction make this far superior to any office chair.





Includes

Chair and Rotating Platform with Leveling Feet



Order Information

Rotating Chair ME-6856

Shown in use with:

Photogate Head ME-9498A

Introductory Rotational Apparatus

ME-9341

- Designed for smart pulley
- Excellent introduction to rotational motion
- Full range of experiments



The Introductory Rotational Apparatus is a versatile, low-friction, rotating system designed for use with PASCO's Photogate/Pulley System. The simplicity of the equipment and the continuous data and high resolution graphs from the Smart Pulley assure that students make the difficult transition from understanding linear motion to truly understanding rotational motion.

How It Works

As the platter rotates on a vertical axle, the Smart Pulley monitors its angular position, velocity, and acceleration.

Features

Low Friction: The axle is supported by dual ball-bearings, minimizing friction and maximizing durability.

Built-in Step Pulley: Use a hanging mass to apply torques of varying momentum and force.

Auxiliary Platter: Drop the auxiliary platter onto the main platter to show that momentum is conserved in a rotational collision.

Bar and Ring: Investigate the relationship between geometry and moment of inertia.

Pulley Clamp: Mount the pulley directly onto the base. No additional mounting hardware is needed.

Photogate Timing: Use a photogate timer to perform these experiments if a Smart Pulley or computer are not available.

Includes

1. Base with Leveling Feet, Main Bearing and Spindle
2. Main Platter with Built-in Step Pulley
3. Auxiliary Platter
4. Steel Ring and Steel Bar for Moment of Inertia Experiments
5. Pulley Clamp
6. Photogate Clamp
7. Level
8. Complete Illustrated Manual (not shown)



Order Information

Introductory Rotational Apparatus	ME-9341	
Required for use with Stand-Alone Timers:		
Photogate Timer	ME-9215B	p. 120
or		
Smart Timer System	ME-8932	p. 118
Super Pulley	ME-9450A	p. 174
Universal Table Clamp	ME-9376B	p. 173
Required for use with ScienceWorkshop:		
Photogate/Pulley System	ME-6838A	p. 39
Universal Table Clamp	ME-9376B	p. 173
Required for use with PASPORT:		
Photogate/Pulley System	ME-6838A	p. 39
Digital Adapter	PS-2159	p. 41
Universal Table Clamp	ME-9376B	p. 173

Gyroscopic Motion

Demonstration Gyroscope

ME-8960



Features

Low Friction: The disk takes almost six minutes to slow to half of its original speed, due to low-friction bearings in the gyroscope axle and vertical shaft.

Large Inertia Disk: With the large rotational inertia of the disk, PASCO's gyroscope generates precession rates similar to smaller, enclosed gyroscopes. The slow rotation speed of PASCO's disk lets students study fast as well as slow precession and use a stopwatch to make measurements.

LAB ESSENTIALS

Accessory Disk

Add a second disk spinning in same or opposite directions.



Order Information

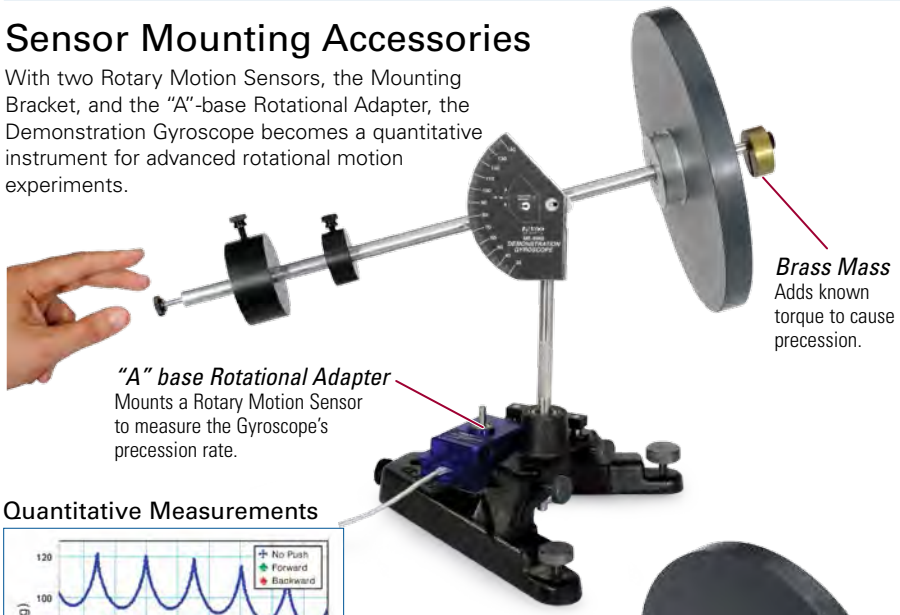
Demonstration Gyroscope ME-8960

Recommended:

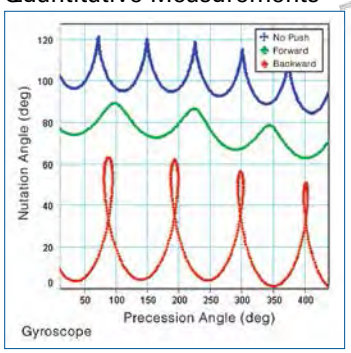
Accessory Disk and Mass ME-8961

Sensor Mounting Accessories

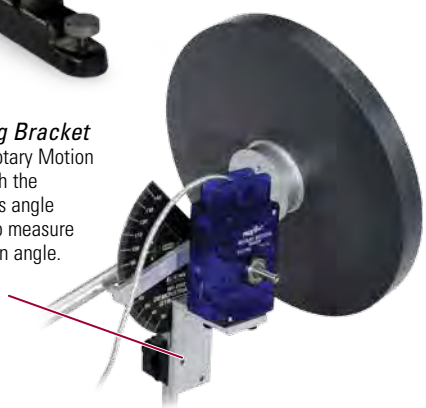
With two Rotary Motion Sensors, the Mounting Bracket, and the "A"-base Rotational Adapter, the Demonstration Gyroscope becomes a quantitative instrument for advanced rotational motion experiments.



Quantitative Measurements



Graph shows nutation pattern for three cases: The blue trace results when Gyroscope is released from rest, with no initial push forward or backward.



Rotary Motion Sensor/Gyroscope Mounting Bracket

ME-8963



Order Information

For Recording Nutation Data:
Rotary Motion Sensor/ Gyroscope Mounting Bracket ME-8963

Required:

Rotary Motion Sensor ..... p. 28

Interface ..... p. 14-23

"A"-base Rotational Adapter

CI-6690



Order Information

For Recording Precession Data:
"A"-base Rotational Adapter CI-6690

Required:

Rotary Motion Sensor ..... p. 28

Interface ..... p. 14-23

Bernoulli Cart Accessory

ME-9481

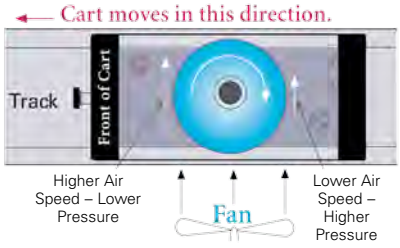


This 5 cm diameter cylinder with precision ball-bearings, can be easily set spinning by pulling a string, which provides an excellent demonstration of the Bernoulli Principle. Requires a fan to provide airflow across the rotating cylinder.

Compatible with all PASCO Carts.



Using the Fan Cart to create wind, the Bernoulli Cart Accessory accelerates down the Dynamics Track.



Top view of the rotating cylinder on the Bernoulli Cart Accessory.

Order Information

Bernoulli Cart Accessory ME-9481

Required:

1.2 m Classic Dynamics System ..... ME-9429B p. 88

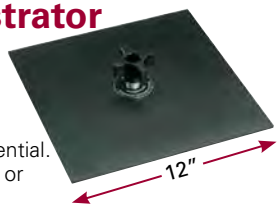
2.2 m Classic Dynamics System ..... ME-9452A p. 88

Fan Cart ..... ME-6977 p. 96

or any highly focused fan

Atmospheric Pressure Demonstrator

ME-8966A



Demonstrate the effect of a pressure differential. Easily lift a box or stool by simply placing the rubber sheet on a smooth surface of the object and lifting up on the handle.



As you pull up on the handle, a low-pressure region is created.

Order Information

Atmospheric Pressure Demonstrator ME-8966A

Air Cannon

SE-7370



The Air Cannon uses a vortex of air for ammunition. Its unique shape creates a stable toroidal vortex. Pull back the flexible membrane, release, and the invisible wave front of air can hit a target 20 feet away! A great demonstration of the energy that can be stored in waves.



Order Information

Air Cannon SE-7370

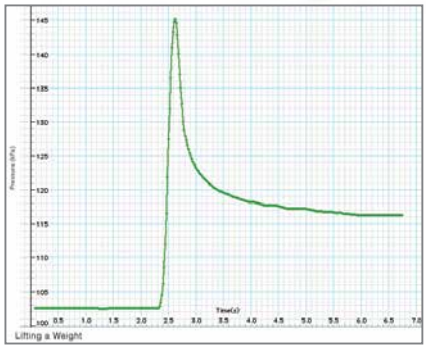
Hydraulic/Pneumatic System

SE-8764A

This system allows students to investigate the differences between a hydraulic and a pneumatic lift system. Water or air can be used to lift heavy objects with a small amount of force. The mechanical advantage can be changed by varying the size of the input syringe. In addition, a Pressure Sensor can be used to monitor the pressure of the pneumatic system as air is added with the input syringe.

Finally, the system can be used with a Pressure Sensor to collect pressure and volume data for the discovery of Boyle's Law.





Using a Pressure Sensor, the pressure vs. time graph is created real-time as air is added to the system with a syringe.

Includes

Stable base unit with mounted 60 cc syringe

Three input syringes: 3 cc, 12 cc, and 20 cc to vary the mechanical advantage

Connecting tubing with one-way valve with inline connector for optional Pressure Sensor

Order Information

Hydraulic/Pneumatic System SE-8764A

Shown with:

Hooked Mass Set ..... SE-8759 p. 181

Student Bell Jar

SE-9790



This bell jar provides a vacuum chamber for students to perform many experiments including:

- Watching a balloon expand or warm water boil as air is pumped from the chamber.
- Observing that a suction cup no longer sticks when the jar is evacuated.



Water boils as air is evacuated from the Bell Jar.

Includes



8 cm x 6 cm dia. clear plastic bell jar with base

Plastic vial, balloons and suction cup

60 cc syringe and valves for evacuating the jar

Order Information

Student Bell Jar SE-9790

Magdeburg Plates

LAB ESSENTIALS

SE-9717A

These two plates are a modern and versatile rendition of a classic demonstration.



Air is evacuated using a syringe; no vacuum pump needed. Clear plastic design lets students see everything. Two different "O" rings allow two different size areas. Tubing is provided so students can connect a Pressure Sensor for use with DataStudio.

Includes

10.7 cm diameter circular polycarbonate plates (2)

O-rings (2) (8.5 cm and 5.4 cm diameter)

60 cc syringe

Connecting tubing with one-way valve and inline connector for optional Pressure Sensor

Order Information

Magdeburg Plates SE-9717A

Gauge Pressure Accessory

SE-8802

Use the Gauge Pressure Accessory with the Student Bell Jar to demonstrate the concept of gauge pressure.





The pressure gauge is placed inside the Student Bell Jar and the syringe is used to create a vacuum. As the air is removed from the bell jar, the gauge pressure increases from 0 to 14.7 psi or 1 atm.

Order Information

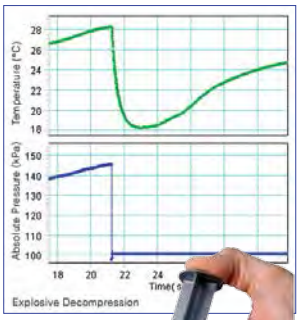
Gauge Pressure Accessory (gauge and base only) SE-8802

Atmospheric Properties Chamber

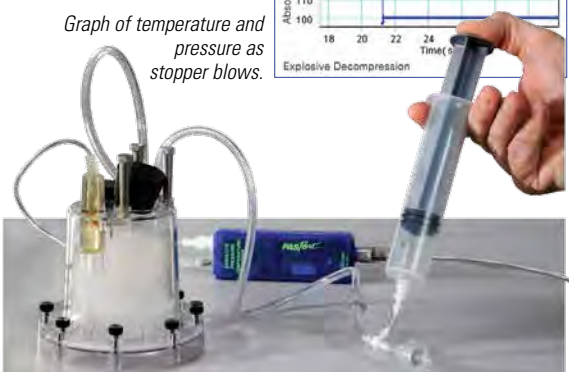
ME-6813A

- Recreate the conditions that lead to cloud formation
- Measure changing temperature and pressure
- Built-in fast response temperature probe

Add a small amount of water and seal the chamber with the rubber stopper. Students add pressure to the chamber using the included syringe. When the pressure is high enough, the rubber stopper will blow out and a cloud will form.



Graph of temperature and pressure as stopper blows.



As stopper blows, quick decompression causes cloud to form in chamber.



Included for safety is a stopper catcher, which keeps the stopper contained within the apparatus.

Order Information

Atmospheric Properties Chamber ME-6813A

Recommended:

Absolute Pressure/Temp Sensor ..... PS-2146 p. 44

Venturi Apparatus

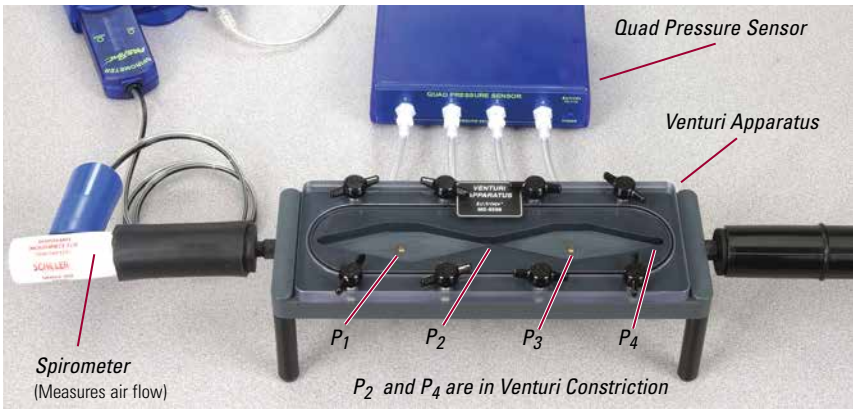
ME-8598

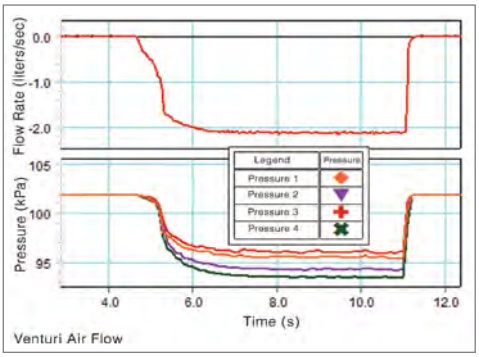
- Bernoulli effect
- Continuity equation

The Venturi Apparatus has a channel with varying cross-section to study the relationship between flow speed and pressure. The open design (2-D cross section) allows students to see inside and directly measure all needed dimensions.

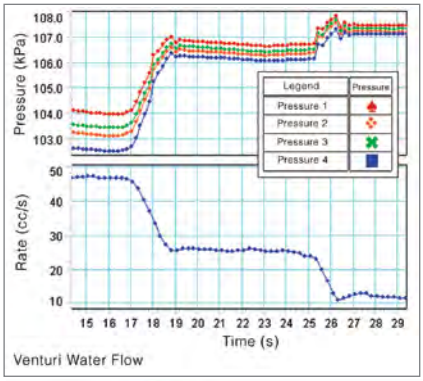
There are four built-in ports to attach pressure sensors to measure the pressure at four places along the stream line simultaneously. Pressure changes caused by both fluid speed and viscosity (drag) can be measured.

Designed to work with both air (see photo at right), and water (see below).





The Venturi Apparatus (above) is shown using a shop vacuum as the air source. A Spirometer measures air flow and a Quad Pressure Sensor measures air pressure in four locations. See graph at left. P_2 and P_4 are in the Venturi constrictions, and P_4 is downstream from P_1.



Note: the captured O-ring seal in the cover.



The clear plastic cover can be easily removed so that students can measure the dimensions of the Venturi channel.



The graph above shows water pressure data at three different flow rates. The flow rate is calculated using Motion Sensor data of the water level in the graduated cylinder.

Venturi Apparatus shown with Quad Pressure Sensor, Motion Sensor, and the Water Reservoir.



Includes

Venturi Chamber
Tubing
(for both air and water)
Restriction Clamps (2)
Quick Connect Couplers

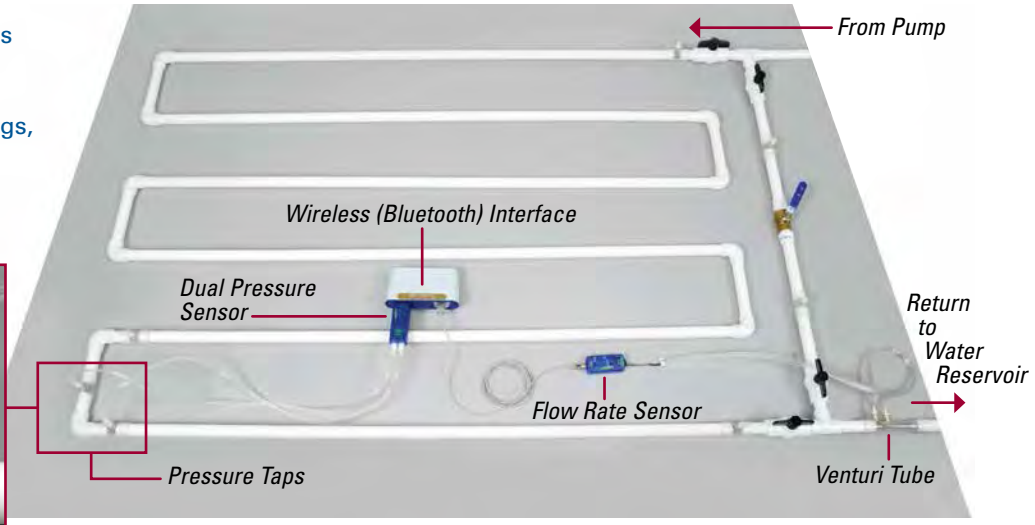
Order Information

Venturi Apparatus	ME-8598	
Shown in use with:		
Quad Pressure Sensor	PS-2164	p. 44
Motion Sensor	PS-2103A	p. 27
Water Reservoir	ME-8594	p. 179
Spirometer Sensor	PS-2152	p. 66
PASPORT Interface		p. 14-23

Pipe Network: Build it your way and instrument it inexpensively.

- Instrument your pipe network with pressure and flow sensors
- Transparent Venturi Tube and pressure taps
- Study head loss in pipes, fittings, and valves
- Find the relationship between pump head and flow rate



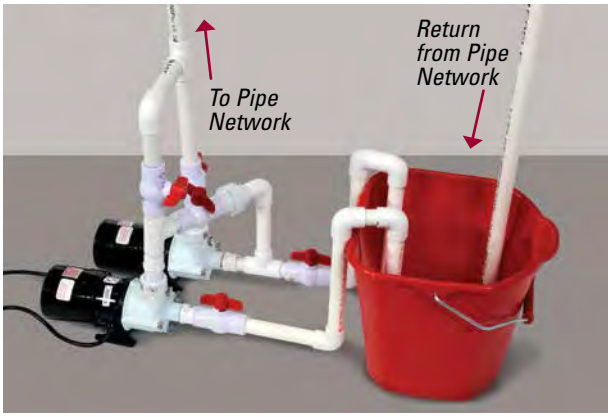


Measure pressure

In constructing a pipe network, it is useful to know the pressure in the fluid at numerous places along the pipe. The transparent Pressure Taps can be glued into a 3/4" PVC pipe network at any place, using a slip joint. Each Pressure Tap has a quick-connect for a Dual Pressure Sensor (PS-2181). Since the quick-connect closes when disconnected, it is possible to move the pressure sensor around the network to determine the pressures at different positions, rather than having a separate pressure sensor for each position.

Measure flow rate

The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network. The Venturi Tube is made of clear PVC so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor (PS-2225) by the matching couplers.



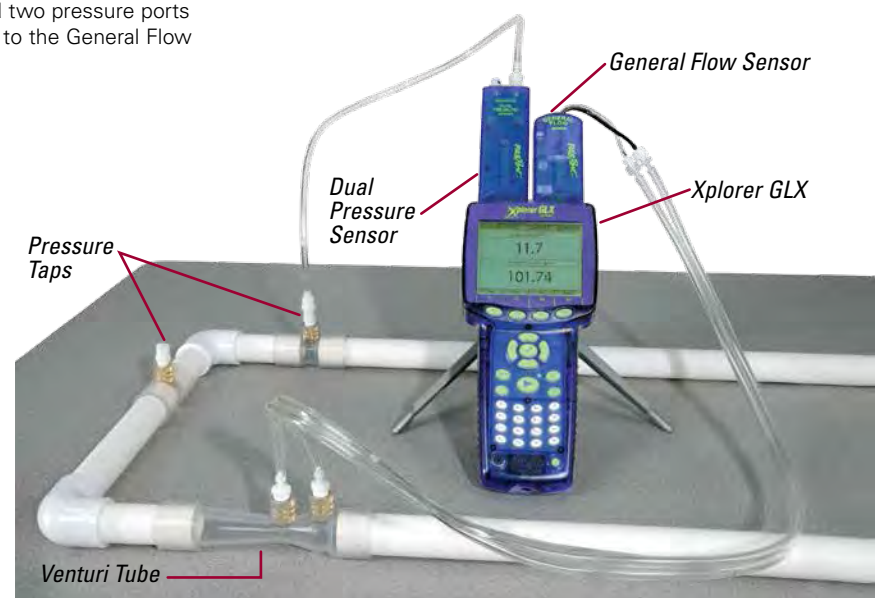
Study one pump or two pumps in series and parallel.

Create pump curves

Create a plot of pressure versus flow rate for a pump and determine the maximum head and flow rate. Study how these change when two pumps are connected in series or parallel.

Portable interface

The Xplorer GLX (PS-2002) with a Dual Pressure Sensor (PS-2181) makes a great portable pressure measurement system. The Xplorer GLX is a datalogger which can accept up to four PASPORT sensors. It can accommodate a General Flow Sensor to measure the volume flow rate and a Dual Pressure Sensor to measure the pressures along the pipe.



Pressure Taps are installed before and after elbow joints to measure the pressure loss. The Venturi Tube measures the velocity.

General Flow Sensor with Venturi

PS-2225



The General Flow Sensor determines fluid velocity in air or water by measuring the difference in pressure between the two input tubes. Either the Venturi Tube or the Pitot Tube ME-2221 (see page 47) must be connected to the General Flow Sensor.

Pressure Taps

ME-2224



ME-2224 Includes six pressure taps and tubing.

The transparent Pressure Taps can be glued into a 3/4" PVC pipe network at any place, using a slip joint. Each Pressure Tap has a quick-connect for a Dual Pressure Sensor (PS-2181). Since the quick-connect closes when disconnected, it is possible to move the pressure sensor around the network to determine the pressures at different positions, rather than having a separate pressure sensor for each position.

Wireless Interface



The SPARKlink Air (PS-2011) is a Bluetooth interface which allows the computer to be away from water spills. See page 22 for more information.



Venturi Tube

The Venturi Tube is made of clear PVC so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor by the matching couplers. The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network.

Dual Pressure

PS-2181



- Measure pressure at two pipe pressure taps at once

The Dual Pressure sensor is capable of reading two absolute pressures, one gauge pressure, or one differential pressure.

Specifications

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Differential Pressure: ±100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Maximum Sample Rate: 1000 Hz

Order Information

General Flow Sensor with Venturi Tube	PS-2225	
Pressure Taps (Set of 6)	ME-2224	
Dual Pressure Sensor	PS-2181	p. 42
Required:		
PASPORT Interface		pp. 14-23
PASCO Capstone Software		pp. 6-13
PVC Pipe and Fittings (Supplied by user)		
Pumps (2) (Supported by user)		
Shown in Use with:		
Xplorer GLX	PS-2002	
SPARKlink Air	PS-2011	p. 22
Optional Pitot Tube	ME-2221	p. 47

Density Circulation Model

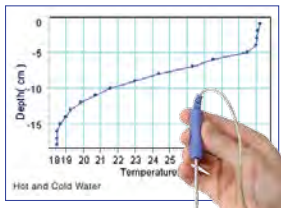
ME-6816

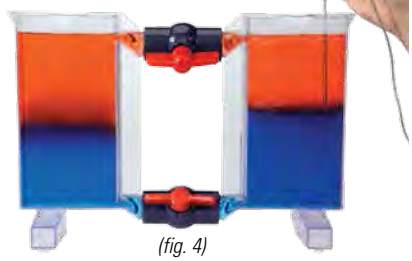
- Model density driven circulation based on temperature, dissolved substances, or different liquids
- Demonstrate the driving forces of vertical ocean currents
- Measure temperature inversions based on density difference



The PASCO Density Circulation Model allows students to model, measure and understand the complex density driven circulation associated with heat transfer through convection. Students can recreate vertical ocean currents driven by water bodies with density differences. They can extend this learning by using sensors to collect data and create graphs showing the thermocline, halocline and pycnocline using a Salinity Sensor PS-2195 (page 67).

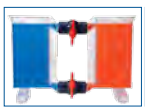
Data showing temperature versus depth. Rapid temperature change occurs in the region where the two water bodies mix.





(fig. 4)

With the valves closed (fig.1), two bodies of liquid can be created that differ in temperature, dissolved materials, or other properties. When the valves are opened, a smooth flow of liquid occurs between the chambers (fig. 2 & fig. 3). Minimal mixing occurs and clearly defined layers of liquid based on density result (fig. 4).



(fig. 1)



(fig. 2)



(fig. 3)

Order Information

Density Circulation Model	ME-6816	
Shown in use with:		
Stainless Steel Temperature Probe		p. 45

Density Set

ME-8569

TEACHER FAVORITE



Use this versatile set of materials with the Overflow Can to investigate Archimedes' Principle of displacement, specific heats, and basic length/volume relationships.

Includes pieces that have the same shape, volume, density, and mass, so the variable of interest can readily be isolated. Each piece has a hole, so it can be suspended from a string.

Includes

Three cylinders: aluminum, brass, plastic; 2.2 cm dia. x 6.4 cm long (plastic is less dense than water)

Two blocks: aluminum: 1.9 x 3.2 x 4.1 cm and brass: 1.6 x 1.9 x 2.8 cm. The mass of each block equals that of the aluminum cylinder.

Irregular shape: aluminum

Instruction manual

Order Information

Density Set ME-8569

Discover Density Set

SE-9719A

TEACHER FAVORITE



This set of 22 separate pieces allows students to discover the relationship between density, volume, and dimensions. Two unique series of pieces hold one dimension constant while varying another.

Includes

Cylinders of same length and different diameters (4)

Cylinders of same diameter and different lengths (4)

Spheres with different diameters (4)

Rectangular shapes of various sizes and materials (10)

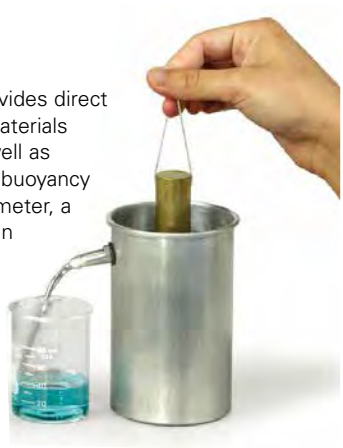
Instruction manual

Order Information

Discover Density Set SE-9719A

Overflow Can

SE-8568



This aluminum Overflow Can provides direct volume measurements for the materials supplied in the Density Set, as well as displacement measurements for buoyancy experiments. It has a 76 mm diameter, a usable volume of 477 cm^3, and an angled downspout. Requires a graduated cylinder or a gram balance to measure the displaced volume.

Includes

Can only

Order Information

Overflow Can SE-8568

Mystery Density Set

SE-7316A



The Mystery Density Set puts a nice "wrinkle" in the typical density experiment. After measuring the mass and volume of the pieces, students graph their results. As students plot the first few points, it appears there is no relationship between the mass and volume. However, as more data is graphed, it becomes obvious that two different linear relationships exist. Even though all the cylindrical pieces have a similar appearance, they are actually made of two different materials.

Includes

Eight Cylindrical Pieces (density = 1.42 g/cm^3)

Seven Cylindrical Pieces (density = 1.03 g/cm^3)

Storage Box

Order Information

Mystery Density Set SE-7316A

Classroom Density Set

SE-7226



The Classroom Density Set includes 12 sets of materials to study the density concept. Each material set includes four pieces of various sizes in a plastic storage tube. This selection of materials allows twelve lab groups to perform a density experiment at the same time. For each set, students measure the mass and volume of each piece and produce a mass vs. volume graph. Students will better understand density as a mathematical concept and realize that density is constant for a given material.

Includes

(Four different sizes of each material listed)

Maple	Polystyrene	PVC	CPVC
Polypropylene	Nylon	PETG	Teflon
HDPE	Acrylic	Acetal	Aluminum

Order Information

Classroom Density Set SE-7226

Glassware

Rugged borosilicate glassware for use in the physics lab.

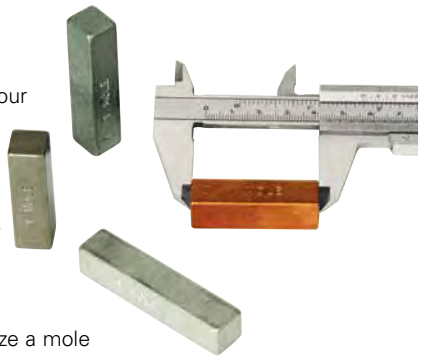


Order Information

100 ml Beaker (12 pack) SE-7287
1000 ml Beaker (6 pack) SE-7288
50 ml Graduated Cylinder (12 pack) SE-7289

Mole Set

SE-7586



The Mole Set contains four element specimens: Copper, Iron, Zinc and Aluminum. Each sample contains approximately one mole, 6.02 x 10^{23} atoms of the element.

Typical Applications

- Helps students visualize a mole in a solid state
- Can be used as specific heat specimens, density specimens and examples of common elements
- Characterize each specimen by density, atomic mass, etc.
- Investigate molar heat capacity and gain a greater understanding of thermodynamics



Includes

Mole samples: Zinc, Aluminum, Iron, Copper

Teaching Suggestions

Order Information

Mole Set SE-7586

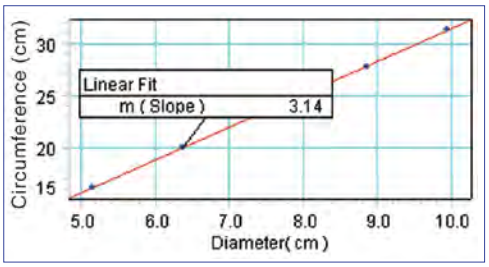
Discover Pi Set (10 pack)

ME-6819A

The student reads the circumference directly from the transparent tape wrapped around the pi circle.



The Discover Pi Set allows students to derive the meaning of π directly from their measurements. This activity transforms π from a constant with unknown origin to a fundamental characteristic of all circular objects.



The slope of the circumference vs. diameter graph is equal to π

Includes

Pi Circles (4): 5.2, 6.4, 8.9, 10.0 cm diameter

Transparent Measuring Tape

Order Information

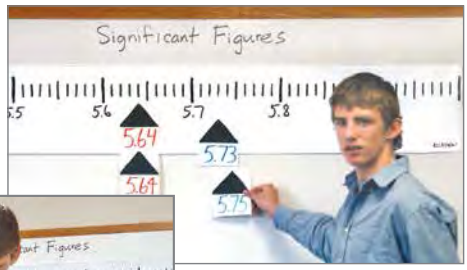
Discover Pi Set (10 pack) ME-6819A

Significant Figures Set

ME-9849

- Connects measurements to Significant Figures
- Includes materials for four student groups
- Detailed activity manual

The series of activities included in the Significant Figures Set emphasizes the connection between measurements and significant figures. Students work through a number of situations in which they experience the concepts of accuracy and precision. Through these activities, students learn the importance of the measuring tool and its role in the uncertainty of measurements. For each activity, student groups are asked to place their measurements and/or calculations along a demonstration number line. The groups can then share their results with the entire class during discussions and presentations. The Number Line and Data Pointers are laminated for use with dry erase markers.





The Ball Drop activity gives students experience with accuracy and precision.



The Four-Scale Meter Stick is an important part of the Significant Figures Kit as it includes four scales of varying precision.

Included Activities

Ball Drop: Students toss small balls on a bulls-eye to discover the relationship between technique and measurements. In addition, the concepts of accuracy and precision are explored.

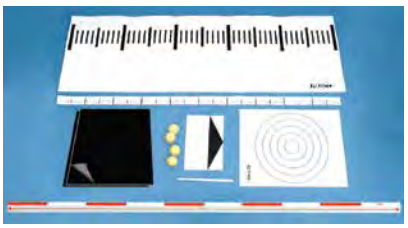
"Forced Error" Measurements: Students use a meter stick that has inaccurate markings to take measurements to reinforce that precise measurements are not always accurate.

Mass/Length Measurements: Students use a balance or Four-Scale Meter Stick with imprecise scales to limit the certainty in their measurements.

Area/Volume/Density Calculations: Students use a variety of measuring devices to calculate the area, volume, and density of various objects.

Includes

Plastic Balls (4)
Carbon Paper (100 pack)
Paper Bull's-Eye (8)
Four-Scale Meter Stick (4)
Number Line
Data Pointer (4)
Meter Stick Label (4)
Balance Label (4)



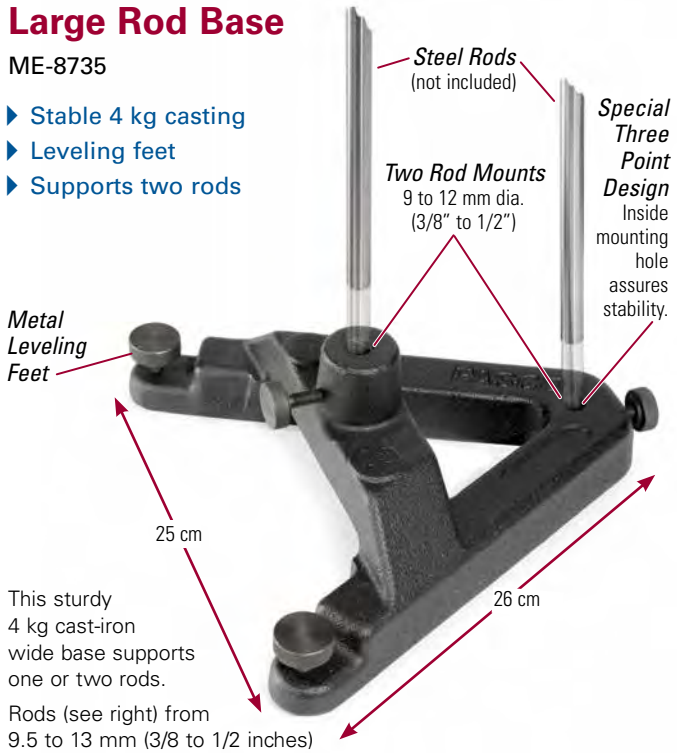
Order Information

Significant Figures Set ME-9849

Large Rod Base

ME-8735

- Stable 4 kg casting
- Leveling feet
- Supports two rods



This sturdy 4 kg cast-iron wide base supports one or two rods.

Rods (see right) from 9.5 to 13 mm (3/8 to 1/2 inches) can be supported. Two adjustable feet provide the necessary leveling capabilities.

Order Information

Large Rod Base ME-8735

Metal Knobs and Feet (4 pack)

ME-8954

These replacement knobs and feet for the ME-8735 Large Rod base are made of solid steel with knurled knobs and 5/16" -24 thread



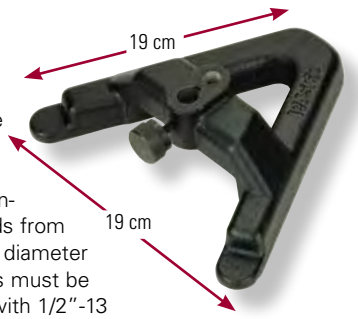
Order Information

Metal Knobs and Feet ME-8954

Small "A" Base

ME-8976

This 1.7 kg cast iron base is smaller than the Large Rod Base (above) and does not have leveling feet. This base can be used with both threaded and non-threaded rods. Non-threaded rods from 9.5 to 13 mm (3/8 to 1/2 inches) diameter can be supported. Threaded rods must be 12.7 mm (1/2 inch) in diameter with 1/2"-13 thread, such as the 60 cm rod shown at right.



Order Information

Small "A" Base ME-8976

Stainless Steel Rods

These 12.7 mm (1/2 in.) diameter stainless steel rods do not mar like aluminum rods. They are non-magnetic, very rigid, and durable.

Three different lengths are available in the non-threaded version.

The 60 cm long rod and 25 cm long rod are threaded (1/2"-13) and fit the Small "A" Base, the Small Round Base, and the Universal Table Clamp ME-9376B.



(Bases shown, not included)

Order Information

Stainless Steel Rods 12.7 mm (1/2 in.) in diameter:

45 cm Long (non-threaded) ME-8736
90 cm Long (non-threaded) ME-8738
120 cm Long (non-threaded) ME-8741
25 cm Long (threaded) ME-8988
60 cm Long (threaded) ME-8977

Small Round Base (2 pack)

ME-8974A

Great for those times when you just need a small support with a low profile, this 525 g cast iron base is 12.5 cm in diameter and has a 1/2"-13 threaded hole to accept threaded rods, such as the 25 cm or 60 cm rods shown above.



Order Information

Small Round Base ME-8974A

PASCO's Flex Rod

ME-8978A

- Flexible rod for holding objects in any orientation

The Flex Rod provides the freedom to place equipment where it's needed. Simply connect the object to the end of the 46 cm long flexible tubing and move it to the desired location. The tubing has enough rigidity to hold many common items in any orientation. In addition, two convenient clamps are included.



The Flex Rod with rod clamp attachment fits sensor handles.



Flex Rod holds photogate for Acceleration Due to Gravity experiment using a picket fence (shown with Table Clamp, not included).



The Flex Rod holds a green laser pointer. Shown with Small "A" Base (not included).



Includes

Flex Rod attached to rigid section
Rod Clamp attachments (2)
3-finger clamp attachment
(Base support not included.)

Order Information

Flex Rod ME-8978A

Suggested Base Supports:

Small "A" Base	ME-8976	p. 170
Aluminum Clamp	ME-8995	p. 173

Sensor Handles (4 pack)

CI-9874



These convenient plastic handles screw into virtually any ScienceWorkshop or PASPORT sensor and can be used with any standard lab clamp. Length: 5.7 cm, diameter: 1.25 cm.

Order Information

Sensor Handles (4 pack) CI-9874

Base and Support Rod

Large
ME-9355

Small
SE-9451



1. **Large Base and Support Rod:** With built-in leveling screws and a threaded aluminum rod that is 12.7 mm (1/2 in.) in diameter and 45 cm long.
2. **Small Base and Support Rod:** The threaded steel rod is 9.5 mm (3/8 in.) in diameter and 50 cm long. Leveling screws not included.

Order Information

Large Base and Support Rod ME-9355

Small Base and Support Rod SE-9451

Mounting Rods (10 pack)

ME-9483



These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) screw into a Super Pulley.

Order Information

Mounting Rods (10 pack) ME-9483

Pulley Mounting Rod

SA-9242



This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Clamp. It has a standard 1/4"-20 thread.

Order Information

Pulley Mounting Rod SA-9242

Plastic Rod and Clamp

ME-6546

This rigid plastic rod with a brass inset screw attached to a plastic clamp makes a simple but effective all-in-one rod clamp. Also, the rod can be unscrewed and used with a Super Pulley (ME-9450A). The rod is 14 cm long and has a diameter of 1.27 cm. The clamp accepts rods up to 1.27 cm diameter.





Includes
Four rods and four clamps

Order Information

Plastic Rod and Clamp	ME-6546	
Shown in use with:		
High Resolution Force Sensor	PS-2189	p. 30
Hooked Mass Set	SE-8759	p. 181
Small "A" Base	ME-8976	p. 170
Stainless Steel Rod (45 cm.)	ME-8736	p. 170

Right Angle Clamp

SE-9444

Buret/Utility Clamp

SE-9446

Three-finger Clamp

SE-9445

LAB ESSENTIALS



Right Angle Clamp (SE-9444)

This standard right angle clamp fits rods up to 18 mm (11/16 inch) in diameter.

Buret/Utility Clamp (SE-9446)

The V-shaped, plastic-coated jaws of this Buret Clamp open from 5 to 35 mm, rotate 360°, and lock in position at any angle. Fits rods up to 16 mm (5/8 inch) in diameter.

Three-finger Clamp (SE-9445)

Clamp tubes, rods, and irregularly shaped objects. The jaws extend 19 mm, open to 57 mm, rotate 360°, and lock securely at any angle. Fits rods up to 19 mm (3/4 inch) in diameter.

Order Information

Right Angle Clamp	SE-9444
Buret/Utility Clamp	SE-9446
Three-finger Clamp	SE-9445

Pendulum Clamp

ME-9506



Hang up to three springs or pendula. Suspension points are 54 mm apart. Fits rods up to 16 mm (5/8 inch) in diameter.

See page 146 for more information.





Order Information

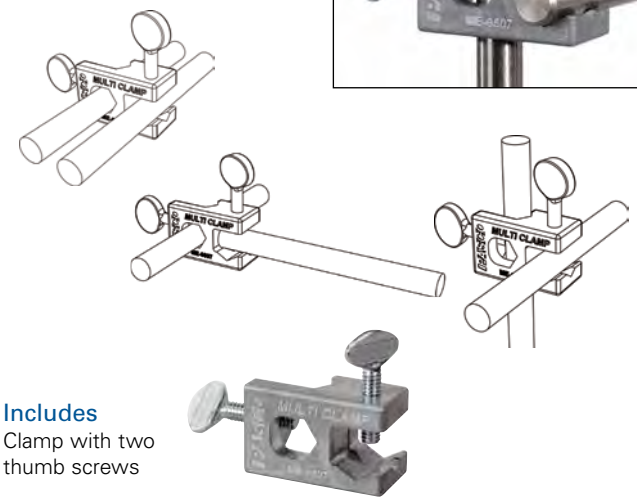
Pendulum Clamp	ME-9506	
Shown in use with:		
Photogate Pendulum Set	ME-8752	p. 149
Small "A" Base	ME-8976	p. 170
Stainless Steel Rod (45 cm.)	ME-8736	p. 170

Multi Clamp

ME-9507

Holds two rods either parallel or at right angles. Fits rods up to 12.7 mm (1/2 inch) in diameter.





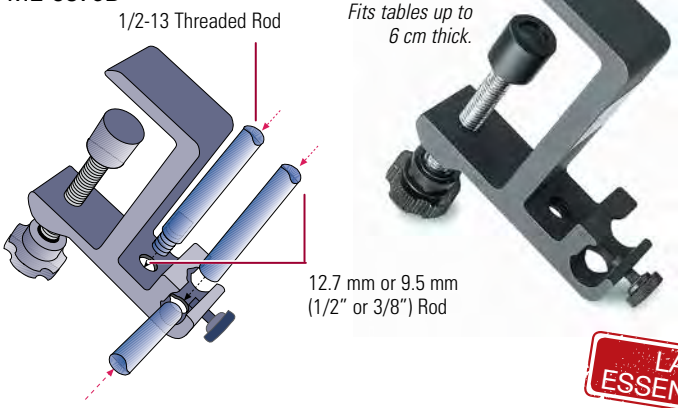
Includes
Clamp with two thumb screws

Order Information

Multi Clamp	ME-9507

Universal Table Clamp

ME-9376B



LAB ESSENTIALS

Attach this Universal Table Clamp to tables or shelves up to 6.0 cm (2 3/8 inch) thick. Can also be mounted on a ring stand.

Mount rods in the clamp either vertically or horizontally. The rods are held securely by stable three-point contacts. Use standard unthreaded lab rods — 9.5 mm (3/8 inch) to 12.7 mm (1/2 inch) — vertically or horizontally. Use 1/2-13 threaded lab rod vertically.

Order Information

Universal Table Clamp ME-9376B

Double Rod Clamp (3 pack)

ME-9873



Holds any two rods up to 12.7 mm (1/2 inch) in diameter, either parallel or perpendicular to one another.

Double Rod Clamp (3 pack) ME-9873

Swivel Clamp (2 pack)

ME-8743



Clamp two rods at any angle or clamp the two rods parallel to each other. Accepts 12.7 mm (1/2 inch) rods.

Includes

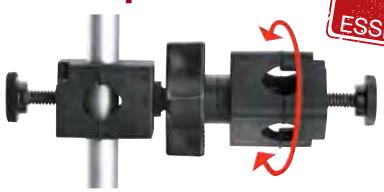
Two Clamps

Order Information

Swivel Clamp (2 pack) ME-8743

Adjustable Angle Clamp

ME-8744



LAB ESSENTIALS

This unique clamp fits any rod up to 12.7 mm (1/2 inch) diameter and can lock the rod in place at any angle.

Order Information

Adjustable Angle Clamp ME-8744

Table Rod Clamps

Both clamps hold up to 12.7 mm (1/2 inch) diameter rods that can be mounted either horizontally or vertically.



Order Information

Large Table Clamp ME-9472
10 cm grip range

Aluminum Table Clamp ME-8995
6 1/2 cm grip range

"C" Clamps

SE-7286 Small

SE-7285 Large



These rugged clamps are perfect for attaching a variety of objects to a table. Available in 8 cm and 10 cm sizes.

Order Information

Small "C" Clamp (6 pack) SE-7286

Large "C" Clamp (6 pack) SE-7285

Laboratory Jacks

Raise, support, and align equipment with these lab jacks. They're rugged, stable, and ensure precise height adjustment. Two sizes are available.



Order Information

Laboratory Jack	Model	Platform (cm)	Height (cm)	Load (kg)
Medium	SE-9373	15x15	7 - 25	25
Large	SE-9372	20x20	7 - 25	25

The PASCO Super Pulley

Super Pulley

ME-9450A

TEACHER FAVORITE

- 20 N Max Load
- Nearly Frictionless
- Durable



The PASCO Super Pulley is the standard in physics labs. Its low-friction design produces excellent results. The precision spacing of the 10 spokes makes it ideal for photogate monitoring with PASCO's computer interfaces and photogate systems.

Features

Low Friction: Dual precision ball-bearings (not cone bearings) keep friction to a bare minimum, support heavier loads, and minimize wear.

Lightweight: The sheave is only 5.5 g, so pulley inertia is negligible in most applications.

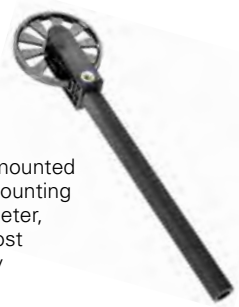
Precision Dimensions: The 10 spokes are accurately spaced, and the inside and outside diameters are machined to precise dimensions. This means accurate results and graphs.

Order Information

Super Pulley ME-9450A

Super Pulley with Mounting Rod

ME-9499



This Super Pulley mounted on a rigid plastic mounting rod (12.7 mm diameter, 14 cm long) fits most standard laboratory clamps.

Order Information

Super Pulley with Mounting Rod ME-9499

Photogate/ Pulley System

ME-6838A



The Super Pulley attaches directly to the Photogate Head, providing a simple, low-friction system to measure position, velocity, and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments. See page 39.

Order Information

Photogate/Pulley System ME-6838A

Super Pulley with Clamp

ME-9448B



Upgrade your force table and inclined plane experiments. The Super Pulley with its integral clamp makes setup and alignment easy. The pulley height is fully adjustable. So you can skim the top of a force table for parallax-free readings, yet keep the force parallel to the track on an inclined plane, as shown in the photo below. Fits tables up to 2.0 cm (13/16 in.) thick.



Order Information

Super Pulley with Clamp ME-9448B

Mounting Rods (10 pack)

ME-9483



These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) screw into a Super Pulley.

Order Information

Mounting Rods (10 pack) ME-9483

Super Pulley Combination

ME-9433



This combination includes parts to assemble either:

1. A Super Pulley with a Rod
   or
2. A Super Pulley with a Clamp



1.



2.

Includes

Super Pulley (1)

Clamp (1)

Mounting Screws (2)

14 cm long, 12.7 mm dia. Plastic Mounting Rod (1)

Order Information

Super Pulley Combination ME-9433

Pulley Mounting Rod

SA-9242



This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Table Clamp (ME-9376B).

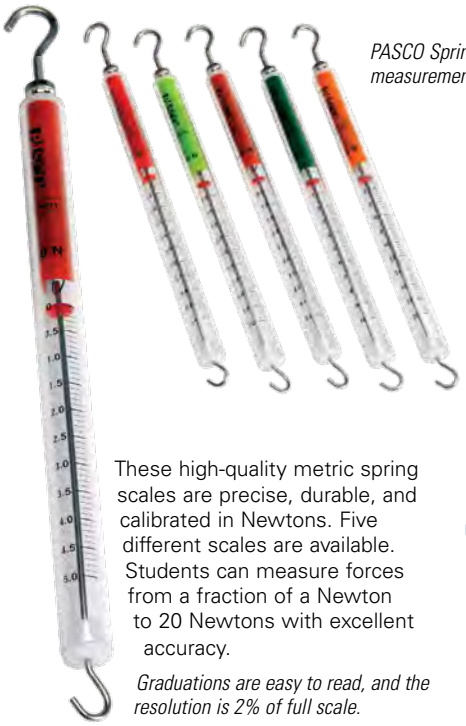
Order Information

Pulley Mounting Rod SA-9242

Metric Spring Scales

(Five different ranges)

LAB ESSENTIALS



PASCO Spring Scales: Five metric spring scales provide accurate measurements over a wide range of forces.

These high-quality metric spring scales are precise, durable, and calibrated in Newtons. Five different scales are available. Students can measure forces from a fraction of a Newton to 20 Newtons with excellent accuracy.

Graduations are easy to read, and the resolution is 2% of full scale.

Features

Accurate: The precision springs provide excellent linearity, and the 10 cm long scales are sharp and clear for superior resolution.

Sealed Spring: Can't get tangled, over-stretched, or lost.

Zero Adjust: Turn the knob to zero the balance.

Scales on Inside: They won't wear off.

Five Color-coded Ranges: Measure almost any force from 0.1 N to 20 N.

Order Information

Metric Spring Scales

Model	Range	Resolution	Color
ME-9509	1.0 N	0.02 N	Red
ME-9510	2.0 N	0.04 N	Lt. Green
ME-9511	5.0 N	0.1 N	Brown
ME-9512	10 N	0.2 N	Dk. Green
ME-9513	20 N	0.4 N	Orange

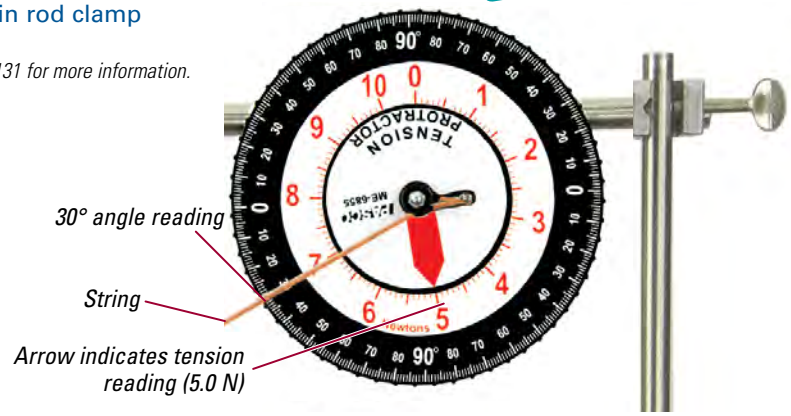
Tension Protractor

ME-6855

- Measure tension and angle with one device
- Large scale for viewing demonstrations
- Zero-adjust for torsion spring scale
- Built-in rod clamp

GREAT DEMO

See page 131 for more information.



Includes

One Tension Protractor



Order Information

Tension Protractor ME-6855

Recommended:

Large Table Clamp	ME-9472	p. 173
90 cm Long Rod	ME-8738	p. 170
Multi Clamp	ME-9507	p. 172
Hooked Mass Set	SE-8759	p. 181

Dial Spring Scales

(10 N) SE-7348 (20 N) SE-7340



7.6 cm diameter

Use these spring scales to measure tension forces by hanging an object on the hook.

The SE-7348 spring scale can measure up to 10 N with a resolution of 0.1 N.

The SE-7340 spring scale can measure up to 20 N with a resolution of 0.2 N.

Each spring scale is 7.6 cm diameter and also features a mounting ring and weighing hook.

Order Information

Dial Spring Scale

(10 N) SE-7348

(20 N) SE-7340

Demo Spring Scale

SE-7349



20 cm diameter

The Demonstration Spring Scale features a large 20 cm diameter faceplate so many students can view demonstrations. With a capacity of 20 N and a resolution of 0.5 N, it provides a versatile and inexpensive way to measure forces.

Order Information

Demo Spring Scale SE-7349

Metric Measuring Tape

SE-8712A



LAB ESSENTIALS

This 30-meter woven fiberglass measuring tape reads metric on one side and English on the other.

Order Information

Metric Measuring Tape SE-8712A

Digital Calipers

SE-8710



This metric/English (15 cm/6 in.) digital caliper measures to 0.01 mm (0.0005 in.). It has auto power-off and includes a sturdy plastic storage case.

Order Information

Digital Calipers SE-8710

Stainless Steel Calipers

SF-8711



These metric/English (18 cm/6 in.) calipers have an expanded Vernier scale of 20 divisions (instead of the usual 10), so it's easier to read and more accurate. The sliding mechanism is smooth and durable. A case is included for added protection.

Order Information

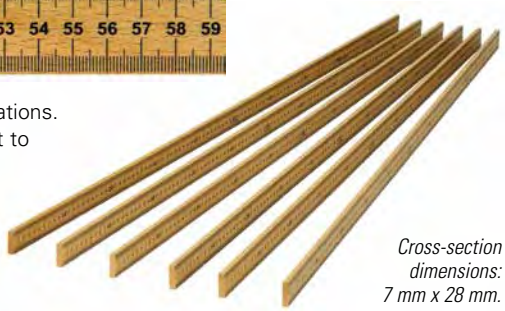
Stainless Steel Calipers SF-8711

High Quality Meter Sticks (6 pack)

SE-8827



Hardwood meter stick with metric graduations. Scale reads left to right on one side, right to left on the other.



Cross-section dimensions: 7 mm x 28 mm.

Order Information

Meter Stick (6 pack) SE-8827

Four-Scale Meter Stick

SE-8695



The Four-Scale Meter Stick is constructed of plastic square channel. One side has millimeter markings, one has centimeter markings, one has decimeter markings, and the last side has only a one-meter mark.

Order Information

Four-Scale Meter Stick SE-8695

Micrometer

SE-7337



This low-cost micrometer provides measurements from 0 to 25 mm with 0.1 mm resolution. The wooden box is form-fitted to protect the micrometer during storage.

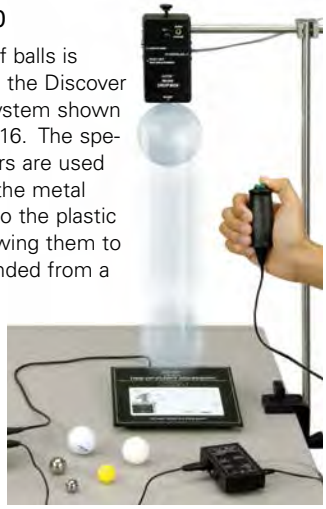
Order Information

Micrometer SE-7337

Freefall Balls Accessory

ME-9890

This set of balls is used with the Discover Freefall system shown on page 116. The special stickers are used to attach the metal washers to the plastic balls, allowing them to be suspended from a magnet.



Includes

Small Nylon Ball (2.5 cm)
Large Plastic Ball (10 cm)
Golf Ball (4.4 cm)
Hollow Golf Ball (4.2 cm)
Steel Ball (2.5 cm)
Steel Ball (1.6 cm)
Release Washers (10)
Release Stickers (50)

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.



Order Information

Freefall Balls Accessory ME-9890

Steel Balls

ME-9864



⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Four pack of 2.5 cm diameter balls for use with PASCO Short- or Long-Range Projectile Launchers (ME-6800 or ME-6801).

Order Information

Steel Balls
(4 pack) ME-9864

Bounce/No Bounce Ball Set (3 sets)

SE-7571



⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

These two black balls look and feel identical, but drop them side by side and students will notice a big difference in their elasticity. One bounces close to the original drop height, while the other doesn't bounce at all. Includes three sets of the Bounce/No Bounce Balls. Each ball has a diameter of 2.5 cm.



Order Information

Bounce/No Bounce
Ball Set (3 sets) SE-7571

Small Steel Balls

ME-9872



⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

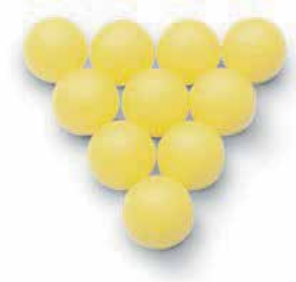
These 1.6 cm diameter steel balls are used with the Mini Launcher (ME-6825).

Order Information

Small Steel Balls
(10 pack) ME-9872

Plastic Balls

ME-6822



⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Extra brightly colored balls are available for the Projectile Launcher. Diameter is 2.5 cm (1 in.).

Order Information

Plastic Balls
(10 pack) ME-6822

Spherical Mass Set

ME-8968

This set includes four balls with a diameter of 2.5 cm each, but featuring various masses, including a hollow steel ball.



⚠WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Includes

Solid Yellow Nylon Ball (10 grams)
Solid Steel Ball (66 grams)
Hollow Steel Ball (21 grams)
Solid Aluminum Ball (24 grams)

Typical Applications

- Race the hollow steel ball and solid aluminum ball down an incline. They have about the same mass, but the solid aluminum ball has a much larger acceleration down the ramp.
- Fire the yellow plastic, solid steel, and hollow steel balls from a PASCO Short- or Long-Range Projectile Launcher.

Order Information

Spherical
Mass Set ME-8968

Large Ball

SE-8842



This solid plastic ball is very round, rolls well, and is big enough to be easily seen by a motion sensor. It is used with the Force Distribution System shown on page 129, and has a diameter of 10 cm and an approximate mass of 800 grams.



Order Information

Large Ball SE-8842

Braided Physics String

SE-8050



▸ 30-lb. Test

This braided Dacron® string is tough, resists stretching, and won't unravel. Withstands up to 133 Newtons of force (equivalent to 13.6 kg). Each roll provides 320 meters of string.

Order Information

Braided Physics String SE-8050

Elastic Wave Cord

SE-9409



Unlike a Slinky®, the tension can be varied. In addition to the Slinky, this Wave Cord is great for wave demonstrations. The cord is 3 mm in diameter. Each roll provides 90 meters of cord.

Order Information

Elastic Wave Cord SE-9409

Yellow Cord

ME-9876



Two rolls of highly visible braided yellow cord. Total length of 140 meters.

Order Information

Yellow Cord (2 pack) ME-9876

Rubber Cord (30 meters)

ME-9986



For Elastic Bumper (ME-8998)

Also fits Air Track Bumpers (page 111)

Order Information

Rubber Cord (Spool of 30 m) ME-8986

Glow String

SE-8690



⚠WARNING
CHOKING HAZARD
Small parts. Not for children under 3 years.

This stretchy "string" glows in the dark after being exposed to light. Use it to demonstrate wave motion, including resonance and standing wave patterns. Two rolls are included, totaling over 15 meters of string.

Order Information

Glow String (2 pack) SE-8690

Black Thread

ME-9875



Includes three spools of black Nylon thread.

Order Information

Black Thread (3 pack) ME-9875

Plumb Bobs (10 pack)

SE-8728



These finished steel plumb bobs are precision-machined to a fine point. Just slide a string through the hole in the top and tie a knot. The plumb bob hangs precisely centered.

Order Information

Plumb Bobs (10 pack) SE-8728

No-Bounce Pad

SE-7347



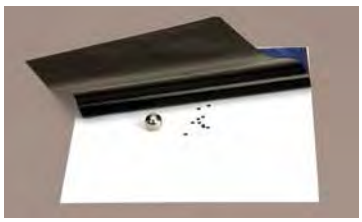
Stop falling objects from bouncing with PASCO's No-Bounce Pad. The 30 cm x 30 cm x 2.5 cm dimensions of the pad provide an ample target for gravity demonstrations. Prevents heavy objects from damaging the floor and prevents falling objects from being damaged on impact.

Order Information

No-Bounce Pad SE-7347

Carbon Paper (100 pack)

SE-8693



Carbon paper is ideal for marking the position of an object as it strikes the floor or other surface.

Order Information

Carbon Paper (100 sheets) SE-8693

Spirit Levels (10 pack)

SE-8729



These 23 cm long Spirit Levels have three vials with striped graduations to indicate vertical, horizontal, and 45° alignment. The frame is a durable plastic with tough acrylic vials. A magnetic tape allows hands-free leveling.

Order Information

Spirit Levels (10 pack) SE-8729

Storage Bins

SE-7560

These stackable plastic bins with lids are useful for storing sensors.
14" long, 9.5" wide, 6.9" high.



Order Information

Storage Bins (set of 5) SE-7560

3.8 Liter Plastic Container Set

ME-7559

These containers are great for experiments needing ice-water baths. See the Heat Engine Experiment on page 334 for an example.

14 cm x 14 cm x 19.5 cm tall



Order Information

3.8 Liter Plastic Container Set (set of 2) ME-7559

Water Reservoir

ME-8594

This calibrated 1000 ml cylinder is useful for experiments (as shown on page 223), requiring either a specific amount of water, a constant flow of water, or water at a constant pressure. The cylinder has three hose connections, one for connection to a source of water, one for overflow, and an outlet near the bottom. The unit comes with six meters of tubing and two restriction clips.

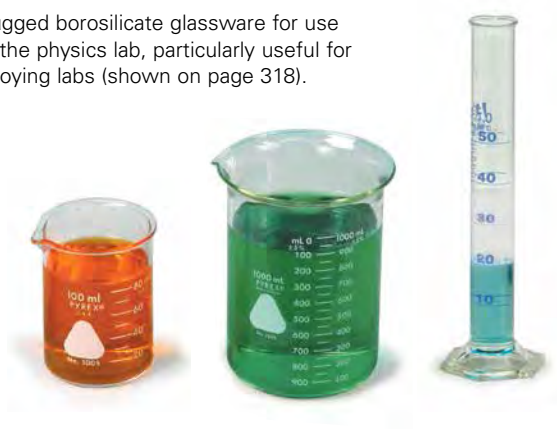


Order Information

Water Reservoir ME-8594

Glassware

Rugged borosilicate glassware for use in the physics lab, particularly useful for buoying labs (shown on page 318).



Order Information

100 ml Beaker (12 pack) SE-7287
1000 ml Beaker (6 pack) SE-7288
50 ml Graduated Cylinder (12 pack) SE-7289

Syringes

SE-7562 Large (60 ml)
SE-7561 Small (24 ml)

General purpose plastic syringes for use with our pressure sensors.



Order Information

Large Syringe (5 pack) SE-7562
Small Syringe (5 pack) SE-7561

Ohaus Scout Pro Balances

SE-8756A (400 g)
SE-8757A (2000 g)
SE-8758A (6000 g)



Specifications

Catalog #	SE-8756A	SE-8757A	SE-8758A
Ohaus #	SPE402	SPE200	SPE6000
Capacity:	0-400 g	0-2000 g	0-6000 g
Resolution:	0.01 g	0.1 g	16.5 cm x 4.2 cm
Pan Size:	12 cm dia	1.0 g	16.5 cm x 14.2 cm

The Scout Pro digital electronic balances from Ohaus combine range, resolution, and low cost, making them ideal for the student physics lab.

Simple two-button operation and visual menu prompts allow students to begin weighing with minimal instruction. The large, crisp display is easily viewed from any angle, so teachers can quickly check student results. A sealed front panel, molded spill ring, and removable stainless steel platforms provide protection from spills and make Scout Pro easy to keep clean.

Order Information

Ohaus Scout Pro Balance
400 g SE-8756A
2000 g SE-8757A
6000 g SE-8758A
Recommended:
USB Connection Kit SE-8788

Ohaus Triple-Beam Balance

SE-8723 (without tare)

SE-8707 (with tare)



LAB ESSENTIALS

Ohaus Cent-o-Gram Balance

SE-8725



Ohaus mechanical balances have been the standard weighing instruments in student laboratories for decades. They're accurate, easy to use, durable, and inexpensive.

Features

Precision-Ground Steel Knives: For exact measurements and a long balance life.

Stainless Steel Weighing Pan: Easy to clean, lasts indefinitely.

Magnetic Damping: For quick, true measurements.

Simple Zero-Adjustment: Just zero the masses, then rotate the knob.

Capacities: See table below.

Specifications

Product #	SE-8723	SE-8707	SE-8725
Ohaus #	750-S0	760-00	311-00
Type:	Triple-Beam	Triple-Beam	Cent-o-Gram
Capacity:	610 g	610 g	311 g
w/add'l. mass set:	2610 g	2610 g	N/A
Readability:	0.1 g	0.1 g	0.01 g
Tare:	None	225 g	None

Order Information

Ohaus Triple-Beam Balance
(without tare) SE-8723
(with tare) SE-8707
Ohaus Cent-o-Gram Balance SE-8725
Recommended:
Ohaus Additional Mass Set SE-8708

Ohaus Additional Mass Set

SE-8708
(for Triple-Beam Balances)



These additional masses can increase the range of the Ohaus Triple-Beam Balance (SE-8723 and SE-8707) by an additional 2 kg. Included are a 0.5 kg and two 1 kg masses.

Order Information

Ohaus Additional Mass Set SE-8708

Ohaus Hooked Mass Set

SE-8705



Convenient when heavier masses (up to 2.1 kg) are required.

Includes

Masses: 1 x 1000 g, 1 x 500 g, 2 x 200 g, 1 x 100 g, 1 x 50 g, 2 x 20 g, 1 x 10 g

Molded mass holder

Order Information

Ohaus Hooked Mass Set SE-8705

Slotted Mass

SE-8726A Set (10 g resolution)
SE-8704A Set (1 g resolution)
SE-8703A Hanger (50 g)





This 50 gram mass hanger is the standard hanger for the slotted masses shown.

These slotted masses provide medium to heavy mass (up to 1.110 kg) with 1 or 10 gram resolution.

The SE-8726A Set Includes

Masses: 1 x 500 g, 2 x 200 g, 1 x 100 g, 1 x 50 g, 2 x 20 g, 1 x 10 g

The SE-8704A Set Includes

The above masses plus a 5 g, 1 g, and two 2 g. Mass hangers available separately.

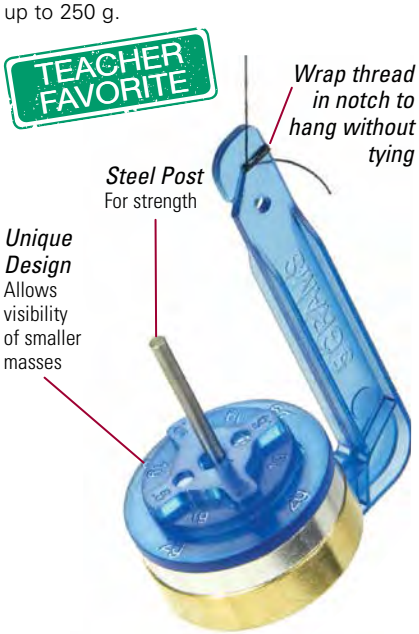
Order Information

10 g Slotted Mass Set SE-8726A
1 g Slotted Mass Set SE-8704A
Slotted Mass Hanger SE-8703A

Mass and Hanger Set

ME-8979 (1/2 g resolution)

PASCO's Mass and Hanger Set features precision 5 gram mass hangers with steel posts, and "holed" masses that will not fall off the hanger. All the masses have their values marked, and each hanger can hold up to 250 g.





Includes

Four mass hangers (5 g each) ± 2%

Brass masses: ± 1%
3 x 100 g 3 x 50 g 6 x 20 g

Aluminum masses: ± 1%
3 x 10 g 3 x 5 g

Plastic masses: ± 2%
3 x 2 g 3 x 1 g 3 x 0.5 g

Molded storage case

Order Information

Mass and Hanger Set ME-8979

Recommended:

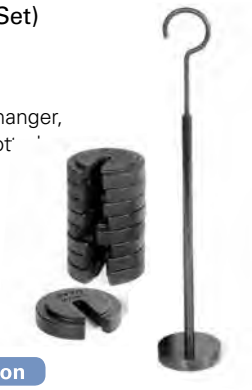
Mass and Hanger Spares Kit ME-8980
(Contains four mass hangers and 10 each of 2 g, 1 g, and 0.5 g plastic masses)

Replacement Mass Sets for ME-8979:

5-gram Mass Set (set of 6) ME-8981
10-gram Mass Set (set of 6) ME-8982
20-gram Mass Set (set of 6) ME-8983
50-gram Mass Set (set of 6) ME-8984
100-gram Mass Set (set of 6) ME-8985

Large Slotted Mass Set

ME-7566 (5 kg Set)



Set Includes

One 0.5 kg mass hanger, and nine 0.5 kg slotted masses.

Diameter of masses: 8 cm.

Height of hanger: 36 cm.

Order Information

Large Slotted Mass Set (5 kg Set) ME-7566

Short Slotted Mass Set

ME-7589 (2 kg Set)



Set Includes

One 0.5 kg mass hanger, and three 0.5 kg slotted masses.

Diameter of masses: 8 cm.

Height of hanger: 15 cm.

Order Information

Short Slotted Mass Set (2 kg Set) ME-7589

Short Mass Hanger ME-7590

Hooked Mass Set

LAB ESSENTIALS

SE-8759



This rugged Hooked Mass Set is made from cast iron and coated with enamel.

Includes

Masses: 1 x 1000 g 1 x 500 g 2 x 200 g
1 x 100 g 1 x 50 g 2 x 20 g
1 x 10 g

Molded mass holder

Order Information

Hooked Mass Set SE-8759

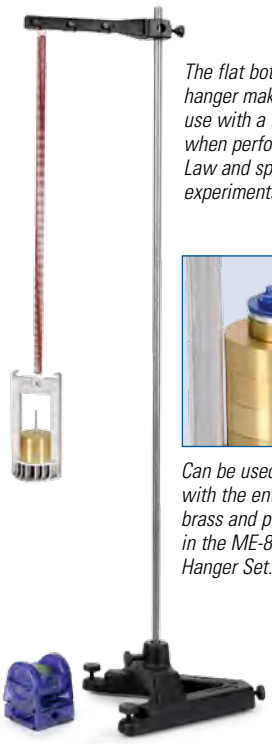
1 kg Mass and Hanger Set

NEW

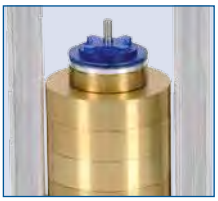
ME-9337 (1 kg set)

Set features a 200 gram cast aluminum mass hanger with a steel post, and four "holed" 200 gram brass masses that will not fall off the hanger. Multiple mass hangers can be used by hooking the top of one into the bottom of another.





The flat bottom on the mass hanger makes it perfect for use with a Motion Sensor when performing Hooke's Law and spring oscillation experiments.



Can be used in conjunction with the entire set of smaller brass and plastic masses in the ME-8978 Mass and Hanger Set.

ME-9337 Includes

(ME-9350) mass hanger and
(ME-9351) set of four masses

Diameter of masses: 5 cm

Height of hanger: 16 cm

Steel pin: 8 cm height, 3.6 mm diameter

Order Information

1 kg Mass and Hanger Set ME-9337

Mass Hanger (200g) ME-9350

200g Masses (set of four) ME-9351

Shown in use with:

Base and Rods ..... p. 171
Equal Length Spring Set ME-8970
Pendulum Clamp ME-9506
Motion Sensor PS-2103A

PASCO Stopwatch

ME-1234

- No alarm or clock
- Memory for stored event times
- Uses one AA battery
- Durable buttons



TEACHER FAVORITE

Two Display Modes: MM:SS.SS (00:25.18) or Decimal Seconds (25.18s)



Are you tired of annoying stopwatch alarms going off all day? Are your students stuck in the clock mode and can't get their stopwatch back into the timing mode? Does your stopwatch stop working after changing that little watch battery? The PASCO Stopwatch solves all these problems!

This stopwatch was designed specifically for science timing. The modes of operation are intuitive and complete instructions are included. The buttons are built to last and it uses a single long-lasting AA battery, which is less expensive than a watch battery (and easier to install).

The PASCO Stopwatch fits comfortably in your hand.



It also sits on the table at a convenient viewing angle.





The EVENT/RECALL button allows you to view the last time, in case students forget to write down their data. The EVENT/RECALL button is also used to store and recall up to nine event times. For example, record a series of events, such as times at which sandbags were dropped along the gym floor.

Specifications

LED Display: Visible indoors and outdoors

Two Display Modes: MM:SS.SS (01:25.34) or Decimal Sec (85.34 s)

Precision: 0.01 sec up to 59:59.99 (MM:SS.SS) or 3599.99 s
Then 1 sec to 99:59:59 (HH:MM:SS) or 359999 s

Max Number of Event Times: Nine

Auto-off: After one hour idle

Can Be Used with a Lanyard (not included)

Includes: AA battery and instruction sheet

Order Information

PASCO Stopwatch ME-1234

PASCO Stopwatch (10 pack)

ME-1235

- Includes fitted foam storage box



Order Information

PASCO Stopwatch (10 pack) ME-1235

Digital Stopwatch

SE-8702C

- Easy to use
- Start/stop/reset



(Appearance may vary)

Features

0.01 Second Resolution: Time up to 10 hours with 0.01 second resolution

Split Timers: Measure two events simultaneously

Countdown Timer with Alarm

Order Information

Digital Stopwatch SE-8702C

Student Timer

SE-8768



(Appearance may vary)

Features

Inexpensive

0.01 Second Resolution

Easy Operation: Start/Stop, Reset and Lap

Order Information

Student Timer SE-8768

Digital Stroboscope

SF-9211

- 1-300 flashes per second (18,000 RPM)
- Digital frequency readout
- Input and output trigger

Front Panel View



Back Panel View



Combines the mesmerizing fun of the traditional strobe with a digital frequency readout for accurate, quantitative data.

Vary the flash rate manually to slow or stop motion, or trigger the flashes with an external signal so they stay in perfect synchronization with motion experiments.

Features

Digital Display: Large, bright digits display the flash rate in Hertz or RPM

Auto Synch: Synchronize the flash with experiments using a 3- to 50-volt input signal

Bright: Xenon flash tube with 14 cm wide reflector

Or Even Brighter: Use one PASCO strobe to trigger another (banana plug connectors needed)

Order Information

Digital Stroboscope SF-9211

PASCO's modular LED Strobe makes it easy for students to visualize motion.

Strobe

ME-6978

- 1 Hz to 500 Hz
- Variable intensity
- Low cost

GREAT DEMO

Unique modular design makes it easy to light any geometry. The Strobe includes the Strobe Control Box and one Strobe Module. Additional Strobe Modules can be purchased separately (see below) for up to a total of four lamp modules per controller. And multiple control boxes can be connected together using the External Trigger. The Strobe Modules have a tilting lamp head on a sturdy base that sits on the table or fastens to a rod stand.

Features

Display frequency in Hz or rpm

Adjustable light intensity

External trigger daisy-chains multiple controllers together

Trigger strobe using external input such as the photogate ME-9498A.

Specifications

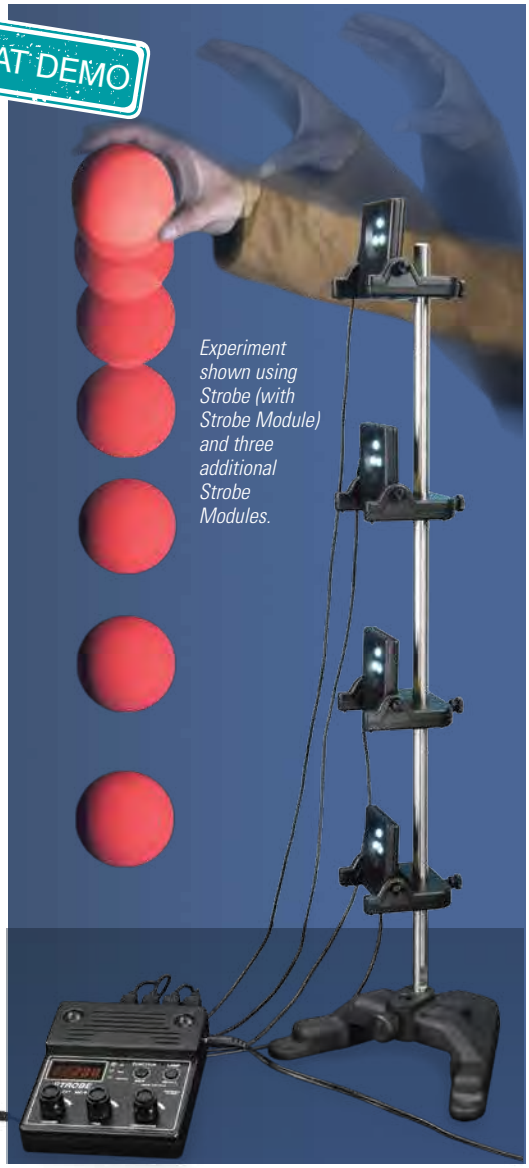
Frequency Range: 1 Hz to 500 Hz

Resolution: 0.1 Hz

Accuracy: 0.1%

Lamp Life: 50,000 hours

Brightness: 230 lumens (peak) per module



Experiment shown using Strobe (with Strobe Module) and three additional Strobe Modules.



Order Information

Strobe ME-6978
(Includes Control Box and one Strobe Module)

Additional Strobe Modules ME-6982
Shown in use with:
Small "A" Base ..... ME-8976 p. 170
Stainless Steel Rod 60 cm long (threaded) ..... ME-8977 p. 170

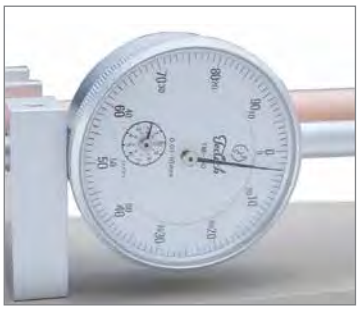
Thermal Expansion Apparatus

TD-8558A

- Easier, more sophisticated, and more accurate than traditional equipment
- Steel, copper, and aluminum tubes included

TEACHER FAVORITE

With PASCO's Thermal Expansion Apparatus, students can accurately and easily investigate the expansion of metals with increasing temperature.

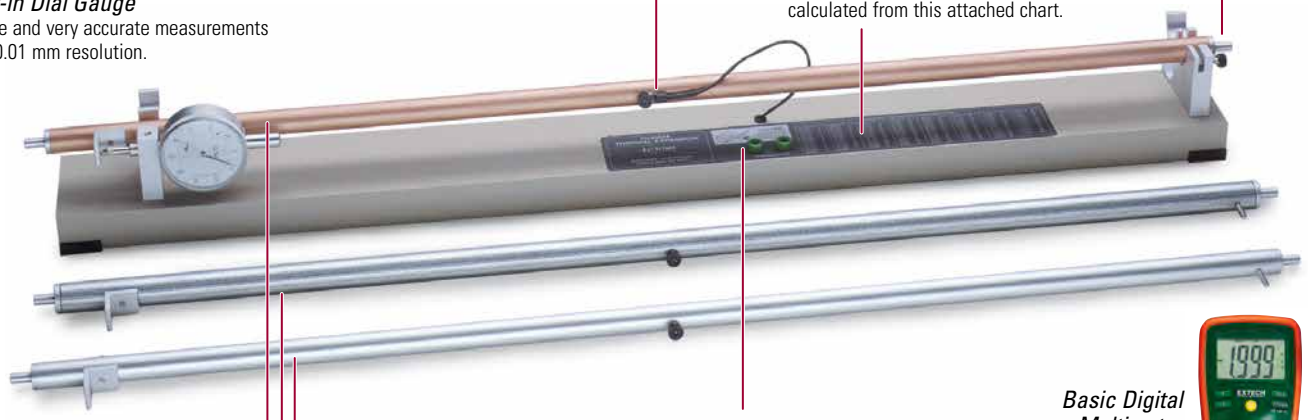


Built-in Dial Gauge
Simple and very accurate measurements with 0.01 mm resolution.

Built-in Thermistor
Together with a digital ohmmeter, directly measures the temperature of the tube (not the fluid moving through it).

Heat with Steam or Water
Steam or water at any temperature can be fed directly through the tube rather than using a troublesome water jacket.

Resistance/Temperature Conversion Chart
Tube temperature is easily calculated from this attached chart.



Three Drop-in Metal Tubes
Steel, copper, and aluminum.

Input Jacks for Digital Ohmmeter
Resistance of the 100 kΩ thermistor is proportional to the temperature of the tube.

Basic Digital Multimeter
(Not included) measures thermistor resistance.



How It Works

Measure the length of a metal tube at room temperature. Then vary the temperature of the tube and remeasure its length to determine the coefficient of linear expansion. The concept is simple ($\Delta L = \alpha L \Delta T$).

Features

Built-in Dial Gauge: While some thermal expansion units only give single point readings of expansion, the PASCO dial gauge continuously measures as the rod expands and gives an accurate measure of the rod expansion (0.01 mm resolution).

Built-in Thermistor: Temperature measurement is simple and accurate. Rather than measuring the temperature of the steam or water moving through the tubes, a 100 kΩ thermistor is placed in direct contact with each tube. Equilibrium is quickly reached, and the temperature can be determined using a digital ohmmeter. (Resistance-to-temperature conversion table is attached to the base.)

Heat with Steam or Water: Since the fluid moves through the tube, there is no troublesome water jacket. The fluid used may be steam or water at any temperature. Students don't need to know the temperature because the thermistor measures the tube temperature directly. This feature allows not only the calculation of the coefficient of linear expansion, but also the determination of the linearity of the relationship between ΔL and ΔT.

Three Drop-in Metal Tubes: Each tube snaps neatly onto the rigid base. The other two can be simultaneously mounted on the base for convenient storage.

Includes

Base: 70 cm long extruded aluminum, with built-in dial gauge and thermistor

Expansion tubes: Steel, copper and aluminum; 16 mm dia.

Foam insulator

Laboratory manual

Order Information

Thermal Expansion Apparatus	TD-8558A	
Required:		
Steam Generator	TD-8556A	p. 186
Basic Digital Multimeter (ohmmeter)	SE-9786A	p. 239

Compact Thermal Expansion Apparatus

TD-8578

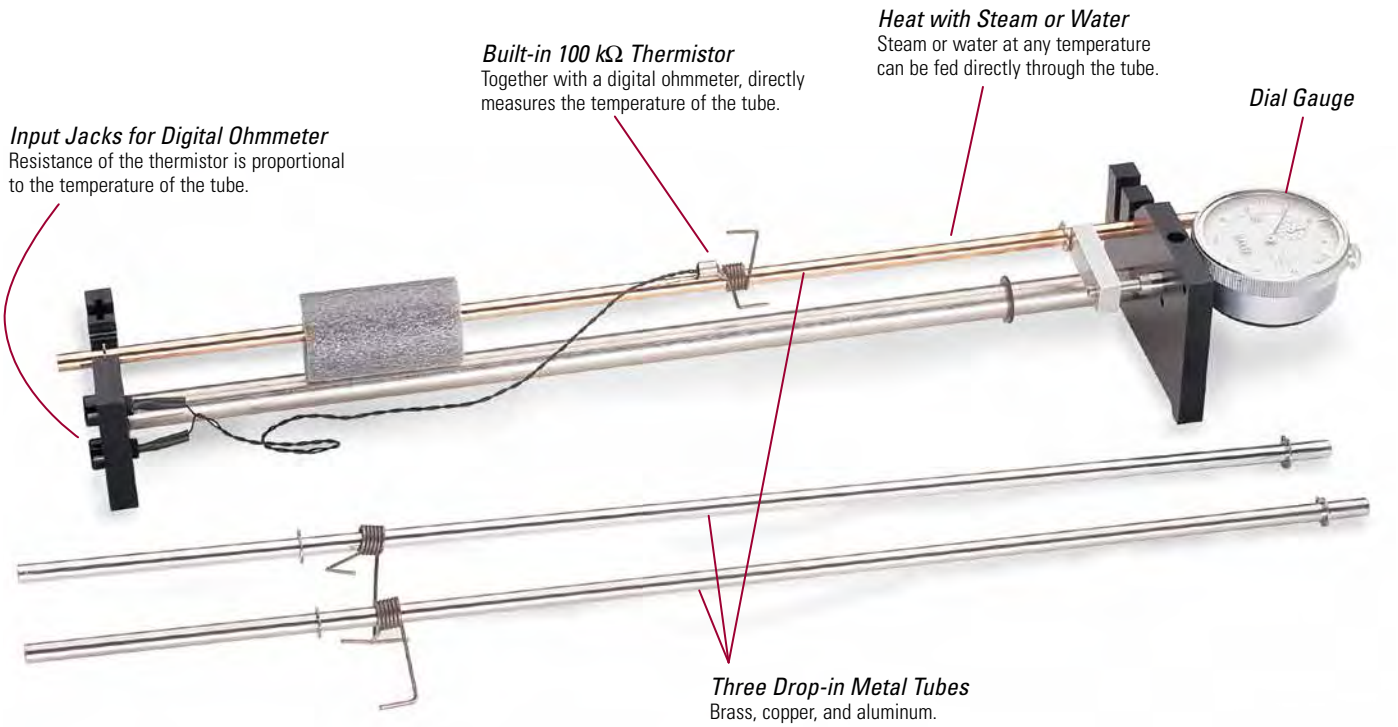
- Compact
- 0.01 mm dial gauge

The Compact Thermal Expansion Apparatus provides experimental results within 5% of the accepted value, yet requires less storage space (tubes are 46 cm long) and is more affordable than the Thermal Expansion Apparatus (TD-8558A).

The free-standing base supports the apparatus on a table without a clamp or stand. The base has storage slots for the 3 tubes. The entire apparatus requires a minimal amount of storage space.

In this experiment, a metal tube expands as steam passes through it. Three tubes (brass, copper, and aluminum) allow students to compare the expansion of different materials. As the tube expands, one end is held fixed, while a clip on the other end pushes against a 0.01 mm division dial gauge.

Initial and final temperatures are determined by measuring the resistance of a 100 kΩ thermistor with a multimeter.





Using the Steam Generator and a digital multimeter, students can accurately find the relationship between temperature and length of a solid.

Includes

0.01 mm dial gauge

Three sample tubes (brass, copper, and aluminum)

Thermistor

Order Information

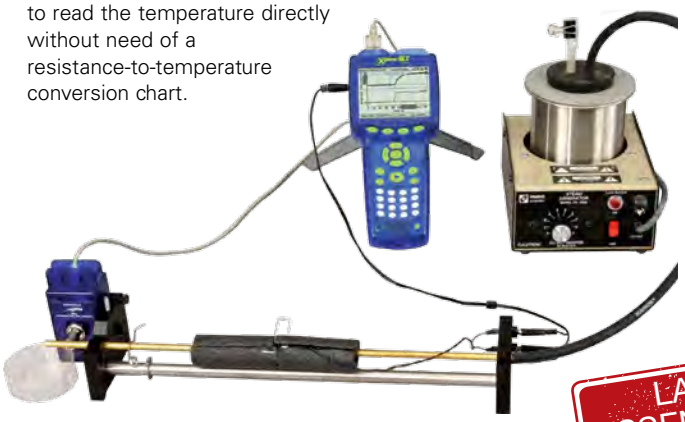
Compact Thermal Expansion Apparatus	TD-8578	
Required:		
Steam Generator	TD-8556A	p. 186
Digital Multimeter (Ohmmeter)	SE-9786A	p. 239
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 214

Computer-Based Thermal Expansion

TD-8579A

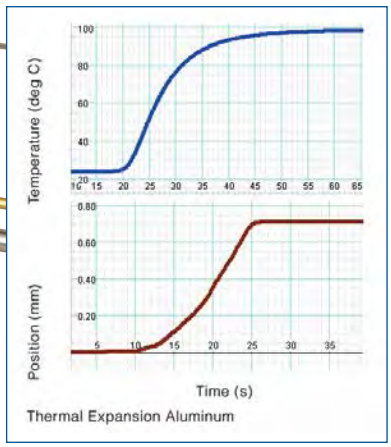
Now students can see the length of the rod increase on a graph as the temperature rises. In this computerized version of the PASCO Compact Thermal Expansion Apparatus, the change in rod length is measured by a Rotary Motion Sensor with a special adapter pin that turns when in contact with the expanding rod. The temperature of the rod is measured using a 10 kΩ thermistor.

The included cable can be connected to either a PASPORT Temperature Sensor or a *ScienceWorkshop* Thermistor Sensor to read the temperature directly without need of a resistance-to-temperature conversion chart.



The Rotary Motion Sensor measures the change in length of the expanding tube.





Temperature (blue line), Expansion (brown line)

Includes

Three Sample Tubes: copper, brass, and aluminum.

Order Information

Computer-based Thermal Expansion	TD-8579A		
Required for use with:	*ScienceWorkshop*	PASPORT	
Steam Generator	TD-8556A	TD-8556A	
Temperature Sensor*	CI-6527A	PS-2125	p. 46, 44
Rotary Motion Sensor	CI-6538	PS-2120A	p. 28

**Note: Model CI-6527A is not compatible with this experiment.*

LAB ESSENTIALS

Steam Generator

TD-8556A

- Variable steam output
- Rapid heating
- Automatic safety shut-off

Hot flowing steam is essential to most introductory thermodynamics experiments. It's inexpensive, plentiful, and the perfect constant temperature heat reservoir.

This Steam Generator brings 3/4 of a liter of water to a boil in ten minutes and provides continuous steam at up to 10 g/min. A baster is also provided to remove hot water for experiments. Includes many convenience and safety features.



See page 185 for additional Steam Generator applications.

Order Information

Steam Generator	TD-8556A

Hot Plate

SE-8830

- Temperature range up to 400°C
- Built-in support rod holder

This compact and durable hot plate can reach up to 400°C in minutes. The cast aluminum top plate provides an even heating surface, and it even has a built-in support rod holder.



This hot plate has a built-in rod holder for a 1/2 inch rod (not included).



Order Information

Hot Plate	SE-8830

Thermal Conductivity Apparatus

TD-8561

- Measure heat flow through five different materials
- Constant temperature differential makes calculations easy
- Easy to use, no mess



One of the most important considerations for buildings in the modern world is their ability to provide good thermal insulation. This apparatus gives students a way to observe and quantify heat flow across a constant temperature differential. Students use five common materials as test samples: glass, wood, polycarbonate, Masonite® and sheetrock.

Features

No Mess: Water from the melting ice runs off into the measuring cup — not on the lab table.

Durable Test Materials: Wood, Masonite, and sheetrock are covered with a thin aluminum sheet for waterproofing and to ensure good thermal contact.

Elevated Steam Reservoir: Hot reservoir is well above the lab table to eliminate heat damage.

How It Works

A block of ice is placed against one side of the test material. The other side is clamped against a steam chamber, establishing a constant 100°C temperature differential. The rate at which the ice is converted to water is a measure of the rate at which heat passes from the steam, through the test material, and into the ice.

Includes

Stand with insulating pads

Steam chamber

Ice molds (2)

Materials: 12.7 cm squares of glass, wood, polycarbonate, Masonite, sheetrock

Plastic tubing to connect steam generator

Instruction manual and experiment guide

Order Information

Thermal Conductivity Apparatus TD-8561

Required:

Steam Generator ..... TD-8556A p. 186

Graduated Cylinder

Ice Melting Blocks

SE-7317

- Great thermal conductivity and heat capacity demonstration



The two Ice Melting Blocks look similar, but are composed of different materials. One block feels cold to the touch, while the other block feels slightly warm. Both blocks are at room temperature but have very different thermal conductivities and heat capacities.

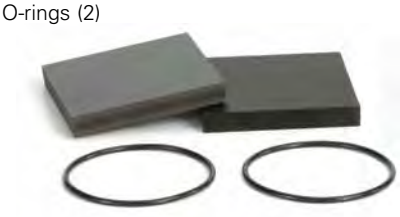
After allowing students to hold the blocks, ask them which block would melt ice more quickly. Place an ice cube on each block and watch their amazement as the "cold" block melts the ice cube within two minutes. Melting the ice cube is barely noticeable on the "warm" block. The "cold" block is aluminum and has a much greater ability to transfer heat to the ice cube or the hand. The "warm" block is plastic, which does not conduct heat as well.

Includes

Aluminum Block

Plastic Block

O-rings (2)



Order Information

Ice Melting Blocks SE-7317

Heat Conduction Apparatus

TD-8513

- Heat flow through metals
- Three types of metals, two cross-sections
- Angstrom's Method

The Heat Conduction Apparatus shows the difference in the rate of heat conduction through bars made of different materials and through bars of the same material that have different cross-sectional areas. The difference in temperature between points along each bar is measured to quantify the rate of heat conduction.

The Heat Conduction Apparatus has four metal bars: one aluminum, one stainless steel, and two brass having different cross-sections. One end of each bar is heated or cooled by applying power to the Peltier Device that is attached to one end. Each bar has two 10 kΩ thermistors embedded in it about 3 cm apart from each other. A cable (male 8-pin mini-DIN to male 8-pin mini-DIN) is supplied to connect the thermistors in this apparatus to the PASPORT Temperature Array, so data can be recorded from all eight sensors simultaneously. Foam insulators are supplied to cover the bars during the experiment.



The DC Power Supply powers the Peltier Device and the thermistors are read by the required Temperature Array.

Specifications

Aluminum, stainless steel, brass bar dimensions:
6.5 cm x 1.2 cm x 0.4 cm
Second brass bar dimensions: 6.5 cm x 0.7 cm x 0.4 cm
Maximum Voltage Input for Peltier: 15 VDC
Board Size: 10 cm x 18.5 cm

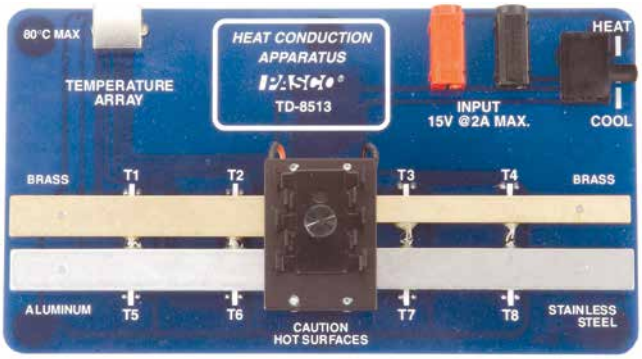
Includes

Heat Conduction Apparatus Circuit Board

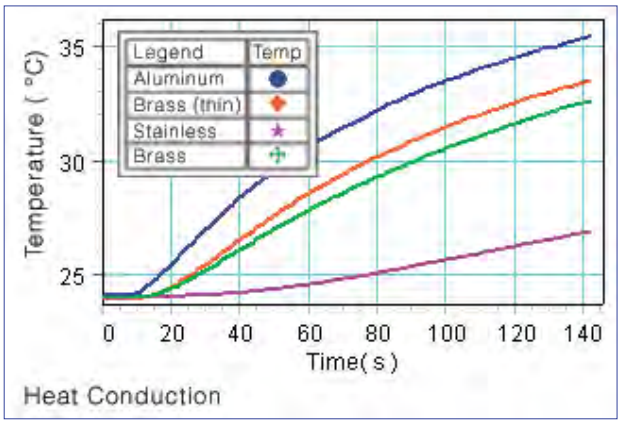
Cable

Foam Insulation (2)

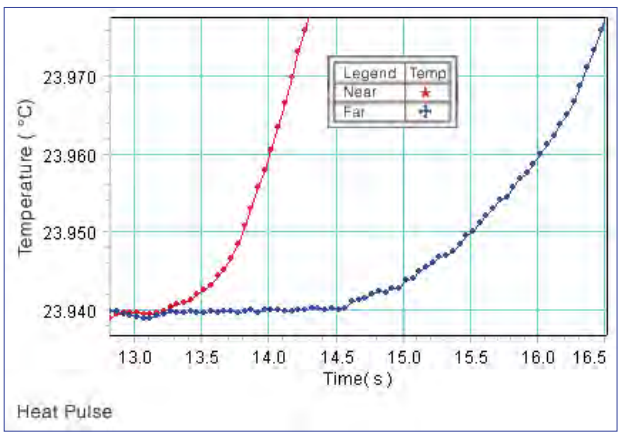




A Peltier Device heats one end of each of the different metal bars. Embedded thermistors detect the rise in temperature along the bars.



Temperature sensors at the end of each type of bar show the different rates of conduction.



The two temperature sensors in the aluminum bar record the difference in time of the temperature rise as heat is conducted through the bar.

Order Information

Heat Conduction Apparatus	TD-8513	
Required:		
Temperature Array	PS-2157	p. 45
Recommended:		
DC Power Supply	PI-9880	p. 231
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 214

Basic Calorimetry Set

TD-8557A

- An affordable introduction to thermodynamics



Styrofoam calorimeter cups (7.5 cm inside diameter, 10 cm deep) have 1.3 cm thick walls for excellent thermal properties. Set includes three different metal samples, a thermometer, plastic tubing, and a water trap that prevents unwanted condensation of steam.

Includes

Six Calorimeters

Alcohol Thermometer: 20°C to 110°C in 1° increments

Samples of Aluminum, Copper and Tungsten: 200 g each

Water Trap and Plastic Tubing

Instruction Manual and Experiment Guide

Order Information

Basic Calorimetry Set	TD-8557A	
Required:		
Steam Generator	TD-8556A	p. 186
Ohaus Triple-Beam Balance	SE-8723	p. 180
Replacement Supplies:		
Calorimetry Cups (set of 6)	TD-8825A	

Specific Heat Set

SE-6849

This specific heat set has five different materials, all having the same mass (80 g). Each has a hole to tie a loop of string to hang the samples in water.



Includes

Aluminum:
1.25" d x 1.5" h

Brass:
3/4" d x 1.5" h

Stainless Steel: 3/4" d x 1.44" h

Zinc: 3/4" d x 1.58" h

Copper: 0.625" d x 1.8" h

Order Information

Specific Heat Set	SE-6849	
Recommended:		
Calorimetry Cups (set of 6)	TD-8825A	

Energy Transfer – Calorimeter

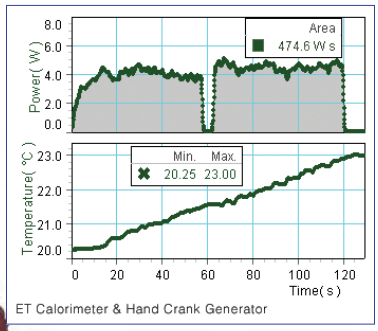
ET-8499

- Compare electrical energy input to changes in internal energy



The Energy Transfer – Calorimeter includes two nested aluminum cups with an air space in between for insulation. While most calorimeters use a coil to heat the water, PASCO's design features a 10 Ω heating resistor mounted to a circuit board. Using temperature, voltage, and current sensors, students can investigate the relationship between the input energy and heat transfer into the water.

Approximately 470 Joules of energy were added to the water using the Hand Crank Generator.



ET Calorimeter & Hand Crank Generator

Includes

Outer Aluminum Cup (8.9 cm tall, 4.7 cm dia)
Inner Aluminum Cup (7.5 cm tall, 3.8 cm dia)
Plastic Lid
Two-Hole Rubber Stopper
Heating Resistor with Input Cables



Order Information

Energy Transfer – Calorimeter	ET-8499	
Recommended for use with ScienceWorkshop:		
Hand Crank Generator	EM-8090	p. 223
Temperature Sensor	CI-6605A	p. 44
Voltage Sensor	UI-5100	p. 52
Current Sensor	CI-6556	p. 52
Recommended for use with PASPORT:		
Hand Crank Generator	EM-8090	p. 223
Temperature Sensor	PS-2125	p. 44
Voltage/Current Sensor	PS-2115	p. 52

Mechanical Equivalent of Heat Apparatus

TD-8551A

LAB ESSENTIALS

- Accurate to 5%
- Rugged ball-bearing construction
- Thermistor— no thermometer to break

This Mechanical Equivalent of Heat Apparatus provides an updated version of one of Joule's most important experiments: converting mechanical work to thermal energy.



How It Works

Turn the crank to perform a measurable amount of work. The crank turns an aluminum cylinder. A flat nylon rope is wrapped several times around the cylinder. As the crank is turned, the friction between the rope and the cylinder is just enough to support a mass hanging from the other end of the rope. This ensures that the torque acting on the cylinder is constant and measurable. A counter keeps track of the number of turns of the crank. The thermal energy is measured by monitoring the temperature of the cylinder using the embedded thermistor.

With this apparatus, the equivalence of work and heat is easily established to within 5%.

Includes

Base, cylinder, crank, and counter with a built-in table clamp

1-gallon can that can be filled with a measured mass of sand or water (if 10 kg of laboratory masses are not available)

3.7 m of flat nylon rope

Laboratory manual including theory, step-by-step instructions, and data tables

Order Information

Mechanical Equivalent of Heat Apparatus	TD-8551A	
Required:		
Basic Digital Multimeter	SE-9786A	p. 239
Triple-Beam Balance	SE-8707	p. 180

A refrigerator (or ice) for cooling the cylinder below room temperature. Calipers and a thermometer for measuring room temperature are helpful, but not necessary.

Replacement Supplies:		
Brush (single)	TD-8583	
Cylinder	TD-8582	

Energy Transfer – Friction

ET-8770

- Demonstrates frictional heating
- Real-time computer measurement of work done and resulting temperature increase
- Brass and aluminum cylinder

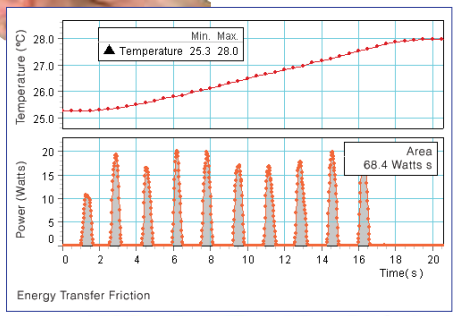
Work is done by pulling on the yellow cord wrapped around the 2.5 cm diameter cylinder and lifting the mass. Using a Rotary Motion Sensor and a Force Sensor, a real-time graph of power versus time can be generated by PASCO Capstone™ Software. The area under this curve is the work performed.

A 10 kΩ thermistor is used to determine the temperature of the cylinder. A PASPORT Temperature Sensor is used to graph the real-time temperature in PASCO Capstone™ Software.



The work done is measured using a Force Sensor and a Rotary Motion Sensor. The amount of thermal energy transferred to the cylinder is measured using a Temperature Sensor.

The area under the Power vs. Time curve shows 68.4 J of work done. The temperature increase of 2.7°C results in 51.3 J (75%) of the work done converted to thermal energy.



Includes

Support base with plastic mounting bolt

Brass and aluminum cylinders

Yellow friction cord

Thermistor temperature cable



Order Information

Energy Transfer – Friction	ET-8770	
Required:		
Small C Clamp (6 pack)	SE-7286	p. 173
Hooked Mass Set	SE-8759	p. 181
Required for use with PASPORT:		
Force Sensor	PS-2104	p. 30
Rotary Motion Sensor	PS-2120A	p. 28
Temperature Sensor	PS-2125	p. 44

Electrical Equivalent of Heat Apparatus

TD-8552

- Investigate the equivalence of heat and electrical energy
- Determine the efficiency of a lightbulb



This Electrical Equivalent of Heat Apparatus is straightforward and accurate. First, fill the clear plastic jar with water and insert the lightbulb. Measure the voltage and current into the bulb to determine the electrical energy input. Then measure the temperature rise of the water to determine the heat that is produced.

Make the measurement once with clear water, so only thermal energy is absorbed. Then measure again with India ink in the water so all the radiant energy is absorbed. The electrical equivalent of heat can then be verified. As a bonus, students can calculate the efficiency of a standard lightbulb.

Includes

Calorimeter: Fully heat-resistant clear plastic jar

Lamp assembly: Lamp is fixed to the lid of the calorimeter and is soldered directly to the terminal posts to minimize resistive losses in the circuit and to prolong the life of the bulb.

Styrofoam insulators (2)

India ink

Order Information

Electrical Equivalent of Heat Apparatus TD-8552

Required:

Power Supply ..... SE-8587 p. 232
or:
equivalent source providing 3 A at 12 V

Digital Multimeter (2) ..... SE-9786A p. 239

Alcohol Thermometer ..... SE-9084B p. 203

Mechanical Equivalent of Heat Tube

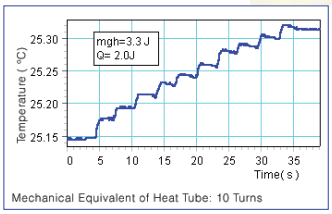
ET-8781

- Compare change in gravitational energy to change in thermal energy
- Monitor real-time temperature changes



How It Works

As the tube is turned over, the steel balls fall the length of the tube and strike the thin metal plate at one end. Embedded in the metal plate is a fast-response thermistor, that is used to continuously measure the temperature of the plate. The thermistor can be directly plugged into either the PASPORT Temperature Sensor or *ScienceWorkshop* Thermistor Temperature Sensor.



The "loss" in gravitational energy is compared to the increase in thermal energy of the metal plate.

Typical Applications

- Conservation of Energy studies
- Analogy for the "disappearance" of kinetic energy during a collision

Includes

Mechanical Equivalent of Heat Tube (70 cm length, 4 cm diameter)

Built-in Fast Response Thermistor Probe

Steel Balls (60)

Order Information

Mechanical Equivalent of Heat Tube ET-8781

Required for use with ScienceWorkshop:

Thermistor Temperature Sensor ..... CI-6527A p. 46

Required for use with PASPORT:

Temperature Sensor ..... PS-2125 p. 44

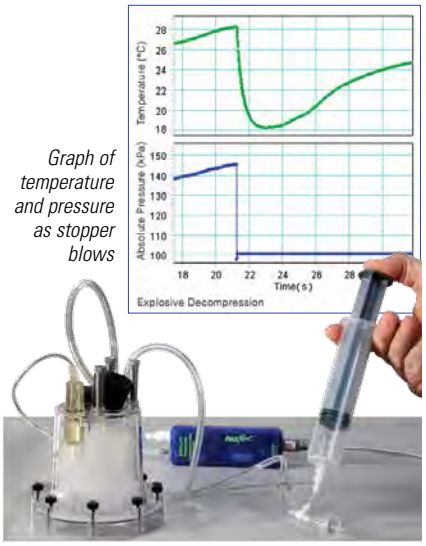
Atmospheric Properties Chamber

ME-6813A

- Recreate the conditions that lead to cloud formation
- Measure changing temperature and pressure
- Built-in fast response temperature probe

Add a small amount of water to the reservoir at the bottom of the chamber. Then seal the chamber and press the rubber stopper into place on the top of the chamber. Students add pressure to the chamber using the included syringe. When the pressure is high enough, the rubber stopper will blow out and a cloud will form.

Included for safety is a stopper catcher, which keeps the stopper contained within the apparatus.



Graph of temperature and pressure as stopper blows

As stopper blows, quick decompression causes cloud to form in chamber.



Order Information

Atmospheric Properties Chamber ME-6813A

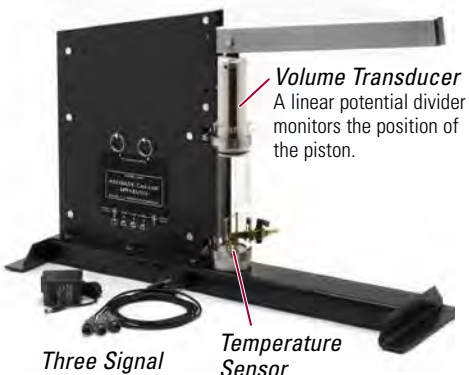
Recommended:

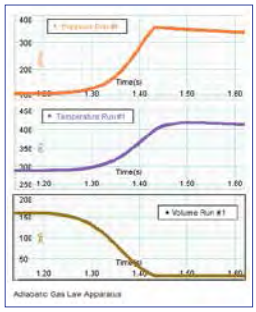
Absolute Pressure/Temp Sensor ..... PS-2146 p. 44

Adiabatic Gas Law Apparatus

TD-8565

- Investigate the compression of gases
- Computer monitors temperature, pressure, and volume





Students monitor pressure, temperature, and volume as a gas is compressed rapidly.

Experiments

PASCO's Adiabatic Gas Law can be used with the 850 Universal Interface. The computer functions as a 3-channel storage oscilloscope, plotting graphs of pressure, temperature, and volume, as well as integrating the area under a pressure versus volume curve to determine the work done on the gas.

Includes

Adiabatic Gas Law Apparatus

Instruction Manual, Experiment Guide

Signal Cables: 3.5 mm plug to 5-pin DIN

Power Adapter: 9 V DC @ 1 A

Order Information

Adiabatic Gas Law Apparatus TD-8565

Required: A computer with an interface that will accept three analog signals simultaneously via 5 or 8-pin DIN connectors such as: PASCO's ScienceWorkshop 500, 750, and 850 Interfaces.

Compression Igniter

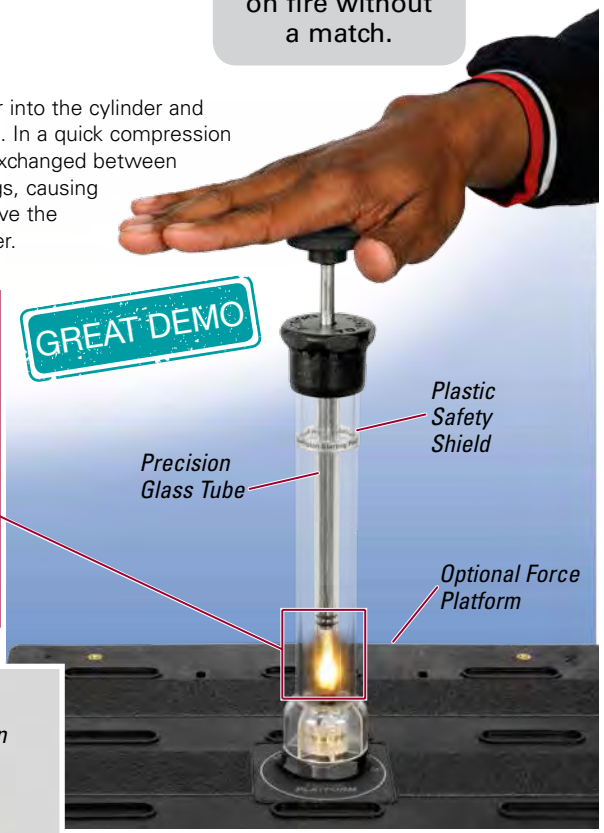
TD-8577

- Adiabatic compression ignites paper!
- Works every time
- Durable and cleanable

Students will be amazed to see the paper catch on fire without a match.

Put a small piece of tissue paper into the cylinder and quickly push down on the piston. In a quick compression there is no time for heat to be exchanged between the air inside and its surroundings, causing the temperature to rise well above the combustion temperature of paper.

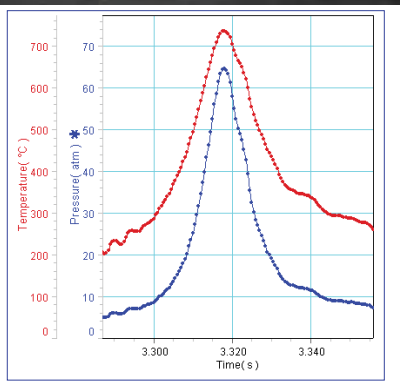






This Compression Igniter has been specially designed to be cleanable. The bottom screws off to clean out the soot and to load the paper. The large piston handle decreases the pressure on your hand and makes it easier to hit the piston quickly.

The glass tube is surrounded by plastic for safety. In the event that the glass tube breaks, the glass tube can be replaced.



Pressure data is calculated using the force measured by the Force Platform. Assuming Adiabatic, the data shown gives a compression ratio of nearly 20:1, and a peak temperature of over 700 °C.

Includes

Compression Igniter

Spare Glass Tube with "O" Rings

Cleaning Wire

Complete Instructions with Theory



Order Information

Compression Igniter TD-8577

Replacement Tubes (2) TD-8498A

Shown in use with:

Force Platform

PASPORT ..... PS-2141 p. 33

ScienceWorkshop ..... CI-6461 p. 33

Ideal Gas Law Apparatus

TD-8596A

TEACHER FAVORITE

- Experimentally determine the Ideal Gas Law
- Large syringe for accurate volume measurements
- Built-in fast response thermistor

Investigating the Ideal Gas Law is simple using PASCO's Ideal Gas Law Apparatus. By connecting a Pressure Sensor and a Temperature Sensor to the syringe, students can quantitatively look at the relationships between pressure, temperature, and volume.

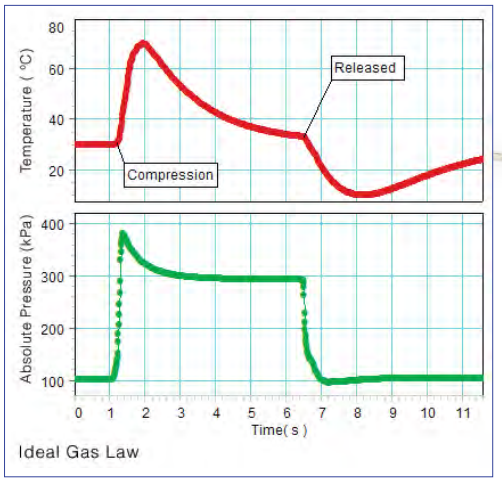
How It Works

A low thermal mass thermistor is mounted within the syringe for real-time measurement of temperature changes inside the syringe. Tubing and a quick-connect port allows a Pressure Sensor to be directly connected to the syringe. As the plunger of the syringe is depressed, the volume decreases while pressure and temperature increase. The data will help students better understand the Ideal Gas Law.

$$PV = nRT$$

A mechanical stop is included on the syringe plunger to prevent damage of the thermistor within the syringe and to allow quick (adiabatic) volume changes.

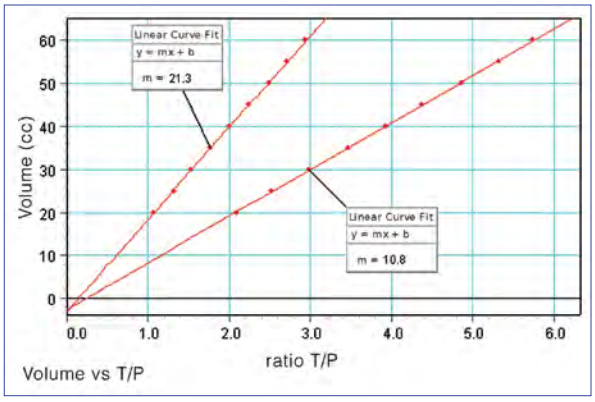




The measured values of Temperature and Pressure are used to calculate the Volume. The student can compare this calculated volume to the actual volume on the syringe in real-time.

Typical Applications

- Discover or verify the Ideal Gas Law
- Investigate relationships such as pressure vs. temperature (Gay-Lussac's Law), pressure vs. volume (Boyle's Law) and temperature vs. volume (Charles' Law)
- Calculate the number of moles of air in the syringe based on pressure, temperature, and volume measurements



Slope of the Volume vs. $\frac{T}{P}$ graph equals nR.



Includes

Ideal Gas Law Syringe
Built-in Fast Response Thermistor Probe
Quick-Connect Pressure Port

Order Information

Ideal Gas Law Apparatus	**TD-8596A**	
Required for use with ScienceWorkshop:		
Thermistor Temperature Sensor*	CI-6527A	p. 46
Absolute Pressure Sensor	CI-6532A	p. 43
Required for use with PASPORT:		
Pressure/Temperature Sensor	PS-2146	p. 44
or		
Temperature Sensor	PS-2125	p. 44
Absolute Pressure Sensor	PS-2107	p. 43

**Note: Model CI-6527 is not compatible with this experiment.*

Absolute Zero Apparatus

TD-8595

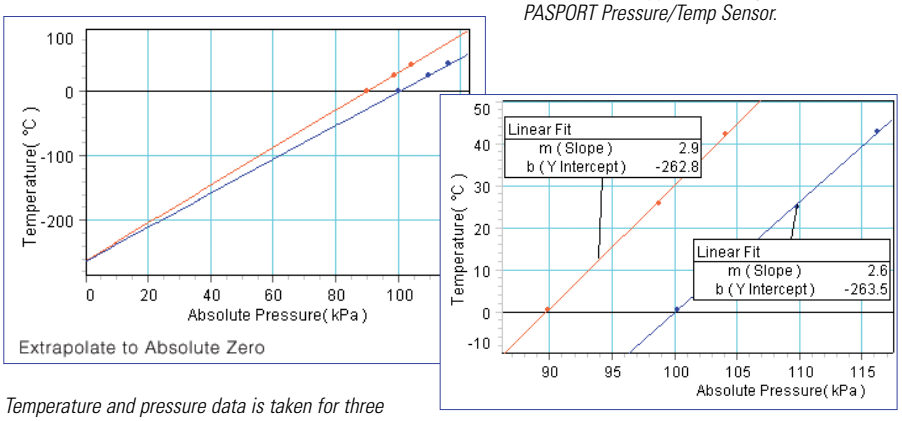
- Constant volume sphere
- Measure pressure and temperature Directly using PASCO Sensors
- Empirically determine the Absolute Zero Temperature

LAB ESSENTIALS



Absolute Zero Apparatus being used with PASPORT Pressure/Temp Sensor.

The Absolute Zero Sphere is an effective tool for determining absolute zero temperature. Connect a Pressure Sensor and Temperature Sensor (either PASPORT or *ScienceWorkshop*) and immerse the sphere in water baths of several different temperatures. As the pressure and temperature change, a graph displays these changes in PASCO Capstone™. Once the data is collected, students can use a linear fit to extrapolate the value of absolute zero.



Temperature and pressure data is taken for three temperature water baths. The experiment is repeated with a different amount of gas initially in the sphere. The slopes of the two graphs reflect the change in the number of moles of gas, and both graphs extrapolate to about the same value for absolute zero.

Typical Applications

- Experimentally determine the temperature of absolute zero
- Investigate the relationship between pressure and temperature (Gay-Lussac's Law)
- Discover the Ideal Gas Law

Includes

Absolute Zero Sphere

Built-in Fast Response Thermistor Probe

Quick Connect Pressure Port



Order Information

Absolute Zero Sphere **TD-8595**

Required:

Thermistor Temperature Sensor* (ScienceWorkshop)	CI-6527A	p. 46
Absolute Pressure Sensor (ScienceWorkshop)	CI-6532A	p. 43
Pressure/Temperature Sensor (PASPORT)	PS-2146	p. 44
or		
Temperature Sensor (PASPORT)	PS-2125	p. 44
Absolute Pressure Sensor (PASPORT)	PS-2107	p. 43
850 Universal Interface		p. 14-17

**Note: Model CI-6527 is not compatible with this apparatus.*

Molecular Motion Model

SF-8563

- Demonstrate the kinetic theory of gases
- Model the relationship between pressure, volume, and temperature



Maxwell's kinetic theory of gases is the long-established point of entry into the difficult but rewarding theory of statistical mechanics. This Molecular Motion Model provides a concrete, qualitative introduction.

Fifty-one chromed steel balls represent the molecules of a gas in a closed vessel. Heat is simulated by supplying vibrations from a wave driver. When this external energy is applied, the steel balls exert a pressure on the container, forcing the top of the container upward. The relationship between temperature, pressure, and volume is clearly demonstrated. Students also gain insight into the effects of temperature and height on the density of an ideal gas in a gravitational field. It can be used on an overhead projector.



As the "temperature" rises, the "gas" expands.

Order Information

Molecular Motion Model **SF-8563**

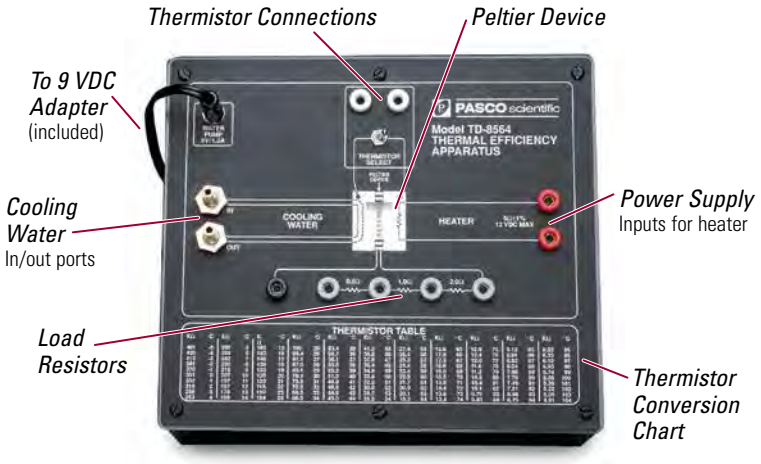
Required:		
Mechanical Wave Driver	SF-9324	p. 244
Required:		
Sine Wave Generator	WA-9867	p. 242
or		
Function Generator	PI-8127	p. 236
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 214

Thermal Efficiency Apparatus

TD-8564

- Real investigation into Carnot Efficiency
- Heat engines and heat pumps
- 5% accuracy

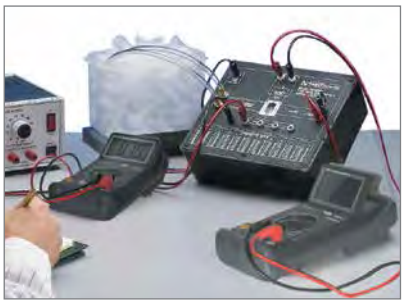
The Thermal Efficiency Apparatus is a real heat engine that can be used to investigate and clarify the principles at work in Carnot's ideal heat engine. Like Carnot's model, it can be operated as a heat engine, converting heat into work, or operated in reverse as a heat pump, transferring heat from a cold source to a hot source. Results are typically accurate to better than 5%.



How It Works

The key element is a Peltier device, a semiconductor that turns thermal energy into electrical energy. The device is sandwiched between two blocks of aluminum, which act as the hot and cold reservoirs. One block is water-cooled using the built-in pump. The other is electrically heated. A 100 kΩ thermistor is implanted in each block so temperatures can be measured with a digital ohmmeter.

The energy supplied to this heat engine is the electrical energy used to heat the aluminum block. The heat engine does work by running a current through the load resistor. Both the energy in and the work out are easily determined by measuring currents and voltages.



Measure the real efficiency of a heat engine when operated between different temperature differentials.

Typical Experiments

1. Real Efficiency vs. Temperature Difference
2. Carnot Efficiency
3. Heat Pump Coefficient of Performance
4. Thermal Conductivity
5. Load for Optimum Performance

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Order Information

Thermal Efficiency Apparatus	TD-8564	
Required:		
Basic-Digital Multimeter(s) (four needed)	SE-9786A	p. 239
Triple Output Power Supply	SE-8587	p. 232
or:		
Two voltmeters, two ammeters, one ohmmeter and a power supply providing 12 VDC @ up to 3 A		
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 214

How Peltier devices work

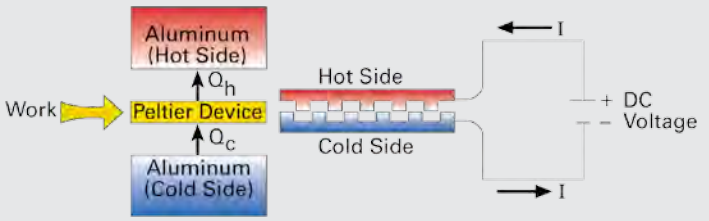
The apparatus on pages 195 and 196 use a thermoelectric Peltier device as the basis of the heat engine/heat pump system.

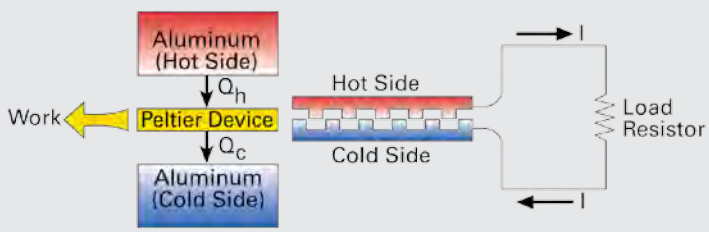
Heat pump

A Peltier device is constructed of two ceramic plates with p and n semiconductors in between. As DC current is passed through the device, one plate warms and the other plate cools, and the voltage across and current through the Peltier device can be measured.

Heat engine

Using the temperature difference across its plates, the Peltier device generates current as the plates move to an equilibrium temperature. The current and voltage generated by the Peltier device can be used with output load resistors to determine the energy generated. The generated energy can be compared to the input energy to determine appropriate efficiencies. Furthermore, the effects on efficiency when changing the load resistance or temperature difference between the plates can be examined.





Energy Transfer – Thermoelectric

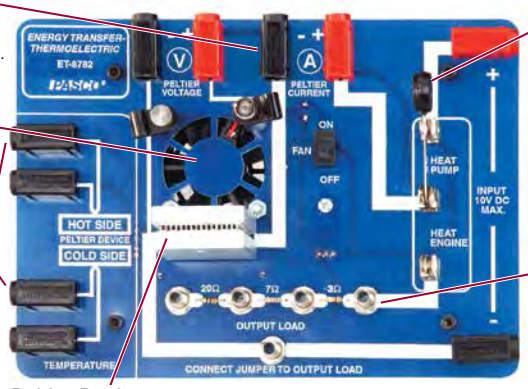
ET-8782

- Fully functional heat pump and heat engine
- Use voltage and current sensors to measure energy conversions
- Temperature sensors can monitor both reservoir temperatures
- Models a refrigeration system

Output Ports
Measure current and voltage in Peltier device to determine energy input.

Cooling Fan
Provides additional heat dissipation from hot side of Peltier device.

Temperature Ports
A 10 kΩ thermistor mounted in each aluminum plate of the Peltier device is used to continuously measure temperature.

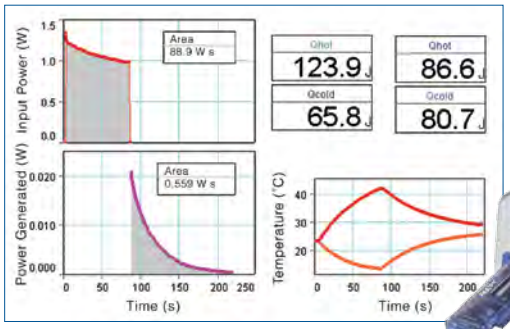


Knife Switch
Use to toggle between heat engine and heat pump modes of operation.

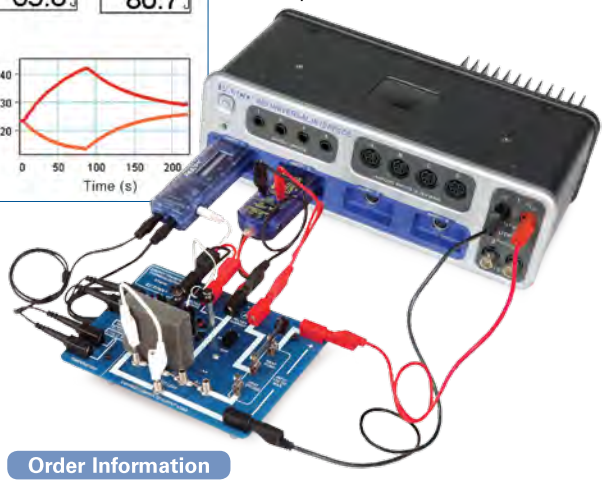
Load Resistors
For output efficiency studies of the Peltier device.

Peltier Device
Two aluminum plates are fastened to each side of the semiconductor Peltier device. One plate heats while the other cools when DC current passes through the device.

The Energy Transfer - Thermoelectric circuit board helps students better understand heat engines and heat pumps. Using a Peltier device, cooling and heating effects can be observed and measured using PASCO probeware. In addition, a cooling fan, heat sink, and foam insulation can be used to determine their effect on the heating and cooling of the Peltier device.



As the device is switched from heat pump to heat engine, PASCO Capstone™ displays Power, Energy, Heat Transfer, and Temperature.



Includes

Energy Transfer – Thermoelectric Circuit Board
Heat Sink
Foam Insulation (2)
Thermistor Temperature Cables (2)
Short Patch Cords (8)



Order Information

Energy Transfer – Thermoelectric	ET-8782	
Required:		
Power Supply (18 Volt DC, 5 A)	SE-9720A	p. 232
Recommended:		
Voltage/Current Sensor	PS-2115	p. 52
Quad Temperature Sensor	PS-2143	p. 45
Fast Response Temperature Probe	PS-2135	p. 45
850 Universal Interface		p. 14-17

Thermoelectric Converter

TD-8550A



- Demonstrate the First Law of Thermodynamics
- Reversible

Features

Demonstrates that a temperature differential is essential for extracting usable energy

Produces electrical energy from a temperature differential

Produces a temperature differential with electrical energy

15 cm tall with 6 cm diameter fan

How It Works

The Thermoelectric Converter uses a series of semiconductor thermoelectric cells to convert thermal energy into electrical energy. The output from the cells drives a small electric motor.

Heat to Electrical Energy

Place one leg of the Thermoelectric Converter into cold water, the other into hot. The fan turns as the converter draws energy from the hot source (typically a 50°C temperature differential is required).

Electrical Energy to Heat

Pass a current (3 A DC at 5 V) through the Thermoelectric Converter. It acts as a heat pump. One leg becomes warmer while the other becomes cooler.



When a temperature differential is established between the two legs, the fan turns.

Order Information

Thermoelectric Converter	TD-8550A	
Required:		
Containers for holding hot water, cold water, etc.		
Triple Output Power Supply	SE-8587	p. 232
Partial Immersion Thermometer	SE-9084B	p. 203

Glass Stirling Engine

SE-8636



See the pistons at work. Look inside the glass cylinders at the Stirling Cycle principle in action. This engine is extremely interesting to watch, is well built, and runs at speeds up to 1500 RPM. To illustrate the versatility of a Stirling Engine, we provide a burner for denatured alcohol and a platform for solid fuel. A sample quantity of ESBIT dry fuel is supplied with the engine as well.





Both cylinders are transparent so the action of the pistons can be viewed.

Features

Gyro-quality ball bearings

Machined flywheel

Aluminum cooling fins

Replaceable,adjustable Pyrex® heat cap

Replaceable Pyrex power cylinder

Dual fuel capability

Solid hardwood platform

Completely assembled and ready to run

Specifications

9" length x 4" height x 6" width.

Order Information

Glass Stirling Engine SE-8636

Low Delta-T Stirling Engine

SE-8576A

- Runs on 4˚C ΔT
- Ultra-low Friction



The Stirling Engine runs on the heat from a warm hand (approximately a 4°C differential from room temperature). This beautifully made engine featuring high precision components, low-friction graphite piston, ball-bearings, and counter-weighted cranks will amaze students. When it's not used in class, teachers can set it on the back of their computer monitor and explain thermodynamics to students who come into their office.

Order Information

Low Delta-T Stirling Engine SE-8576A

Stirling Engine

SE-8562



This sturdy engine is manufactured completely from precision-machined metal parts. Simply add a little alcohol for fuel and a match (denatured is recommended—do not use rubbing alcohol).

The included book, *Stirling Cycle Engines*, includes over 100 pages of history, illustrations, and descriptions of the operation of various Stirling engines.

Order Information

Stirling Engine SE-8562

Required: Denatured Alcohol

"Visible" Stirling Engine

SE-8575



A Stirling Engine is a straightforward, practical example of a heat engine. A piston coupled to a foam air displacer shuffles air back and forth between hot and cold reservoirs. The expansion and contraction of air as it is heated and cooled drives the engine.

This "Visible" Stirling Engine will run while sitting on top of an ice bath, a hot coffee mug, or even a dish of ice cream. It provides a vivid demonstration of the thermodynamics of a Stirling Engine.

Features

Easily Visible: All movable parts are clearly visible for a more in-depth demonstration

Small Temperature Differences: Runs on temperature differentials as low as 20°C

Flexible Piston: Piston is a gray silicone rubber diaphragm that moves so students can see the air expand and contract



Order Information

"Visible" Stirling Engine SE-8575

Visible Stirling Engine Kit

SE-8590

This kit includes all the parts and instructions to build the Visible Stirling Engine shown above. No machining is required. Some common hand tools and glue are required but not included.

Order Information

Visible Stirling Engine Kit SE-8590

Heat Engine/Gas Law Apparatus

TD-8572

- Near-frictionless piston and cylinder system
- Demonstration or computer data collection
- Heat Engine and Gas Law experiments

An affordable, general-purpose apparatus for quantitative experiments involving the Ideal Gas Law and for investigations of a working heat engine.

Features a nearly friction-free piston/cylinder system. The 32.5 mm diameter graphite piston fits snugly into a precision-ground Pyrex® cylinder so that the system produces almost friction-free motion of 10 cm and minimal leakage.

Specifications

Piston diameter: 32.5 mm

Maximum piston displacement: ≈10 cm

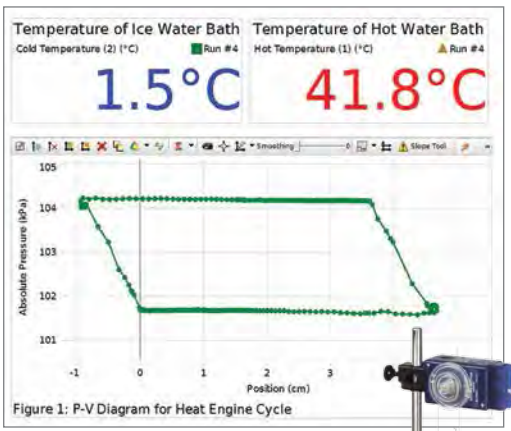
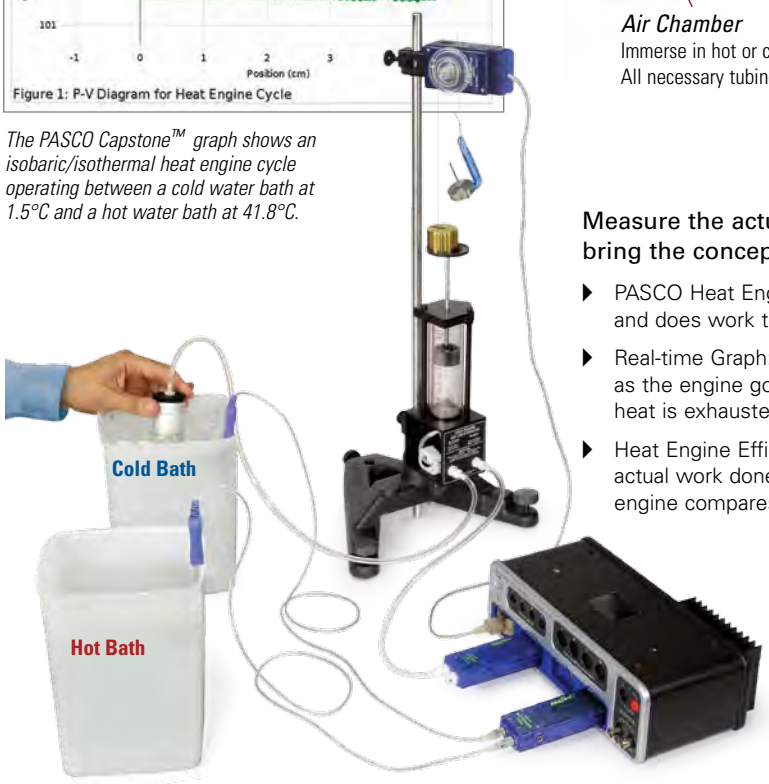


Figure 1: P-V Diagram for Heat Engine Cycle

The PASCO Capstone™ graph shows an isobaric/isothermal heat engine cycle operating between a cold water bath at 1.5°C and a hot water bath at 41.8°C.



When the air chamber is moved from the cold water bath to the hot bath, the piston moves up and lifts the 200 g mass, doing work. The mass is removed, and then the air chamber is returned to the cold bath, creating an isobaric/isothermal cycle.

LAB ESSENTIALS



Mass Platform
Add a mass to do work experiments.

Locking Screw
Secures piston in any position for fixed volume.

Precision-bore Pyrex Cylinder Inside a Protective Plastic Shield

Millimeter Scale
Measures piston displacement.

Rod Clamp Mount
Mount engine on a rod stand.

Ultra-Low-Friction Graphite Piston

Quick-Connect Ports
Two ports connect to the air chamber tubing or to a Low Pressure Sensor.

Air Chamber
Immerse in hot or cold water. All necessary tubing is included.

Two Port Shut-off Valves

Measure the actual efficiency of a real heat engine, and bring the concept of P-V diagrams to life

- PASCO Heat Engine: Extracts heat from a large hot-water reservoir and does work to lift a weight.
- Real-time Graph: The heat engine cycle is traced on a Pressure vs. Volume graph as the engine goes through each part of its cycle, closing the cycle as waste heat is exhausted to the ice-water reservoir.
- Heat Engine Efficiency: Students compare the area inside the P-V cycle to the actual work done lifting the weight, and see how the efficiency of this heat engine compares to the theoretical maximum.

Heat Engine Accessory

TD-8581

The Heat Engine Accessory includes a set of parts for those items in the Heat Engine/Gas Law Apparatus most likely to need replacement after extensive use.



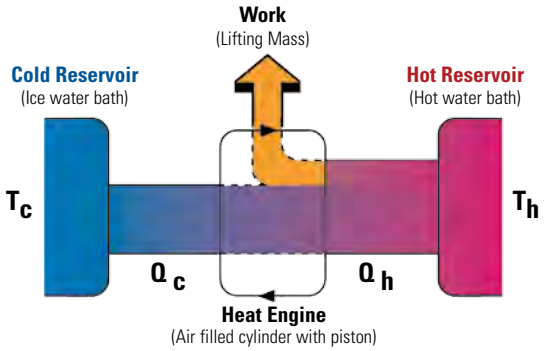
Includes

Air Chamber
Rubber Stoppers (one and two hole)
Tubing with Quick Connect Fittings
Shut-off Valve and One-way Valve

Order Information

Heat Engine Accessory TD-8581

Give meaning to the abstract drawing of a heat engine cycle and let your students see the connection to the real world.





Includes

Heat Engine
Air Chamber
Rubber Stoppers (one and two hole)
Tubing with Quick Connect Fittings
Shut-off Valve and One-way Valve

Order Information

Heat Engine/ Gas Law Apparatus TD-8572

Shown in use with:

850 Universal Interface	UI-5000	pp. 14-17
Dual Pressure Sensor	PS-2181	p. 42
Rotary Motion Sensor	PS-2120A	p. 28
3 Liter Plastic Container Set (2)	ME-7559	p. 179
Small "A" Base	ME-8976	p. 170
60 cm Rod	ME-8977	p. 170

Small Piston Heat Engine

TD-8592

- Small piston (8.1 mm dia.) is more sensitive to pressure and temperature changes
- Connect to heat engine to study Pascal's Principle

The Small Piston Heat Engine features a piston with one-quarter the surface area of the original Heat Engine. It includes the same high-quality Pyrex® cylinder and low-friction graphite piston. In addition, the Quick Connect ports allow the two heat engines to be used with one another or with the same set of accessories.



Pascal's Principle is demonstrated by connecting two pistons of different diameters. More weight is required on the bigger piston to balance the weight on the smaller piston. Shown with Heat Engine.



Typical Applications

- Investigate Pascal's Principle
- Demonstrate a Real-Time Heat Engine Cycle

Includes

Small Piston Heat Engine
Air Chamber with Rubber Stopper
Plastic Tubing with Quick-Connect Fittings



Order Information

Small Piston Heat Engine TD-8592

Solar Constant Set

TD-8497

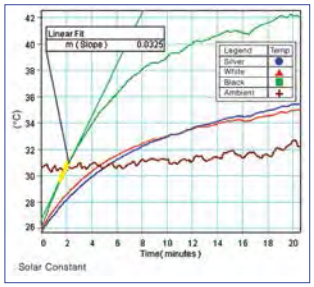
- Measure the temperature of three cylinders in real-time
- Discover the rate at which radiant energy Is received from the sun



The Solar Constant Set includes five cylinders, three of which have identical size and mass. One cylinder is painted white, one is painted black, and one has a shiny finish. A black brass cylinder of equal size and a black aluminum cylinder of twice the radius are also included. Using the included bracket and a standard ring stand, these cylinders can be used to discover the solar constant or to simply compare the energy transfer to the various cylinders.

How It Works

The cylinders are each placed on a Temperature Sensor and secured in the bracket. The cylinders are then taken outside and positioned so that each cylinder is perpendicular to the sun's light rays. Using a fourth temperature probe (such as our Fast Response PS-2135), the ambient temperature can be measured throughout the entire experiment. Collect temperature vs. time data for approximately 20 minutes.



Data shows that the black cylinder heats up most quickly. After 20 minutes the white cylinder is the coolest. The slope of the temperature vs. time graph shows the rate of temperature change when the black cylinder reaches ambient temperature. This slope, along with the mass and surface area of the cylinder, gives a value for the solar constant of 1150 W/m².



Includes

Black, White, and Polished Aluminum Cylinder
1.9 cm dia x 3.8 cm long

Black Brass Cylinder (same size)

Black Aluminum Cylinder (twice the radius)

Mounting Bracket with Rod Clamp

Order Information

Solar Constant Set	TD-8497	
Required for use with PASPORT:		
Quad Temperature	PS-2143	p. 45
Temperature Probe (three needed)	PS-2153	p. 45
Required for use with ScienceWorkshop:		
Temperature Sensor (three needed)	CI-6605A	p. 44

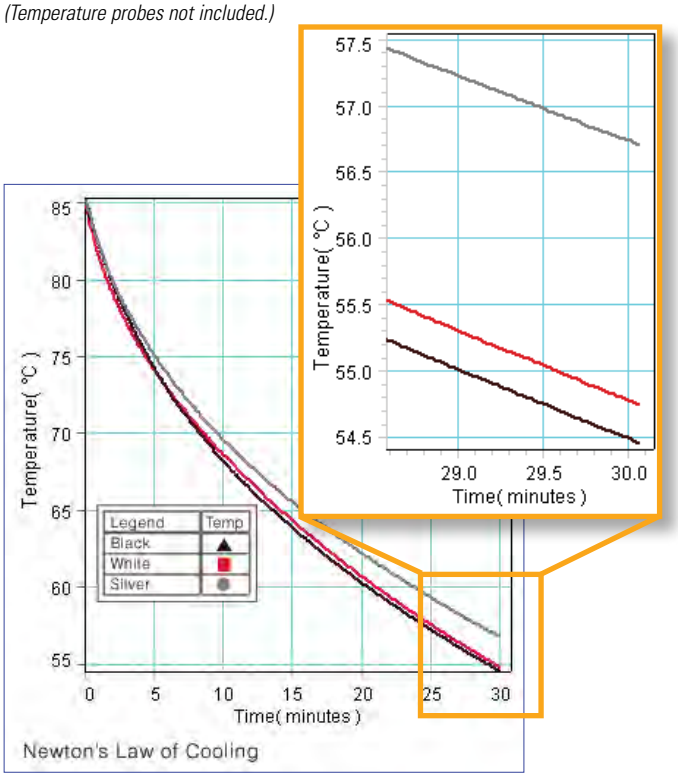
Radiation Cans

TD-8570A



These three aluminum cans have different surface finishes: silver (unpainted), white, and flat black. They are 15 cm high and hold about 350 ml of water. Their large thermal mass ensures good results with both temperature probes and standard glass thermometers. Fill them with cool water and place them outside in the sunlight to investigate the effect of the surface finish on solar heating. Or place them inside filled with hot water to discover Newton's Law of Cooling.

(Temperature probes not included.)



The black, white, and silver Radiation Cans are filled with hot water and allowed to cool.

Order Information

Radiation Cans (set of three)	TD-8570A

Thermal Radiation Laboratory

TD-8855



With the Radiation Sensor, a versatile Radiation Cube, and the Stefan-Boltzman Lamp, four key experiments in thermal radiation can be performed.

Students begin with a study of thermal radiation from different types of surfaces at the same temperature. The Thermal Radiation Cube has four different surfaces that can be monitored (black matte, white matte, polished aluminum, and dull aluminum). The cube is heated electrically with a 100-watt bulb (its output can be varied). The thick aluminum walls assure the same temperature on all four walls to within a fraction of a degree. The Radiation Sensor provides an accurate measure of thermal radiation throughout the infrared region. Its output is a voltage that is proportional to the intensity of radiation.

Another important introductory experiment is the Inverse Square Law. The Stefan-Boltzman Lamp uses a special bulb to provide a near-perfect point source, providing accurate results.

Finally, students can verify the Stefan-Boltzman Law for both low and high temperatures by using the Radiation Cube for the low temperatures and the Stefan-Boltzman Lamp for the high temperatures.







Typical Experiments

With Teacher's Guide and Sample Data.

1. Introduction to Thermal Radiation
2. Stefan-Boltzman Law at Low Temperatures (Rrad = σT^4)
3. Inverse Square Law
4. Stefan-Boltzman Law at High Temperatures

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Includes

Thermal Radiation Cube
Stefan-Boltzman Lamp
Radiation Sensor

See this page for component details.

Order Information

Thermal Radiation Laboratory TD-8855
Required:
Basic Digital Multimeter ..... SE-9786A p. 239
Low Voltage Power Supply ..... SF-9584B p. 233
Shown in use with:
2 Meter Patch Cord Set ..... SE-9415A p. 214

Thermal Radiation Cube (Leslie's Cube)

TD-8554A



▸ Low-temperature radiation source

Features

Electrically Heated: The 100-watt bulb inside eliminates the danger of an open flame and the inconvenience of water-heated cubes.

Thick Aluminum Walls

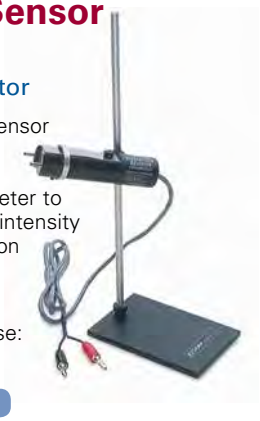
Thermistor: A 100 kΩ thermistor embedded in one wall for temperature measurement.

Order Information

Thermal Radiation Cube TD-8554A
Required:
Radiation Sensor TD-8553
Basic Digital Multimeter ..... SE-9786A p. 239

Radiation Sensor

TD-8553



▸ Radiation detector

Point the Radiation Sensor toward any object – open the shutter and read the digital voltmeter to measure the relative intensity of the thermal radiation emitted.

Flat Spectral Response: 0.6 to 30 µm

Order Information

Radiation Sensor D-8553
Required:
Basic Digital Multimeter ..... SE-9786A p. 239

Stefan-Boltzman Lamp

TD-8555



▸ A high-temperature radiation source

The temperature of this 12-V incandescent lamp filament can be accurately determined by measuring the voltage and current that students supply to the lamp (a graph of temperature versus resistivity is provided).

Order Information

Stefan-Boltzman Lamp TD-8555

Thermal Cavity

TD-8580A

- Three different surfaces
- Cavity radiator
- Control and measure temperature
- Computer-compatible



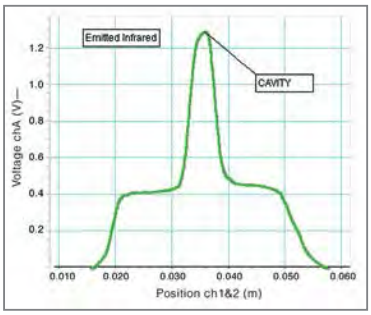
This version of Leslie's thermal radiation cube has a hole that acts as a cavity radiator. The aluminum cube has four different surfaces (black, white, polished, and matte) to show students how surfaces radiate differently.

Use an Infrared Sensor to detect the amount of radiation from each surface. The cube has a built-in heating element (10 VDC max., 1 A) to raise the temperature to 100°C. It can be powered by the Power Amplifier (CI-6552A or PS-2006) or a separate DC power supply. A 10 kΩ thermistor is embedded in the cube to measure its temperature. Use a Thermistor Sensor (CI-6527A) or a PASPORT Temperature Sensor (PS-2125) to read the thermistor temperature.

The cavity is the special feature of this cube. When the surface containing the cavity is scanned using a visible Light Sensor, the hole looks dark. However, when the cavity is scanned using an Infrared Sensor, the hole is brighter than the surrounding matte surface.



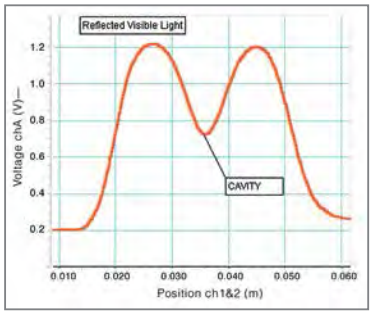
To scan the surface intensity of the cube, the Light Sensor is placed on the Linear Translator (page 266).



In the infrared part of the spectrum, the hot cavity is brighter than the surrounding matte aluminum surface.



The hot cube can be safely rotated by the large plastic knob.



In the visible part of the spectrum, the cavity is darker than its surroundings.



The top opens to reveal that the black-looking cavity is actually a matte finish, the same as the surface.

Order Information

Thermal Cavity	TD-8580A	
Required:		
60 cm Optics Bench	OS-8541	p. 261
Linear Translator	OS-8535A	p. 266
Aperture Bracket	OS-8534A	p. 266
Light Sensor	PS-2106A	p. 48
IR Sensor	PS-2148	p. 51
Temperature Sensor	PS-2125	p. 44
or		
Thermistor Sensor	CI-6527A	p. 46
Rotary Motion Sensor	PS-2120A	p. 28
850 Universal Interface	UI-5000	pp. 14-17

Infrared Thermometer

SE-9785C



-50° to 270°C Range

An excellent classroom tool for measuring the temperature of a surface without contact. A built-in laser indicates the area to be measured. Unit automatically holds last measurement after "Measure" button is released. Uses two AAA batteries (included).

Specifications

Range: -50° to 270°C; -58° to 518°F
Resolution: (1°F/1°C)
Distance to Target Ratio: 6:1
Emissivity: 0.95, fixed
Display: Backlit LCD
Recommended Measure Distance: 5 to 91 cm

Order Information

Infrared Thermometer	SE-9785C

Non-Contact Temperature Sensor

PS-2197



- Non-contact
- -70°C to 380°C

The Non-Contact Temperature Sensor measures surface temperature by detecting the emitted infrared light. Record the temperature of objects without touching them!

Typical Applications

- Compare temperature of hands, skin, face, and clothes
- Measure the temperature of different outdoor ground surfaces
- Map the temperature profile of an exterior wall

Specifications

Range: -70°C to 380°C
Accuracy: ±0.5°C
Response Time: Less than 0.1 s
Maximum Sample Rate: 200 Hz
Field of View: ±35°

Order Information

Non-Contact Temperature Sensor	PS-2197

Requires an Interface (see pages 14-23)

See a variety of Temperature Sensors on pages 44-46.

Partial Immersion Thermometer

SE-9084B



-20° to 110°C Range

Features 1°C accuracy or better. Filled with environmentally safe non-toxic, non-hazardous, biodegradeable Enviro-Safe® liquid. Measure from -20° to 110°C with this 30 cm long thermometer. It is clearly marked at 1 degree intervals, and a ring on top allows students to suspend it from a string.

Order Information

Partial Immersion Thermometer SE-9084B

Digital Dial Thermometer

SE-9082



-50° to 150°C Range

This 5 cm diameter Digital Dial Thermometer has a range from –50° to 150°C with 0.1° resolution. The probe is 13 cm long and includes a protective case.

Order Information

Digital Dial Thermometer SE-9082

Waterproof Thermometer

SE-7139



Here is a pocket-sized digital thermometer for measuring the temperature of liquids. Slide the sleeve off to reveal the stainless steel probe that detects a temperature range of –40°C to 200°C (–40°F to 392°F). Features include Min/Max recall, data hold, and automatic shut-off.

Order Information

Waterproof Thermometer SE-7139

Digital Thermometer

SE-9086A



Specifications

Range: -50°C to 1000°C; 0.3% accuracy
Range: 1000°C to 1300°C; 0.5% accuracy
Resolution: Switchable from 1°C to 0.1°C
Sampling Rate: 3 Hz
Hold Button: Freezes display
Battery Life: Approximately 200 hours

Order Information

Digital Thermometer SE-9086A

Energy Transfer–Solar

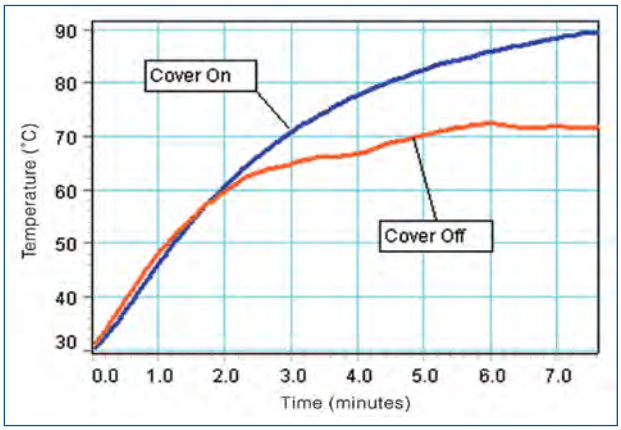
ET-8593

- Converts solar energy to thermal energy
- Demonstrates the greenhouse effect
- Built-in thermistor for measurement of temperature



Energy Transfer–Solar shown in use. The Xplorer GLX, with its two built-in temperature ports, measures both the ambient outside temperature and the temperature inside the Energy Transfer–Solar.

A sturdy plastic housing is covered with a transparent plastic lid to transmit visible light. The black aluminum plate inside has a 10 kΩ thermistor attached to measure the temperature. The amount of energy transferred to the plate can be calculated. Also, the maximum temperature reached and the rate of heating can be investigated with or without the plastic cover. The attached rod clamp is used to adjust the angle of the box toward the sun.



Shows the difference in the heating rates with the transparent plastic lid on and off.

Includes

Plastic box with lid and built-in rod clamp

Black aluminum plate (23 cm x 16 cm) with 10 kΩ thermistor

Cable for PASPORT Temperature Sensor



Order Information

Energy Transfer–Solar	ET-8593	
Required for use with PASPORT:		
PASPORT Temperature Sensor	PS-2125	p. 44
Xplorer GLX	PS-2002	p. 19
Small Tripod Base and Rod	SE-9451	p. 171

Electrostatics: Van de Graaff Generator

Van de Graaff Generator, High Voltage

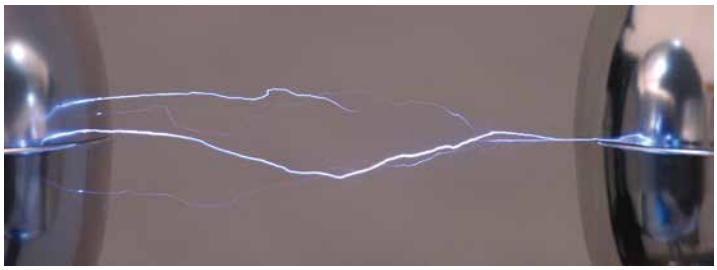
SE-8691

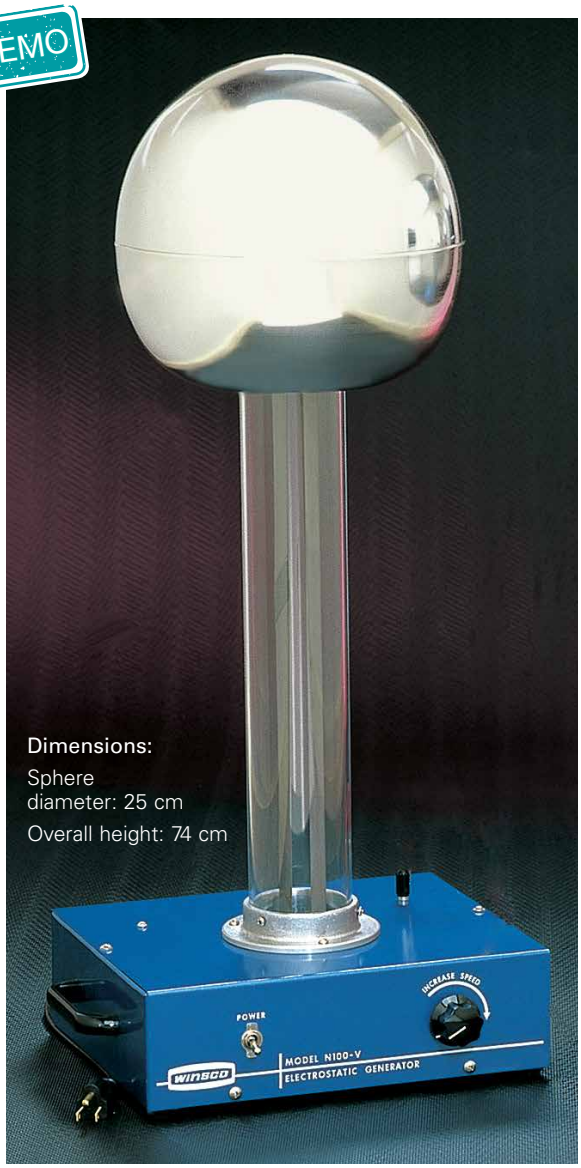
GREAT DEMO

- Large sphere creates higher voltage
- Sparks up to 35 cm in length
- Large size ideal for demonstrations

The High Voltage Van de Graaff Generator features a 25 cm diameter sphere that can generate approximately 400,000 volts. The size of the sphere, its rounded edges, and its height from the demonstration table contribute to the high voltages generated.

Its large size, long sparks, and high voltages make it ideal for use in larger rooms or lecture halls. An extra belt is included.



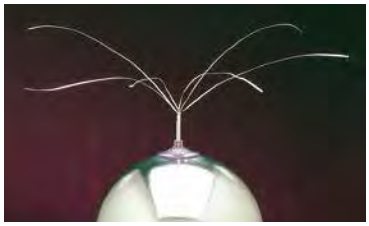


Dimensions:
Sphere
diameter: 25 cm
Overall height: 74 cm

Electric Plume

SE-7232

The lightweight ribbons are connected to a stand that rests on top of the Van de Graaff Generator. As the generator operates, the ribbons stand on end, due to the repulsive force between their like charges.



Discharge Sphere

SE-7231



This 25 cm sphere is supported on a Lucite® column with a cast iron base. Includes cabling for connection to the Van de Graaff Generator or to a ground.

Electric Whirl

SE-7233



When held near the sphere of the generator, the spokes are propelled by charge leaving the points.

Van de Graaff Replacement Belt



Order Information

Replacement Belt SE-7355

Order Information

Van de Graaff Generator, High Voltage SE-8691
Electric Plume SE-7232
Discharge Sphere SE-7231
Electric Whirl SE-7233

Replacement Supplies:

Replacement Belt SE-7355

Charge, Equipotential and Field Mapper

ES-9060



The Charge, Equipotential, and Field Mapper is an excellent addition to the Basic Electrostatics System.

Draw any set of two-dimensional conductors with the conductive ink. Investigate the electric field and the equipotential field lines between and around the conductive paper to any shape. Charge it and investigate the distribution of charge on its surface.

Similar to the Field Mapper Kit, except it includes electrometer probes, a "point charge" holder, and larger sheets of conductive paper for investigating charge distributions on conductive surfaces.

Includes

Conductive paper for mapping charge distributions: 30 x 45 cm (50 sheets)

Conductive paper with cm grid for mapping equipotentials and field gradients: 23 x 30 cm (100 sheets)

Pushpins (10), connecting wire (1) and electrometer probes (2)

Conductive ink pen and a circular template for drawing conductors

"Point charge" holder

Plastic tray with corkboard top: 32 x 48 cm

Manual with 13 experiments

Order Information

Charge, Equipotential, and Field Mapper ES-9060

Replacement Supplies:

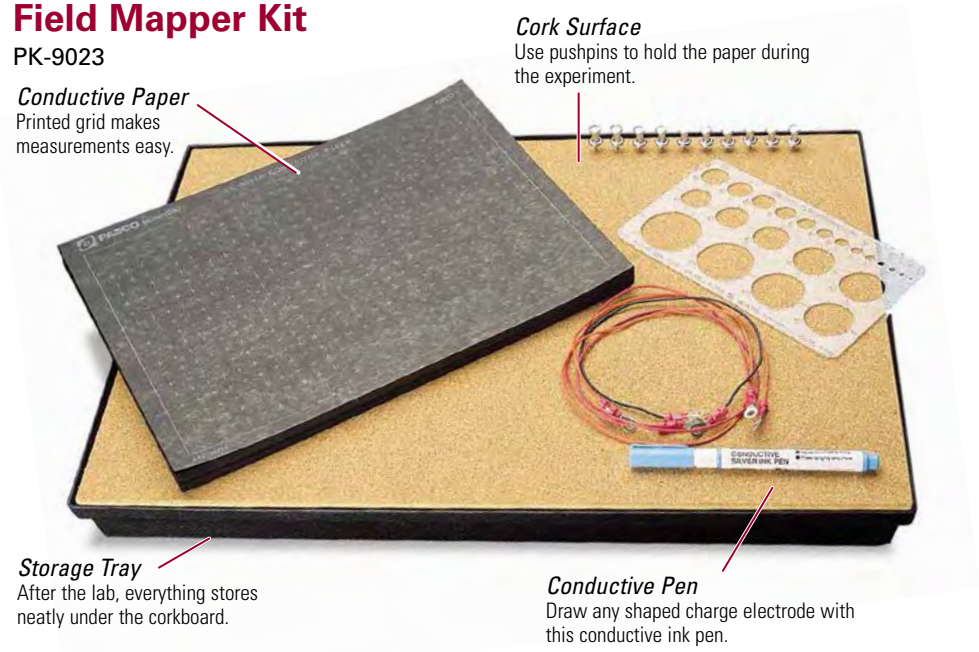
Conductive Ink Pen PK-9031B
(limited shelf life of six months; pen is not refillable)

Conductive Paper with grid (50 sheets, 23 x 30 cm) PK-9025

Conductive Paper (no grid) (100 sheets, 30 x 43 cm) PK-9026

Field Mapper Kit

PK-9023



How It Works

With this kit students can map both the potentials and the electric fields around any conceivable system of two-dimensional charged conductors.

The procedure is simple:

1. **Draw Any Electrode:** Draw the electrode with the special conductive silver ink pen. It is easy to use, dries quickly, and there is no mess.
2. **Plot the Equipotentials:** Connect a battery or power supply across the electrodes, then use a voltmeter to locate the equipotential lines.
3. **Plot the Electric Field:** Tape voltmeter probes together, then hold one probe on the paper and rotate the other probe around it like a compass. The maximum voltage reading indicates the direction of the electric field.

Includes

Conductive paper with cm grid: 23 x 30 cm (50 sheets)

10 pushpins; three wires

Conductive ink pen and circular template

Plastic tray with corkboard top: 32 x 48 cm

Instruction manual with 10 experiments

Special Conductive Ink Pen

The PASCO Conductive Silver Ink Pen makes it easy to study field patterns. Draw over 60 meters of patterns with a single pen. Pen shelf life is six months. Not refillable.

Order Information

Conductive Ink Pen PK-9031B

Typical Experiments

1. Dipoles of Like Charges
2. Dipoles of Opposite Charges
3. Parallel Plate Capacitor
4. Point Source and Guard Ring (cylindrical capacitor)
5. Floating Electrode

Plus five more experiments.

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Order Information

Field Mapper Kit PK-9023

Required:

Basic Digital Multimeter ..... SE-9786A p. 239
(or any voltmeter with at least a 10 MΩ input impedance)

Power Supply ..... SE-8587 p. 232
(or another low voltage DC power supply or battery)

Replacement Supplies:

Conductive Ink Pen PK-9031B
(limited shelf life of six months; not refillable)

Conductive Paper with grid (50 sheets, 23 x 30 cm) PK-9025

Conductive Paper (no grid) (100 sheets, 30 x 43 cm) PK-9026

Basic Electrostatics System

ES-9080B



- Quantitative electrostatics
- Comprehensive experiment manual included
- Individual or demonstration use

The PASCO Basic Electrostatics System includes all the components necessary for a quantitative investigation into the basics of electrostatics. With this integrated set of equipment, students can study:

- Production of charges, equal and opposite
- Charge by induction
- Principle of the Faraday Ice Pail
- Charge transfer
- Charge distribution in electric fields
- Capacitors and the Q=CV relationship
- Moving charges and current

Order Information

Basic Electrostatics System ES-9080B

Recommended:
Charge, Equipotential, and Field Mapper ..... ES-9060 p. 205

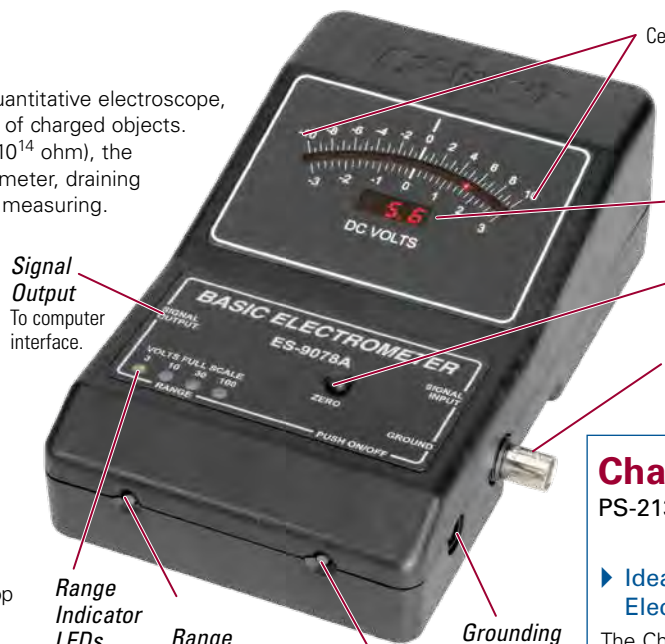
Includes

Basic Electrometer ES-9078A
Charge Producers and Proof Plane ES-9057C
Faraday Ice Pail and Shield ES-9042A
Conductive Spheres, 13 cm ES-9059C
Conductive Shapes ES-9061
Basic Variable Capacitor ES-9079
Electrostatics Voltage Source ES-9077
Experiment Manual

Basic Electrometer

ES-9078A

The PASCO Basic Electrometer is a quantitative electroscope, measuring the polarity and magnitude of charged objects. With almost infinite input resistance (10^{14} ohm), the Electrometer is a high-impedance voltmeter, draining almost no charge from the object it is measuring.



Features

Center-Zero Meter:
Polarity is indicated directly.

3, 10, 30, and 100 VDC Switch-Selectable Ranges:
LED lamps indicate the range in use.

Zeroing Switch: For removing all charge from the input and bringing the meter to zero.

Automatic Shutoff: Unit turns off about three hours after being used.

Output Compatible with the 850 Universal Interface and ScienceWorkshop Interfaces:
For recording data or producing a demonstration-sized meter display.

Battery Operation: Uses four "AA" cells (included). Range indicator lights flash when batteries need to be replaced.

Includes

Shielded input cable to connect the Electrometer to the Faraday Ice Pail or other source of charge
Grounding cable with clip
Interface cable
Instruction and experiment manual

Order Information

Basic Electrometer ES-9078A

Charge

PS-2132

DIGITAL sensor



- Ideal for Electrostatics

The Charge Sensor is designed for experiments in electrostatics such as inductive charging, charge production/distribution, and charge on a capacitor. When used with the Faraday Ice Pail, the Charge Sensor can measure the total charge on an object by the induction method.

The Charge Sensor can also be used as a high impedance voltmeter (10^{12} Ω).

See page 51 for more information.

Order Information

Charge Sensor (PASPORT) PS-2132

Electrostatics Voltage Source

ES-9077



This compact unit is ideal for performing experiments in electrostatics. It may be used as a source of charge or to maintain an object at a constant potential.

Output voltages are 1000, 2000, and 3000 VDC for charging spheres, capacitor plates, etc. A 30 VDC source is also provided for experiments with capacitors.

Specifications

Output: 30, 1000, 2000, 3000 VDC ±3%, line regulated

Resistance in Series with Output: 120 MΩ/kV

Operating Voltage: 115/220, 50/60 Hz

AC Adapter: 9 VDC

Order Information

Electrostatics Voltage Source ES-9077

Basic Variable Capacitor

ES-9079



Two 18 cm diameter plates allow the capacitance to be varied from 225 pF to zero by sliding the movable plate in its 28 cm long track. The sliding plate has adjustment screws to make the plates parallel to each other. Electrical connection studs are located on each plate.

A BNC connector cable is provided for connection to an Electrometer.

Order Information

Basic Variable Capacitor ES-9079

Conductive Spheres

ES-9059C



These Conductive Spheres (two per set) can be used to store charge or to investigate the charge distribution on one or two spherical conductors. A terminal on the bottom of each sphere provides a connection point for the power supply. Each sphere is attached to a heavy base (for stability) with an insulating rod. The spheres are 13 cm in diameter and 30 cm high.

Order Information

Conductive Spheres ES-9059C

Charge Producers and Proof Plane

ES-9057C



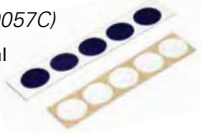
The Charge Producers create equal positive and negative charges when rubbed together. The Proof Plane samples the charge density from a charged object. The charge can then be measured using the Electrometer and Faraday Ice Pail.



Replacement Pad Set

ES-9056 *(for ES-9057C)*

Includes five artificial leather pads and five blue vinyl pads.



Order Information

Replacement Pad Set ES-9056

Order Information

Charge Producers and Proof Plane ES-9057C

Classic Electrostatics Materials Kit

SF-9068

Providing the classic introduction to electrostatics, this kit allows students to rub any of the three rods with rubbing cloths to produce a positive or negative charge. Place the rods on the insulated pivot stands to investigate electrostatic forces.



Includes

Three rods (acrylic, glass, PVC), Two insulated pivot stands, and Three rubbing cloths (wool, silk, fur)

Order Information

Classic Electrostatics Materials Kit SF-9068

Conductive Shapes

ES-9061



This set includes a conductive sphere with a hole in it. Demonstrate that static charge resides outside the surface of a conductive sphere by sampling the inside surface with the ball end of the proof plane (on this page). Also included is an oblong shape for demonstrating the difference in charge densities on a large-radius surface versus a small-radius surface. The whole surface is at the same potential, and students seem surprised to find that the charge density is greater on the smaller end.

Order Information

Conductive Shapes ES-9061

Faraday Ice Pail and Shield

ES-9042A



With the Faraday Ice Pail, students can use the Electrometer to measure charge as well as potential. Touch the Proof Plane to the point of interest on the charged body, then place the Proof Plane inside the Ice Pail. The Electrometer reading will be directly proportional to the charge on the Proof Plane.

The Faraday Ice Pail is 10 cm in diameter and 15 cm deep. It is made of wire mesh, so it is easy to see what is going on inside. The outside shield has a diameter of 15 cm.

Order Information

Faraday Ice Pail ES-9042A

Electroscope

SF-9069



When this Electroscope is charged, the conductive rod rotates to indicate charge magnitude. The shield ring is 15 cm in diameter and can be grounded with banana plug connectors (not included).

Includes

Charge Sampler: For transferring charge to the Electroscope

Capacitor Plates (5.6 cm dia.): To demonstrate charge polarization

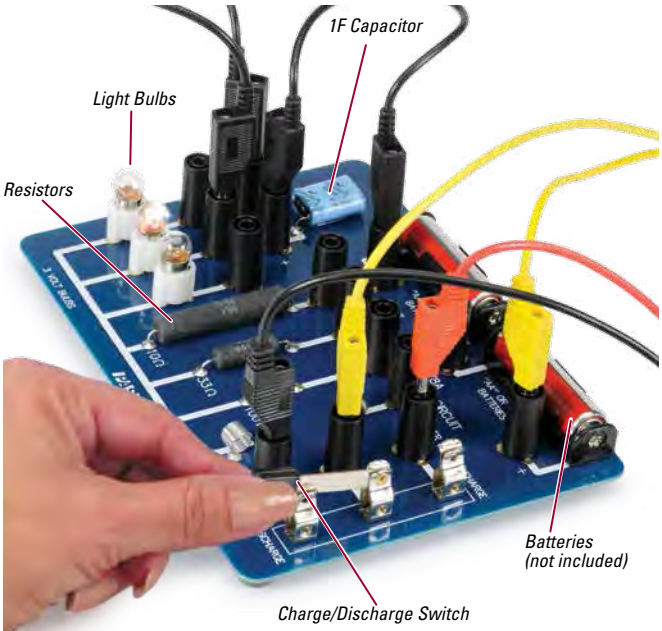
Order Information

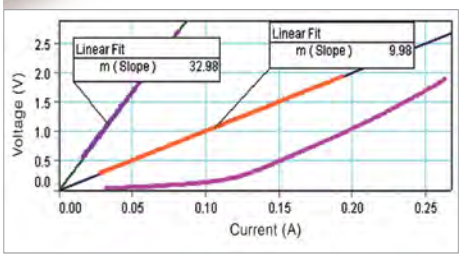
Electroscope SF-9069

Charge/Discharge Circuit

EM-8678A

The Charge/Discharge Circuit offers a unique way to observe and measure the behavior of DC circuits including batteries, capacitors, light bulbs, and resistors. It also includes an open slot that allows a component to be inserted for further experimentation.





Voltage vs. Current for a 33 Ω resistor, a 10 Ω resistor, and a light bulb. Note the non-linearity for the bulb.

Experiment Example

Charge the capacitor using batteries, then discharge through a resistor or light bulb. Students measure the voltage and current as the capacitor discharges, and can graph the relationship between voltage and current for various components.

Includes



1 Farad Capacitor
#14 Light Bulbs (3)
10 Ω Resistor
33 Ω Resistor
100 Ω Resistor
Battery Holders (uses AA or AAA)
Double-Throw Knife Switch
Instruction Manual

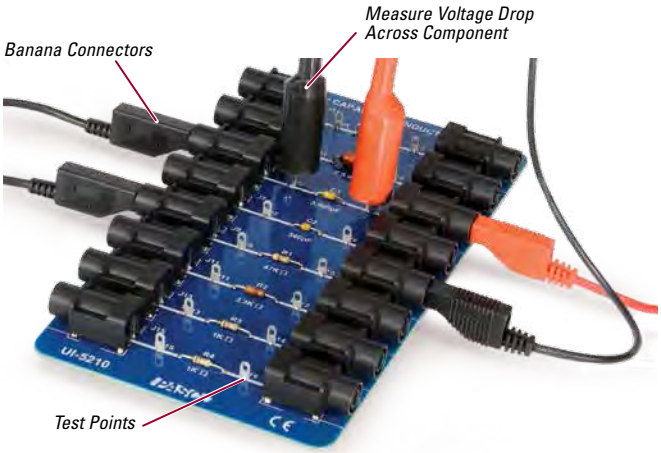
Order Information

Charge/Discharge Circuit EM-8678A
Recommended:
#14 Light Bulbs (25 pack) ..... EM-8627 p. 216
Batteries AA (4 pack) ..... PI-6601 p. 216

Resistor Capacitor Inductor Network

UI-5210

Board components can be used to investigate Kirchhoff's circuit laws, Ohm's Law, RC circuits, and A.C. LRC circuit theory with resonant frequencies between 55 kHz and 135 kHz, depending on values used.





The circuit board accepts patch cords with shrouded banana terminals (see page 215).



Shown in using the 850 Universal Interface power amplifier. Both the applied voltage and the resulting current are measured directly by the 850.



Resistor Capacitor Inductor component board includes two inductors: 6.8 mH; 2.5 mH, two capacitors: 3900 pF, 560 pF; and four resistors: 47 kΩ, 3.3 kΩ, and two 1.0 kΩ.

Order Information

Resistor Capacitor Inductor Network UI-5210

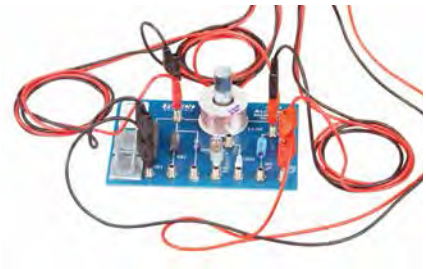
RLC Circuit

CI-6512

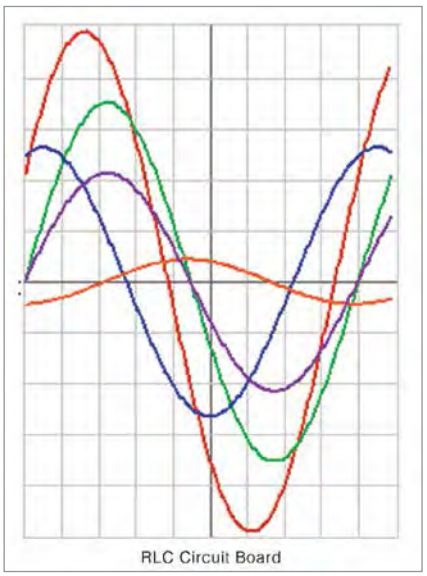


This board offers a unique set of components for demonstrating:

- Voltage/Current Phase Relationships
- RLC Resonance
- Non-Ohmic Characteristics, components include resistors, capacitors, and an inductor coil.



The 850 Interface can measure current and voltage as well as provide power to the RLC Circuit.



Phase relationships between the voltage across the capacitor, resistor, and inductor can be studied.

Order Information

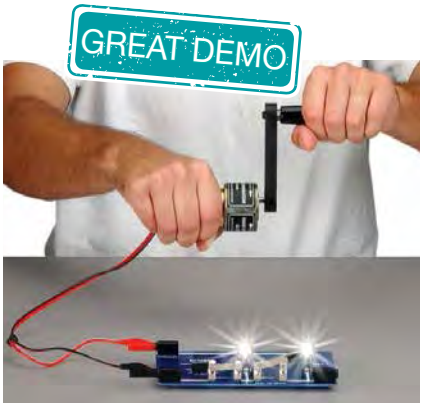
RLC Circuit CI-6512

Series/Parallel Circuit

EM-8677



PASCO's Series/Parallel Circuit is designed for use with the Hand-Crank Generator (page 221). The two 12 V bulbs can be wired in series or parallel. The two knife switches enable students to switch on one or both bulbs.



Using the Hand-Crank Generator



Close the switch to add an extra branch and twice the load to the parallel circuit.



Bulbs are dimmer when wired in a series circuit.

Order Information

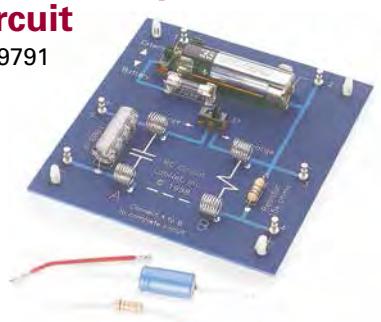
Series/Parallel Circuit EM-8677

Recommended:

Replacement Bulbs (5 Pack)	EM-8679	
Hand-Crank Generator	EM-8090	p. 223

Resistor-Capacitor Circuit

SE-9791



The Resistor-Capacitor Circuit contains everything students need for studying resistor-capacitor circuits in the lab.

Experiment Manual Includes

Charging and Discharging Capacitors

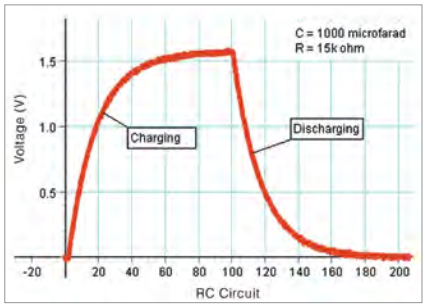
Series RC Circuits

Parallel RC Circuits

Combinations of Series and Parallel RC Circuits

A built-in battery (included) or external power supply can be used for experiments. A fuse protects components from overload. Two resistors and two capacitors are provided (one each soldered to the board). Unique spring connectors, the same as used on the Basic Electricity Laboratory (EM-8622) are used for easy component connection.

Measurements can be made either with a voltmeter and stopwatch (for graphing charge and discharge curves) and a ScienceWorkshop or PASPORT Interface with Voltage Sensors.



A 1000 µF capacitor charging and discharging through a 15 kΩ resistor

Order Information

Resistor-Capacitor Circuit SE-9791

Recommended:

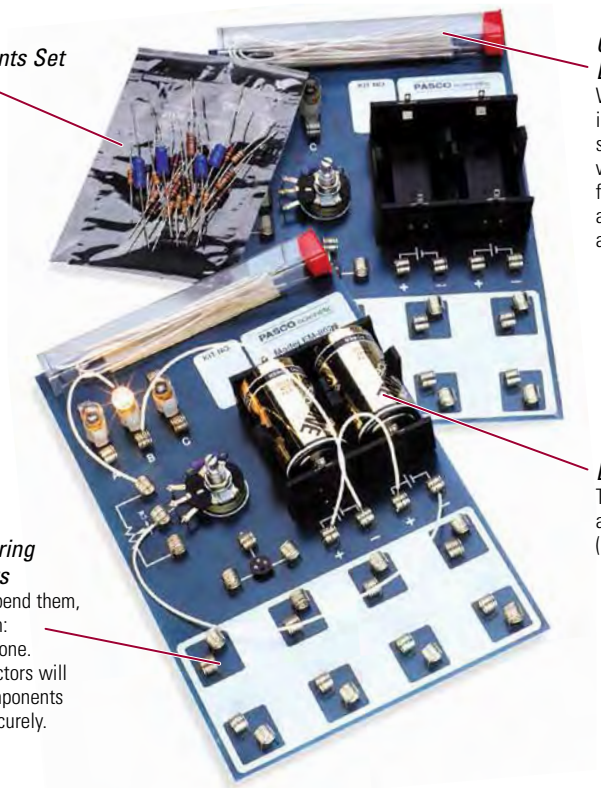
Basic Digital Multimeter	SE-9786A	p. 239
PASCO Stopwatch	ME-1234	p. 182
Voltage Sensor	UI-5100	p. 52
PASPORT Interface		pp. 14-23
Voltage/Current Sensor	PS-2115	p. 52

Basic Electricity

EM-8622

- Durable, easy-to-use kits
- Explore basic electronics
- Complete lab manual

These simple kits provide a strong foundation for future studies in electronics. They take students from the basics of Ohm's Law through simple series and parallel circuit analysis, and into some elementary aspects of electronics where they will build circuits using capacitors, transistors, and diodes. One kit per two students is recommended, giving each student his or her own circuit board.



Includes

Two Circuit Boards with the following features:
Battery holders: (2)
Resistor: (1) 3.3 Ω, 2 W
Light sockets: (3) with 3 bulbs (#14)
Potentiometer: (1) 25 Ω, 2 W
Spring connectors: (32)
Transistor socket: (1)
Storage tube for holding components (components stay with the kit longer)

Components Package containing:
Resistors: (23) (10 Ω - 220 kΩ, 5%, 1/2 W)
Capacitors: (4) (100 µf, 330 µf)
Diodes: (2)
Transistors: (2)
Wire leads: 22 gauge

Typical Experiments

With Teacher's Guide and Sample Data.

1. Getting Acquainted
2. Series vs. Parallel Circuits
3. Ohm's Law
4. Resistances in Circuits
5. Voltages in Circuits
6. Currents in Circuits
7. Kirchhoff's Rules (nodes and loops)
8. Capacitors in Circuits
9. Diodes
10. Transistors

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

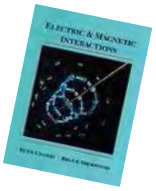
Order Information

Basic Electricity Laboratory (2 boards)	EM-8622	
Required:		
"D" Cell Batteries (4-pack)	PI-6602	
Basic Digital Multimeters (2)	SE-9786A	p. 239
Replacement Supplies:		
Light Bulbs (#14, 25 pack)	EM-8627	
Electronic Components – Basic Electricity Lab	EM-8663	

Innovative physics textbooks and PASCO physics products

Matter & Interactions is a two-volume textbook and curriculum by Ruth Chabay and Bruce Sherwood, published by Wiley & Sons. It is intended for science and engineering students taking calculus-based introductory university physics. For more information on purchasing these textbooks, visit www.wiley.com.

Electric and Magnetic Interactions



Electric and Magnetic Interactions (Vol. 2 of 2) continues the emphasis on atomic-level descriptions and analysis and modeling physical systems. Electrostatics and circuit phenomena are treated as one integrated subject. The Desktop Electricity Kit allows students to carry out just-in-time desktop experiments on electrostatics, magnetism, and circuits.

Desktop Electricity Kit EM-8675



When used in tandem with the *Electric and Magnetic Interactions* textbook, this kit gives students the conceptual tools to further their understanding of electric and magnetic interactions. While its components look simple, they provide hands-on opportunities for students to build powerful conceptual models.

Desktop experiment kit Includes

Capacitor 1F, 2.5 V
Resistor 47 Ω, 0.5 W
Resistor 100 Ω, 0.5 W
Lamp Holder T3-1/4 (qty 2)
#48 Miniature Lamp 2.0 V, 0.6 A (qty 2)
Incandescent Lamp 2.5 V, 0.3 A (qty 2)
Battery Holder
Alkaline Battery D-cell (qty 2)
Bar Magnet (0.375" x 1")
Compass, Liquid Filled
Wire-Red 22AWG (6 ft)
Alligator Clip Leads (12") (qty 7)
Nichrome Wire #26 (18")
Nichrome Wire #30 (18")

Order Information

Desktop Electricity Kit	EM-8675

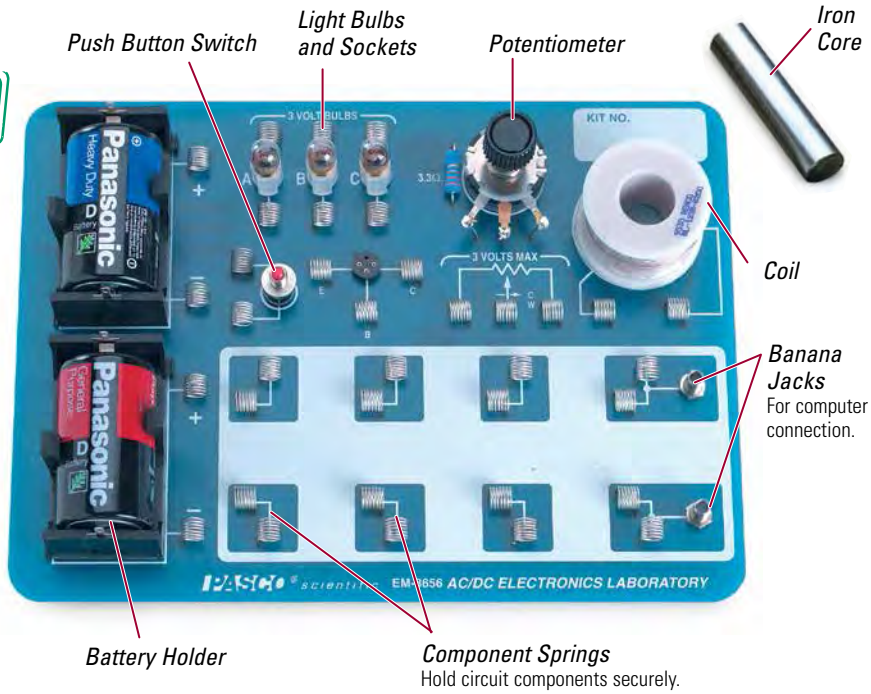
AC/DC Electronics Laboratory

EM-8656

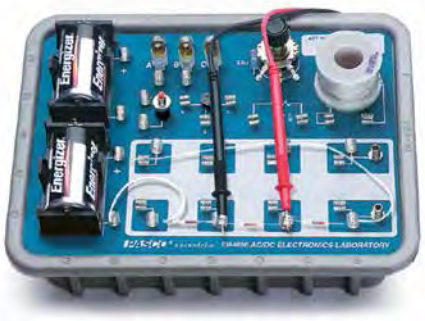
TEACHER FAVORITE

- Stand-alone operation
- Computer compatible
- Includes coil and iron core

The AC/DC Electronics Laboratory dynamically teaches the basics of AC/DC circuits. Students can use this kit with a **ScienceWorkshop** Computer Interface and Power Amplifier or as a stand-alone unit. The storage tray holds all included components, reducing the chance of losing capacitors, resistors, etc. Two D batteries are required for stand-alone use (not included).

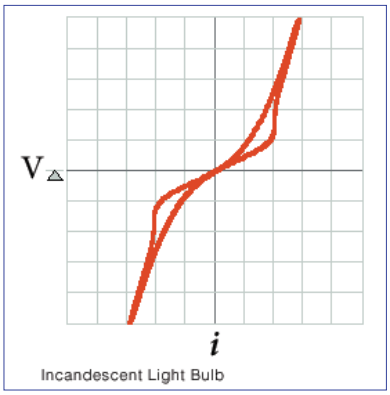


Experiments

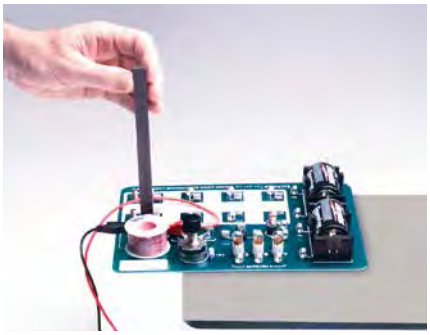


The AC/DC Electronics Laboratory can be used as a stand-alone electricity learning center.

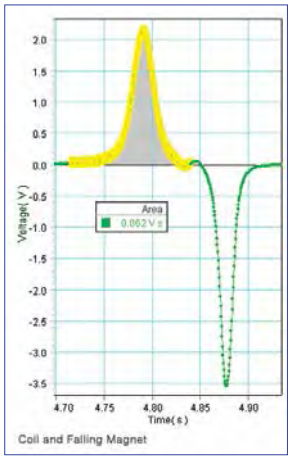
Students study how the resistance of a light bulb filament changes as it heats up. The graph below displays voltage vs. current for an incandescent light bulb. It is clear that the resistance is not linear but changes as the bulb begins to glow.



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.



Using PASCO Capstone and a Voltage Sensor, students can measure the electromotive force (EMF) created when a magnet is dropped through a coil. By integrating the voltage-time graph, students can also measure the changes in magnetic flux created by the magnet.



Includes

18 cm x 25 cm circuit board
Resistors (24) (4.7 Ω–220 kΩ, 5%, 0.25-5 W)
Capacitors (7) (1 µF – 330 µF)
Diodes (6), Transistors (2), and LEDs (4)
Wire leads (22 gauge)
Push-button switch
Storage tray and laboratory manual
Battery holders (2)
Light sockets (3) and lamps (3)
25 Ω, 2 W potentiometer (1)
Component connectors (36)
Transistor socket (1)
8.2 to 19 mH coil and iron core



Order Information

AC/DC Electronics Laboratory EM-8656
Electronic Components – AC/DC Electricity EM-8668

Resistance Apparatus

EM-8812

- Slide-wire potentiometer
- Measure resistance and resistivity
- Four wire diameters, five wire materials

A current is established in a wire of known diameter, and the voltage drop across a section of the wire is measured. Students can calculate the resistance of the wire and the resistivity of the material.

$$R = \frac{\rho L}{A}$$

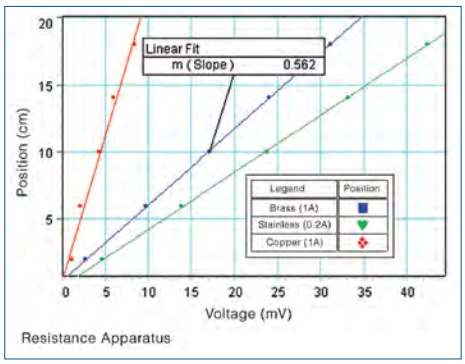
Features

Vary wire length: Slide-wire potentiometer pick-up makes it easy. Use the built-in scale to measure the length of the wire.

Vary wire diameter: Four different diameters of brass wire are included. Investigate the difference between resistance and resistivity. Interchange wires quickly and easily.

Vary wire material: Five different material wires are included. Investigate how resistivity depends on the wire material.

Storage: Built-in storage tray holds wires.



Graph shows voltage drop across various lengths for three different material wires. The slope of the line (along with wire diameter and current) is used to calculate the resistivity of the material.

Includes

Two each of the following (30 cm long) wires:

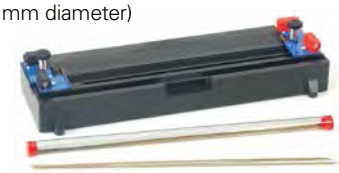
Copper (1.0 mm diameter)

Aluminum (1.0 mm diameter)

Stainless Steel (1.0 mm diameter)

Nichrome (1.0 mm diameter)

Brass (0.5 mm, 0.8 mm, 1.0 mm, 1.3 mm diameter)



Built-in cm scale *and slide wire probe make it easy to measure the voltage drop across various wire lengths.*

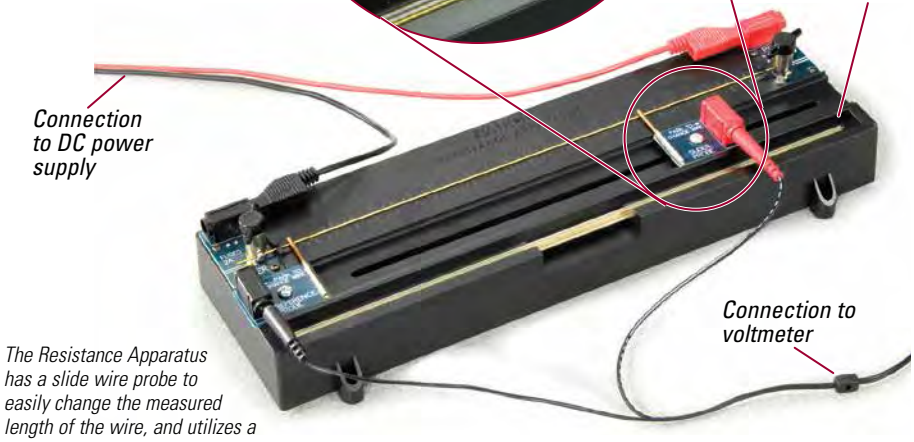
Sample wire
Wires are held securely and straight by the wire guides and lugs.

Slide wire probe
Spring-loaded wire probe slides easily along the wire, making contact at a single point.

Wire storage tray

Connection to DC power supply

Connection to voltmeter



The Resistance Apparatus has a slide wire probe to easily change the measured length of the wire, and utilizes a four wire hook-up to accurately measure the voltage drop. It comes with four different brass wire diameters and four other wire materials.



For the experiment shown, the 850 Universal Interface produces a 10 second voltage ramp to apply a varying current through a brass wire. A graph of voltage drop vs. current is created, and the slope of this line is the resistance of that length of wire.

Order Information

Resistance Apparatus	EM-8812	
Recommended:		
Galvanometer Sensor	PS-2160	p. 53
Replacement Wires	EM-8813	
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 214

CASTLE "2005" Curriculum

Capacitor-aided system for teaching and learning electricity

- Complete electricity curriculum
- Redesigned sections to facilitate beginning CASTLE curriculum in grade 8 or 9

CASTLE Kit

(for 2 students) EM-8624A

Economy CASTLE Kit

(for 8 students) EM-8654

The CASTLE™ Approach

CASTLE is a high school electricity curriculum that leads students from initial naive ideas to an increasingly expert understanding of electrical phenomena. A sequence of self-guided experiments uses large capacitors and transient bulb lighting to help students confront misconceptions, grasp the physics of current propulsion, and build intuitive explanatory models.

Typical Experiments

Core Curriculum investigates

1. What is happening in the wires?
2. What do the bulbs do to moving charge?
3. Where does the moving charge originate?
4. What makes charge move in a circuit?
5. How do wires distribute electric pressure in a circuit?
6. How are values of circuit variables measured?

Advanced Curriculum investigates

7. Does all matter contain charge? What are electrons?
8. What is the cause of distant action effects?
9. What pushes on tiny charge carriers like electrons?
10. How do semiconductors work? What is AC?
11. How do motors and generators work?
12. How are magnetic and electromagnetic fields produced?

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

The Curriculum Guide

Download the Manuals FREE.

Download the CASTLE Curriculum Guide for FREE. At *www.pasco.com* just type CASTLE in the search box and click GO!

The teacher's manual helps teachers put the CASTLE Kits to the best possible use. The student manual has investigations for each stated experiment, plus commentaries to prepare students for labs as well as summary exercises to reinforce the lab experience.

TEACHER FAVORITE



Carbon Resistors
These impede flow similar to low resistance bulbs, but don't glow and divert attention to role as energy sinks.

Battery Holder
Securely holds batteries and yet makes them visible so their function within the circuit is evident.

High-Quality Compass
Non-invasive monitoring of movement in wires enables students to visualize the direction of charge flow.

Miniature Light Bulbs
Different shaped bulbs have different resistance values.

Screw Sockets and Stands
Stands provide a sturdy support for bulbs and are easy to quickly connect into a circuit.

25,000 µf Capacitor
Provides the foundation for this intuitive introduction to current electricity.

Wires with Alligator Clips
These 10 color-differentiated wires make circuit connections quick and easy—no soldering or wire twisting required.

Auxiliary Equipment for Core Curriculum



The Mini Generator (1) enables students to distinguish charge circulation from energy transfer. The 100,000 µf Capacitor (2) lengthens the time scale of transient bulb lighting.

Auxiliary Equipment for Advanced Curriculum



Bi-color LEDs detect electric vectors in electromagnetic fields produced in these coils (3) by accelerating charge when current is turned on and turned off.

The Kits

Each CASTLE Kit includes all the materials needed (except for three D batteries) for two students to work through a complete introduction to basic electricity. Each Economy CASTLE Kit includes all the materials needed (except batteries) for eight students.

Materials Included in Each Kit

Component	CASTLE Kit	Economy Kit
25,000 µF capacitor (20 volts, nonpolar)	1	4
#14 light bulbs (round)	4	25
#48 light bulbs (oblong)	6	25
10 Ohm resistor	4	16
Miniature light bulb sockets and stands	4	16
Wires with alligator clips	10	40
Battery holder (spring-loaded)	1	4
High-quality compass	1	4
Storage box	1	0

Order Information

CASTLE Kit EM-8624A
Three "D" batteries are required per kit, (not included).

Economy CASTLE Kit EM-8654
12 "D" batteries are required per kit, (not included).

Recommended:

Mini Generator ..... SE-8645 p. 223
Capacitor (0.1 F) EM-8655
(Minimum of two each per class)
Primary and Secondary Coils ..... SE-8653 p. 226
(Minimum of two each per advanced class)

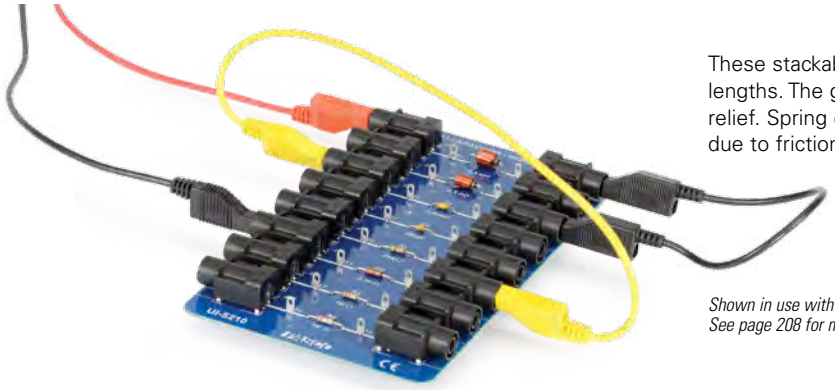
Replacement Supplies:

We recommend the purchase of one EM-8627 and one EM-8628 spare bulb set for every five CASTLE Kits, or for every Economy CASTLE Kit.

Light Bulbs (#14, 25 pack) EM-8627
Light Bulbs (#48, 25 pack) EM-8628
Light Bulb Sockets (10 pack) EM-8630
D cell batteries (4 pack) PI-6602
Lightbulbs (#50, 4 pack) and Sockets (2 pack) EM-9099
Liquid-Filled Compasses (5 pack) EM-8631A
Capacitors (0.025 F, 2 pack) EM-8632

Electricity: Patch Cords

Banana plug cord sets 15 cm, 30 cm, 75 cm, and 2 m Lengths



These stackable patch cords come in four convenient lengths. The grips are made of soft plastic for flexible strain relief. Spring connectors rotate in the grips, reducing wear due to friction.

LAB ESSENTIALS

Shown in use with UI-5210 circuit board.
See page 208 for more information.

2 Meter Patch Cord Set

SE-9415A

Two each of black and red. 2 m long.



Order Information

2 Meter Patch Cord Set SE-9415A

Short Patch Cords

SE-7123

30 cm long, two each red, yellow, blue, black.



Order Information

Short Patch Cords (set of 8) SE-7123

Patch Cord Jumper Set

EM-9737 (set of 5)

15 cm long, available in black only.



Order Information

Patch Cord and Jumper Set (set of 5) EM-9737

Long Patch Cords

SE-9750, SE-9751

75 cm long, available in red or black.



Order Information

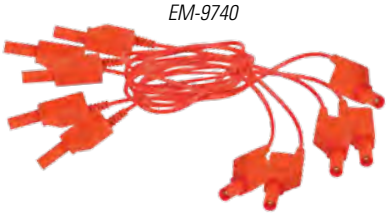
Red (set of 5) SE-9750
Black (set of 5) SE-9751

Shrouded Long Patch Cords

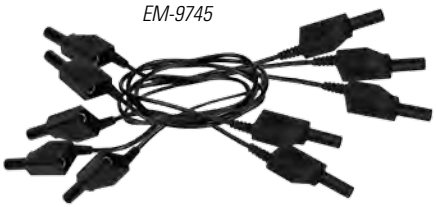
EM-9740, EM-9745

75 cm long, five black or five red. Terminals are shrouded banana plugs. Maximum rating: 30 Vrms or 60 VDC, 10 Amps.

EM-9740



EM-9745



Order Information

Red (set of 5) EM-9740
Black (set of 5) EM-9745

Alligator Clip Adapters

SE-9756 (10 pack)



Convert banana plugs into alligator clips with this set of 10 adapters. The 4 mm banana plug clips are bright tin-plated steel.

Includes five red and five black.

Order Information

Alligator Clip Adapters (set of 10)	SE-9756

Shrouded Alligator Clip Adapters

SE-9758

(10 pack)



For use with both regular and shrouded banana plugs.

Includes five red and five black adapters.

Order Information

Shrouded Alligator Clip Adapters (set of 10)	SE-9758

Spade-to-Banana Adapters

EM-8629

(10 pack)



For use with both regular and shrouded banana plugs.

Includes five red and five black adapters.

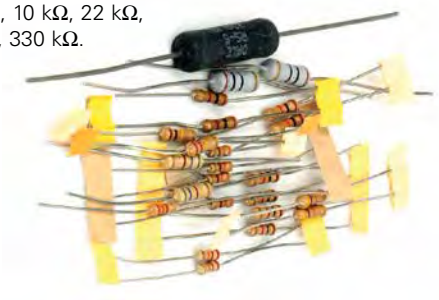
Order Information

Spade-to-Banana Adapter (10 pack)	EM-8629

Resistors and Capacitors

Resistor Pack (10 ea.) EM-8784

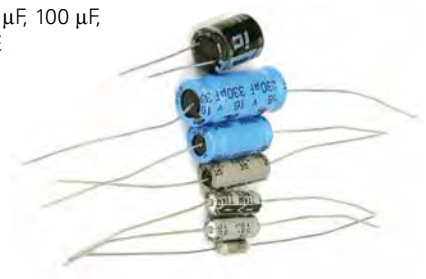
10 Ω, 100 Ω, 330 Ω, 560 Ω, 1000 Ω, 3300 Ω, 10 kΩ, 22 kΩ, 100 kΩ, 220 kΩ, 330 kΩ.



Resistors

Capacitor Pack (10 ea.) EM-8785

1 µF, 10 µF, 47 µF, 100 µF, 330 µF, 470 µF.



Capacitors

Order Information

Resistor Pack	EM-8784
Capacitor Pack	EM-8785

Capacitors

EM-8655 (0.1 F)

EM-8632 (0.025 F)

SE-8626 (1.0 F)



0.1 F



0.025 F

1.0 F

EM-8655:
(0.1 F) Electrolytic, bipolar, 10 Volt capacitor with screw terminals, 4.5 cm diameter, 14 cm long.

EM-8632:
(0.025 F) Electrolytic, bipolar, 25 Volt capacitor with screw terminals, 5 cm diameter, 8 cm long. Contains two capacitors.

SE-8626:
(1.0 F) Electrolytic, bipolar, 5 Volt capacitor.

Order Information

Capacitors	0.1 F	EM-8655
	0.025 F (2 pack)	EM-8632
	1.0 F	SE-8626

Series/Parallel Battery Holder

SE-8799 (10 pack)

This unique battery holder allows "D" cell batteries to be easily connected in both series and parallel. Metal extensions on both sides of the holder are also convenient for use with alligator clips.



Series – Use the snaps to connect the batteries end to end.



Parallel – Use the metal slides to use the batteries side by side.

Order Information

Series/Parallel Battery Holder (10 pack) SE-8799

Recommended:

Light Bulbs (#14, 25 pack) EM-8627
Light Bulb Sockets (10 pack) EM-8630
Alligator Clip Leads (set of 10) EM-8634

Batteries

PI-6601 AA (4 pack)
PI-6602 D (4 pack)
PI-6603 C (4 pack)



Each pack contains four alkaline batteries.

Order Information

AA (4 pack) PI-6601
D (4 pack) PI-6602
C (4 pack) PI-6603

Switch Set

EM-8815 (6 pack)

This single-pole single-throwknife switch has screw terminals and a Bakelite™ base. Through-holes allow for mounting base to another surface.



Order Information

Switch Set (SPST) 6 pack EM-8815

Light Bulb and Stand

EM-9099

Miniature socket has a plastic base with spring-loaded metal clips to hold wire leads. Accepts screw-type miniature bulbs. Includes two sockets and four #50 7.5 V, 0.22 A bulbs.



Order Information

Light Bulb and Stand EM-9099

Light Bulb Sockets

EM-8630

Miniature socket has a plastic base with spring-loaded metal clips to hold wire leads. Accepts screw-type miniature bulbs. Includes ten sockets.



Order Information

Light Sockets (10 pack) EM-8630

Light Bulbs

EM-8627: 2.5 V, 0.3 A bulbs (25 bulbs.)
EM-8628: 2.0 V, 0.06 A bulbs. (25 bulbs.)
EM-8814: 7.5 V, 0.22 A bulbs. (25 bulbs.)

Screw-type base, suitable for use with EM-8630 Sockets.



Order Information

2.5 V, 0.3 A (25 pack #14)	EM-8627
2.0 V, 0.6 A (25 pack #48)	EM-8628
7.5 V, 0.22 A (25 pack #50)	EM-8814

Alligator Clip Leads

EM-8634 (10 pack)

Use these 30 cm long Alligator Clip Leads for almost any application — from hooking up instruments to bread boarding circuits. They come in sets of 10: two each of yellow, white, red, green and black.



Order Information

Alligator Clip Leads (set of 10) EM-8634

MR 200 Digital/Analog Breadboard

SE-9982

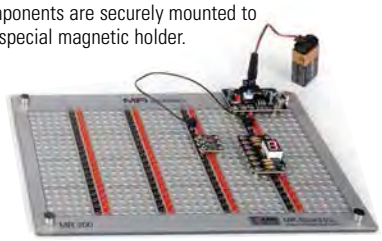
- Magnetic connections
- Locking metal storage case
- Includes wide variety of digital components

Plastic Cover over ferromagnetic strips has holes to guide the magnets on the components.



Magnet makes the electrical connection to the conducting strips.

Components are securely mounted to the special magnetic holder.



The MR Board is a reusable magnetic breadboard that eliminates the need to solder or strip wires when constructing an electronic circuit. By using components that connect through magnetic attraction to the board, students are able to quickly check and expand their knowledge of electronics concepts. Components are protected from damage. DIP sockets are provided to allow users to insert their own devices.

Parts list

12 holed connectors

10 2-PIN free connectors

4 ea. LEDs, transistors

2 ea. MR-TR (transistors), MR-PS1 switches, Gates: AND, NAND, OR, NOR, NOT, XOR, Buffers, MR-14PIN, MR-16 PIN red jumper wires, black jumper wires, 74HC74N, HD74S76AP, resistors: 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ

1 ea. MR-CDS photo cell, MR-PS8 switch panel, MR-FND 7 segment display, 555 timer, MR-20 PIN, MR-7447, power connector, 9 V battery connector (battery not included), MR Board, capacitors: 47 µF, 1 µF, 100 µF, 1 KPX G1205A

Includes

Locking Storage Case, Magnetic Breadboard, Pre-mounted Digital and Analog Components, and Mounted DIP Sockets to Accept Customers Components

Order Information

MR 200 Digital/Analog Breadboard SE-9982

Required: 9 V Battery

MR 100 Analog Breadboard

SE-9981

- Magnetic connections
- Fiberboard storage case
- Includes analog components

The MR Board is a reusable magnetic breadboard that eliminates the need to solder or strip wires when constructing an electronic circuit. By using components that connect through magnetic attraction to the board, students are able to quickly check and expand their ideas regarding electronics concepts.

Components are protected from damage, and user provided components can be inserted in pre-mounted sockets.





Parts list

14 holed connectors

4 MR-Free connectors

2 ea. LEDs, resistors: 100 Ω, 1 kΩ, 10 kΩ,

100 kΩ, capacitors: 10 µF, 100 µF, 0.1 µF, NPN transistors

1 ea. variable resistor, capacitors: 47 µF, 0.01 µF, 0.022 µF, 0.22 µF, PNP transistor, switch, power connector, battery holder (battery not included), speaker, AMP, 555 timer, MR-66T, keyboard, MR board, component storage board

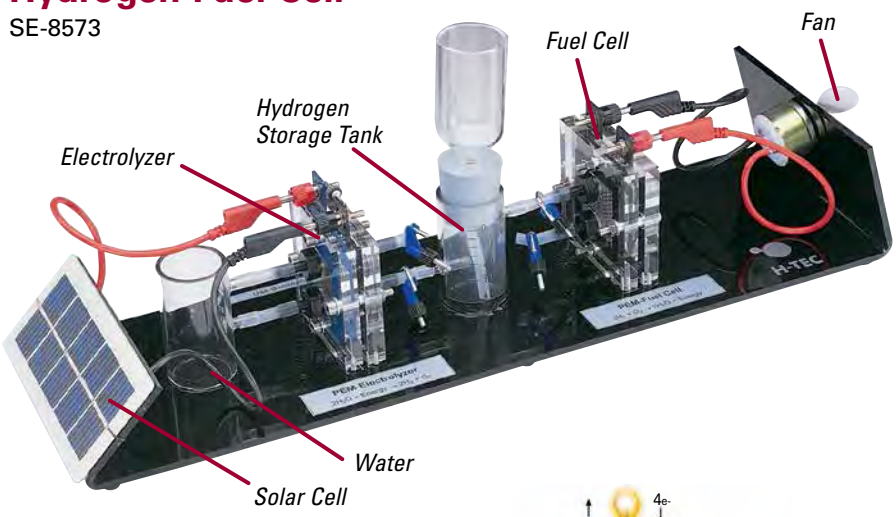
Order Information

MR 100 Analog Breadboard SE-9981

Required: 9 V Battery

Hydrogen Fuel Cell

SE-8573



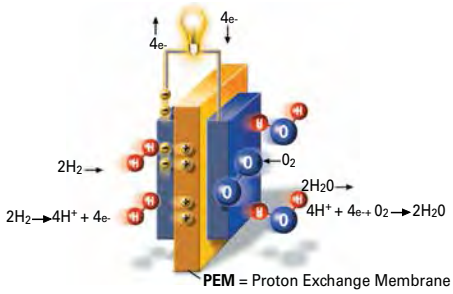
A hydrogen fuel cell is a clean and efficient way of storing energy and generating electricity. With this Hydrogen Fuel Cell, students see a real-world example of cutting-edge energy technology.

Electricity from the solar panel is used in the process of electrolysis to split water into oxygen and hydrogen.

The hydrogen is used as fuel in the fuel cell. The process that takes place in the fuel cell is the opposite of electrolysis: the hydrogen is combined with oxygen to make water and produce electricity.

In this demonstration, the electricity produced by the fuel cell is used to operate a fan. The fuel cell has an efficiency of about 50%.

This apparatus uses Proton Exchange Membrane (PEM) technology. A PEM is a proton-conducting polymer membrane that is covered with a layer of catalyst material on both sides. These two layers form the cell's cathode and anode. One PEM is used to separate the hydrogen from the water, and a second PEM is used to recombine the hydrogen with oxygen to make water.



The fuel cell contains a Proton Exchange Membrane that facilitates energy production.

Specifications

Dimensions: 15 cm x 53 cm x 18 cm
Solar Cell: 2.5 V, 300 mA
Fuel Cell Voltage Range: 0.3-0.9 V
Fan Power: 20 mW

Order Information

Hydrogen Fuel Cell	SE-8573	
Recommended for use with ScienceWorkshop:		
Voltage Sensor	UI-5100	p. 52
Current Sensor	CI-6556	p. 52
Recommended for use with PASPORT:		
Voltage/Current Sensor	PS-2115	p. 52

Fuel Cell Tutorial Set

SE-8837



This complete fuel cell tutorial kit includes everything needed to study the operation of fuel cells. Students cover the metal base-plate with templates from the tutorial book. These act as guides to which students attach the magnetically mounted components.

Solar cells, fuel cells, gas storage tanks, and a fan can be combined for numerous experiments such as solar car, hydrogen production in a solar hydrogen gas station, air-breathing fuel cell car, solar hydrogen system, and reversible fuel cell system. A detailed textbook, *Fuel Cell Technology for Classroom Instruction* with exercises is included.

Specifications

Electrolyzer Cell 5:
5 cm3/min H_2;
2.5 cm3/min O_2;
1.16 W
Reversible Fuel Cell H_2/O_2/Air
H_2/O_2 mode: 500 mW
H_2/Air mode: 150 mW
Gas storage: 30 cm^3 H_2; 30 cm^3 O_2
Solar Module: 2.0 V / 600 mA; 13 cm x 9 cm
Battery Box: 4.5 VDC / 0.8 A
(Three AA batteries, not included)
Power Supply: 1.2 A
Load (fan): 10 mW
Load (car): 150 mW
Cable Length: 250 mm
H x W x D: 140 x 450 x 380 mm
Weight: 3.5 kg



Fuel Cell Tutorial Set Includes

- Reversible Fuel Cell H_2/O_2/Air: for production of hydrogen and oxygen and conversion of hydrogen to electricity
- PEM Electrolyzer Cell 5: for hydrogen and oxygen production
- Two Hydrogen/Oxygen Storage Tanks
- Solar Cell
- Fan: to use as an electrical load
- Car: to use as an electrical load
- Experimentation Plate with Templates
- 110 V Power Supply: for use when solar is not available
- Battery Box (Three AA batteries, not included)
- Connector Cables and Tubing
- 250 ml Distilled Water
- Fuel Cell Technology Textbook
- Carrying Case



Template: This template for the Solar Hydrogen Setup shows students how to connect the components. The components mount magnetically to the steel backing plate.



Solar Hydrogen Car Setup: The car can also be powered directly by the solar cell outside in full sunlight.



Solar Hydrogen Setup: Uses solar energy to power the electrolyzer that separates the hydrogen from the oxygen in the water. Then the hydrogen and oxygen are used in the fuel cell to run electricity through the fan.



Hydrogen Gas Station and Fuel Cell Car H_2/Air Setup: Students can construct this hydrogen gas station to fill the tanks on the fuel cell car.

Order Information

Fuel Cell Tutorial Set (110V) SE-8837

Dissectible Fuel Cell

SE-8834



This fully functional fuel cell can be completely taken apart and then reassembled in working condition. Satisfy your students' curiosity about what is inside a fuel cell.

Specifications

Fuel Cell Power Output H_2/O_2: 600 mW
Fuel Cell Power Output H_2/Air: 200 mW
Dimensions: 56 x 42 x 50 mm
Weight: 60 g

Exploded View of Fuel Cell



Order Information

Dissectible Fuel Cell	SE-8834
Required (Hydrogen Fuel Source):	
Electrolyzer 10	SE-8836
Solar Cell	SE-8838
or	
Power Supply	SE-8839

Solar Cell

SE-8838



This solar cell outputs 4 V at 350 mA in full sunlight. Used to power the Electrolyzer.
Dimensions: 13 x 9 cm.
Connection: 2 mm banana

Order Information

Solar Cell	SE-8838

Solar Cell 1.00 W

SE-8847



Power: 1 W nominal power output;
2.40 V open circuit voltage
Dimensions: 127 x 152 x 8 mm
outside dimensions; 30.5 cm^2 actual cell area
Includes one pair of 2 mm banana plug cables.

Order Information

Solar Cell 1.00 W	SE-8847

Hydrogen Fuel Supply

Electrolyzer 10

SE-8836



This electrolyzer supplies hydrogen by separating the hydrogen from water. It requires a power source: Either a solar cell (see below) or an AC power adapter (at right).

Includes

Double-cell PEM electrolyzer with water tanks, hydrogen, and oxygen tanks

Specifications

Hydrogen Production: 10 cm^3/min
Oxygen Production: 5 cm^3/min
Power: 2.33 W
Dimensions: 200 x 180 x 120 mm

Order Information

Electrolyzer 10	SE-8836

Power Supply

SE-8839



This power supply plugs into line voltage and outputs 5 VDC at 3 A. Used to power the Electrolyzer when sunlight is not available.

Connection: 2 mm banana

110 V version pictured.
220 V version is also available.

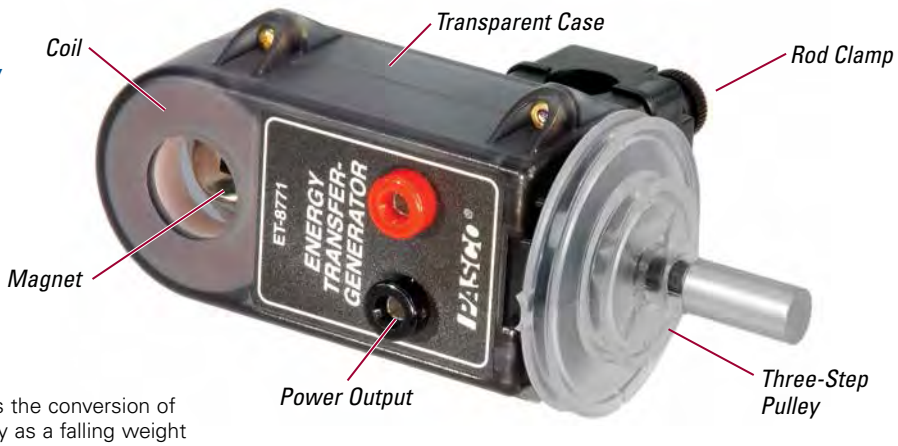
Order Information

Power Supply	SE-8839

Energy Transfer – Generator

ET-8771B

- Transfers gravitational potential energy to electrical energy
- Open design: 19 mm neodymium magnet can be seen spinning between the two coils
- Real-time computer measurement of output power

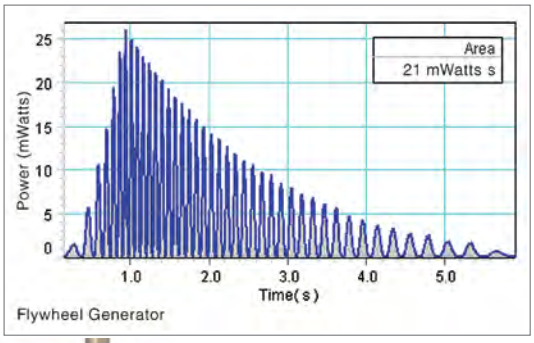


PASCO's Energy Transfer Generator demonstrates the conversion of gravitational potential energy into electrical energy as a falling weight turns a magnet between two coils. The open design permits easy identification of the essential parts of the generator. The supplied lamp or load resistor can be plugged into the output banana jacks. A Voltage/Current Sensor can be used to measure the generated current, voltage, and power.

By wrapping the string around different-sized steps on the three-step pulley, the generator will spin at different speeds. The smaller the pulley radius, the slower the weight falls and the greater percentage of the potential energy is converted to electrical energy.

The AC power generated by spinning the shaft by hand easily lights the included red-green LED. The LED goes from red to green, indicating the direction of the current.

The built-in rod clamp is used to mount the generator on a rod stand.





Shown using optional Flywheel

As the hanging mass falls, rotational kinetic energy is stored in the flywheel, and converted to electrical energy.

Energy Transfer Flywheel Accessory

ET-8773

The Flywheel Accessory is attached to the Generator (see photo to the right) to demonstrate the storage of rotational kinetic energy. The solid aluminum disk (6.3 cm diameter, 80 g mass) keys into the shaft of the Generator to prevent slipping. A thread attached to a hanging weight easily wraps around the built-in pulley.



Flywheel Accessory has a built-in pulley and a spiral pattern on the label to show rotational motion.

Order Information

Energy Transfer Flywheel Accessory ET-8773

Required:

Energy Transfer Generator ET-8771B



Includes

Generator with three-step pulley
Red-Green LED mounted on plug
100-ohm load resistor mounted on plug
Spool of thread

Order Information

Energy Transfer Generator	ET-8771B	
Recommended:		
Flywheel Accessory	ET-8773	
Hydro Accessory	ET-8772	p. 221
Hooked Mass Set	SE-8759	p. 181
Large Rod Base	ME-8735	p. 170
Steel Rod (90 cm)	ME-8738	p. 170
No Bounce Pad	SE-7347	p. 178
Required for use with PASPORT:		
Voltage/Current Sensor	PS-2115	p. 52

Energy Transfer Generator Gearing

ET-8775



Use the Generator Gearing with the Energy Transfer Generator to create a measurable power output with a few turns of the hand. Simply connect the gearing to the same rod stand as the generator and stretch the drive belt over the two pulleys. Use the LED on the generator or voltage and current sensors to monitor the output.



Includes

Generator Hand Crank Disc
Built-in Rod Clamp
Drive Belt (2)

Order Information

Energy Transfer Generator Gearing	**ET-8775**	
Required:		
Energy Transfer Generator	ET-8771B	
Large Base and Support Rod		p. 170-171
Recommended for use with PASPORT:		
Xplorer GLX	PS-2002	pp. 18-19
Voltage/Current Sensor	PS-2115	p. 52

Energy Transfer Hydro Accessory

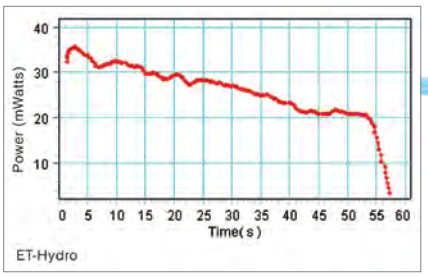
ET-8772

- Demonstrates hydroelectric power generation
- Open design gives view of spinning turbine and water stream
- Falling water lights an LED



The Hydro Accessory is used with the Energy Transfer Generator to demonstrate how falling water generates electricity. The gravitational potential energy of the water is converted into electrical energy as the falling water turns the turbine. The water can be supplied using the optional Water Reservoir. The water that has passed through the turbine is caught in a beaker and measured to determine the total mass that has fallen.

The water nozzle size and angle can be adjusted to optimize performance. By changing the height of the Water Reservoir, different efficiencies are achieved.





Power data as water falls from the reservoir through the turbine



Includes

Turbine housing
Plastic turbine (4 cm diameter)
Water nozzles (5)
Tubing (2 m long)
Plastic hose clamp
Screwdriver for attaching Hydro Accessory to Generator

Order Information

Energy Transfer Hydro Accessory	**ET-8772**	
Required:		
Energy Transfer Generator	ET-8771B	
Recommended:		
Water Reservoir	ME-8594	p. 179
Large Rod Base	ME-8735	p. 170
Steel Rod (90 cm)	ME-8738	p. 170
Three-Finger Clamp	SE-9445	p. 172
1000 ml Beaker (6 pack)	SE-7288	p. 179

Energy Transfer Wind Turbine

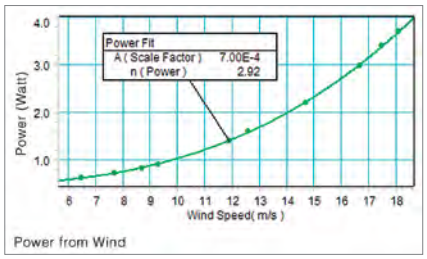
ET-8783



Attach this clear propeller to the Energy Transfer Generator for a complete wind energy turbine. Students will better understand the process of electrical energy production from wind after using the turbine.



Power generated by the Wind Turbine is measured using the Xplorer GLX, and the wind speed is measured using the Weather/Anemometer Sensor (see page 70). In the graph below, the resulting data shows that power generated by a wind turbine depends on the cube of the wind speed.



Includes

Fan and mounting hardware



Order Information

Energy Transfer Wind Turbine	ET-8783
Required:	
Energy Transfer Generator	ET-8771B

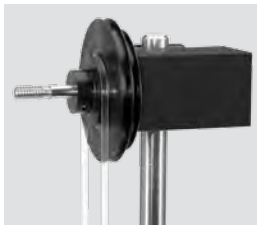
Propeller Wind Turbine

ET-8776

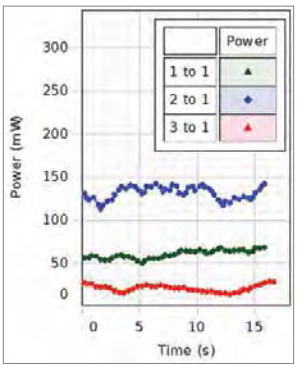
- Generate electrical energy
- Vary prop type
- Vary gear ratio

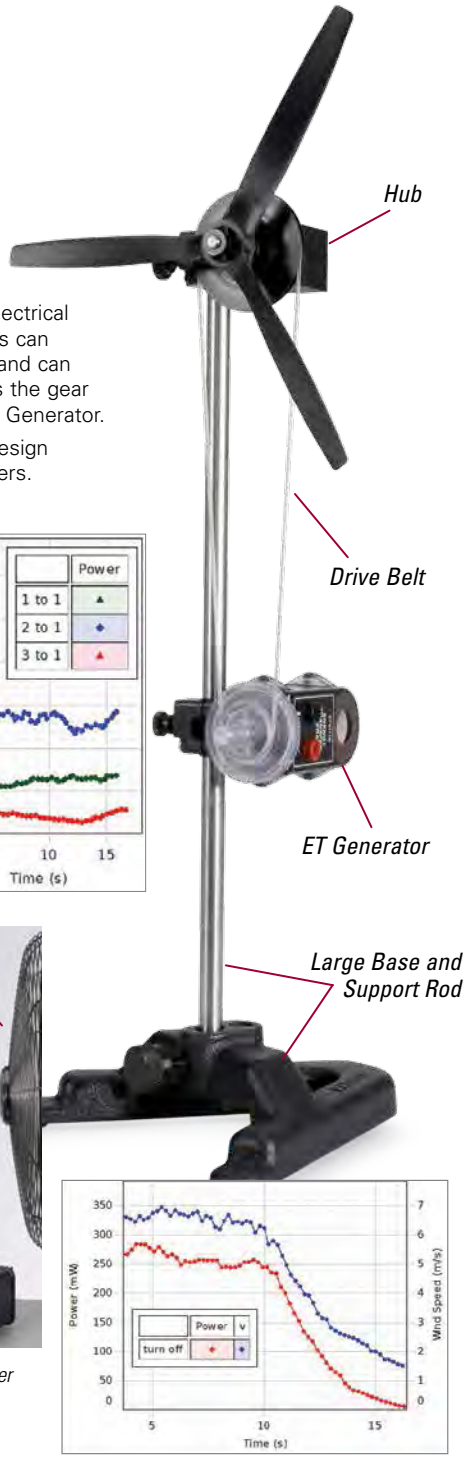
This accessory to the Energy Transfer–Generator (ET-8771B) generates electrical power from wind on a small scale. Students can learn about how a real wind turbine works and can vary propeller type and diameter, as well as the gear ratio between the propeller hub and the ET Generator.

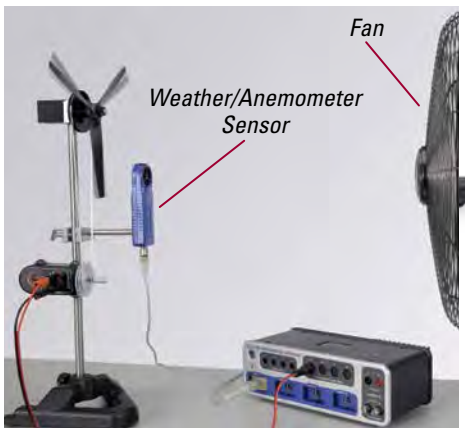
To extend the investigation, students can design their own props or use other hobby propellers.



The hub has 3 different diameter pulleys which when used with the 3-step pulley on the ET Generator allows gear ratios of 1:1, 2:1 and 3: 1. The graph shows that the 2:1 gear ratio outputs the most power.







Shown in use with the PS-2174 Weather/Anemometer to measure wind speed from the large house fan. Note the correlation between the wind speed and power generated as the fan is turned off.

Order Information

Propeller Wind Turbine	ET-8776
Required for use:	
Energy Transfer Generator	ET-8771B p. 220
Shown in use with:	
Weather/Anemometer Sensor	PS-2174 p. 70
Large Base and Support Rod	p. 170-171

Includes

Three blade Propeller (10" diameter)
Two blade Propeller (11" diameter)
Gearing Hub
Drive Belt

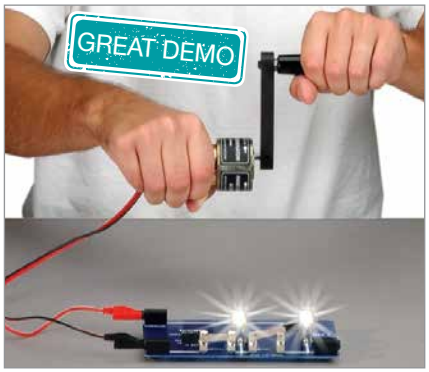


Hand-Crank Generator

EM-8090



- Heavy-duty geared generator outputs up to 25 watts



This generator produces up to 12 Volts with a sturdy handle, designed to be cranked by hand. When used to power the light bulbs on the Series/Parallel Circuit board (sold separately), students can feel the difference in effort required for lighting one bulb, two bulbs, or no load.

Order Information

Hand-Crank Generator EM-8090
Shown in use with:
Series/Parallel Circuit EM-8677

Mini Generator

SE-8645



Use the Mini Generator with the recommended accessories:
Light bulb and Stand
1 Farad Capacitor

The Mini Generator produces up to 6 volts DC for basic experiments in electricity, electromagnetism, and electrolysis. It replaces the usual power supply with a device that students can see, operate, and understand.

Order Information

Mini Generator SE-8645
Recommended:
Capacitor (1 Farad) SE-8626
Light Bulb and Stand EM-9099
Replacement Bulb #50, 7.5 V, 0.22 A

Ring Launcher

EM-8661

GREAT DEMO

- Electromagnetic induction
- Shoots ring 2 meters high
- Improved design with thermal shutoff

In this classic demonstration of electromagnetic induction, an aluminum ring is propelled straight up a maximum distance of 2 meters. The changing magnetic field from the AC-powered coil causes a changing magnetic flux through the aluminum ring. The induced EMF in the ring sets up a current that produces a magnetic field. The induced magnetic field opposes the field of the coil, pushing the ring up.

The PASCO Ring Launcher has been optimized to launch the ring higher and to maximize safety by enclosing all wiring inside the case. A thermal shutoff switch protects the coil by preventing overheating when the momentary launch switch is held down for a prolonged time. A red light indicates when the thermal switch is activated, and further launches are prohibited until the device cools.

Ring Launcher design ideas contributed by Carl Schneider and John Ertel from the U.S. Naval Academy.



Order Information

Ring Launcher (120 VAC only) EM-8661

Ring Launcher Accessories

EM-8662

Includes a coil with a bulb that lights by induction when the coil is placed over the launcher core. Also includes three additional rings: one split aluminum ring that will not launch, one copper ring, and one shorter aluminum ring.



Lighting a bulb connected to a coil by induction. The coil and bulb are included in the Ring Launcher Accessories.

Includes

Coil with Light Bulb
Split Aluminum Ring
Short Aluminum Ring
Copper Ring



Order Information

Ring Launcher Accessories EM-8662

Variable Gap Magnet

EM-8618

LAB ESSENTIALS

- Lower cost
- Larger magnets (1 inch diameter)
- Greater field (1 Tesla maximum)
- Great for induction experiments



The redesigned Variable Gap Magnet is rugged and durable while providing excellent results as a demonstration tool. The two one inch (2.54 cm) diameter neodymium magnets are mounted on a heavy-duty cast iron base that has a threaded hole for mounting on a support rod to provide even more versatility.

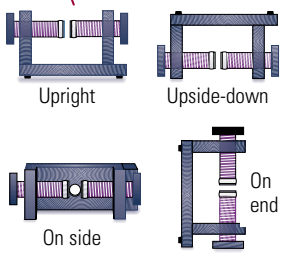
The gap may be varied from 0.5 cm to 8.9 cm using the adjustment screws. Two flat pole pieces are also included to provide a uniform magnetic field when needed.

Demonstrate Diamagnetism and Paramagnetism

The diamagnetic glass rod (figure a) aligns transverse to the field; the paramagnetic aluminum rod (figure b) aligns with the field.









Demonstrate Magnetic Damping

Swing the solid aluminum paddle through the gap and it stops dead, the motion damped due to eddy currents. Now try the slotted paddles. One swings freely while the other is immediately damped.



Demonstrate Force on a Current-Carrying Wire

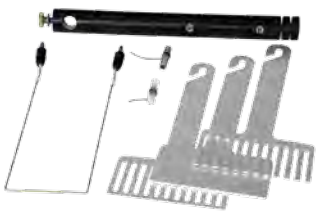
Pass a current through the wire swing (power supply not included) to investigate the right-hand rule for magnetic forces.

Magnetic Force Accessory

EM-8642A

Includes

Three aluminum paddles (solid, slotted, closed slotted)
Glass rod
Aluminum rod
Wire swing
Special mounting rod



Order Information

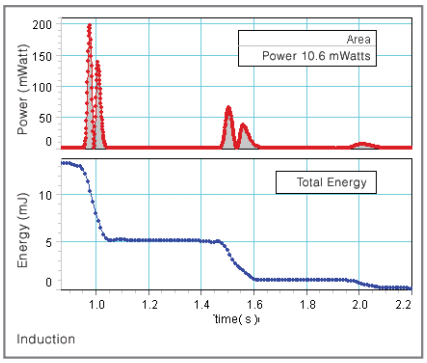
Variable Gap Magnet	EM-8618	
(Includes Variable Gap Magnet with Pole Pieces)		
Magnetic Demonstration System	EM-8644B	
(Includes EM-8618 and EM-8642A)		
Magnetic Force Accessory	EM-8642A	
Required:		
Power Supply (18 V DC, 5A)	SE-9720A	p. 232
or		
Mini-Generator	SE-8645	p. 223
Base and Support Rod	ME-9355	p. 171
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 214

Induction Wand

EM-8099



The Induction Wand is a rigid pendulum with a coil at the bottom end, connected to the banana terminals at the other end. A through-hole allows the pendulum to be connected to a Rotary Motion Sensor *(page 28, not included)*, for detailed investigations of induction as the coil is swung through a magnetic field.



The energy of the pendulum decreases with each pass of the coil through the magnet. The energy dissipated in the resistor is obtained from the area under a power versus time plot. For more information, see page 348.

Includes

Wand with screw
Resistive load



Order Information

Induction Wand EM-8099

AC/DC Motor (Accessory to Variable Lab Magnet)

SE-8657



The Motor Accessory is an electromagnet designed as an armature that will rotate when placed in a magnetic field and connected to an AC or DC power supply. The Motor Accessory can transform:

- The Variable Gap Magnet into a DC and a synchronous AC motor and generator. Students can explore the relationships between motor speed, voltage, and AC frequency, as well as armature direction, rotation and polarity.
- The Basic Coil Set into a universal motor. Students learn the relationships between current and magnetic field direction, the effects of voltage, AC current frequency, and DC voltage changes on motor speed.

Experiments

All experiments with the Motor Accessory can be performed with either a Digital Function Generator or the 850 Universal Interface.



Motor Accessory with the Basic Coil Set

Includes

Armature
Brushes
Mounting Rod



Order Information

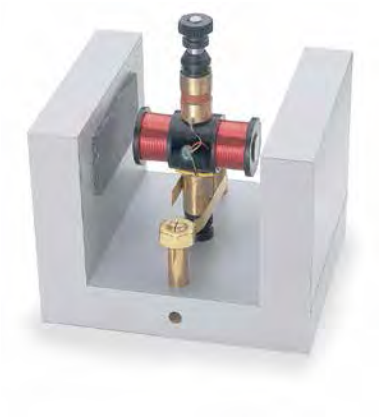
AC/DC Motor Accessory SE-8657

Required:

Function Generator	PI-8127	p. 236
or		
850 Universal Interface		p. 14-17
Variable Gap Magnet	EM-8618	p. 224
Basic Coil Set	SF-8616	p. 226

Permanent Magnet Motor

SE-8658A



The Permanent Magnet Motor teaches principles involved in the operation of DC and synchronous AC motors, as well as AC and DC power generation.

Open construction permits students to trace the wiring and relate motor performance to basic laws of electromagnetism. A few seconds and no additional parts are required to reverse the armature and change from a DC split-ring commutator to AC slip rings. Powerful ceramic field magnets and ample windings give excellent performance with minimal current.

Experiments

This motor will operate with simple flashlight cells or a function generator/amplifier, but it is designed to take advantage of the features of DataStudio. Photogates can measure the motor's speed as frequency, voltage, and current are varied. Powering the motor with the Power Amplifier permits control from the computer keyboard.

Order Information

Permanent Magnet Motor SE-8658A

Required:

Function Generator	PI-8127	p. 236
or		
850 Universal Interface		p. 14-17

Coils and Cores

Basic Coil Set SF-8616



These high-quality coils and laminated iron cores provide an effective introduction to electromagnetic theory. Purchase them individually or as a complete set. The coils are color-coded and each coil is labeled with the number of turns and the direction of the winding. Use them to investigate:

Electromagnetism: Show how the magnetic field can be increased by increasing the current, by adding an iron core, or by using a coil with more turns.

Induction: Pass a magnet through a coil and detect the resulting electromotive force (EMF) with a galvanometer. Show how the EMF depends on the number of turns in the coil and on the relative velocity of the magnet and coil.

Transformers: Mount coils onto the U- or E-shaped iron cores to demonstrate mutual inductance and transformer theory. Then connect a load to investigate power transfer. Investigate basic transformer theory with an AC power supply and a voltmeter. Advanced principles require a high power output function generator (Model PI-9587C or PI-9598) and an oscilloscope. For better experiments and demonstrations, use a computer with PASCO's 850 Universal Interface (pp. 14-17).

Complete Coil Set SF-8617



Using the signal generator capability of the 850 Universal Interface and oscilloscope display of PASCO Capstone™ Software, students can investigate transformer theory.

Basic Coil Set SF-8616	Complete Coil Set SF-8617	Model	Individual Parts Description
1	1	SF-8609	Coil (200 turn)
2	2	SF-8610	Coil (400 turn)
1	1	SF-8611	Coil (800 turn)
-	1	SF-8612	Coil (1600 turn)
-	1	SF-8613	Coil (3200 turn)
1	1	SF-8614	U-shaped core
-	1	SF-8615	E-shaped core

Order Information

Basic Coil Set SF-8616
Complete Coil Set SF-8617
Individual parts sold separately (see chart above).

Primary and Secondary Coils

SE-8653



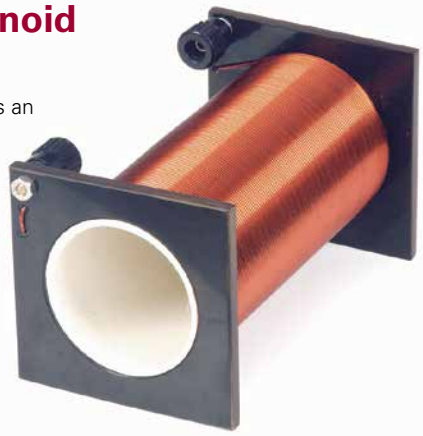
Transformer theory can be studied with this set of nested coils consisting of an outside coil (length = 11 cm) having 2920 turns, an inner coil (length = 12 cm) having 235 turns, and a removable 0.96 cm diameter soft iron core. The outer coil is large enough (inner diameter = 2 cm) to drop a bar magnet (SE-8604, page 230) through to demonstrate induction.

Order Information

Primary and Secondary Coils SE-8653

Air Core Solenoid

SE-7585



This air core solenoid has an inner diameter of 5.5 cm and a length of 13.5 cm, allowing ample room to insert an experimental apparatus into its uniform magnetic field. The maximum current of 5 A produces a 200 gauss magnetic field.

Specifications

Total Number of Turns: 550-570
Wire Gauge: 16
Capacity: 5 A continuous
Core Inner Diameter: 5.5 cm

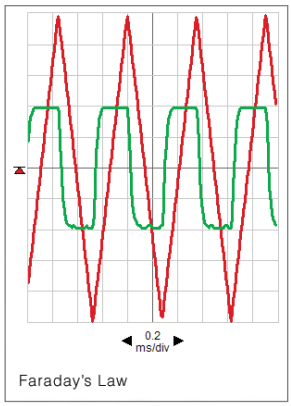
Order Information

Air Core Solenoid SE-7585

Field and Detector Coils

LAB ESSENTIALS





A 5 volt triangle wave (red trace) is applied to the Field Coil, and the induced voltage in the 2000-turn Detector Coil is a square wave (green trace).



1. *EM-6711 Field Coil: 200 turns of #22 copper wire, 18.6 cm ID, 22.1 cm OD. Max. current 2 A.*
2. *EM-6723 500 turns of #22 copper wire. Max current 2 A.*
3. *EM-6712 Detector Coil (400 turn): 400 turns of #28 copper wire.*
4. *EM-6713 Detector Coil (2000 turn): 2000 turns of #36 copper wire.*
5. *EM-6714 Bi-color LED Indicator.*

Features

Verify Faraday's Law: Verify all aspects of Faraday's Law.

Qualitative Demonstration: With the Bi-Color LED Indicator and the Variable Gap Magnet, students can see when a current is induced in the detector coil. With the LED indicator plugged into a detector coil, the LED flashes red or green as the detector coil passes through the magnet.

Quantitative Demonstration: PASCO's coils can be used with a function generator and an oscilloscope, or connected to the 850 Universal Interface.

Developed for Workshop Physics® activities

For details of experiments using these coils, see Christopher C. Jones, "Faraday's Law Apparatus for the Freshman Laboratory". *Am. J. Phys.* 1987; 55(12):1148-1150.

Order Information

Field Coil (200-turn)	EM-6711	
Field Coil (500-turn)	EM-6723	
Detector Coil (400-turn)	EM-6712	
Detector Coil (2000-turn)	EM-6713	
LED Indicator	EM-6714	
Recommended:		
Variable Gap Magnet	EM-8618	p. 224
850 Universal Interface		p. 14-17
or		
Low Voltage AC/DC Power Supply	SF-9584B	p. 233
and:		
Function Generator	PI-8127	p. 236

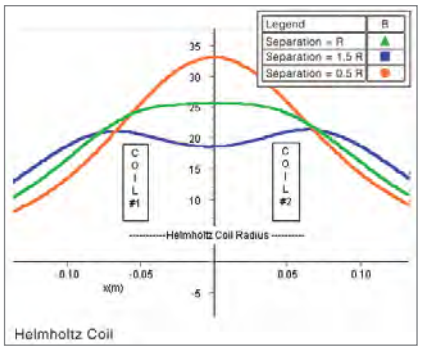
Helmholtz Coils

EM-6722 with 200-turn Coils

EM-6724 with 500-turn Coils



The Helmholtz Coils consist of two coils mounted on a base to provide a uniform magnetic field between the coils. The base has a slot that allows the coils to be spaced apart at any distance from 3 cm to 20 cm (center-to-center distance). The proper separation for Helmholtz coils (e.g., the radius of the coils) is marked on the base. Two 0.635 cm (0.25 inch) diameter holes between the coils accommodate mounting devices in the uniform magnetic field.



This plot shows the magnetic field strength along the axis of Helmholtz coils for three different coil separations: the green data is the magnetic field with the coils separated at the proper distance (the radius of the coils).

Order Information

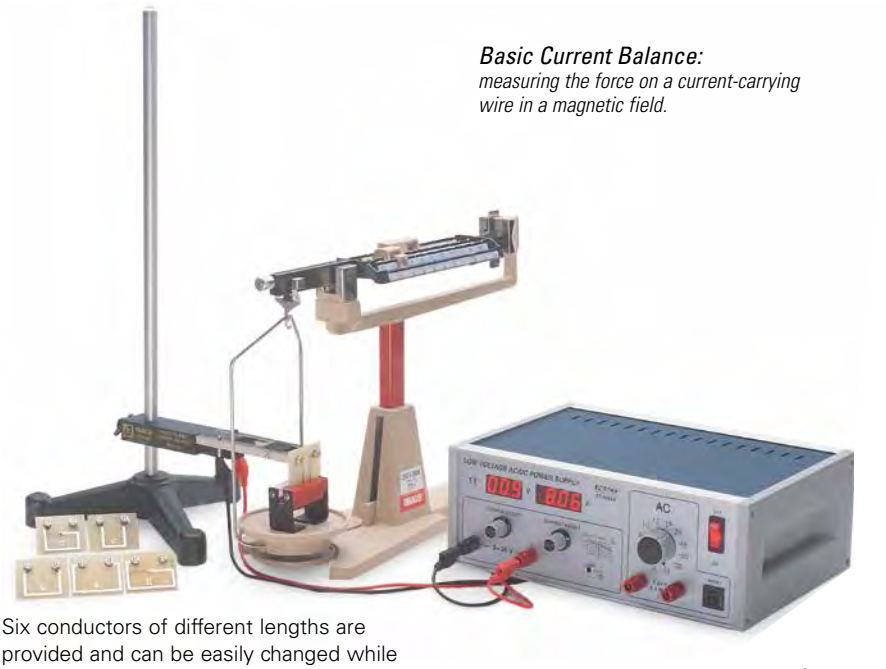
Helmholtz Coils (200-turn Coils)	EM-6722
Helmholtz Coils (500-turn Coils)	EM-6724
Helmholtz Coil Base (without coils)	EM-6715

Basic Current Balance

SF-8607

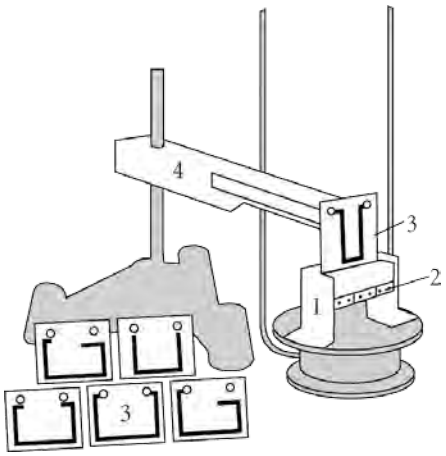
- Measure force vs. current, wire length, magnetic field, and angle
- Use a gram balance to measure force

One to six magnets are mounted on an iron yoke, which is placed on a gram balance. A conductor is suspended between the magnets. The weight of the magnets and yoke is measured, then a current (0-5 A) is passed through the conductor. The change in the reading of the balance (0-4 grams) measures the force between the conductor and the magnetic field.



Basic Current Balance:
measuring the force on a current-carrying wire in a magnetic field.

Six conductors of different lengths are provided and can be easily changed while maintaining a repeatable position with respect to the magnetic field.



Includes

1. *Iron Yoke (holds magnets)*
2. *Removable Magnets (six)*
3. *Six Conductors (1, 2, 3, 4, 6 and 8 cm in length)*
4. *Mount (for holding/positioning conductors)*

Order Information

Basic Current Balance	SF-8607	
Required:		
Ohaus Balance	SE-8725	p. 180
Power Supply	SF-9584B	p. 233
Base and Support Rod	ME-9355	p. 171
Recommended:		
Basic Digital Multimeter	SE-9786A	p. 239
Tesla Meter	SF-7579	p. 230
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 214

The Current Balance Accessory Kit

SF-8608

The Current Balance Accessory Kit completes the Basic Current Balance, allowing the angle between the conductor and the magnetic field to be varied. The experiment is the same as with the Basic Current Balance, but a 10-turn rectangular coil is used. The coil can be turned through a full 180°, and a built-in degree scale lets students accurately measure the angle between the coil and the field of the fixed magnet.



Includes

Fixed Magnet with Yoke
10-turn Rectangular Coil

Order Information

Current Balance Accessory Kit SF-8608

Eddy Current Rods

SE-7361



This dramatic demonstration uses falling ring-shaped neodymium magnets to create eddy currents in three rods of differing materials. Due to the difference in conductivity of the rods, the magnets fall at different rates. The demonstration is performed by turning the apparatus upside down and can be repeated by continuing to invert the apparatus. The 15-cm long rods are made of copper, aluminum, and plastic (in order of decreasing conductivity).

Order Information

Eddy Current Rods SE-7361

Lenz's Law Demonstrator

MG-8600



GREAT DEMO

For a 3 m Lenz's Law Demonstration, add the 1.5 m Extension Tube (see below)

Drop a mass through the 1.5 meter tube. It takes about half a second to drop. Then drop a magnet with an identical mass. It takes over 10 times as long to fall. As the magnet falls, it generates a current in the tube, moving in one direction above the magnet and in the opposite direction below. Both currents obey Lenz's Law and induce magnetic fields that oppose the magnet's motion (scale included).

Order Information

Lenz's Law Demonstrator MG-8600

Recommended:

1.5 m Extension Tube MG-8601

Dip Needle

SF-8619



This rotatable compass has durable and almost frictionless bearings. Use it horizontally as a standard compass or vertically to find the dip angle of the Earth's magnetic field. Instruction sheet included.

Order Information

Dip Needle SF-8619

2-D Magnetic Field Demonstrator

SF-8602A



Consists of four plastic plates (each containing 98 small iron bars), a bar magnet, and four cardboard disks. Place a magnet above or below this demonstrator. Magnetic field lines are clearly revealed as the iron bars align with the field. Lay the plates together to form a large plate, or stand them on edge to map out a 3-D field. Can be viewed directly or used with an overhead projector.

Order Information

2-D Magnetic Field Demonstrator SF-8602A

3-D Magnetic Field Demonstrator

SE-8603



(Magnet not included)

With this 3-D Magnetic Field Demonstrator, the iron filings are suspended in oil in a sealed acrylic container. Insert a magnet into the 10 mm opening, or two magnets with opposing polarities, and watch the filings line up. View the demonstration directly or with an overhead projector.

Order Information

3-D Magnetic Field Demonstrator SE-8603

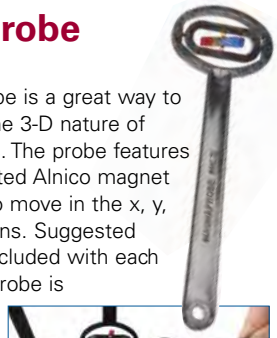
Recommended:

Bar Magnets (set of 2) ..... SE-8604 p. 230

Magnaprobe

SE-7390

The Magnaprobe is a great way to demonstrate the 3-D nature of magnetic fields. The probe features a gimbal-mounted Alnico magnet which is free to move in the x, y, and z dimensions. Suggested activities are included with each probe. Magnaprobe is 12 cm long.





GREAT DEMO

Order Information

Magnaprobe (1 each) SE-7390

Plotting Compass

SE-8680



(Appearance may vary)



Includes 20 compasses (19 mm diameter).

Order Information

Plotting Compass (20 pack) SE-8680

Liquid Filled Compasses (5 pack)

EM-8631A



2.5 cm long needle has north end marked in black. This compass is perfect for investigating the magnetic fields around straight wires. 4.5 cm diameter liquid filled plastic case. Contains five compasses.

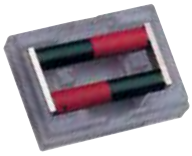
Order Information

Liquid Filled Compasses (5 pack) EM-8631A

Replacement part for CASTLE Kits (EM-8624A and EM-8654).

Bar Magnets

SE-8604 (2 pack)



These cylindrical magnets (10 x 50 mm) are small, strong, and color-coded for polarity. Plastic case and keeper plates included.

Order Information

Bar Magnets (2 pack) SE-8604

Rotating Magnet Stands

SE-8605 (2 pack)



These clear acrylic stands have low-friction swivels and can be used with an overhead projector for demonstrations with magnets and charged rods. The agate bearings are smooth and durable. An azimuth scale is molded into each base. Shown with above Bar Magnets (not included).

Order Information

Rotating Magnet Stands (2 pack) SE-8605

Alnico Bar Magnets

EM-8620 (2 pack)



These magnets (150 x 13 mm) are stronger and last longer than iron magnets. They fit a St. Louis motor and the north poles are notched. Case included.

Order Information

Alnico Bar Magnets (2 pack) EM-8620

Bar Magnets

SE-8687 (2 pack)



These economical Bar Magnets (100 mm x 12 mm) are color coded to distinguish between the north and south poles. Align the similar poles together and watch the magnets repel. Align the opposite poles together and watch them attract.

Order Information

Bar Magnets (2 pack) SE-8687

Magnetizer

SE-8637

Re-magnetize bar and horseshoe magnets or magnetize iron bars for experiments. Insert a magnet into each cavity and press the button. Three keeper bars are included. Magnet not included.



Specifications

Coil Current: 100 A peak (min.)
Magnetization Field: At least 7 kG peak
Operating Voltage: 115/220 V AC, 50/60 Hz

Order Information

Magnetizer SE-8637

Tesla Meter

SF-7579

- 0–2 Tesla range
- Range autoscaling

A 6-12 Volt DC power supply is required to use the Tesla Meter.



Includes

Tesla Meter with Digital Display
Probe (80 mm x 8 mm x 2 mm)
Power Adapter: 110V AC to 9V DC, 200 mA

Specifications

Resolution: 0.1 mT (0 – 200 mT)
1 mT (200 mT – 2T)
Accuracy: ±5% of measurement

Order Information

Tesla Meter SF-7579

Neodymium Magnets

Neodymium magnets are some of the strongest commercial magnets available. They come either bare or with a protective coating to prevent the brittle metal from chipping. Plastic case included.

⚠ WARNING
This product contains small magnets. Swallowed magnets can stick together across intestines causing serious infections and death. Seek immediate medical attention if magnet(s) are swallowed or inhaled.

Without Hole EM-8648B

13 mm dia. x 5 mm



Order Information

Neodymium Magnets (16) (without hole) EM-8648B

With Hole EM-9980A

13 mm dia. x 10 mm



Hole fits a #2 screw



Order Information

Neodymium Magnets (8) (with hole) EM-9980A

Plastic Coated EM-8621

19 mm dia. x 10 mm



Order Information

Neodymium Magnets (2) (Plastic Coated) EM-8621

DC Programmable Power Supply

PI-9880

- 1 amp at 18 VDC
- Digital display
- Ramp or step positive voltage up or down

Provides a current of 1 A at 18 V, with a resolution of 0.01 V and typical ripple of 10 mV. This DC power supply has added features to cycle the voltage on and off, to ramp the voltage up or down between the maximum and minimum set, and to change the voltage in steps. A positive offset can be introduced so the ramp can start at a voltage other than zero. Minimum period is 0.1 sec (10 Hz) and the maximum period is 999 seconds.

The digital display has four digits (0.76 cm high) and can display voltage, current, or time. The time is displayed to set the period, duration, or duty cycle.

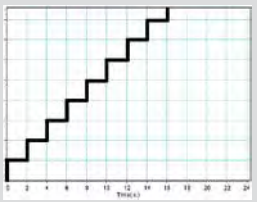
There are both coarse and fine adjustment knobs. As a safety factor, a maximum current and a maximum voltage can be set to protect your students' external circuits. The output is voltage-regulated but not current regulated.

The power supply is connected to AC power using a universal power adapter.

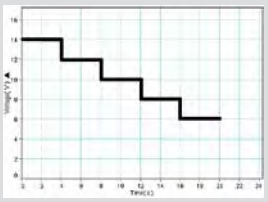


Small and light weight; 12 cm x 13 cm x 5.5 cm high and approximately 300 g.

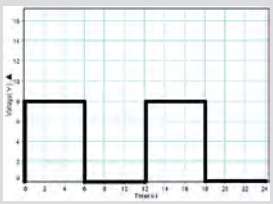
Available Functions:



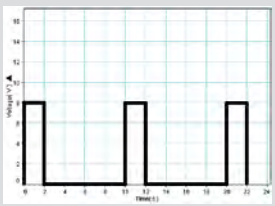
Step Voltage Up



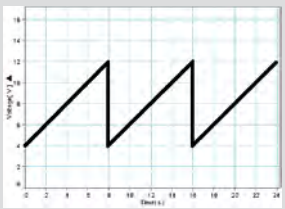
Step Voltage Down from Max to Min



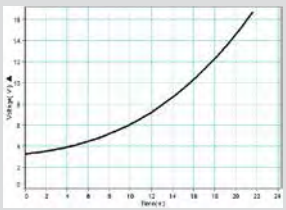
Cycle On and Off



Cycle On and Off with Different Duty Cycles



Ramp Up with Offset



Programmable

Includes

DC Power Supply

Universal Power Adapter



Order Information

DC Programmable Power Supply PI-9880

Power Supply (18 VDC, 5 A)

SE-9720A

- 0-18 VDC at 0-5 A
- Serial and parallel operation



This power supply has a remote control connector and switch on the rear panel, so units can be connected in series or parallel with each other to provide higher voltage, higher current, and higher power output.

Specifications

Digital Meter: Voltage or current

Constant Voltage Mode: Output voltage: continuously variable, coarse and fine control; line regulation: ≤0.01% ±3 mV; load regulation: ≤0.01% +3 mV; ripple and noise: ≤0.5 mV rms at low current, ≤1 mV rms at high current

Constant Current Mode: Output voltage: continuously variable, coarse and fine control; line regulation: ≤0.02% ±3 mA; load regulation: ≤0.02% ±3 mA; ripple and noise: ≤3 mA rms

Power Source: AC 100, 120, 220, 240 V ±10%, 50/60 Hz; Protection – overload and reverse polarity protected

Dimensions: 29 x 13 x 15 cm (5.5 kg)

Order Information

Power Supply (18 Volt DC, 5 A) SE-9720A

Power Supply (30 VDC, 6 A)

SE-9721A

- 0-30 VDC at 0-6 A
- 0.01% high regulation



This medium-size power supply is conservatively designed for long-term stability and durability. Dual display allows for fast checking of both voltage and current.

Specifications

Digital Meters: Voltage and current

Constant Voltage Mode: Output voltage: continuously variable, coarse and fine control; line regulation: ≤0.01% ±3 mV; load regulation: ≤0.01% +3 mV; ripple and noise: ≤0.5 mV rms at low current, ≤1 mV rms at high current

Constant Current Mode: Output voltage: continuously variable, coarse and fine control; line regulation: ≤0.02% ±3 mA; load regulation: ≤0.02% ±3 mA; ripple and noise: ≤3 mA rms

Power Source: AC 100, 120, 220, 240 V ±10%, 50/60 Hz; Protection – overload and reverse polarity protected

Dimensions: 34 x 26 x 15 cm (11.5 kg)

Order Information

Power Supply (30 Volt DC, 6 A) SE-9721A

Triple Output Power Supply

SE-8587

- 0-30 VDC at 0-3 A
- Digital voltage & current meters



This power supply offers adjustable voltage output (0-30 V), adjustable current output (0-3 A), and two independent constant voltage outputs (5 V and 12 V). Digital displays of both current and voltage allow students to easily gather data. Features overload and short-circuit protection.

Specifications

Digital Meters: Voltage and current

Constant Voltage Mode: Output voltage: continuously variable; line regulation: ≤0.05% ±10 mV; load regulation: ≤0.05% +10 mV; ripple and noise: ≤0.5 mV rms

Constant Current Mode: Output voltage: continuously variable; line regulation: ≤0.05% +10 mA; load regulation: ≤0.05% +10 mA; ripple and noise: ≤3 mA rms

Power Source: AC 110/220 VAC, 50/60 Hz

Dimensions: 29 x 13 x 15 cm (5.5 kg)

Order Information

Triple Output Power Supply SE-8587

Student Power Supply (18 VDC, 3 A)

SE-8828

- 0-18 VDC at 0-3 A
- Constant voltage or current
- Short-circuit protected
- Current limiting
- Low noise/ripple

This high quality, compact power supply provides the DC voltage and current levels necessary for most introductory student labs.



Specifications

Digital Meters: Voltage and current

Constant Voltage Mode: Output voltage: continuously variable; line regulation: <0.01% ±3 mV; load regulation: <0.01% ±2 mV; ripple and noise: <0.5 mV rms

Constant Current Mode: Output current: continuously variable; line regulation:<0.2% ±3 mA; load regulation: <0.2% ±3 mA; ripple and noise: <3 mA rms

Power Source: AC 110/220 VAC, 60/50 Hz

Dimensions: 24 x 11 x 15.4 cm (3 kg)

Order Information

Student Power Supply (18 Volt) SE-8828

AC/DC Power Supply 12V 3A

SF-9581

- Combined DC and AC supply at a low price
- Stabilized, continuously adjustable DC: 0 to 12 V
- AC presets: 2, 4, 6 and 12 V
- Currents up to 3 A for both outputs
- Outputs are overload protected



Specifications

DC Output Voltage: 0-12 V (stabilized), continuously adjustable
Maximum DC Output Current: 3 A
Maximum Ripple: 100 mV
AC Output Voltage: 2, 4, 6, 12 V, stepwise adjustable
Maximum AC Output Current: 3 A
Power Consumption: 110 W (Max.)
Fuse: T 1A (slow)
Dimensions (WxDxH): 20.3 x 20.5 x 11.7 cm

This power supply delivers a stabilized DC voltage, continuously adjustable between 0 and 12 V. Moreover, an AC voltage is supplied, which can be set to 2, 4, 6 or 12 V. The two outputs can simultaneously supply up to 3 A. Both outputs are overload protected. The DC part is protected electronically and resets automatically, while the AC part is provided with a circuit breaker that must be reset manually if it trips.

Order Information

AC/DC Power Supply SF-9581

High Voltage Power Supply

SF-9585A

- 0 to 50 VDC at up to 50 mA
- 0 to 500 VDC at up to 50 mA
- 2 to 7 VAC at up to 3 A



A versatile and reliable supply for experiments requiring medium to high voltages at relatively low currents.

The 50 and 500 VDC outputs are independently variable, providing up to 50 mA, and the output displays can be switch-selected to read voltage and current in either range.

A separate set of output terminals provides 2, 4, 5, 6 and 7 VAC at up to 3 A, a convenient source for electron tube filaments.

Note: The positive terminal of the 50-volt supply is internally connected to the negative terminal of the 500-volt supply.

Specifications

Ripple: Less than 0.1%, ±1 digit line
Regulation: <1% at 98-130 V (line voltage)
Load Regulation: <1% at 0-100% load
Displays: Digital readouts 0-50 V, 0-500 V, 0-50 mA (switch-selectable)
Power Source: 115/220 VAC, 50/60 Hz
Dimensions: 21 x 29 x 11 cm
(8 x 12 x 4 in.)

Order Information

High Voltage
Power Supply SF-9585A

Kilovolt Power Supply

SF-9586B

- 0 to 6 kVDC
- 6.3 VAC, 2 A filament source
- Digital readout



This Kilovolt DC Power Supply is used for electron tubes, electrostatics, the Millikan Oil Drop experiment, etc.

The high voltage section is by design "floating" relative to ground. This means that either the black (negative) terminal or the red (positive) terminal may be connected to ground to give a voltage range of 0 to +6 kV, resp. 0 to -6 kV relative to ground.

The output is well regulated and current limited for safety. (The maximum short circuit current is 2 mA).

Specifications

DC – Output Voltage: 0-6 k V stabilized, continuously adjustable
Short circuit current: 2 mA (Max.)
Ripple and noise (max.): Less than 1%
Readout accuracy: Better than 1% + 1 digit
AC – Output Voltage: 6.3 V
Output Current (max.): 3 A
Dimensions (W x D x H): 312 x 225 x 117 mm

Order Information

Kilovolt
Power Supply SF-9586B

Low Voltage AC/DC Power Supply

SF-9584B

- 0 to 24 VDC at 0 to 10 A
- 0 to 24 VAC at up to 6 A
- Digital readouts

TEACHER FAVORITE



The low voltage Power Supply has been designed specifically for use in teaching physics, chemistry, and other science subjects. It can provide both direct current (DC) and alternating current (AC). The Power Supply can provide both types of electrical power at the same time, and they can be adjusted independently of one another.

Separate digital displays are provided for DC and AC output.

Specifications

DC – Output Voltage: 0 to 24 V DC
Current: From 0 to 12 V, 10 A maximum. From 12 to 24 V, linearly decreasing from 10 A to 6 A, dependent on voltage setting
Meter: Digital display (volts/amps); 1% ±2 LSD; Ripple: <25 mVpp
AC – Output Voltage: 0 to 24 V AC, continuously adjustable; Current: 0 to 6 A; Overload Protection Meter: Digital display (volts/amps); 2% ± LSD
Power Source: AC 115/230 VAC, 50/60 Hz
Power Use: 320 W
Dimensions: 30 x 23 x 12 cm (12 x 9 x 5 in.)

Order Information

Low Voltage AC/DC
Power Supply SF-9584B

Power Supplies and a Current Amplifier for Advanced Physics Experiments

The power supplies and instruments on this page are used in various advanced physics experiments involving finding fundamental constants (Photoelectric Effect, Franck-Hertz, and e/m). Since each experiment uses some combination of these, it is possible to purchase one of each to perform all three experiments, one at a time.

Experiment	DC Power Supply I	DC Power Supply II	DC (Constant Current) Supply	DC Current Amplifier
Photoelectric Effect (page 290)	X			X
Franck-Hertz (page 291)	X	X		X
e/m (page 289)		X	X	

Connect to an 850 Interface:

These instruments can be used stand-alone by reading the digital displays. However, they have special data collection ports for connecting an 850 Universal Interface UI-5000 (see page 15) to record data and analyze it in PASCO Capstone. Each type of voltage and current reading is automatically identified when the power supply is connected to an 850 analog port with the special cord (included).

DC (Constant Voltage) Power Supply I

SE-6615

- 0 to 6.3 V DC, 1 A maximum
- -4.5 to 0 V DC, 10 mA maximum
- -4.5 to 30 V DC, 10 mA maximum

The (0 to 6.3 V) output is independent of the (-4.5 to 0 V) and (-4.5 to 30V) outputs, which share an output and are selected by pushing a button.



Specifications

Independent floating ground reference

Ripple: <1%

Order Information

DC (Constant Voltage) Power Supply I SE-6615

DC (Constant Voltage) Power Supply II

SE-9644

- 0 to 12 V DC, 1 A maximum
- 0 to 100 V DC, 30 mA maximum
- 0 to 200 V DC, 30 mA maximum

The (0 to 12 V) output is independent of the (0 to 100 V) and (0 to 200V) outputs, which share an output and are selected by pushing a button.



Specifications

Independent floating ground reference

Ripple: <1%

Order Information

DC (Constant Voltage) Power Supply II SE-9644

Tunable DC (Constant Current) Power Supply

SE-9622

- 0 to 3.5 A DC, 20 V maximum
- Fixed 6.3 V AC, 1A maximum



This constant current power supply has a digital readout for the current, which can be tuned from zero to 3.5 A DC. It also has a 6.3 V AC power supply for heating filaments. A High Current Sensor (PS-2193 or CI-6740) can read the current when using this power supply with interfacing experiments. Both DC and AC outputs are available simultaneously on separate floating output terminals.

Order Information

Tunable DC (Constant Current) Power Supply SE-9622

DC Current Amplifier

SE-6621

- Detects Picoamp currents
- Six ranges from 10^{-8} A to 10^{-13} A



Specifications

Independent floating ground reference

Maximum Voltage Input: 15 V

Zero drift: ≤ 0.2% of full range 10^{-13}A after 30 min.

Order Information

DC Current Amplifier SE-6621

Tunable DC Power Supply 6A

NEW

SE-9656

- Used in Zeeman Effect experiment
- Can be used in the e/m experiment to power the coils
- Maximum current of 6 A

The Tunable DC Power Supply supplies power to the pen-type mercury lamp and the electromagnet (SE-9655) in the Zeeman Effect Apparatus (SE-9654). The output for the mercury lamp is 1500 V AC and the output for the electromagnet is zero to 6 A with a maximum voltage of 36 V DC.



Specifications

AC Output: Fixed 1500 V, maximum current 145 mA

DC Output: Constant current: adjustable from zero to 6 A
Maximum voltage: 36 V
Digital readout
Extra fuse included: 250 V T5A

Order Information

Tunable DC Power Supply 6A SE-9656

Wide Range Function Generator

SB-9549A

This function generator is similar to the Basic Function Generator, but it provides a wider frequency range and greater output voltage.



Specifications

Ranges: 0.2 Hz to 5 MHz in seven ranges, (±1 count)

Waveforms: - sine (distortion <1% below 100 kHz) - square (2% symmetry, 50 nS max rise and fall time) - triangle (98% linearity below 100 kHz, 95% above 100 kHZ

Outputs: - 20 Vp-p no load, 10 V p-p max into 50 Ω load - continuously variable, 20 dB range with 20 dB step - DC offset: ±10 V (no load), ±5 V (50 Ω load) - TTL/CMOS-compatible pulse

Sweep: external voltage-controlled oscillator, 0-10 V signal can produce 100:1 frequency change

Power Source: 115/220 VAC, 50/60 Hz

Accessories: BNC to insulated clips

Order Information

Wide Range Function Generator SB-9549A

High-Frequency, High-Power Function Generator

SF-9580

- Wide frequency range: 0.001 Hz to 10 MHz
- 10 Watts up to 100 kHz to drive speakers
- Sweep mode
- Step mode



Simple design

For basic use, you just operate two large buttons:
One for frequency – one for amplitude. That's it. If you want to change waveform or to utilise the new step and sweep modes, the display keeps you updated on the status of the generator.

Unique frequency control

The frequency is set by a speed sensitive button. Turn slowly to set the display's last digit. Turn faster, and the response accelerates softly. We have designed this function to work intuitively in practical experiments with common physics equipment.

Drive speaker and vibrators directly

The built-in 10 W power amplifier drives effortlessly power-consuming equipment such as a vibrator or speaker. The amplifier can deliver more than 1 A for all frequencies between 0.001 Hz and 100 kHz.

Advanced features

The generator connects to your PC through a standard USB cable. Custom defined waveforms (e.g. created by means of a spreadsheet) can be saved to the generator. Sequences of settings can be programmed for automatic execution.

Specifications

Built-in Waveforms: Bipolar: Sine, triangle, square; Positive: Square pulse, triangle pulse, ramp up, ramp down

Distortion (sine): < 0.1 % up to 20 kHz; < 1 % otherwise

Frequency Range: 50 Ω and sync outputs: 0.001 Hz to 10.00 MHz; Power output: 0.001 Hz to 100.0 kHz

Frequency Stability: Better than 0.005 %

Amplitude: 50 Ω output, no load: 0 to 10 V (20 V p-p for bipolar waveforms); Sync output: 5 V (TTL signal: 0 to 5 V); Power output: 0 to 10 V (20 V p-p for bipolar waveforms)

Max Current: 50 Ω output, short circuit: 200 mA (only briefly); 50 Ω output, into 50: 100 mA (unlimited); Power output: 1 A (unlimited)

Power Consumption: 85 W (max); 21 W (idle)

Dimensions (WxDxH): 31.2 x 20.5 x 11.7 cm

Order Information

High-Frequency, High-Power Function Generator SF-9580

Function Generator

PI-8127

LAB ESSENTIALS

- 0.001 Hz to 150 kHz
- Programmable frequency sweep
- 10 Volts at 1 amp
- Use for circuits and/or driving speakers
- Use the ramp function to vary the speed of DC motors
- Frequency resolution of 0.001 Hz over entire range





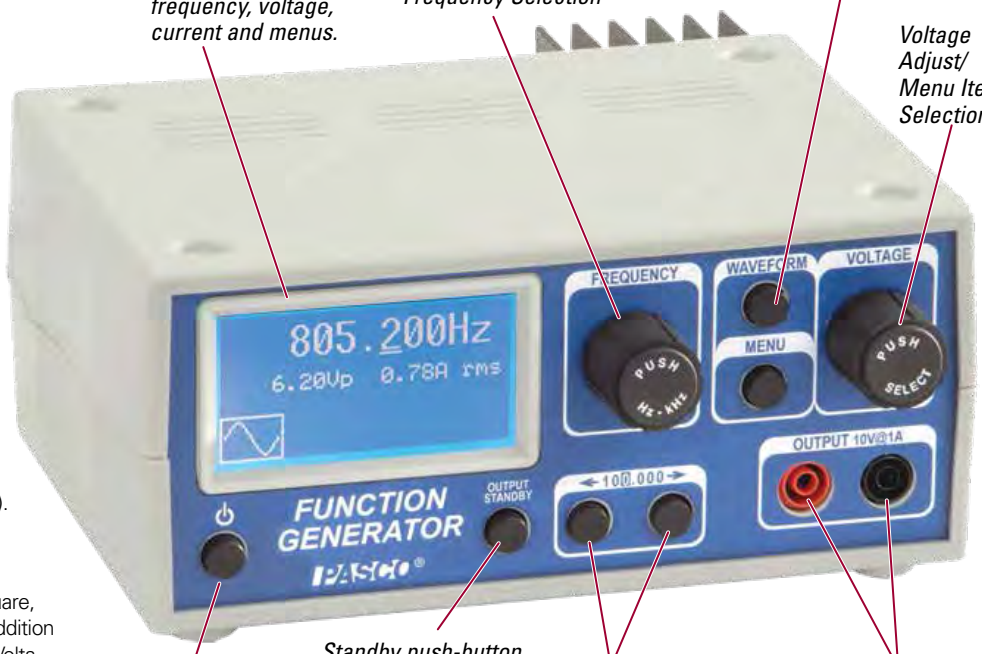
Menu driven selection makes the Function Generator intuitive to use.



LCD displays frequency, voltage, current and menus.

Frequency Selection

Voltage Adjust/ Menu Item Selection



Power Button

Standby push-button enables/disables output voltage

Resolution Selection Buttons

Output Jacks

Upgradable Firmware

Download the latest features for your PI-8127: The built-in USB port allows users to access and upgrade firmware whenever the unit is attached to a computer running current versions of PASCO Capstone™ Software (pp. 6-13).

Features

The Function Generator outputs sine, square, triangle, positive and negative ramps in addition to DC. It's powerful output, 1 Amp at 10 Volts, makes it useful for driving speakers, string vibrators, and circuits. Set maximum current and voltage outputs for safety. The LCD display is used to show readouts of frequency, voltage amplitude, and rms current.

LCD Readout: The LCD displays frequency, voltage, current, waveform, and menus. The backlight has two levels, low and high, selectable using the menu. The low backlight is useful in dark rooms.

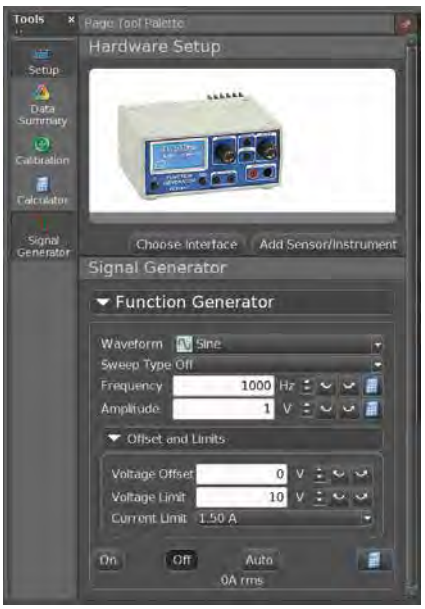
Frequency/Range Selection: There are two ranges, 0.001 Hz to 100 Hz and 1 Hz to 100 kHz, selected using the range push-button switch (integrated with the frequency knob).

Output Standby: Pushing the standby button disables the output without changing settings.

Output Current/Voltage Maximum: The maximum current or maximum voltage can be set using the menu. This is useful when the instructor needs to limit the voltage applied to a light bulb.

Offset Voltage: Any waveform may be offset with a DC voltage ranging from -10 V to +10 V, provided the peak voltage does not exceed 10 V.

Frequency Sweep: Sweep between any two frequencies at a selectable rate.



Use the Function Generator stand alone or connect to a computer via USB cable and control all its functions from PASCO Capstone™. Use it with PASPORT interfaces and sensors.

Specifications

Input Power: 15 V @ 1.6 A.

Voltage Output: ±10 V @ 1 A.

Frequency Range: DC to 100 kHz. Sine wave retains its form to 150 kHz.

Frequency Resolution: 0.001 Hz over entire range.

Offset Voltage: ±10 V.

Waveforms: Sine, Triangle, Square, Positive Ramp, Negative Ramp, DC

External Voltage Input: ±10 V Maximum

Trigger Output: TTL Compatible; BNC jack on back of unit

Display: LCD Graphics Monochrome Display, 128 x 64, with Two-Level Backlight

Displays: Frequency, Waveform, Voltage, Current, Offset Voltage.

Amplitude Modulation: Modulate the signal of one function generator using another.

Order Information

Function Generator PI-8127

Decade Capacitance Box

SE-8689



This Decade Capacitance Box supplies five decades of capacitance from 100 pF to 11.111 µF in 100 pF steps. Add or subtract capacitance with slide switches. Three color-coded binding posts provide reliable connections.

Specifications

Accuracy: ±5%

Maximum Voltage: 50 VDC

Order Information

Decade Capacitance Box SE-8689

Decade Resistance Box

SE-7122



This Decade Resistance Box delivers seven decades of resistance from 1 Ohm to 11,111,110 Ohms in 1 Ohm steps. Add or subtract resistance values with slide switches. Three color-coded binding posts provide reliable connections.

Specifications

Accuracy: ±1%

Power Dissipation: up to 0.3 Watt

Order Information

Decade Resistance Box SE-7122

Decade Resistance Box

SE-7124



Resistance is plainly displayed with this six-decade resistance box since a rotary switch selects the resistance within each decade. With 1% accuracy and 1/2 Watt resistor, it will accommodate most student experiments.

Specifications

Resistance: 0 to 1, 111, 110 Ω in 1 Ω increments

Accuracy: ±1.0% ±0.1 Ω

Power Dissipation: 1/2 Watt resistors

Order Information

Decade Resistance Box SE-7124

Heavy-Duty Voltmeter

SF-9568A



The Voltmeter has three ranges and is switch-selectable to measure AC or DC voltages.

Specifications

DC Ranges: 0 to 3 V/15 V/30 V

AC Ranges: 0 to 3 V/15 V/30 V

Accuracy: ±2%

Sensitivity: 10 k Ω/V

Order Information

Heavy-Duty Voltmeter SF-9568A

Heavy-Duty Ammeter

SF-9569A



The Ammeter has three ranges and is switch-selectable to measure AC or DC values. All ranges are overload-protected up to 15 amps.

Specifications

DC Ranges: 0 to 50 mA/500 mA/5 A

AC Ranges: 0 to 50 mA/500 mA/5 A

Accuracy: ±2%

Max Volt Drop: 0.23 V

Order Information

Heavy-Duty Ammeter SF-9569A

Heavy-Duty Galvanometer

SF-9500A



A "push-to-read" switch protects the galvanometer during hookup by shunting the current through an equivalent resistor.

Specifications

DC Ranges: 50 µA/500 µA/5 mA

Internal Resistance: 1.5 k Ω/170 Ω/17 Ω

Accuracy: ±2%

Order Information

Heavy-Duty Galvanometer SF-9500A

Digital Storage Oscilloscopes

SB-9620A (70 MHz) SB-9621A (100 MHz)

- 2 M points of memory gives finer detail
- FFT/FFTrms/Zoom FFT
- Delay on/off
- USB Flash storage and data logger
- Go/NoGo function
- Print directly to printer
- PC remote control software



Specifications

Bandwidth: 70/100 MHz (SE-9620A/SE-9621A), 2 Input Channels

Sampling Rate: 1 GSa/s Real-Time and 25 GSa/s Equivalent-Time

Record Length: 2 Mega Points

Vertical Scale: 2 mV to 10 V

Horizontal Range: 1 ns to 50 s

Number of Auto Measurements: Up to 27

Functions: +, -, x, FFT, FFTrms, Zoom FFT

Display: 5.7" Color TFT LCD

Ports: USB Host and Device Ports

Data Logger

See www.pasco.com for complete specifications.

Order Information

Digital Storage Oscilloscopes

70 MHz SB-9620A

100 MHz SB-9621A

20 MHz Dual Trace Oscilloscope

SB-9591A



Features

Dual Channel: Allows two variables to be monitored on the y-axis simultaneously

X-Y Operation: Displays one variable on the y-axis and the other on the x-axis

Built-in Calibration Source

Algebraic Add and Subtract: For differential measurements

Two 10:1 probes are included, along with a detachable power cord, spare fuse, schematic diagrams, and parts list.

Order Information

20 MHz Dual Trace Oscilloscope SB-9591A

Replacement Supplies:

Oscilloscope Probe SB-9648

Specifications

Vertical Deflection

Deflection Factor: 5 mV/div to 5 V/div in 10 calibrated steps (1-2-5 sequence) with variable control

Magnification: 5x increase in sensitivity of selected range (provides 1 mV to 1 V/div)

Accuracy: ±3% at CAL'D position; ±5% at CAL'D position for 5x gain Bandwidth (referenced to 5 divisions at 50 kHz)— DC to 25 MHz (at –3 dB); DC to 10 MHz (at –3 dB) on 1 mV/div range

Rise Time: Approximately 18 ns

Input Impedance: 1 M Ω shunted by 25 pF ± 10 pF

Max. Input Voltage: 400 VDC + AC peak

Operating Modes: CHA, CHB, DUAL (ALT or CHOP) and ADD Chop Frequency—approx. 500 kHz Channel B Polarity—waveform inversion selectable

Horizontal Deflection

Triggered Operation:

Sweep Time: 0.2 s to 0.1 ms/div; 20 steps in 1-2-5 sequence with variable control

Magnification: 10x (provides sweep expansion to 10 ns/div)

Accuracy: ±3% at CAL'D position except ±6% on 0.2 s and ±20% on 0.1 ms (add ±3% when using 10x magnifier) Trigger Holdoff Time: Adjustable to longer than five times full-width sweep length on all ranges

X-Y Operation

Inputs: Channel A: x-axis; channel B: y-axis

Sensitivity: Same as channel A and channel B deflection factor switch setting on corresponding axis

Frequency Response: DC to 1 MHz (at -3 dB)

Phase Shift: Less than 3° at DC to ~100 kHz

Trigger

Source: CHA, CHB, LINE and EXT

Coupling/Sensitivity: AUTO— 100 Hz-30 MHz: 1.5 div (int.); ≥ 0.1 V p-p (ext.) NORM— DC-30 Mhz: 1.5 div (int.); ≥ 0.1 V p-p (ext.) TV-V— 20 Hz-1 kHz: 0.5 div (int.); ≥ 0.05 V p-p (ext.) TV-H— 1 kHz-100 kHz: 0.5 div (int.); ≥ 0.05 V p-p (ext.)

Slope— Normally "+"; pull TRIG LEVEL control for "-"

External Input

Input Impedance: 1 M Ω, 30 pF Maximum

Input Voltage: 300 V (DC + AC peak)

Basic Digital Multimeter

SE-9786A



This basic meter includes all functions and ranges needed for most introductory lab work.

Features

20 Amp range

Backlit display with 25 mm digits

Soft rubber boot for drop protection

Built-in tilt stand

Type K thermometer built in for surface or air measurements

Auto power off saves battery life

Specifications

DC Voltage: 0.1 mV to 600 V with ±0.5% accuracy

AC Voltage: 1 mV to 600 V with ±0.3% accuracy

DC Current: 0.1 µA to 20 A

AC Current: 0.1 mA to 20 A

Resistance: 0.1 Ω to 20 MΩ

Additional Functions: Input fuse protection, audible and visible misconnection signals, data hold freezes display reading

Display: 3-1/2 digit display with 25 mm digits, polarity indication, low battery indication

Power: 9 V battery (included)

Order Information

Basic Digital Multimeter SE-9786A

General Purpose Digital Multimeter

SE-9589A



This durable, general purpose meter is recommended for general use in the student lab.

Specifications

DC Voltage: 200 mV, 2 V, 20 V, 200 V, 1000 V; ±(0.5% +1 digit) 10 M Ω input impedance

AC Voltage: 200 mV, 2 V, 20 V, 200 V; ± (1% + 4 digits) 750 V; ± (1.5% + 4 digits) 10 M Ω input impedance

DC Current: 200 µA, 2 mA, 20 mA, 200 mA; ± (1% + 2 digit) 2 A; ± (2% + 3 digits)

AC Current: 200 µA, 2 mA, 20 mA, 200 mA; ± (1.5% + 5 digits) 2 A; ± (2.5% + 5 digits)

Resistance: 200 Ω, 2 k Ω, 20 k Ω, 200 k Ω, 2 M Ω; ± (1% + 4 digits) 20 M Ω; ± (3% + 5 digits)

Additional Functions: diode test, logic probe, audible continuity test

Display: 3-1/2 digit LCD, 17 mm high digits, polarity indication, low battery indication

Power: 300-hour life on 9 V alkaline (battery included)

Protection: Overload on all ranges

Order Information

General Purpose Digital Multimeter SE-9589A

Precision Digital Multimeter, Component Tester, and Thermometer

SB-9631B



An excellent general purpose multimeter. Features high-accuracy overload protection on all ranges and a built-in digital thermometer. It can measure capacitance and transistor gain (hFE).

Specifications

DC Voltage: 200 mV, 2 V, 20 V, 200 V, 1000 V; ± (0.5% + 1 digit) 10 M Ω input impedance

AC Voltage: 200 mV, 2 V, 20 V, 200 V; ± (1% + 4 digits) 750 V; ± (1.5% + 4 digits) 10 M Ω input impedance

DC Current: 200 µA, 2 mA, 20 mA, 200 mA; ± (1% + 1 digit)

AC Current: 200 µA, 2 mA, 20 mA, 200 mA; ± (1.2% + 4 digits)

Resistance: 200 Ω; ± (1% + 3 digits) 2 k Ω, 20 k Ω, 200 k Ω, 2 M Ω; ± (0.8% + 1 digit) 20 M Ω; ± (3% + 3 digit)

Capacitance: 20 nF, 200 nF, 2 µF, 20 µF, 200 µF; ± (3% + 10 digits)

Temperature: -4° to 1400°F; -4°F to 900°F; ±2.0% reading + 4°F; 900°F to 1,400°F; ±3.0% reading + 4°F

Additional Functions: Diode test, transistor hFE, audible continuity test, fold-out stand

Display: 3-1/2 digit LCD display, 17 mm high digits, polarity indication, low battery indication

Drop Resistant

Power: 200-hour life on 9 V alkaline (battery included). Test leads, temperature probe and battery are included.

Order Information

Precision Digital Multimeter SB-9631B

Replacement Supplies:

Thermocouple Probe SB-9632

Digital LCR Meter

SE-8792



Measure inductance, capacitance, and resistance. Test leads are included, along with a battery, a protective holster, and a manual.

Features

Accuracy: 1% or better on most ranges

Easy to Use: Push-button selection for all measurements

Digital Display: 4-1/2 digit backlit LCD

Built-in Tilt Stand: Convenient tabletop use

Specifications

Inductance: 2000.0 µH, 20.000 mH, 200.00 mH, 2000.0 mH, 20.000 H, 200.00 H, 20.000 H (± 0.7% rdg + Lx/10000 + digit)

Capacitance: 2000.0 pF, 20.000 nF, 200.00 nF, 2000.0 nF, 20.000 µF, 200.00 µF, 2000.0 µF (± 0.7% rdg + 5 digit)

Resistance: 20.000 Ω, 200.00 Ω, 2.0000 kΩ, 20.000 kΩ, 200.00 kΩ, 2.0000 MΩ, 20.000 MΩ (± 0.5% rdg + 8 digit)

Power: 9 V alkaline battery (included)

Accessories: Test leads (2), alligator clips (2), protective holder

Order Information

Digital LCR Meter SE-8792

Ripple Tank System

WA-9899

- Completely redesigned system
- More affordable
- Integrated strobe/ripple generator simplifies operation
- Foam "beach" design dramatically reduces reflections from walls
- Silent operation

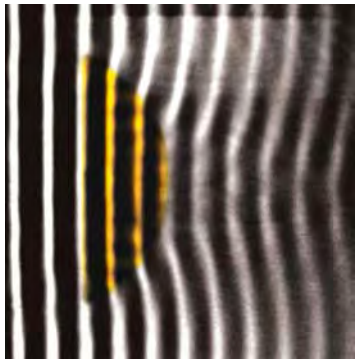
PASCO has completely redesigned its Ripple Tank System to make it easier to use, more reliable, and more affordable. The strobe and rippler are controlled by the same unit, and a new feature makes it possible to introduce a small frequency difference between the strobe and the rippler to make the waves appear to move slowly. A simple switch changes the phase of the two ripplers from 0 to 180 degrees.

The rippler uses voice coil actuators for precise and silent operation. The frequency range (1.0 Hz to 50.0 Hz) includes those important low frequencies that make refraction more prominent. The LED digital frequency readout can be seen in low lighting. The rippler has knobs to easily adjust the dipper depth and the amplitude of the dipper stroke.

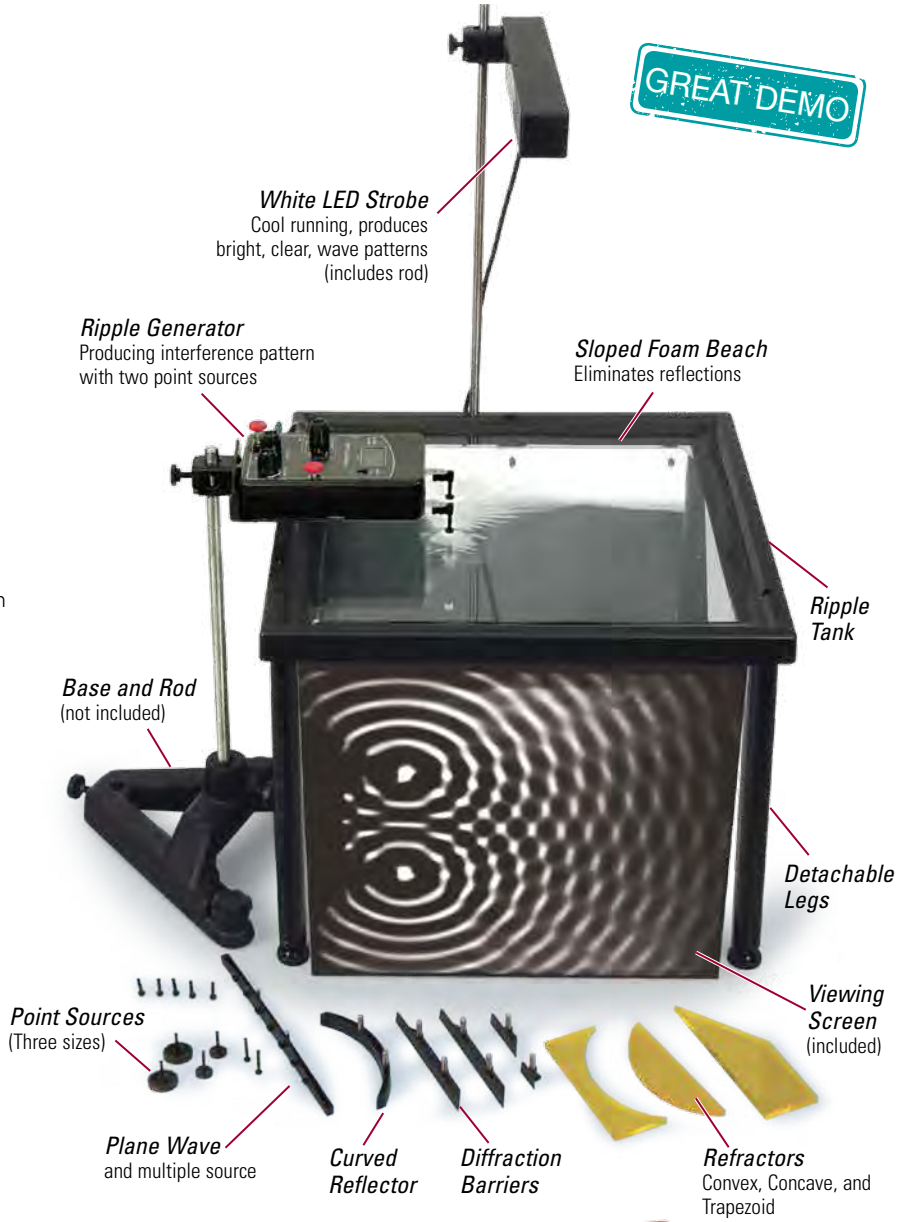
The new light source is a white LED that remains cool during operation and produces a bright, clear wave pattern. The light can be used as a strobe or in steady mode.

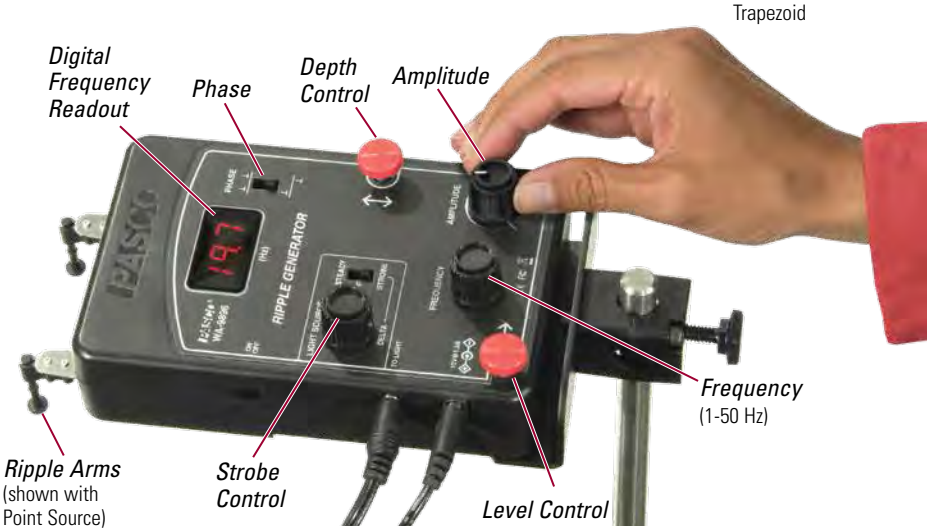
Typical Applications

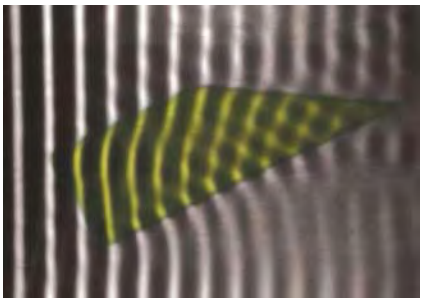
- Speed of Wave Propagation
- Superposition of Waves
- Effects of Varying Water Depth
- Reflection, Refraction, and Diffraction



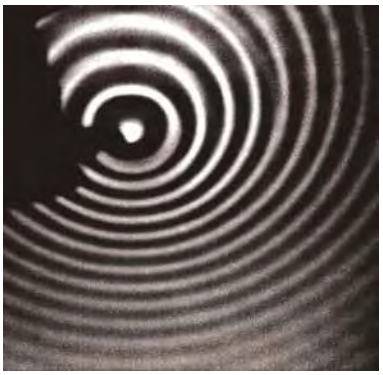
The yellow convex lens focuses the plane water waves. The waves show a pronounced refraction due to the abrupt change in depth of the water over the plastic lens.



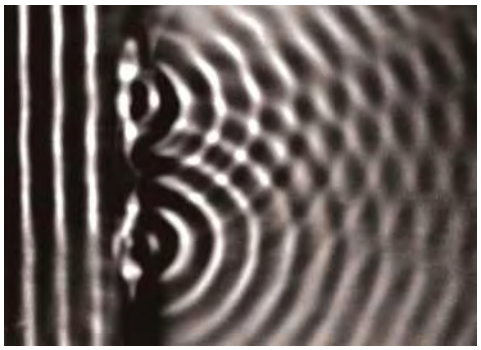




Refraction occurs at the boundaries of this rhomboid shape.



The Doppler Effect is clearly demonstrated by moving the dipper. In this picture the movement is downward.



Diffraction Barriers are used to create a double slit to show interference. The barriers can be changed to adjust the slit width and slit separation.

Specifications – Ripple Tank (WA-9897)

Viewing Area: 34 cm x 34 cm
Usable Tank Depth: 1 cm
Drain Tube: 30 cm long
Projection Screen: 35.6 cm x 38.8 cm wide
Acrylic Mirror: 49.8 cm x 38.8 cm wide
Light Source Support Rod: 46 cm long
Water-Resistant Storage Box: 64 cm x 52 cm x 17 cm

Specifications – Ripple Generator/Light Source (WA-9896)

Voice Coil Actuator Frequency Range: 1.0 to 50.0 Hz with 0.1 Hz Resolution
Light Source: Strobe or Steady, 5 W White LED
Digital LED Display: Frequency/Delta
Adjustable Delta Frequency Between Ripple Generator and Strobe:
± 45% frequency setting in steps of 9%
Phase Switch: 0 or 180 degrees
Depth, Tilt, and Amplitude Adjustment Controls
Power Supply: 15 VDC at 1.5 A with On/Off Switch
Rippler Case Dimensions: 10.5 cm x 16.3 cm x 3.9 cm

Includes

Ripple Tank
(complete components list at right)
Ripple Generator/Light Source
(complete components list at right)
Water Resistant Storage Box included
(64 cm x 52 cm x 17 cm)



Order Information

Ripple Tank System	WA-9899	
Required:		
Large Rod Base	ME-8735	p. 170
90 cm Rod	ME-8738	p. 170
Replacement:		
Ripple Tank Replacement Set	WA-9898	

Ripple Tank

WA-9897



Includes

Tank with Legs
Projection Mirror and Screen
Strobe Mounting Rod
Refractors (convex, concave, rhomboid)
Curved Reflector
Diffraction Barriers (2 long, 1 short, 1 mini)
Plastic Storage Box for components
Surfactant
Drainage Tube (30 cm) with Clamp
1 liter Plastic Beaker
Pipette
Clear Plastic Ruler
Water Resistant Storage Box for Entire System

Specifications given at left

Order Information

Ripple Tank	WA-9897

Ripple Generator/Light Source

WA-9896



Includes

Ripple Generator/Strobe Driver with Power Adapter
LED Strobe Assembly
Plane Wave Generator with Multi-point Dippers
Point Sources (3 sizes)

Specifications given at left

Order Information

Ripple Tank Generator/ Light Source	WA-9896

Ripple Tank Replacement Set

WA-9898

Includes

Plastic Storage Box for Components
Dippers
Pipette
Foam Beach
Refractors
Curved Reflector
Diffraction Barriers

Specifications given at left

Order Information

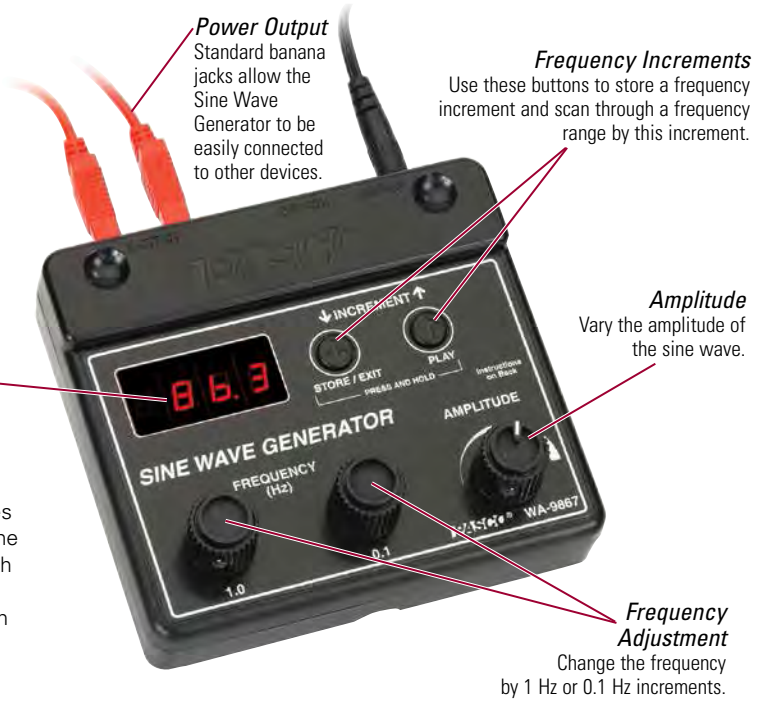
Ripple Tank Optics	WA-9898

Sine Wave Generator

WA-9867

- Sine wave output up to 800 Hz
- Ideal for driving speakers and wave drivers
- Auto-scan of resonant frequencies

LAB ESSENTIALS



The Sine Wave Generator is an effective tool for generating waves with speakers or wave drivers. It enables users to change both the frequency (0-800 Hz) and amplitude of the sine wave output. Both fine and coarse frequency controls are included and the digital display features a 0.1 Hz resolution. In addition, the generator can "learn" the fundamental frequency for a particular configuration. Students can observe the quantum nature of standing wave patterns as the Sine Wave Generator jumps from one resonant frequency to the next.

Typical Applications

- Wave Patterns in Strings: The Sine Wave Generator can drive the following:

  String Vibrator

  Economy Wave Driver

  Mechanical Wave Driver

- Resonant Frequencies in Air: Use the generator with the Open Speaker and Economy Resonance Tube to produce easily audible standing waves in air.



By varying the amplitude and frequency of the AC signal, standing waves are created in the vibrating string.

Features

Custom Plastic Case: Designed to withstand student use; includes angled rubber feet for ease of use and rear rod clamp for additional mounting options. Cases are also stackable for easy storage.

Digital Display: Frequency is displayed with 0.1 Hz resolution using red LEDs.

Frequency Adjustment: Adjust the frequency of the output with either the fine (0.1 Hz) or coarse (1 Hz) knobs. The knobs include a "smart scan" feature so they change frequency more quickly when continuously turned.

Amplitude Adjustment: Change the voltage of the sine wave signal.

"Learn" Frequency: The Sine Wave Generator will store a frequency increment then it will cycle through the selected frequency range by the increment automatically, which is very useful for resonance demonstrations or activities.

Includes

Sine Wave Generator

Power Supply



Order Information

Sine Wave Generator	WA-9867	
Recommended:		
String Vibrator	WA-9857	p. 243
Economy Wave Driver	WA-9854	p. 245
Mechanical Wave Driver	SF-9324	p. 244
Open Speaker	WA-9900	p. 248
Economy Resonance Tube	WA-9495	p. 248
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 214

String Vibrator

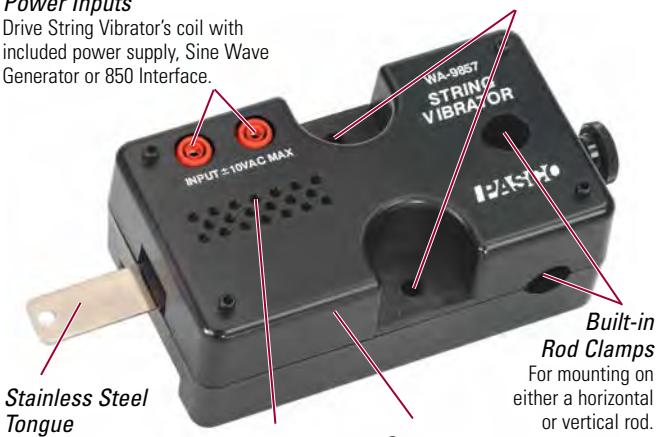
WA-9857

LAB ESSENTIALS

- Great tool for mechanical wave demonstrations
- Uses magnetic field to drive flexible tongue
- Includes constant frequency power supply

Clamping
Convenient for clamping the String Vibrator to the tabletop or any other edge. Holes allow permanent mounting to a surface.

Power Inputs
Drive String Vibrator's coil with included power supply, Sine Wave Generator or 850 Interface.



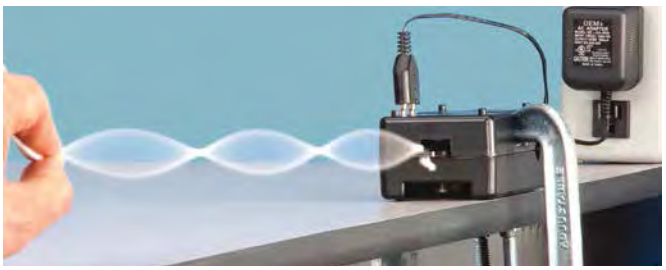
Built-in Rod Clamps
For mounting on either a horizontal or vertical rod.

Stainless Steel Tongue
Flexible metal strip mounted to a powerful neodymium magnet; includes a hole for connecting string or wave cord.

Air Vents
Provide good circulation of air around coil.

Custom Plastic Case
Tough enough for student use; stacking posts allow several units to be vertically stacked for storage.

The String Vibrator transforms mechanical wave demonstrations to hands-on activities that every lab group can easily perform. Featuring an elegant design with no motors or speakers, the String Vibrator allows students to study the fundamental characteristics of mechanical waves including wave speed, frequency, wavelength, amplitude, interference, and resonance.



Power the String Vibrator by plugging the included power supply into the wall outlet. The waveform is varied by changing the tension in the elastic Wave Cord.

Includes

String Vibrator Unit

Constant Frequency Power Supply (60 Hz)

Wave Cord (3 meters) (not shown)



Order Information

String Vibrator	WA-9857	
Recommended:		
Sine Wave Generator	WA-9867	

Strobe

ME-6978

- 1 Hz to 500 Hz
- Variable intensity
- Low cost
- External trigger

Unique modular design makes it easy to light any geometry. The Strobe includes the Strobe Control Box and one Strobe Module. Additional Strobe Modules can be purchased separately (see below) for up to a total of four lamp modules per controller, and multiple control boxes can be connected together using the External Trigger. The Strobe Modules have a tilting lamp head on a sturdy base that sits on the table or fastens to a rod stand.

Specifications

Frequency Range: 1 Hz to 500 Hz

Resolution: 0.1 Hz

Accuracy: 0.1%

Lamp Life: 50,000 hours.

Brightness: 230 lumens (peak) per module



Shown using Strobe (with Strobe Module) and three additional Strobe Modules.

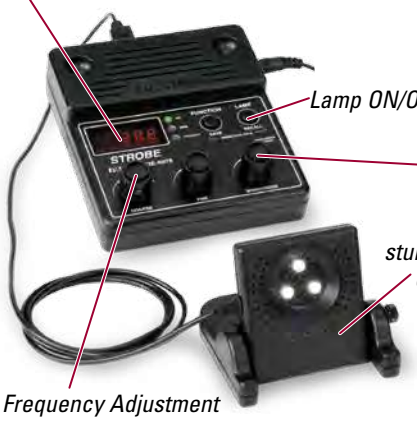
Digital Display

Lamp ON/OFF

Brightness Control

Tilting lamp head on a sturdy base sits on the table or fastens to a rod stand.

Frequency Adjustment



Includes

Control Box and one Strobe Module

Order Information

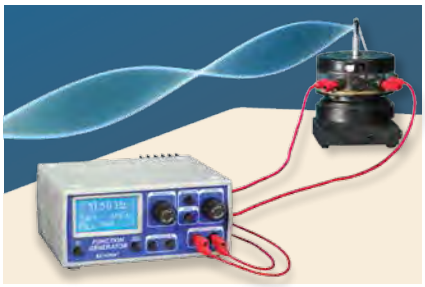
Strobe	ME-6978	
(Includes Control Box and One Strobe Module)		
Additional Strobe Module	ME-6982	
Shown in use with:		
String Vibrator	WA-9857	
Small "A" Base	ME-8976	p. 170
Large Rod Base	ME-8735	p. 170
60 cm long Steel Rod (threaded)	ME-8977	p. 170
90 cm long Steel Rod (non-threaded)	ME-8738	p. 170
Pendulum Clamp	ME-9506	p. 172

Mechanical Wave Driver and Accessories

Mechanical Wave Driver

SF-9324

- Drive any wave experiment at specified frequencies
- Variable amplitude
- Tough and versatile





SF-9324
8 Ω Impedance

Powering the Wave Driver

Different PASCO products can be used to power the Wave Driver:

Features

Frequency Response: From 0.1 to 1000 Hz with an amplitude of approximately 5 mm up to about 50 Hz.

Mounts Vertically or Horizontally: Designed to sit upright on a table, on its side, or mounted on a 12.7 mm (1/2 inch) rod.

Driving Signal Required: Requires a function generator with a minimum of ±8 V@0.5 A. An accurate measurement of frequency is necessary for quantitative resonance experiments.

Order Information

Mechanical Wave Driver SF-9324
Required:
Banana Plug Patch Cord ..... SE-9751 p. 214
and one of the following function generators:
Sine Wave Generator ..... WA-9867 p. 242
Function Generator ..... PI-8127 p. 236
with
850 Universal Interface ..... p. 14-17
Equivalent function generator providing up to 1 A to an 8 Ω impedance.
Shown in use with:
2 Meter Patch Cord Set ..... SE-9415A p. 214

Chladni Plates Kit

WA-9607

GREAT DEMO



In the early nineteenth century, Ernst Chladni added another dimension to wave experiments by sprinkling sand on a thin plate and using a violin bow to induce vibrations. The sand collected along the nodal lines of the wave patterns painted clear and beautiful pictures of the various modes of vibration.

The Chladni Plates Kit and a Wave Driver allow continuous vibrations to be produced at measurable frequencies. Students can determine the resonant frequencies of the plates and examine the modes of vibration at any frequency.

The Chladni Plates Kit includes a 24 cm x 24 cm square plate, round plate, 0.8 kg of extra-fine sand, and a sand shaker. The round plate can be vibrated about its center or about an offset point to investigate both symmetric and asymmetric modes of vibration.



Order Information

Chladni Plates Kit WA-9607

Longitudinal Wave Spring

WA-9401

Using the Longitudinal Wave Spring accessory, it is easy to demonstrate and visualize the nodes and antinodes of longitudinal waves. Unstretched length is 13 cm.



Longitudinal waves can be easily demonstrated with the Longitudinal Wave Spring.

Order Information

Longitudinal Wave Spring WA-9401

Violin Chladni Plate

SE-7319



This 40 cm-long plate is shaped like a standard violin. Place sand on the plate and excite with either a violin bow or wave driver. Includes a standard banana jack connector for use with the Mechanical Wave Driver (on opposite page).

Order Information

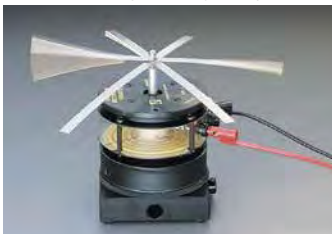
Violin Chladni Plate SE-7319

Mechanical Wave Driver Accessories (cont)

Metal Resonance Strips

SF-9404

These resonance strips demonstrate standing waves, harmonics, and the relationship between length, frequency, and resonance.



Investigate the unique resonant frequencies of the Metal Resonance Strips.

Order Information

Metal Resonance Strips SF-9404

Resonance Wire Loop

SF-9405



Use this wire loop (29 cm diameter) to introduce Bohr's quantum atom using a classical model.

Order Information

Resonance Wire Loop SF-9405

String Holders

Slot (set of 4)
SF-9322



Hole (set of 4)
SF-9323



4 mm diameter banana plugs fit into shaft of Wave Driver.

Order Information

Slot String Holder (set of 4) SF-9322

Hole String Holder (set of 4) SF-9323

Structures Resonance

PASCO's Structures System is perfect for demonstrating resonance in complex systems. The plastic I-Beams clearly show two different bending moments and can be connected together to build a variety of structures. See page 246 for more examples.



Composite I-Beam
1.2 m tall

The long plastic I-Beam is constructed of components from the Advanced Structures Set (p. 135). It is driven using the Mechanical Wave Driver and the Function Generator (PI-8127), demonstrating the three lowest harmonics.

Order Information

Advanced Structures Set ..... ME-6992B p. 134

Large Slotted Mass Set ..... ME-7566 p. 181

45 cm Stainless Steel Rod ..... ME-8736 p. 170

Large Rod Base ..... ME-8735 p. 170

Economy Wave Driver

WA-9854

- Economical tool for the study of mechanical waves
- Includes constant frequency power supply



Using the Sine Wave Generator, the frequency and amplitude of the Economy Wave Driver can be varied to facilitate the study of standing wave patterns.

How it Works

A molded plastic post is attached directly to the cone of the speaker and the wave cord is fed through the groove on the top of the post. The two ends of the cord are tied off or held with suspended masses. Using the included power supply, students can drive the speaker at a constant 60 Hz and vary the tension to create standing wave patterns.

The Economy Wave Driver can be used with any function generator that outputs 0 – 7 Volts and 0.3 – 0.6 Amps.



Includes

5 ¼" Sub Woofer Speaker with Wave Driver Post

Elastic Cord, three meters (not shown)

Power Supply (60 Hz)

Order Information

Economy Wave Driver WA-9854

Wave Driver Post

WA-9870 (2 pack)



The Wave Driver Post can also be purchased separately for use with existing 5 1/4" speakers. Actual diameter is 3 1/4" (8.3 cm).

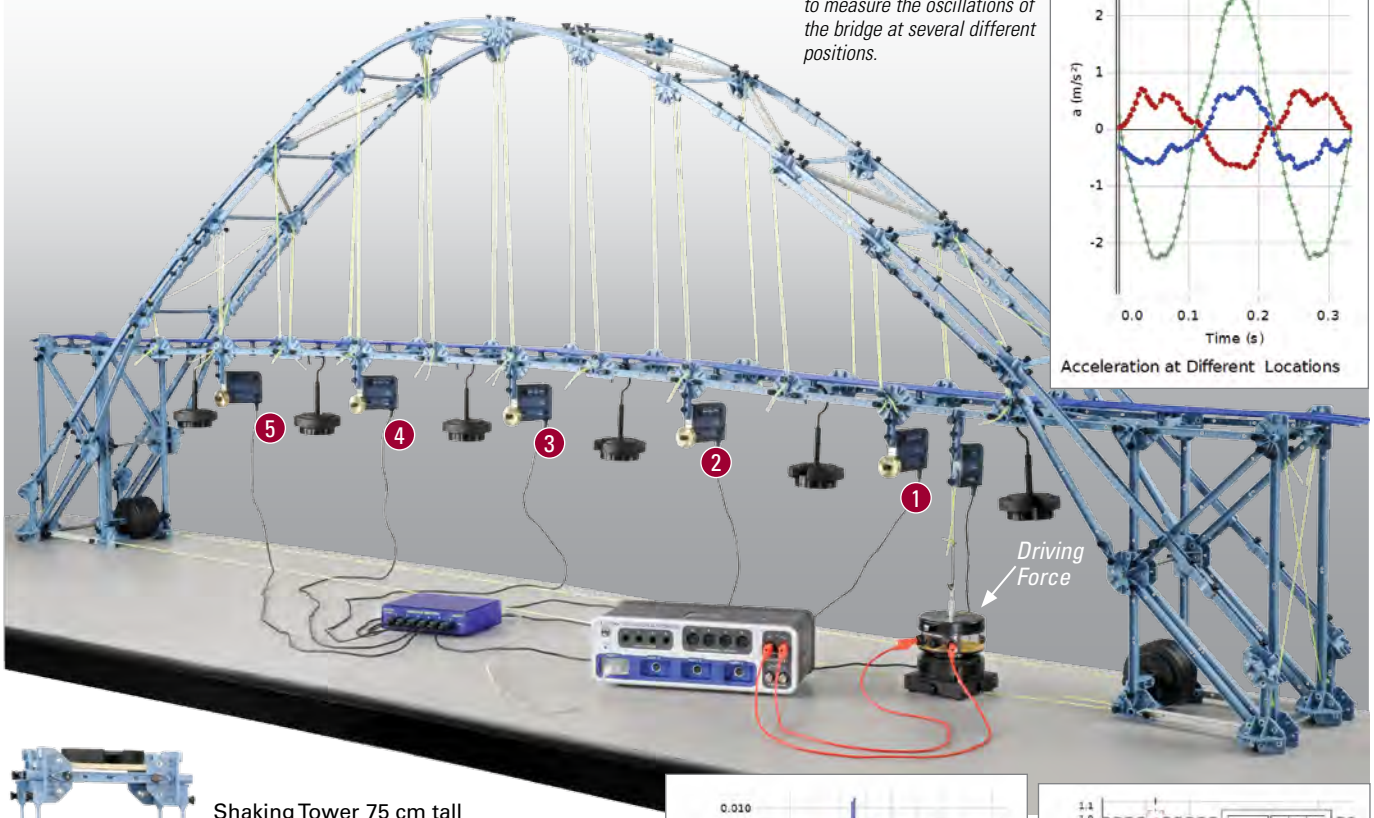
Order Information

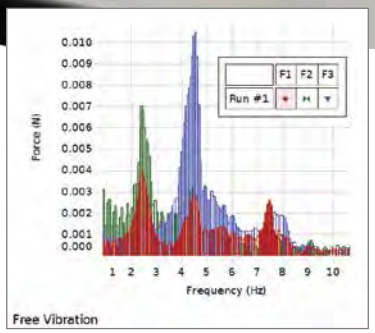
Wave Driver Post (2 pack) WA-9870

Study Vibrational Modes in Complex Bridges

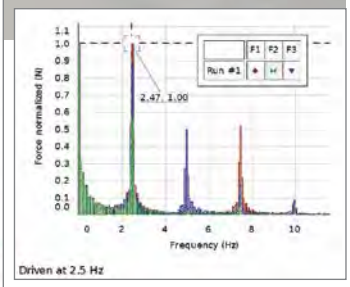
- Resonance in complex systems
- Driven vs. free vibrations

The 5 N Load Cells are used to measure the oscillations of the bridge at several different positions.

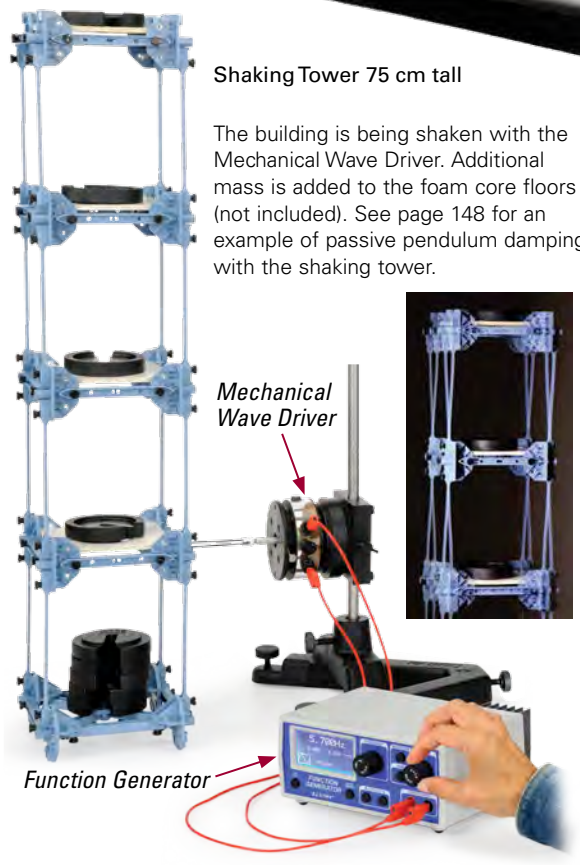




The bridge is struck by hand and allowed to freely oscillate. The FFT (using PASCO Capstone™) shows that there are several resonant frequencies. Note how different the amplitudes are at different locations on the bridge.



The resonance of the bridge is characterized by driving the bridge at different resonant frequencies. Note how different the amplitudes are at different locations on the bridge.



Shaking Tower 75 cm tall

The building is being shaken with the Mechanical Wave Driver. Additional mass is added to the foam core floors (not included). See page 148 for an example of passive pendulum damping with the shaking tower.

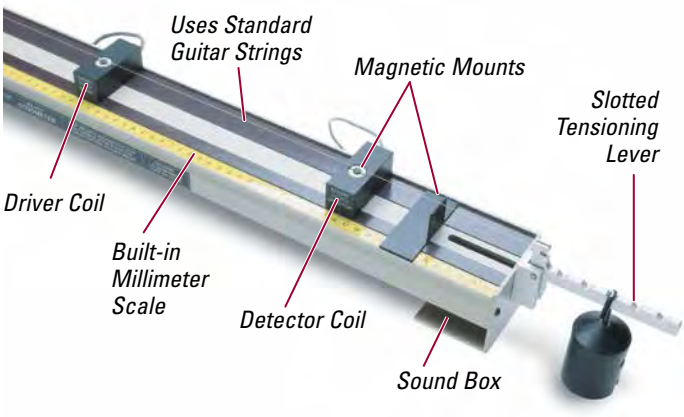
Experiments on this page shown in use with

Large Structures Set	ME-7003	p. 135
Load Cell Amplifier	PS-2198	p. 34
5 N Load Cell	PS-2201	p. 35
Function Generator	PI-8127	p. 236
Mechanical Wave Driver	SF-9324	p. 244
Mass and Hanger Set	ME-8979	p. 181
Short Slotted Mass Set	ME-7589	p. 181
Rods and Stands		p. 170
2 Meter Patch Cord Set	SE-9415A	p. 215

Sonometer System

WA-9757

- Investigate waves on a wire
- Control length, tension, density, and driving frequency
- Observe and measure the waveforms on an oscilloscope



With the PASCO Sonometer and the Driver/Detector Coils, students can vary the density, tension, and length of the wire; adjust the driving frequency; and examine the resulting waveform in full detail on an oscilloscope or computer interface. This is all done quantitatively.

Features include a slotted tensioning lever, magnetic mounts, built-in scale, and a sound box.



The Sonometer System Includes

1. Base with magnetic mounting strip, sounding board, tensioning lever, and wire positioning screw
2. 10 Solid Steel Wires—two each of 0.245, 0.356, 0.432, 0.508, and 0.559 mm diameter
3. Driver and Detector Coils
4. BNC-to-Banana Plug Adapter (not shown—used to connect to an interface)
5. Instruction Manual and Experiment Guide (not shown)

Order Information

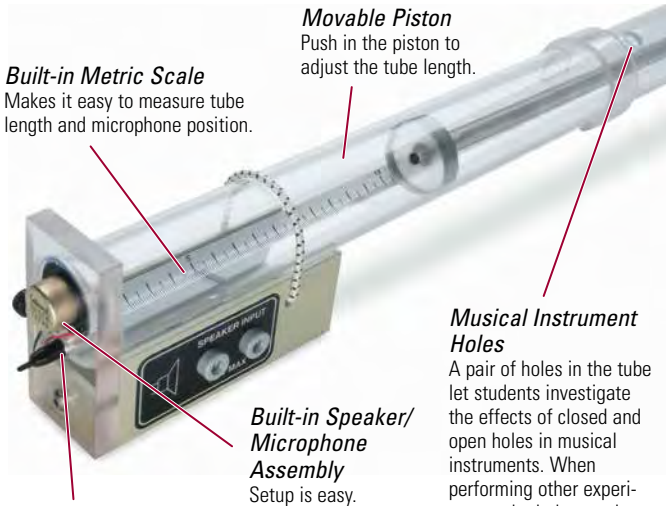
Sonometer System	**WA-9757**	
Sonometer (No Coils)	**WA-9611**	
Sonometer Driver/Detector Coils (pair)	**WA-9613**	
Required:		
Slotted Mass Hanger	SE-8703A	p. 180
Slotted Mass Set	SE-8704A	p. 180
850 Universal Interface	UI-5000	p. 14-17
Voltage Sensor		p. 52

Resonance Tube

WA-9612

- Investigate sound waves in a closed or open tube
- Observe waveforms on an oscilloscope
- Movable piston and microphone

Drive the speaker with a function generator to create stable wave patterns at specified frequencies. Then connect an oscilloscope or computer interface to the microphone to examine the waveforms in detail. The 90 cm long, clear plastic tube is simple and rugged.



Movable Piston
Push in the piston to adjust the tube length.

Built-in Metric Scale
Makes it easy to measure tube length and microphone position.

Musical Instrument Holes
A pair of holes in the tube let students investigate the effects of closed and open holes in musical instruments. When performing other experiments, the holes can be covered with the included slip rings.

Built-in Speaker/ Microphone Assembly
Setup is easy. A function generator is used to drive the speaker.

Movable Microphone
Position the microphone at the edge of the tube or use the probe to position it anywhere inside the tube. Easily locate all the nodes and antinodes of a standing wave pattern.

Includes

1. 90 cm Acrylic Tube with mounting stand and built-in millimeter scale
2. Piston and Rod for adjusting tube length
3. Miniature Microphone
4. Microphone Probe Rod for examining the waveform inside the tube
5. Speaker Assembly
6. Two holes with slip ring covers
7. BNC-to-Banana Plug Adapter (not shown— used to connect to ScienceWorkshop Interface)
8. Instruction Manual and Experiment Guide (not shown)

Equipment Required:

850 Universal Interface
Voltage Sensor to monitor the detector

Order Information

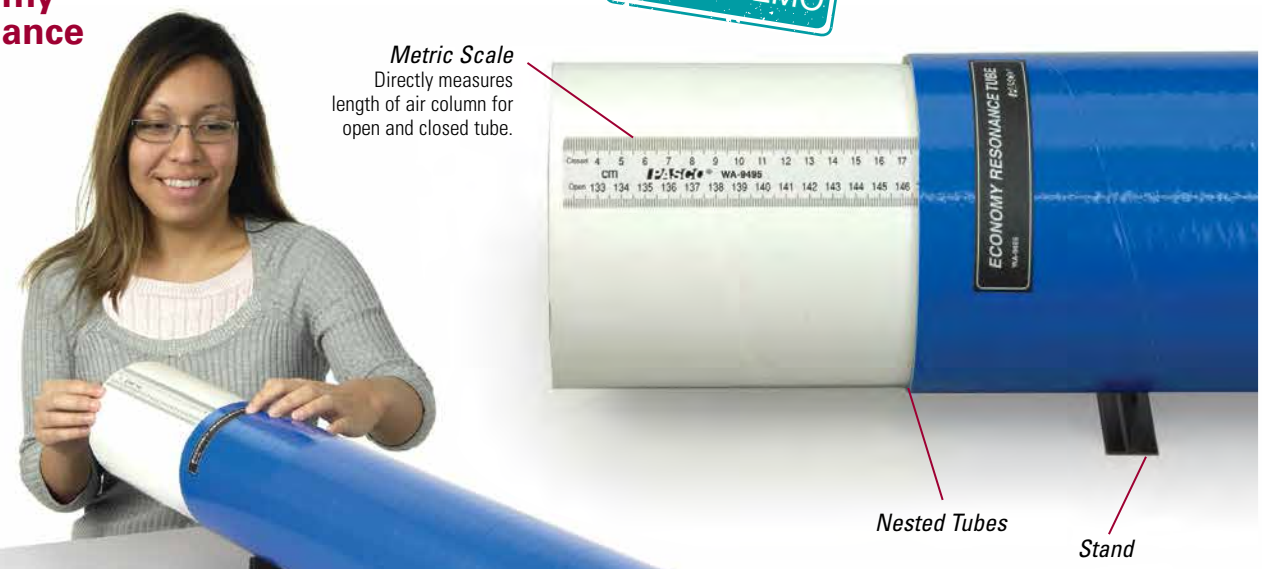
Resonance Tube	**WA-9612**	
850 Universal Interface	UI-5000	p. 14-17
Voltage Sensor		p. 52
Required for use without sensors:		
20 MHz Dual Trace Oscilloscope	SB-9591A	p. 238
Function Generator	PI-8127	p. 236
Replacement Supplies:		
Replacement Speaker	WA-9662	

Demonstrate Acoustic Resonance

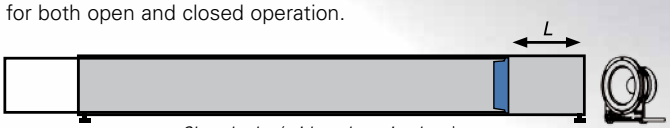
GREAT DEMO

Economy Resonance Tube

WA-9495



Students will have no difficulty hearing resonant frequencies from this tube. Two nested cardboard tubes allow the length of the air column to be easily varied. And the inner tube contains a removable end-cap to change from a "closed" to an "open" tube. The length of the resonating column can be read directly off the metric scale for both open and closed operation.

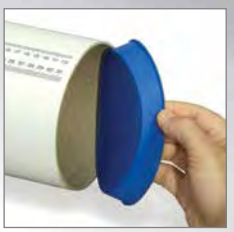


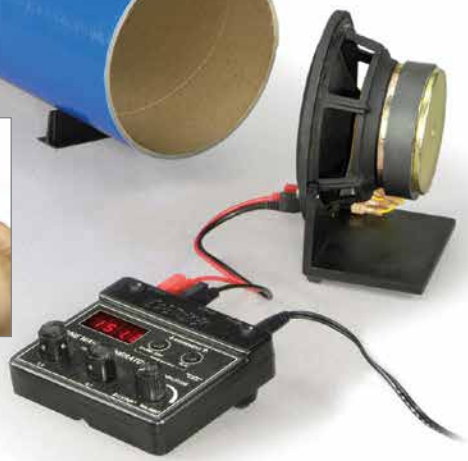
Closed tube (with end cap in place)



Open tube (with end cap removed)

The removable end-cap on the inner tube allows the air column to act as either an "open" or a "closed" tube.





Shown in use with the Open Speaker and the Sine Wave Generator

Open Speaker

WA-9900

Features a high-quality, 13.3 cm woofer mounted on a sturdy base with standard banana jack inputs. The Open Speaker is not enclosed inside a case, making it perfect for resonance experiments.



Specifications

Frequency Response: 75 - 8000 Hz
Impedance: 8 ohms
Input Power: 60 watts (max)

Order Information

Open Speaker	WA-9900

WA-9495 Includes

Outer Tube (length 1.3 m; diameter 0.15 m)
Inner Tube (includes measuring tape and removable end-cap)
Tube Stands (2)

Order Information

Economy Resonance Tube	WA-9495	
Shown in use with:		
Open Speaker	WA-9900	
Sine Wave Generator	WA-9867	p. 242
2 Meter Patch Cord Set	SE-9415A	p. 214

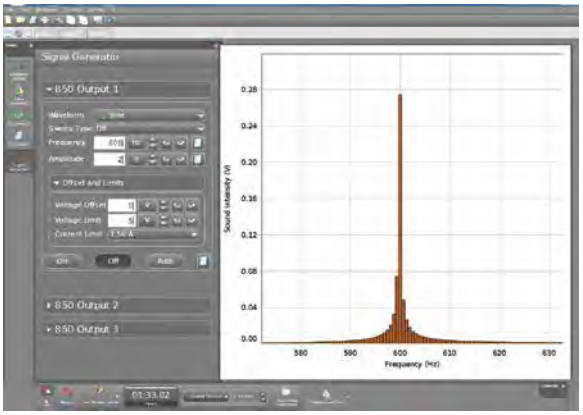
Resonance Air Column with Speaker

WA-9594

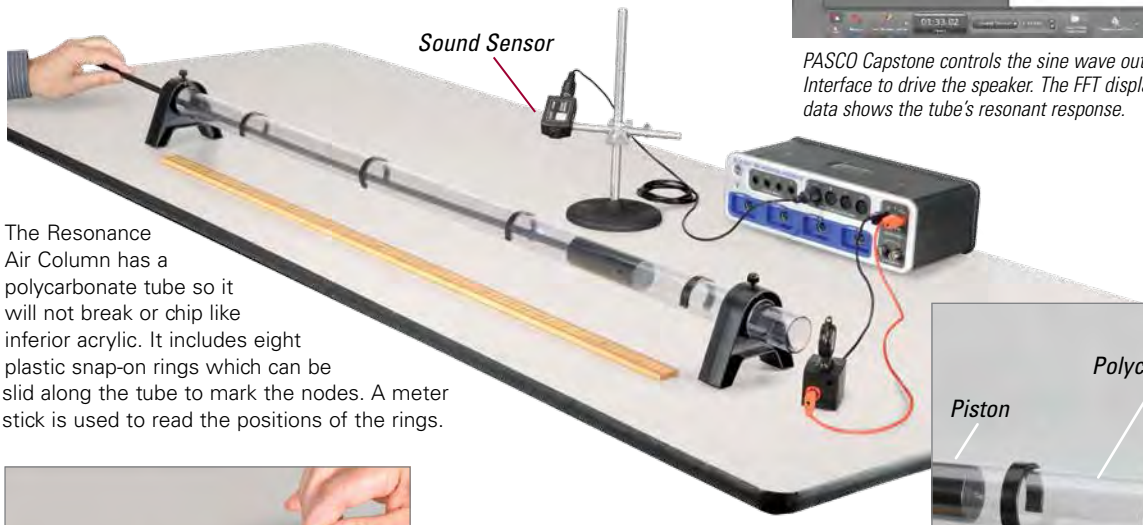
LAB ESSENTIALS

- Very loud resonance
- Tough polycarbonate tube
- Use with speaker or tuning fork

The Resonance Air Column (WA-9606) emits a very loud sound when the plunger is moved to a node position. It works as well as a water column but without the mess. The secret is in the long molded piston head which is very efficient in reflecting the sound waves. The plunger handle is made of flexible acetyl so it will not break.



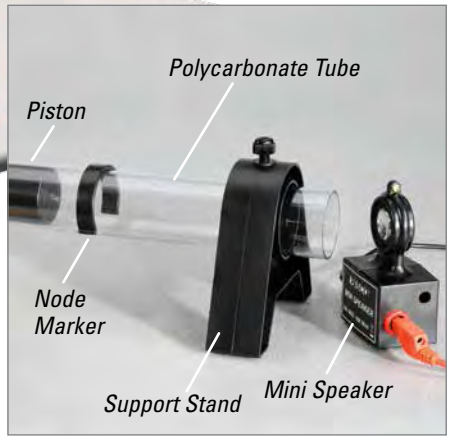
PASCO Capstone controls the sine wave output of the 850 Universal Interface to drive the speaker. The FFT display of the Sound Sensor data shows the tube's resonant response.



The Resonance Air Column has a polycarbonate tube so it will not break or chip like inferior acrylic. It includes eight plastic snap-on rings which can be slid along the tube to mark the nodes. A meter stick is used to read the positions of the rings.



The Resonance Air Column can be used as a closed or open tube. In the closed mode, tuning forks or speakers are suitable for sound sources. In the open mode, a speaker with a signal generator is required to vary the frequency until the tube sounds a resonance.



Specifications:

Material: Polycarbonate
Length: 4.0 ft (1.2 m)
Diameter: 1.5" O.D. (3.8 cm)
Wall thickness: 1/16" (1.6 mm)
Plunger Length: 4.2 ft (1.3 m)
Plunger Handle: Acetyl

WA-9594 includes: Resonance Air Column (WA-9606) and Mini Speaker (WA-9605)

WA-9606 includes: Tube and plunger, eight node markers and two detachable stands.



Order Information

Resonance Air Column with Speaker	WA-9594
Resonance Air Column (without speaker)	WA-9606

Shown in use with:

850 Universal Interface	UI-5000	pp. 14-17
Sound Sensor	CI-6506B	p. 55
Tuning Fork Set	SE-7342	p. 253
2 Meter Patch Cord Set	SE-9415A	p. 214
Meter Stick (6 pack)	SE-8827	p. 176

Mini Speaker

WA-9605

The Mini Speaker (WA-9605) is specially made to work with the Resonance Air Column. It can be powered with the Function Generator (PI-8127) or an 850 Universal Interface (UI-5000). It is also useful as a stand-alone speaker for doing interference demonstrations. Two of these essentially point sources can output the same frequency and the spatial interference pattern can be explored.



Specifications:

Maximum Voltage: 10 V
Power: 2 W
Impedance: 8 Ω
Protection Resistor: 15 Ω, 2 W

Order Information

Mini Speaker	WA-9605

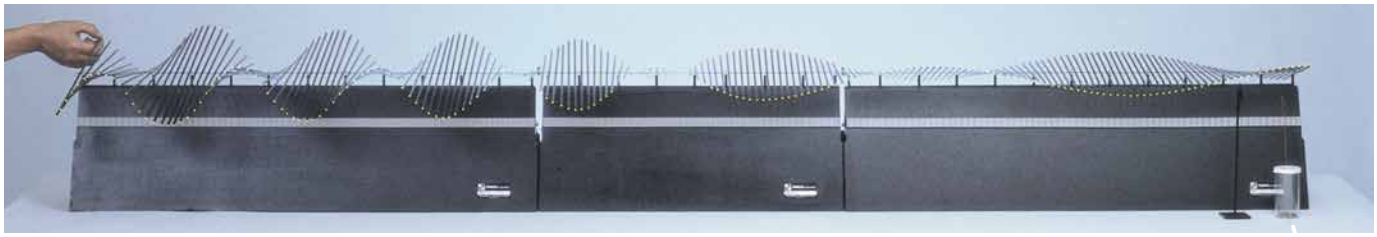
Complete Wave Motion Demonstrator

GREAT DEMO

SE-9600

- Produces slow-moving, high-amplitude transverse waves
- Demonstrates all basic wave phenomena

The PASCO Complete (Transverse) Wave Motion Demonstrator allows mechanical waves to be created to demonstrate the behavior and properties common to many types of waves.



The Complete Wave Motion Demonstrator in three sections. The high-amplitude, slow-moving waves provide a fascinating introduction to basic wave phenomena.

Features

2.3 Meters Long: Plenty of room to watch the wave develop and interact.

Three Wave Sections: Each section has rods of different lengths, allowing reflection and transmission demonstrations.

- Section 1 is 92 cm long with 46 cm rods.
- Section 2 is 92 cm long with 23 cm rods. The resulting wave velocity is about three times as fast.
- Section 3 is 46 cm long with rods that vary exponentially from 46 cm to 23 cm. This section acts as an impedance-matching unit.

Yellow Rod Tips: Easy viewing and highlights wave motion.

Folds for Compact Storage

Easy Setup

How It Works

A series of steel rods is attached at their centers to a torsion wire. When a rod is displaced and released, a wave propagates along the rod. Velocity depends on the torsion constant of the wire and the moment of inertia of the rods.

Order Information

Complete Wave Motion Demonstrator SE-9600

Wave Motion Actuator

NEW

SE-7125

- Sinusoidal driver
- Reproducible pulse
- Digital readout

The Actuator sinusoidally drives the Wave Motion Demonstrator (SE-9600). It can also generate a reproducible pulse. The Actuator arm is magnetically coupled to the rod of the Wave Demonstrator



The frequency of the sine wave is continuously variable from 0.1 Hz to 3 Hz and the frequency and period are displayed on the digital readout.

Demonstrate:

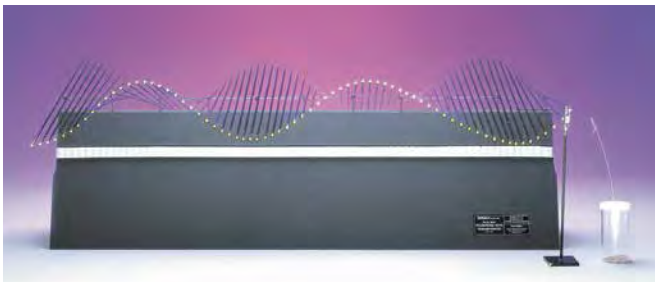
- Wave propagation velocity
- Wave reflection boundary conditions
- Wave interference and standing waves

Order Information

Wave Motion Actuator SE-7125

Single Section Wave Motion Demonstrator

SE-9601



A-frame design collapses for easy storage.

Includes

Section 1 (46 cm long rods)
Length of section: 92 cm
Clamp for rigid termination
Dash pot for liquid damping

Order Information

Single Section Wave Motion Demonstrator SE-9601

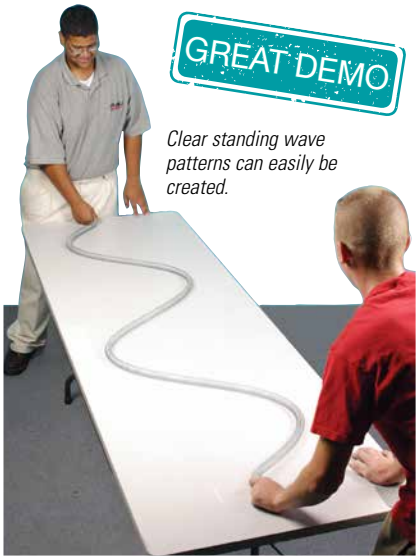
Demonstration Wave Spring

WA-7334



The Demonstration Wave Spring is ideal for illustrating mechanical wave properties such as frequency, wavelength, and interference. Because it's not as stiff as the Snakey (below), the Demonstration Wave Spring provides a different medium in which to study waves. Two hooks on either end allow students to stretch this spring to a length of 8 meters.

It has a diameter of 2.3 cm and an unstretched length of 80 cm.



Clear standing wave patterns can easily be created.

Order Information

Demonstration Wave Spring WA-7334

Snakey

SE-7331



The extra-long metal spring is ideal for the study of mechanical waves. The Snakey has an unstretched length of 2 meters. Pull the convenient end loops more than 10 meters apart to demonstrate transverse, longitudinal, and standing waves.

Order Information

Snakey SE-7331

Double-Length Slinky

SE-8760



The Slinky is an excellent tool for demonstrating transverse and longitudinal wave phenomena. This Double-Length Slinky is twice as long as a traditional slinky, allowing students to create well-defined wave pulses and standing wave patterns. The tension in the Slinky is very low, causing wave pulses to travel slowly throughout its length.

Order Information

Double-Length Slinky SE-8760

Digital Stroboscope

SF-9211

- 1-300 flashes per second (18,000 RPM)
- Digital frequency readout
- Bright: a Xenon flash tube with a 14 cm wide reflector



See page 183 for more information.

Order Information

Digital Stroboscope SF-9211

Elastic Wave Cord

SE-9409



This highly visible elastic cord can be used to set up standing transverse waves. Or, pluck it to watch wave propagation. Approximately 3 mm diameter and 90 meters in length.

Order Information

Elastic Wave Cord SE-9409

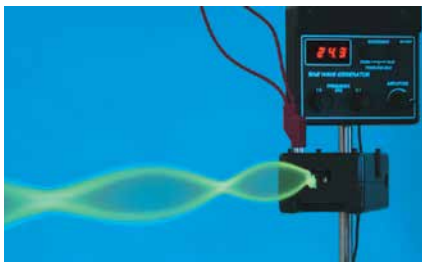
Glow String (2 pack)

SE-8690



⚠ WARNING
CHOKING HAZARD
Small parts. Not for children under 3 years.

This string glows in the dark after being exposed to light. Use it to demonstrate wave motion, including resonance and standing wave patterns. Two rolls are included, totaling over 15 meters of string.



Glow String forming a standing wave using PASCO's String Vibrator WA-9857, Sine Wave Generator WA-9867, and a UV Light Source SE-7228.

Color of string may be different from that shown.

See page 282 for more information on UV Light Source.

Order Information

Glow String (2 pack) SE-8690

WAVEPort® Software

Single User CI-6872D
Classroom License CI-6858B
Site License CI-6874D

- No sensors required
- Uses computer sound card to generate and record sound
- Intuitiveyet powerful analysis tools

WAVEPORT engages students' senses, allowing them to see, hear, and feel sound waves. WAVEPORT software uses only the internal sound capability of the computer, so no additional equipment is necessary.

WAVEPORT also enables students to collect and analyze sound waves. Using an external sound source or a favorite music CD, students can see the changes in the sound waves as they change the input sound. Students can whistle into the computer microphone and observe the waveform on the screen.

WAVEPORT allows students to directly manipulate a waveform to see, feel, and hear the effects of their manipulations. Students can change the frequency of the waveform by dragging an intuitive icon across the screen. As the students change the frequency on the screen, they can hear the changing sound waves from the computer's speakers! All data created in WAVEPORT can easily be exported into DataStudio for more detailed analysis.

Each WAVEPORT CD Includes

WAVEPORT Software

Six DataStudio Workbooks:
- Sound Creator Tutorial
- Creating Sound
- Constructive/Destructive Interference
- Sound Analyzer Tutorial
- Beat Frequency
- Capturing Sound

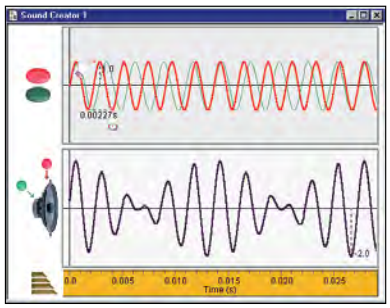
DataStudio Lite

MAC • WINDOWS

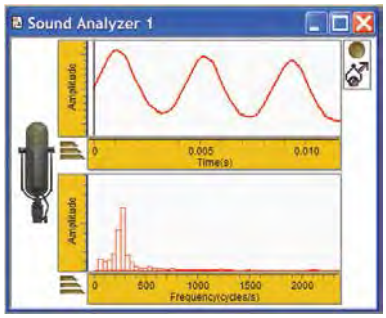
WAVEPORT Computer Requirements

Windows™: 2000 or higher (Windows 8 not supported)
Free RAM: 8 MB (16 MB preferred),
CD-ROM drive, hard disk (20 MB free)

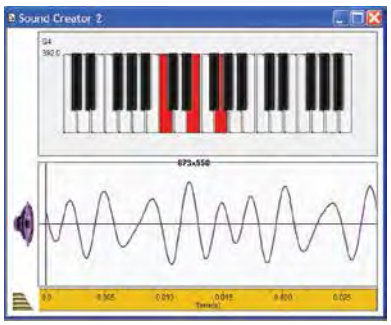
Macintosh®: MAC OS X v. 10.4 or higher (Universal Binary),
Free RAM: 8 MB (16 MB preferred),
CD-ROM drive, hard disk (20 MB free)



Using the hand icons, students can change the frequency, wavelength, and phase of sound waves. In this case, the sum of the waves is shown and beats can be seen and heard.



In the Sound Analyzer mode, the computer listens to sound through a microphone. The waveform and the FFT of the frequencies comprising the sound are displayed. In this case, a student was singing a note centered on 280 Hz.



In the Piano mode, students can relate pressing piano keys to the notes they hear and the waveform they see.

WAVEPORT may be purchased as a single copy for use with one computer, a Classroom License, or as a Site License for use on all computers in a high school or college/university department.

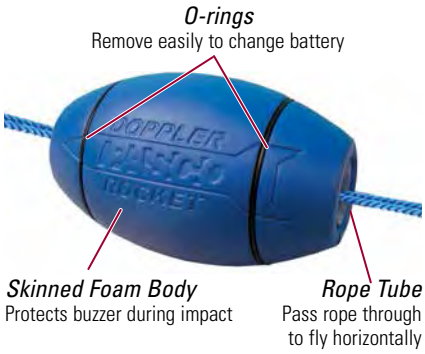
Order Information

WAVEPORT Software
(Single User) CI-6872D
(Classroom License) CI-6858B
(Site License) CI-6874D

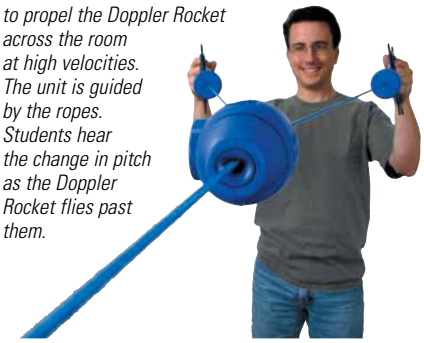
Doppler Rocket

WA-9826

- Experience the frequency shift of sound waves
- Easily generate high velocity motion
- Rugged construction



Flying Horizontally — A set of two ropes can be passed through the center of the unit. This allows students to use the included handles to propel the Doppler Rocket across the room at high velocities. The unit is guided by the ropes. Students hear the change in pitch as the Doppler Rocket flies past them.



The Doppler Rocket combines the elements of a toy with an audio Doppler shift to create an educational experience students won't forget. The Doppler Rocket emits a true, sinusoidal sound waveform at a constant frequency of approximately 620 Hz. The circuit and speaker are housed in skinned foam that protects the unit during normal impacts. The circuit is powered by a 9 V battery. As the Doppler Rocket passes the students, they hear a noticeable shift in frequency. Velocities of 10 m/s can be easily achieved, resulting in a 20 Hz shift in frequency.

Includes

Doppler Rocket
Rope (30 meters)
Handles (4)
Handle Cushions (4)
Battery (9 Volt)



Order Information

Doppler Rocket WA-9826

Chime Set

SE-9081

Ideal for use with WAVEPORT



The Chime Set features three chimes that produce easily heard tones at 1750, 2650, and 3500 Hz. The highest frequency chime is one octave above the lowest frequency chime. Use WAVEPORT software to analyze the sound waves from the Chime Set. Length of bars (1.2 cm diameter): 17.7 cm, 14.4 cm, 12.4 cm.

Order Information

Chime Set SE-9081

Digital Sound Level Meter

SE-9761C

- Compact, easy to use
- Versatile measurements
- ±1.5 dB accuracy



Specifications

Ranges: 40 to 130 dB
Accuracy: ±1.5 dB
Frequency Range: 31.5 Hz to 8 kHz
Frequency Weighting: A and C
Time Weighting: Fast and Slow
Auxiliary Outputs: AC conditioned, 0.707 V rms
Display: 3-1/2 digit LCD
Power: Four AAA batteries (included)

Order Information

Digital Sound Level Meter SE-9761C

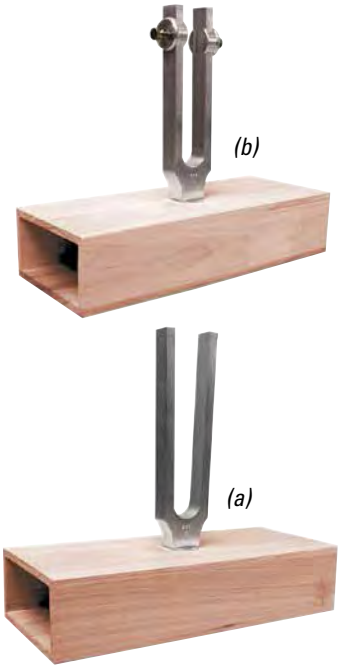
Resonance Boxes

Resonance Box (Single) SE-7344

Sympathetic Resonance Box Set SE-7345

Ideal for use with WAVEPORT

GREAT DEMO



Resonance boxes are great instruments for amplifying sound from a tuning fork. These boxes are constructed from hardwood and feature an A4 tuning fork mounted directly to the box. Use WAVEPORT software to measure the sound waves and beat frequencies created by these resonance boxes.

Resonance Box (Single)

Hardwood resonance box with a 256 Hz A4 tuning fork (a)

Sympathetic Resonance Box Set

Hardwood resonance box with a 256 Hz A4 tuning fork (a) and a hardwood resonance box with an adjustable tuning fork (b)

Order Information

Resonance Box SE-7344
Sympathetic Resonance Box Set SE-7345
Recommended:
WAVEPORT Software CI-6872D

Tuning Fork Set

SE-7342

Ideal for use with WAVEPORT

LAB ESSENTIALS



The tuning fork has long been the tool of choice for helping students understand the relationship between wave frequency and pitch. These high-quality aluminum tuning forks are both rugged and economical. The set includes eight forks representing a full octave of frequencies, a soft protective case, and a rubber mallet.

Note	Frequency
C	256 Hz
D	288 Hz
E	320 Hz
F	341.3 Hz
G	384 Hz
A	426.7 Hz
B	480 Hz
C	512 Hz

Order Information

Tuning Fork Set SE-7342

Adjustable Tuning Fork

SE-7343



Use the Adjustable Tuning Fork to demonstrate how to change the frequency of a tuning fork. Includes a 240 Hz tuning fork and two adjustable masses. The adjustable masses can be moved up and down to change the pitch. Conveniently labeled notches allow an entire octave from "C" to "B" to be produced.

Order Information

Adjustable Tuning Fork SE-7343

Basic Optics System

OS-8515C

LAB ESSENTIALS

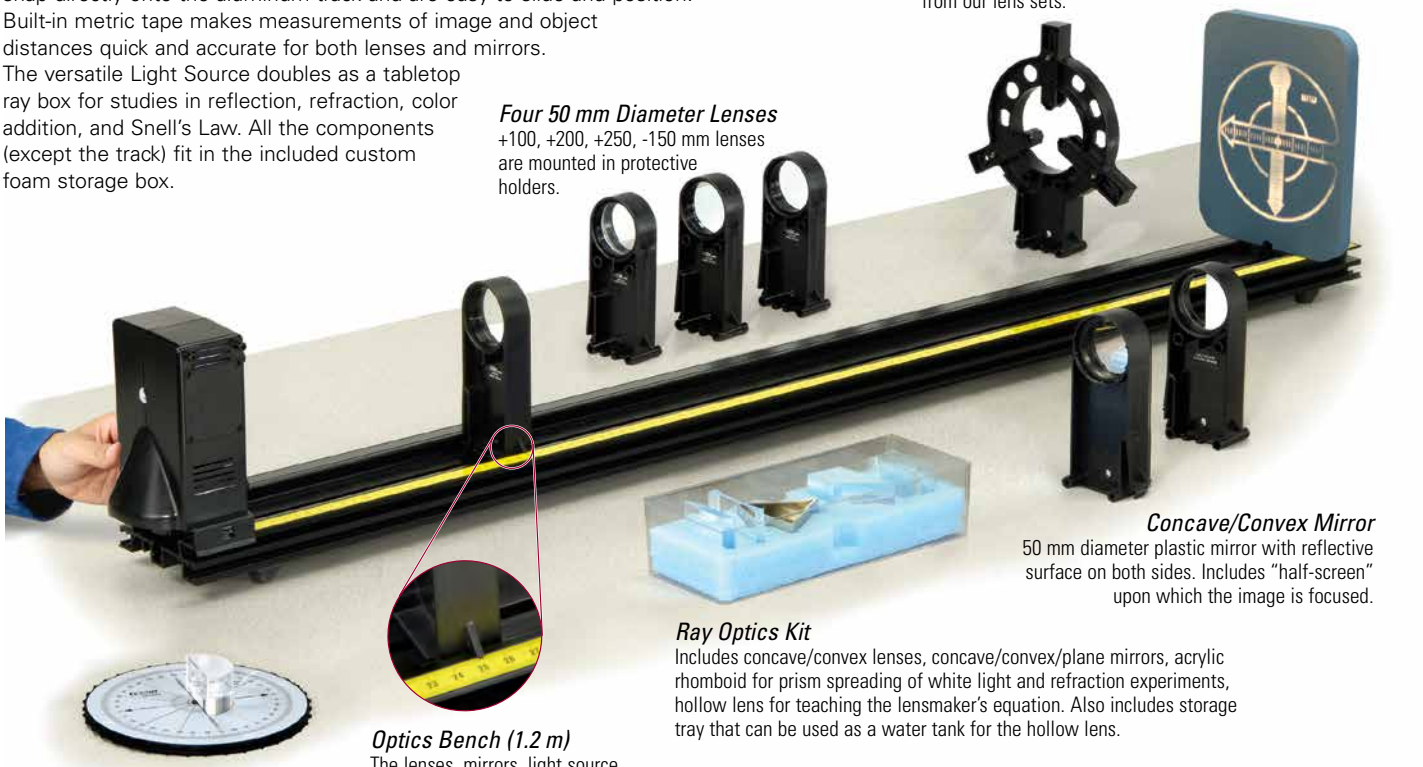
- Geometric and Ray Optics
- Concave and convex lenses
- Concave/convex mirror

PASCO's Basic Optics System is easy-to-use, affordable, and ruggedly designed. Large 50 mm diameter optics components are mounted in protective holders that snap directly onto the aluminum track and are easy to slide and position. Built-in metric tape makes measurements of image and object distances quick and accurate for both lenses and mirrors. The versatile Light Source doubles as a tabletop ray box for studies in reflection, refraction, color addition, and Snell's Law. All the components (except the track) fit in the included custom foam storage box.

Four 50 mm Diameter Lenses
+100, +200, +250, -150 mm lenses are mounted in protective holders.

Adjustable Lens Holder
Use your own lenses (from 19 mm to 75 mm in diameter) or choose from our lens sets.

Viewing Screen
White plastic screen snaps into the optics bench and the position of the screen can be read directly on the bench scale.

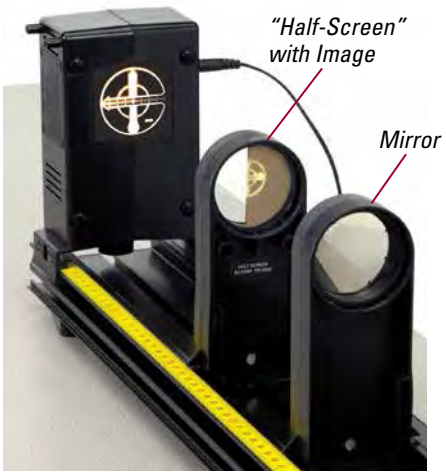


Concave/Convex Mirror
50 mm diameter plastic mirror with reflective surface on both sides. Includes "half-screen" upon which the image is focused.

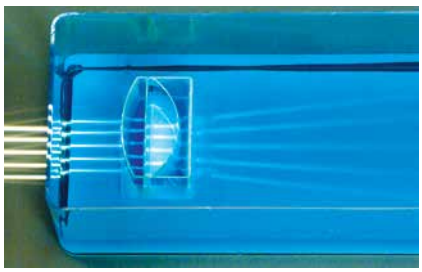
Ray Optics Kit
Includes concave/convex lenses, concave/convex/plane mirrors, acrylic rhomboid for prism spreading of white light and refraction experiments, hollow lens for teaching the lensmaker's equation. Also includes storage tray that can be used as a water tank for the hollow lens.

Optics Bench (1.2 m)
The lenses, mirrors, light source, and screen snap into this rugged aluminum extrusion. The metric tape makes position measurements easy.

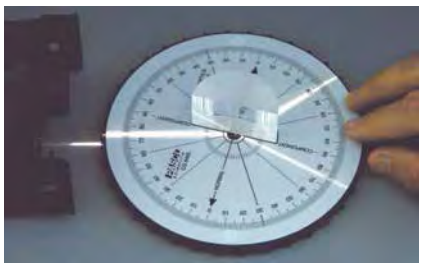
Ray Table
Two-piece construction allows the table to be rotated for studying Snell's Law or the Law of Reflection. Includes D-shaped acrylic lens.



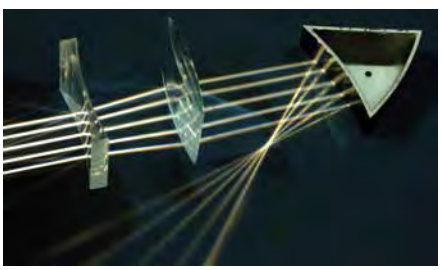
Light Source: Has a lighted crossed arrow target with metric scale for focusing images through lenses or using with the concave mirror.



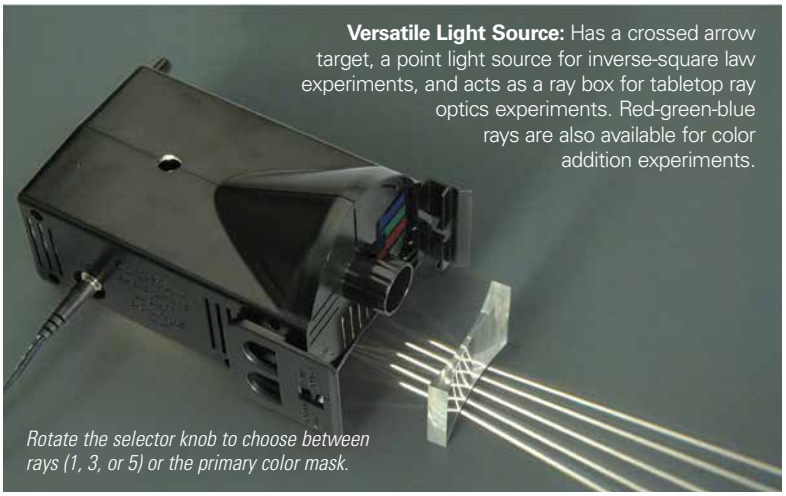
The storage tray is used to create a "hollow" air-filled convex lens. Note that the rays diverge.



Ray Table in use showing both the Reflected and Refracted rays.

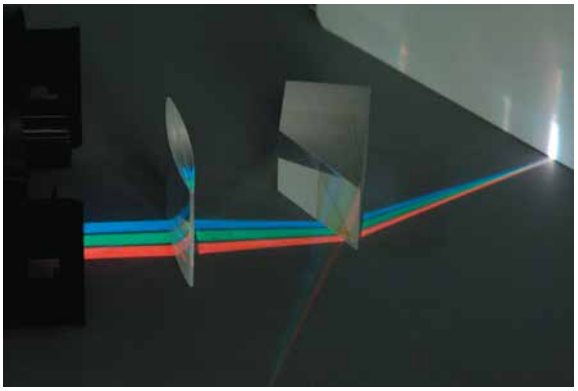


Components from the Ray Optics Kit showing Refraction and Reflection.



Versatile Light Source: Has a crossed arrow target, a point light source for inverse-square law experiments, and acts as a ray box for tabletop ray optics experiments. Red-green-blue rays are also available for color addition experiments.

Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.



The primary color mask allows experiments in color addition using components from the Ray Optics Kit.

Basic Optics System Experiments Included

1. Color Addition
2. Prism
3. Reflection
4. Snell's Law
5. Total Internal Reflection
6. Convex and Concave Lenses
7. Hollow Lens
8. Lensmaker's Equation
9. Apparent Depth
10. Reversibility
11. Dispersion
12. Focal Length and Magnification of a Thin Lens
13. Focal Length and Magnification of a Concave Mirror
14. Virtual Images
15. Telescope
16. Microscope
17. Shadows

Basic Optics System Storage Box

All components (except the track) fit in the custom foam box. There are additional slots for accessory lenses (see page 258).



Includes

1.2 m Optics Bench
Basic Optics Light Source
50 mm diameter Glass Lenses in Holder
+100 mm, -150 mm, +200 mm,+250 mm
Adjustable Lens Holder
Concave/Convex Mirror with Screen
Ray Optics Kit
Ray Table with D-shaped Lens
Viewing Screen
Storage Box

Order Information

Basic Optics System OS-8515C

Basic Optics Components and Accessories

Pages 256-269

System Components

pg 256



Color Mixer

pg 257



Lens Sets

pg 258



System Accessories

pg 259-261



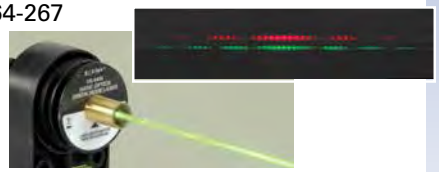
Human Eye Model

pg 262-263



Diffraction

pg 264-267



Dynamics Track Optics

pg 269



Basic Optics Light Source

OS-8470

- One, three, or five parallel rays
- Three primary color source
- Crossed arrow object and point source

The Basic Optics Light Source is an excellent source for a variety of optics experiments. A single 10-watt quartz-halogen bulb provides bright, easy-to-see illumination without a lot of heat. By turning the box to a different side, it becomes a:

1. Crossed Arrow Object with Metric Scale. Ideal for showing images, focal point, and magnification.
2. Bright Point Source. The very small filament of the halogen bulb provides an excellent point source for experimenting with shadows or the Inverse Square Law.
3. Three Primary Colors Source. The red, green, and blue filters provide three rays of light that are easily combined with a lens for color mixing.
4. One,Three, or Five Ray Source. Just rotate the knob on front of the light source to vary the number of rays produced.



Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.



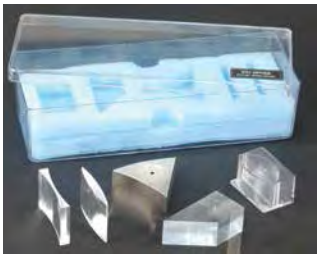
The Basic Optics Light Source provides a point source and an extremely bright crossed arrow target. Use free-standing or easily clip directly to Basic Optics Track.

Order Information

Basic Optics Light Source OS-8470

Ray Optics Kit

OS-8516A



Includes

Double-Convex Lens

Double-Concave Lens

Rhomboid

Eye-Dropper

Triangular mirror accessory with concave, convex, and plane reflective surfaces

Hollow lens to fill with a liquid or use as an air lens.

Order Information

Ray Optics Kit OS-8516A

Concave/Convex Mirror Accessory

OS-8457

- 50 mm diameter
- ±100 mm focal length
- Plastic mirror

This double-sided convex/concave plastic mirror is mounted in a lens holder for easy placement on the Basic Optics Track. The Accessory also includes a "half screen" that allows light to pass through on one side, and an opaque screen on the other half to focus the real image formed by the concave mirror.





Includes

Concave/Convex Mirror

Half Screen

Order Information

Concave/Convex Mirror Accessory OS-8457

Ray Table

OS-8465

- Angle of reflection
- Snell's Law
- Total internal reflection

The Ray Table provides an excellent viewing surface for ray optics. The table can be rotated about its axis to quickly change the incident angle of the ray. The resulting angles of reflection and refraction are easily measured directly off the polar grid printed on the table. The (included) acrylic cylindrical D lens simplifies the experiment by having the rays bend at only one surface. Investigate Snell's Law for both cases of rays either entering or leaving the acrylic.



Includes

Table

D-shaped Lens

Order Information

Ray Table OS-8465

Color Mixer

OS-8496

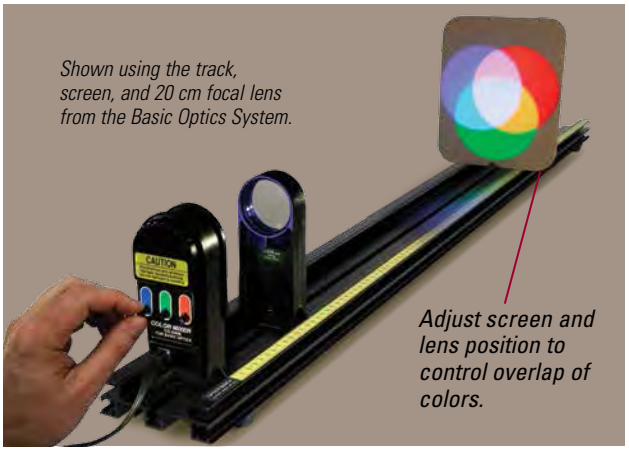
GREAT DEMO

- Demonstrates additive color mixing
- Accessory to Basic Optics System

The Color Mixer has separate controls for each of the red, blue, and green LEDs that allow brightness to be adjusted from off to full output.



Individually adjust the intensity of the super bright red, green, and blue LEDs.



Use free-standing, hand-held, or clip it directly to the Basic Optics Track.



Includes

Tri-color light source and power supply

Order Information

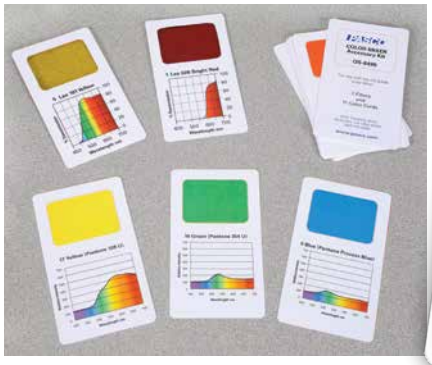
Color Mixer OS-8496

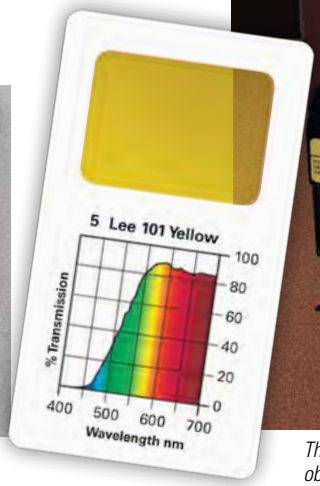
Color Mixer Accessory Kit

OS-8495

- Accessory to the Color Mixer
- 7 filter cards
- 11 printed color cards
- Manual with 9 lab activities

Each card includes a graph showing its transmitted or reflected spectrum. Sets are enclosed in a clear envelope.





Includes

7 Filter cards

11 Printed Color cards

Manual (not shown)



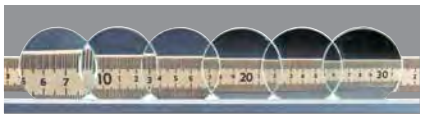
The red filter's spectral chart shows it transmits only red light. Students observe that the blue and green circles disappear and the overlapping areas of magenta, yellow, and white become red.

Order Information

Color Mixer Accessory Kit OS-8495

Ground Glass Lenses (set of 6)

SE-9013



These precision ground glass lenses provide a useful range of focal lengths. Each lens has a 50 mm diameter – small enough for easy mounting, yet large enough for effective viewing. The set of six comes in a convenient storage box.

Focal Length	Description	Focal Length	Description
500 mm	concave convex	-150 mm	double concave
300 mm	plano convex	-300 mm	plano concave
150 mm	double convex	-500 mm	convex concave

Order Information

Ground Glass Lenses (set of 6) SE-9013

Lens Holder Set

OS-8522



These holders for the Basic Optics System are an excellent way to permanently mount 50 mm diameter lenses.

Order Information

Lens Holder Set (2 pack) OS-8522

General Quality Lens Sets

Geometric Lens Set

OS-8466A



This is a set of three unmounted 50 mm diameter glass lenses with focal lengths of +100 mm, +200 mm, and -150 mm. These are the same lenses included in the Dynamics Track Optics Kit (OS-8471A) and the Beginning Optics System (OS-8459). They can be mounted in the Adjustable Lens Holder below.

Order Information

Geometric Lens Set OS-8466A

50 mm Diameter Lens Assortment

SE-7581

This set of six lenses is made of polished glass with ground edges and comes in a wooden storage box.

Focal Length (mm)	Description	Focal Length (mm)	Description
+1000	double convex	-1000	double concave
+300	double convex	-200	double concave
+150	double convex	-150	double concave

Order Information

50 mm Diameter Lens Assortment SE-7581

50 mm Diameter Convex Class Sets

These class sets each contain six identical 50 mm diameter lenses made of polished glass with ground edges. They come in a wooden storage box.



Order Information

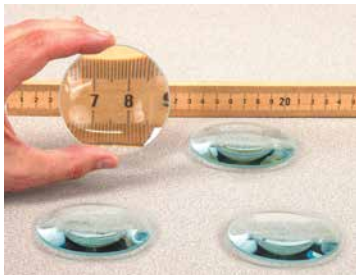
100 mm Focal Length Class Set SE-7582

200 mm Focal Length Class Set SE-7583

75 mm Diameter Convex Class Set

SE-7584

This class set contains four identical 75 mm diameter 200 mm focal length lenses made of polished glass with ground edges. Shipped in a cardboard box with thermoform packing.



Order Information

75 mm Diameter Class Set SE-7584

Adjustable Lens Holder

OS-8474



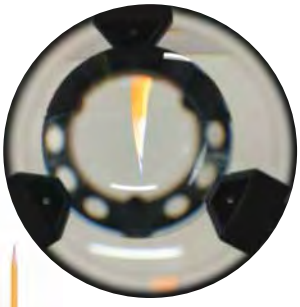
The Adjustable Lens Holder for the Basic Optics System is designed for use with lenses and mirrors with diameters between 19 mm and 75 mm.

Place the lens or mirror in the holder and adjust the three arms to hold the component. A set screw in each adjustable arm ensures that the mirror or lens will remain in place.

The holder snaps into the Basic Optics Track and is designed to position all mirrors and lenses at the same height as the rest of the Basic Optics System components.

Order Information

Adjustable Lens Holder OS-8474



Actual view through the lens of the magnified image of the pencil.



Build a telescope or microscope: Shown with 1.2 m Basic Optics Track OS-8508.

Lens Sets

Basic Optics Geometric Lens Set (set of 2)

(+200, +100 mm)

OS-8456

Each lens is mounted in a lens holder for protection and easy storage. The lens holder clips directly to the Basic Optics track.

Accessory Lens Set (set of 2)

(+250, -150 mm)

OS-8519



Order Information

Basic Optics Geometric Lens Set (set of 2) OS-8456
Accessory Lens Set (set of 2) OS-8519

Concave Mirror Accessory (Glass)

OS-8532



The Concave Mirror Accessory is made of glass and has a 50 mm focal length. Using the "crossed arrow" object of the light source, students will shine the light through the open section of the "half-screen" onto the concave mirror. The light rays will reflect off the mirror and form a partial image on the screen. Students can use the Lensmaker's Equation to verify the focal length of the mirror.

Order Information

Concave Mirror Accessory (Glass) OS-8532

Basic Optics Viewing Screen

OS-8460



This white plastic screen is used with Basic Optics systems. The screen snaps into the optics bench and the position of the screen can be read directly on the bench scale. Also fits the Dynamics Track Optics Carriages (OS-8472 on page 269) for use with a Dynamics Track.

Order Information

Basic Optics Viewing Screen OS-8460

Basic Optics Spares Kit

OS-8510

The Basic Optics Spares Kit includes many of the small parts that are sometimes lost after student use. Also includes two replacement bulbs for the Light Source. Suitable for all versions of the Basic Optics System (OS-8515).



All parts are organized in a plastic case for easy storage.

Includes

10 W bulb for Basic Optics Light Source OS-8470 or OS-8517A (2)
6-32 1 1/2" Screw for the Basic Optics Light Source OS-8517A (8)
3/8" Screw for optics accessories (6)
3/8" Brass thumbscrew for optics track brackets (4)
1/4-20 1/2" Nylon thumbscrews (8)
1/4-20 Square nuts (20)
Nylon washers (6)
1/4-20 9/16" Round steel thumbscrews (4)
1/4-20 3/8" Round steel thumbscrews (4)
6-32 5/8" Round steel thumbscrews (6)
6-32 3/8" Round steel thumbscrews (4)
4-40 5/16" Round steel thumbscrews (4)
6-32 3/16" Round steel thumbscrews (4)
Replacement rubber feet for optics bench (6)
Replacement rubber feet for Basic Optics Light Source OS-8517A (15)
Replacement screws for Basic Optics Light Source OS-8470 (4)
Plastic storage box (1)

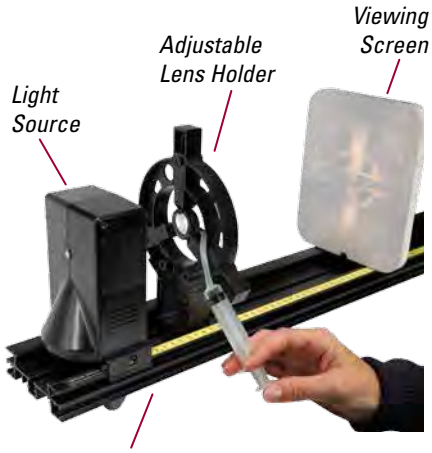
Order Information

Spares Kit – Basic Optics OS-8510

Adjustable Focal Length Lens

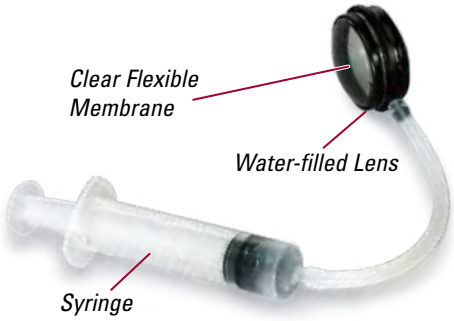
OS-8494

Use the syringe to adjust the amount of water in the lens. Changing the curvature of the clear flexible membranes changes the focal length of the lens.



Use the Adjustable Focal Length Lens with your Basic Optics System.

See page 263 for use with Human Eye Model.





Removable membranes make it easy to clean.

Includes

10 mL Syringe
1 ft. Silicon Tubing
Lenses (2)



Order Information

Adjustable Focal Length Lens OS-8494

Shown in use with:
Basic Optics System ..... OS-8515C p. 254

Aperture Accessories

OS-8524



Aperture Disk

Simulate the compound lens system of a camera using the Aperture Disk. Simply snap the disk onto one face of a lens. The disk offers six different *f*-number settings for controlling the amount of light that reaches the viewing screen.

The f-number is designated as f / #, where # equals the focal length of the lens, f, divided by the diameter of the aperture, D. (Example uses a +100 mm lens.)

f-Number	Aperture Diameter (mm)
f / 4	25.0
f / 5.6	17.7
f / 8	12.5
f / 11	8.8
f / 16	6.3
f / 22	4.4

Spherical Aberration Attachments

Do the center and outside parts of a lens focus light differently? With the Spherical Aberration Attachments, students will be surprised by the answer. Simply snap the attachments onto a lens from the Basic Optics System and compare the image distance for each attachment.



The Peripheral Mask passes light through the center only.



The Center Mask passes light through an outside ring.



Peripheral Mask shown mounted on +250 mm lens.

Includes

Aperture Disk and Holder

Spherical Aberration Attachments

Order Information

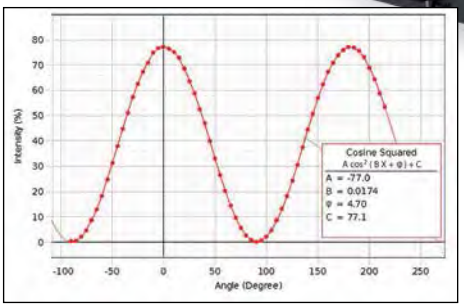
Aperture Accessories OS-8524

Polarizer Demonstrator

OS-9477A

Confirm Malus' Law using the Polarizer Demonstrator and a Light Sensor. The angle is read directly from the polarizer, which is marked in 5° increments. Any light source can be used, but the experiment works especially well with the Color Mixer, as shown here.





As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.

Order Information

Polarization Demonstrator ..... OS-9477A p. 275

Shown in use with:

Optics Bench (60 cm) ..... OS-8541 p. 261

Aperture Bracket ..... OS-8534A p. 266

Color Mixer ..... OS-8496 p. 257

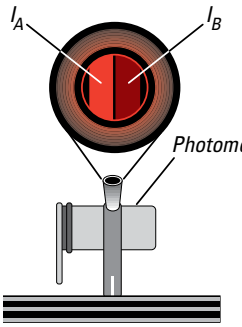
High Sensitivity Light Sensor ..... PS-2176 p. 49

Photometer

OS-8520



PASCO's Photometer is an easily understood, nonelectronic device that allows students to measure relative light intensities. By looking through the eyepiece, students can see if the two fluorescent disks, each receiving light from an opposite side of the photometer, are equal in intensity. Students can verify the Inverse Square Law.



View through Photometer for the case that $I_A > I_B$



Includes

Photometer

Set of polarizers and an accessory holder

Disk of neutral density filters—25, 50, 75, and 100% transmittance

Order Information

Photometer OS-8520

Polarizer Set

OS-8473

This accessory set includes two polarizer disks and an optics holder. Rotate the polarizers relative to one another to view the effect on light intensity.



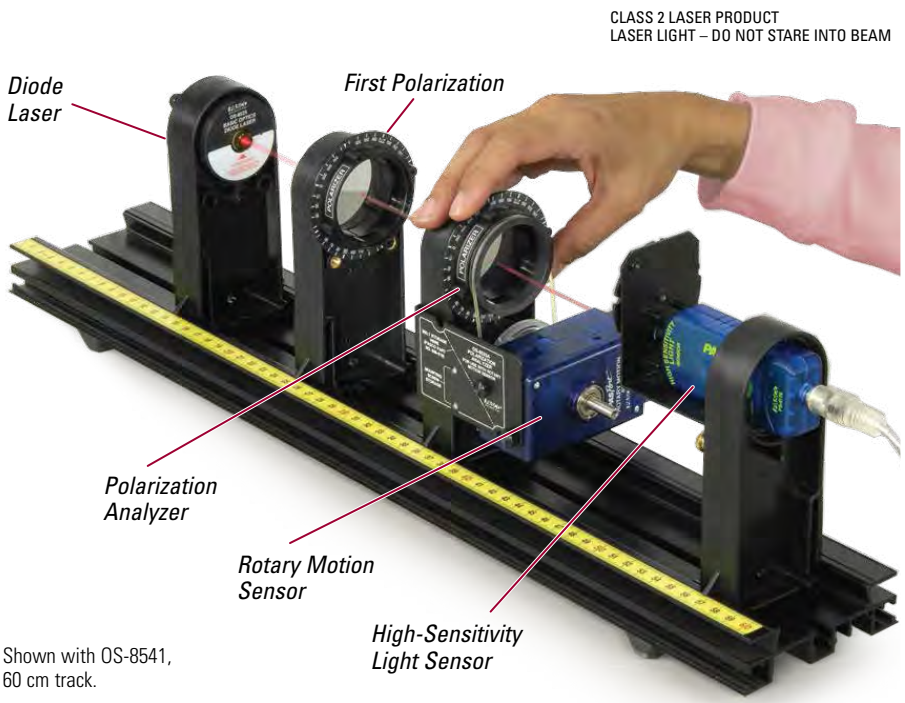
Order Information

Polarizer Set OS-8473

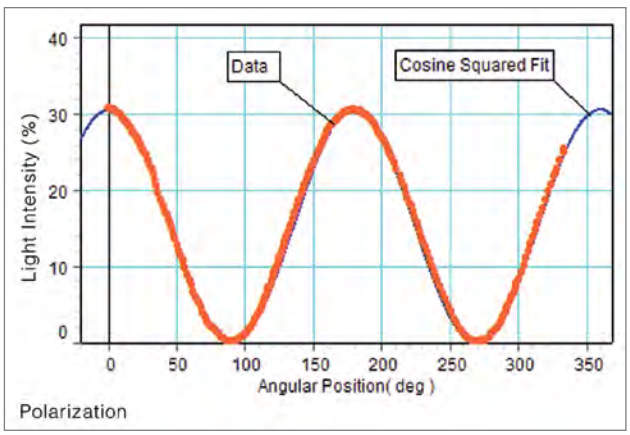
Polarization Analyzer

OS-8533A

Students can confirm Malus' Law of Polarization by using the Polarization Analyzer with the Basic Optics System. All components mount directly to PASCO's Basic Optics Bench OS-8515B. The Rotary Motion Sensor is used to measure the angle between the two polarizing disks. The Light Sensor measures the intensity of light that passes through both polarizers.



Shown with OS-8541, 60 cm track.



As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.

See page 354 for complete experiment.

Includes

Polarizer Disks (2)
Polarizer Holder
Aperture Bracket
Accessory Holder with Mounting Bracket
Accessory Holder for Aperture Bracket
Retarder Disk



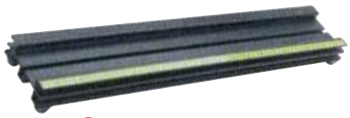
Order Information

Polarization Analyzer OS-8533A

Required:

Rotary Motion Sensor	PS-2120A	p. 28
High-Sensitivity Light Sensor	PS-2176	p. 49
Basic Optics System	OS-8515C	p. 254
Diode Laser	OS-8525A	p. 266

Optics Benches



60 cm Optics Bench

OS-8541

The short optical bench is for experiments such as polarization and spectrophotometry.

120 cm Optics Bench

OS-8508

This optics bench is used for lens and mirror experiments, inverse-square law, and diffraction/interference experiments. If you want a bench longer than 120 cm, use the Optics Bench Connectors, shown below.

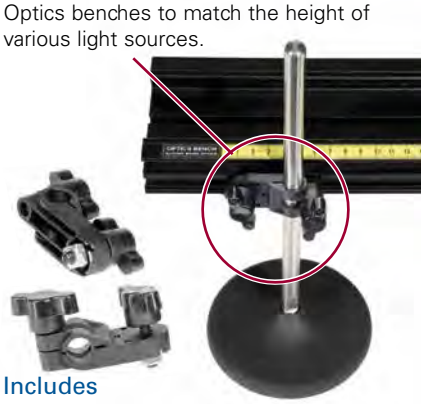
Order Information

60 cm Optics Bench OS-8541
120 cm Optics Bench OS-8508

Optics Bench Rod Clamps

OS-8479

Rod Clamps are used to elevate Basic Optics benches to match the height of various light sources.



Includes

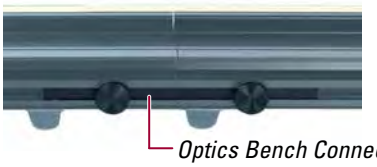
Two Rod Clamps

Order Information

Optics Bench Rod Clamps OS-8479

Optics Bench Connectors

OS-8538



Optics Bench Connector

These Connectors slide into the T-slot to couple two Basic Optics Benches together. Includes two connectors.

Order Information

Optics Bench Connectors OS-8538

Human Eye Model

OS-8477A

- Classic eye model at an affordable price
- 3-D working model of the human eye

TEACHER FAVORITE



Features

Working Model of the Human Eye: Two lenses are used to form images on the retina. Sealed tank holds water to simulate the vitreous humor. Size and orientation of the illuminated object can be easily measured.

Study the Optics of Normal Vision and Vision Correction: Use the included plastic lenses to create images for normal vision, far-sightedness, near-sightedness, and astigmatism. Additional lenses are placed in front of the eye to correct for vision problems.

Fixed Corneal Lens and Interchangeable Crystalline Lens: The crystalline lens is surrounded by water (vitreous humor). By changing the crystalline lens, the eye can focus on both near and far objects.

Moveable Retina: Three positions to demonstrate near-sightedness, far-sightedness, and normal vision.

Variable Pupil Size: Students can observe the change in brightness and clarity of the image as the pupil size is reduced.



Use the Pupil Aperture to reduce the pupil size, or to change the shape to a "cat's eye."



The Eye Model can image any illuminated picture, or use with the Basic Optics System and Eye Model Bracket shown on page 263.

Includes

Molded Plastic Eyeball
Plastic Lenses (2 sets of 6)
Pupil Aperture
Retina Screen
Optics Caliper (1)
Adjustable Focal Length Lens with Syringe, Tubing, and 2 Flexible Lenses
Experiment Manual



Specifications

Focal Lengths in Air of Plastic Lenses: +62 mm (+16d), +120 mm (+8.3d), +400 mm (+2.5d), -1000 mm (-1.0d), -128 mm (-7.8d) cylindrical, +307 mm (+3.26d) cylindrical

Corneal Lens Focal Length in Air: +140 mm (+7.1d)

Dimensions: 15 cm x 17 cm x 10 cm high

Order Information

Human Eye Model	OS-8477A	
Recommended:		
Basic Optics Light Source	OS-8470	p. 256
Human Eye Replacement Set (includes lenses, screen, and pupil)	OS-8476	
Optics Caliper (set of 5)	OS-8468	p. 263

Eye Model Bracket

OS-8469

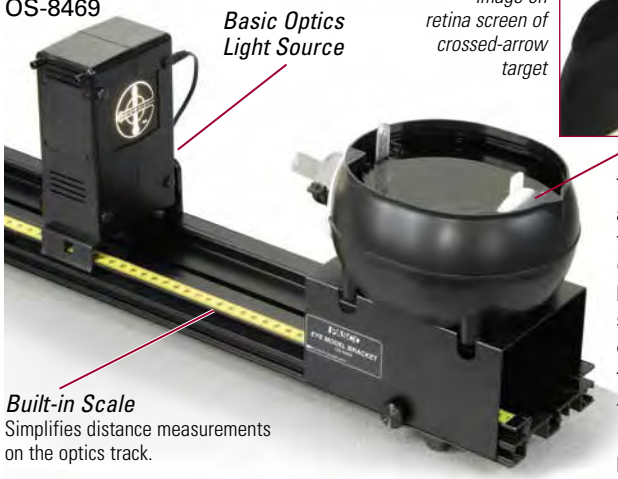




Image on retina screen of crossed-arrow target

The Eye Model Bracket allows the Human Eye Model to be used with the Basic Optics System (OS-8515). The bracket holds the Eye Model securely on the track at the correct optical height.

The illuminated crossed-arrow target on the Basic Optics Light Source makes the perfect object. Easily measure object and image distances, as well as the size of the object and image for calculations of magnification.



Eye Model and Bracket shown with a telescope made using two Adjustable Lens Holders (OS-8474) and accessory lenses (see page 258). Students can see the image through the telescope with their own eyes, and then place the Eye Model on the track and see the same image projected on the retina screen.

Includes

Bracket

Two 1/4-20 thumb screws with nuts



Order Information

Eye Model Bracket	OS-8469
Shown in use with:	
Basic Optics System	OS-8515C
Human Eye Model	OS-8477A

Optics Caliper

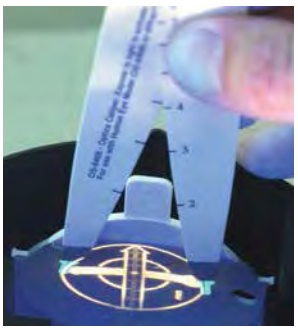
OS-8468

- Glow-in-the-dark tips
- Waterproof

This lightweight plastic caliper is perfect for measuring images in the dark. Simply span the object and then use a scale to measure the distance. For approximate measurements, use the built-in cm scale on the calipers.



The tips of the caliper glow in the dark. Activate with an incandescent or UV lamp.



Use the Optics Caliper to measure image sizes in the Human Eye Model. Glow-in-the-dark tips activated using a UV light source.

Order Information

Optics Caliper (Set of 5)	OS-8468
Recommended:	
UV Light Source	SE-7228 p. 282

Adjustable Focal Length Lens

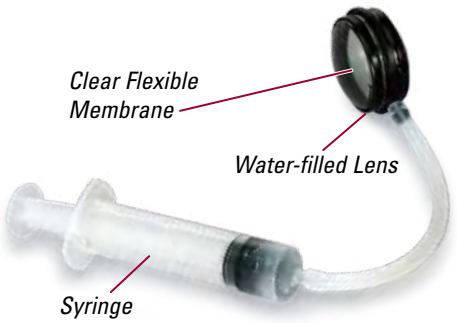
OS-8494

Use the syringe to adjust the amount of water in the lens. Changing the curvature of the clear flexible membranes changes the focal length of the lens.



Demonstrate accommodation:
Show how the eye lens changes focal length by changing its surface curvature.

See page 254 for use with Basic Optics System.





Removable membranes make it easy to clean.

Includes

10 mL Syringe
1 ft. Silicon Tubing
Lenses (2)



Order Information

Adjustable Focal Length Lens	OS-8494
Shown in use with:	
Human Eye Model	OS-8477A p. 262

Diffraction Optics Kit

OS-8531A

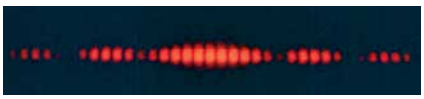
Add this kit to the Basic Optics System to allow the investigation of a wide variety of diffraction slit patterns. The slits are constructed using vacuum deposited chromium on glass. The following patterns are included:

- Single Slit (four variations)
- Variable Width Single Slit
- Double Slit (four variations)
- Multiple Slit (3,4,5)
- Single Slit/Double Slit Comparison
- Variable Spacing Double Slit



CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Single Slit Pattern (a = 0.04 mm)



Double Slit Pattern (a = 0.08 m, b = 0.05 mm)

Slit Accessory
Snaps into position on the bench for automatic slit alignment with laser. Rotate disk to select a different pattern.

LAB ESSENTIALS

Red Diode Laser



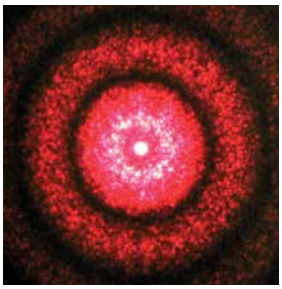
4-Slit Pattern (a = 0.04 mm, d = 0.125 mm)

Single/Double Slit Comparison

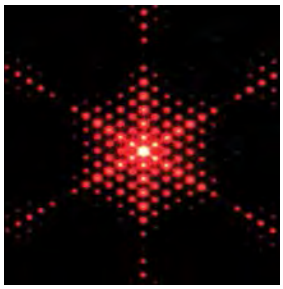


Easy Laser Alignment
The laser beam can be aimed through the slits using two thumb screws. Once the beam is aligned, either the laser or the slits can be removed from the optics bench and returned to the bench without re-aligning the beam.

Change Slits in the Dark Without Re-aligning Everything.
The slit wheels eliminate the frustration of trying to change the slits in a darkened room. Simply rotate to the next positive click to lock a different slit into position. The alignment of the disk only has to be done once. After that, all the slits on that wheel will be aligned.



Circular Diffraction Pattern



Hex diffraction Pattern

Optics Caliper

OS-8468



This lightweight plastic caliper is perfect for measuring interference and diffraction patterns in the dark. Glow-in-the-dark tips are activated using an incandescent or UV lamp. *See page 263 for more information.*

Order Information

Optics Caliper (Set of 5)	OS-8468	
Recommended:		
UV Light Source	SE-7228	p. 282

Includes

Red Diode Laser
(OS-8525A)

High Precision Diffraction Slit
(OS-8453)



For components and accessories, see pages 266-267.

Order Information

Diffraction Optics Kit	OS-8531A	
Recommended:		
Green Diode Laser	OS-8458	p. 266

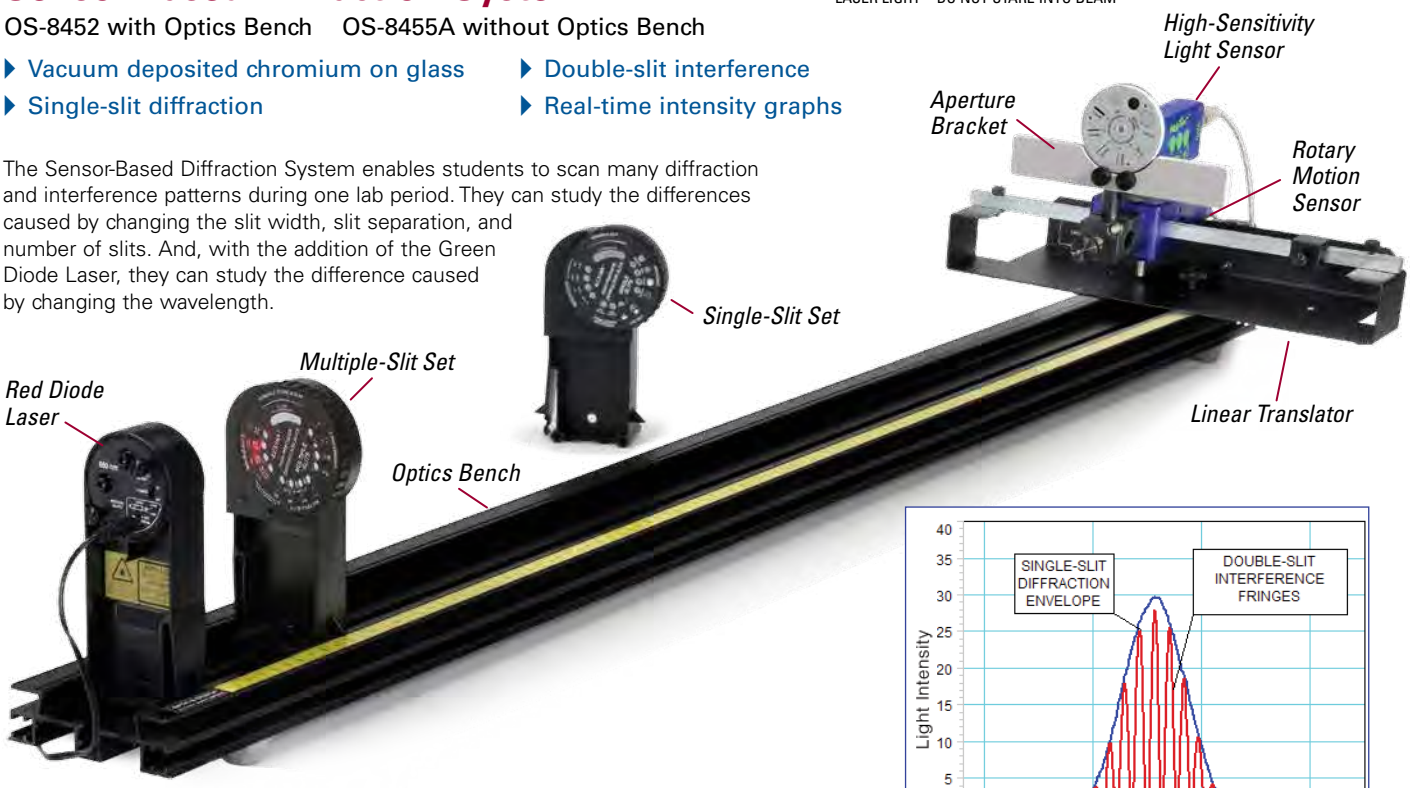
Sensor-Based Diffraction System

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

OS-8452 with Optics Bench OS-8455A without Optics Bench

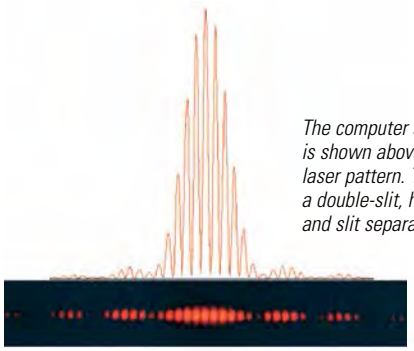
- Vacuum deposited chromium on glass
- Single-slit diffraction
- Double-slit interference
- Real-time intensity graphs

The Sensor-Based Diffraction System enables students to scan many diffraction and interference patterns during one lab period. They can study the differences caused by changing the slit width, slit separation, and number of slits. And, with the addition of the Green Diode Laser, they can study the difference caused by changing the wavelength.

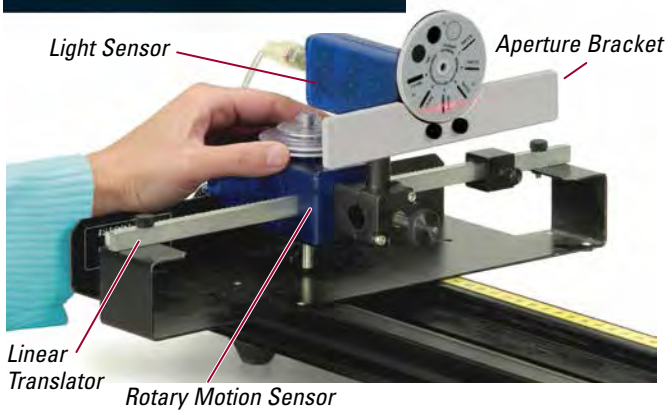


Scanning with the Linear Translator In this unique scanning system, the diffraction pattern is scanned using a light sensor attached to a Rotary Motion Sensor. As the wheel on the Rotary Motion Sensor is rotated by hand, the Rotary Motion Sensor moves along a gear rack (called the Linear Translator). Students make the association between the diffraction pattern they see and the real-time graph of the light intensity versus position.

Computer scan of a single-slit and double-slit having the same slit width.



The computer scan of an interference pattern is shown above a photograph of the actual laser pattern. The pattern was produced with a double-slit, having a slit width 0.08 mm and slit separation 0.50 mm.



Includes

- Red Diode Laser (OS-8525A)
- Linear Translator (OS-8535)
- Aperture Bracket (OS-8534A)
- Optics Bench (OS-8508)
- High Precision Diffraction Slit (OS-8453)



For components and accessories, see pages 266-267.

Order Information

Sensor-Based Diffraction (with Optics Bench)	OS-8452
Sensor-Based Diffraction Kit (without Optics Bench)	OS-8455A
Required for use with ScienceWorkshop:	
Light Sensor	CI-6504A
Rotary Motion Sensor	CI-6538
Required for use with PASPORT:	
High Sensitivity Light Sensor	PS-2176
Rotary Motion Sensor	PS-2120A
Recommended:	
Green Diode Laser	OS-8458 p. 266

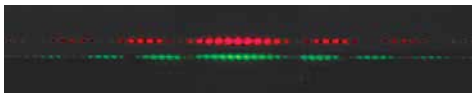
Diode Laser – Basic Optics

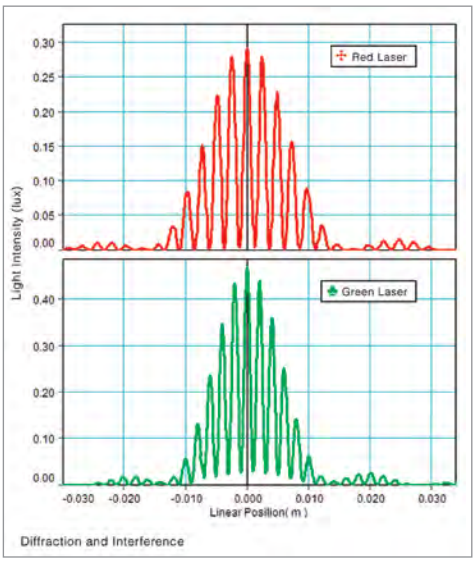
OS-8525A (Red)

OS-8458 (Green)

These unique diode lasers take the frustration out of aligning the laser beam with the diffraction slits. With both lasers, you can demonstrate the effect of changing wavelength on the diffraction and interference patterns.

A red laser beam was passed through a double slit. Then the Red Diode Laser was replaced by the Green Diode Laser by simply pulling the Red Laser off the optics track and clipping the Green Laser into its place. The recorded patterns from red and green lasers show clearly that the longer wavelength (red) is spread out more than the green.







The horizontal and vertical positions of the beam can be adjusted by turning the thumb screws on the back of the laser.



Demonstrate the effect of changing wavelength on the diffraction and interference patterns.

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Specifications

Output Power: <1 mW

Wavelength: 650 nm (OS-8525A) 532 nm (OS-8458)

Power Supply: 9-V adapter (included)

Order Information

Diode Laser – Red OS-8525A

Diode Laser – Green OS-8458

Linear Translator

OS-8535A



The Linear Translator transforms a Rotary Motion Sensor into a linear motion device. The toothed rack of the Linear Translator fits into the slot in the side of the Rotary Motion Sensor. As the Rotary Motion Sensor pulley is rotated by hand, the Rotary Motion Sensor moves along the rack. *Rotary Motion Sensors not included.*

Specifications

Resolution for Rotary Motion Sensor: 0.055 mm (CI-6538)

0.020 mm (PS-2120)

Maximum Travel: 20 cm

See page 265 for more information.

Order Information

Linear Translator OS-8535A

Optics Bench (120 cm)

OS-8508



This is the optics bench included in the Basic Optics System OS-8515C.

Order Information

Optics Bench (120 cm) OS-8508

Aperture Bracket

OS-8534A

The Aperture Bracket acts as a mask for a light sensor. The wheel is rotated to select different size slits, defining the spatial resolution. Narrow slits are used to scan diffraction patterns having fine detail. Wider slits are used to let in more light when scanning dimmer patterns. The diffuser selection is used for inverse square law experiments.

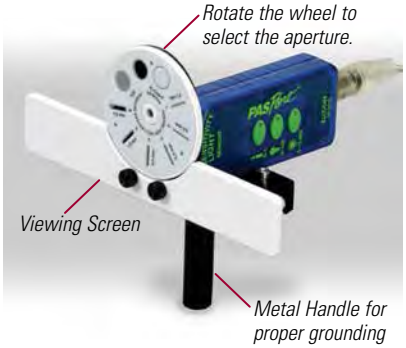
Specifications

Six Slits: From 0.1 mm to 1.5 mm width

Open Aperture: No reduction in intensity

Screen Aperture: 10% transmittance

Diffuser





Includes

Aperture Bracket with Screen, Metal Handle and Accessory Holder

Order Information

Aperture Bracket OS-8534A

High-Precision Diffraction Slits

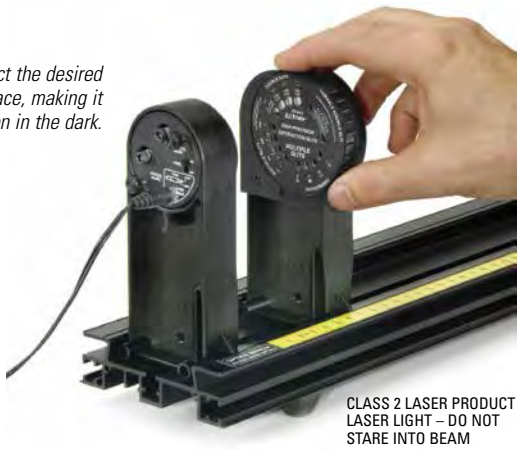
OS-8453

- Vacuum deposited chromium on glass
- Single-slit and double-slit wheels

OS-8453 includes two slit wheels with holders designed to match the height of the slits to the height of the diode laser. All components clip directly to the Optics Bench from the Basic Optics System OS-8515C. The slit wheels eliminate the frustration of trying to change the slits in a darkened room. To change the slit being illuminated by the laser, the slit wheel is simply rotated to the next positive click to lock another slit into position.

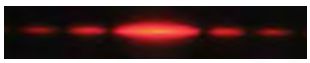
Shown in use with the red OS-8525A and green OS-8458 Diode Lasers.

Simply rotate the wheel to select the desired slit. Each position locks into place, making it easy to use, even in the dark.



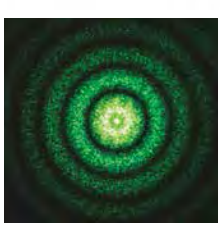
The Single-Slit Wheel
includes four single slits of different widths, two circular apertures, one line/slit comparison, one opaque line, a variable width slit, and four patterns.

The Multiple-Slit Wheel
includes four double slits, a set of four multiple slits having the same slit width and separation (2, 3, 4, and 5 slits), four slit comparisons, and a variable double slit.

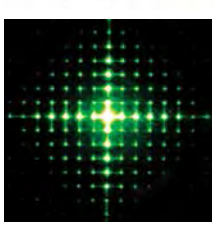


Single-Slit Diffraction Pattern

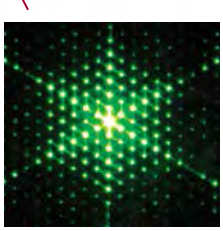




The Circular Diffraction pattern has the same dimensions for both the dots and the holes.

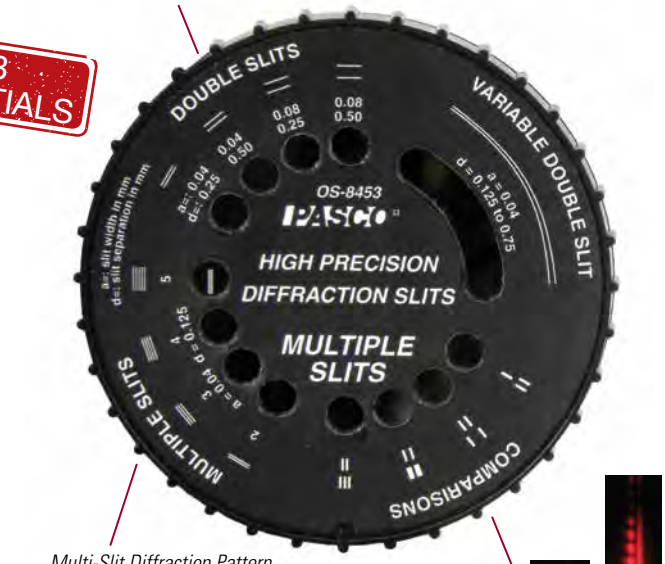


The diffraction geometry represents the structure of the Square and Hex pattern.

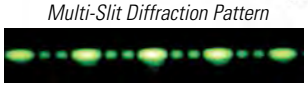




Double-Slit Diffraction Pattern

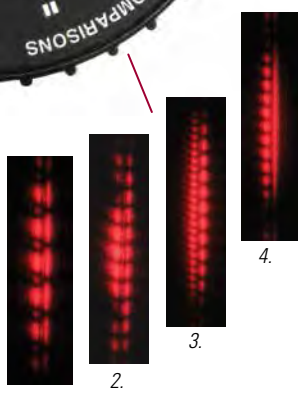


Multi-Slit Diffraction Pattern



The comparisons have two slits illuminated by the same red laser beam, so that the patterns can be viewed side by side.

1. *Two-slit and three-slit comparison*
2. *Different slit widths*
3. *Different slit separation*
4. *Single-slit and double-slit*





Includes

Single-Slit wheel with Holder
Multiple-Slit wheel with Holder

Order Information

High Precision Diffraction Slits	OS-8453	
Recommended:		
Basic Optics System	OS-8515C	p. 254
Diode Laser – Red	OS-8525A	p. 266
Diode Laser – Green	OS-8458	p. 266

PASCO Optics Systems

Basic Optics System OS-8515C
Basic Optics System II OS-8546C
Computer-Based Optics System II OS-8548C

These optics systems provide a wide range of optics laboratories from the very basics of ray tracing to quantitative measurement of blackbody radiation.



		Basic Optics System OS-8515C	Basic Optics System II OS-8546C	Computer-Based Optics System II OS-8548C	Page
1.	1.2 m Optics Bench	1	1	1	261
2.	OS-8456 Geometric Lens Set (+100, +200 mm lens)	1	1	1	259
3.	OS-8460 Viewing Screen	1	1	1	259
4.	OS-8470 Basic Optics Light Source	1	1	1	256
5.	OS-8516A Ray Optics Kit	1	1	1	256
6.	OS-8465 Optics Table (for ray experiments)	1	1	1	256
7.	OS-8474 Adjustable Lens Holder	1	1	1	258
8.	OS-8519 Accessory Lens Set (+250, -150 mm lens)	1	1	1	259
9.	OS-8457 Convex/Concave Mirror Accessory	1	1	1	256
10.	Experiment Manual and Storage Box	1	1	1	
11.	OS-8524 Aperture Accessories (for studying *f*-stop settings)		1	1	260
12.	OS-8525A Diode Laser		1	1	266
13.	OS-8453 Slit Accessories		1	1	267
***14.**	OS-8520 Photometer (with polarizers)		1	0	260
15.	CI-6504A Light Sensor (for interference experiments)			1	48
16.	CI-6604 High Sensitivity Light Sensor (for spectrophotometry)			1	49
17.	CI-6538 Rotary Motion Sensor			1	28
18.	CI-6630 Broad Spectrum Light Sensor			1	50
19.	OS-8544 Prism Spectrophotometer Kit			1	277
20.	OS-8537 Spectrophotometer Accessory Kit			1	276
21.	OS-8535 Linear Translator			1	266
22.	OS-8533A Polarization Analyzer			1	261

***14. Not included with OS-8548C.**

***NOTE:** The computer-based systems include the necessary sensors for the experiments but not the necessary Interface (850 Universal Interface). See pages 14-17.*

Basic Optics System (OS-8515C)

Includes the lenses and mirrors required for geometrical and ray box optics. Experiment manual and storage box included.

Basic Optics System II (OS-8546C)

Adds to the Basic Optics System a wider assortment of lenses and mirrors, plus components for polarization, interference, and diffraction.

Computer-Based Optics System II (OS-8548C)

Adds to the Basic Optics System II a wider assortment of lenses and mirrors, plus components for prism and grating spectrophotometers.

Additionally the sensors to allow a computer to record and analyze data from diffraction, interference, polarization and Inverse-Square Law experiments are included.

Order Information

Basic Optics System OS-8515C
Basic Optics System II OS-8546C
Computer-Based Optics System II OS-8548C

Entry Optics Systems

Dynamics Track Optics Kit

OS-8471A

- Turns your dynamics track into an optical bench
- Use with 1.2 or 2.2 m Dynamics Tracks and PAStrack
- Expandable with Basic Optics System components



The PASCO Dynamics Track Optics Kit includes specially designed slides (carriages) that snap on the dynamics track. PASCO Basic Optics components attach directly to the carriage for positioning anywhere on the track.

Choose from a wide range of optics components to expand your system. **See pages 256-267 for more components.**

Includes

Basic Optics Light Source
Two Adjustable Lens/Mirror Holders
+100 mm, +200 mm, and -150 mm Focal Length Lenses
Viewing Screen
Three Optics Carriages



Order Information

Dynamics Track Optics Kit	OS-8471A
Required:	
Dynamics Track 1.2 m	ME-6953
or	
Dynamics Track 2.2 m	ME-9779
or	
PAStrack	ME-6960

Dynamics Track Optics Carriages

OS-8472

The Dynamics Track Optics Carriages are designed to snap onto the PASCO Dynamics Track. Basic Optics components attach directly to the carriages for positioning anywhere on the track.



Includes

Carriages (3)



Order Information

Dynamics Track Optics Carriages	OS-8472

Beginning Optics System

OS-8459

- New lab manual with five experiments
- Expandable with Basic Optics System components
- The most affordable optics system with a metal bench

This economical system has everything needed to do the five included experiments.



It is a good start for studying optics and can be expanded using the components of the Basic Optics System (see pages 256-267).

Included Experiments

1. Focal Length and Magnification of a Thin Lens
2. Telescope
3. Microscope
4. Shadows
5. Virtual Images

Includes

Basic Optics Light Source (Point, Luminous Object, Rays, and Primary Colors)
Two Adjustable Lens/Mirror Holders
Geometric Lens Set (+100 mm, +200 mm, and -150 mm focal length lenses)
Viewing Screen
1.2 m Optics Bench
Lab Manual

Order Information

Beginning Optics System	OS-8459

Geometric Optics Kit

OS-8518



Includes

Optics Bench
Two Lenses in Holders: +100 and +200 mm
Viewing Screen

Order Information

Geometric Optics Kit	OS-8518

Introductory Optics System

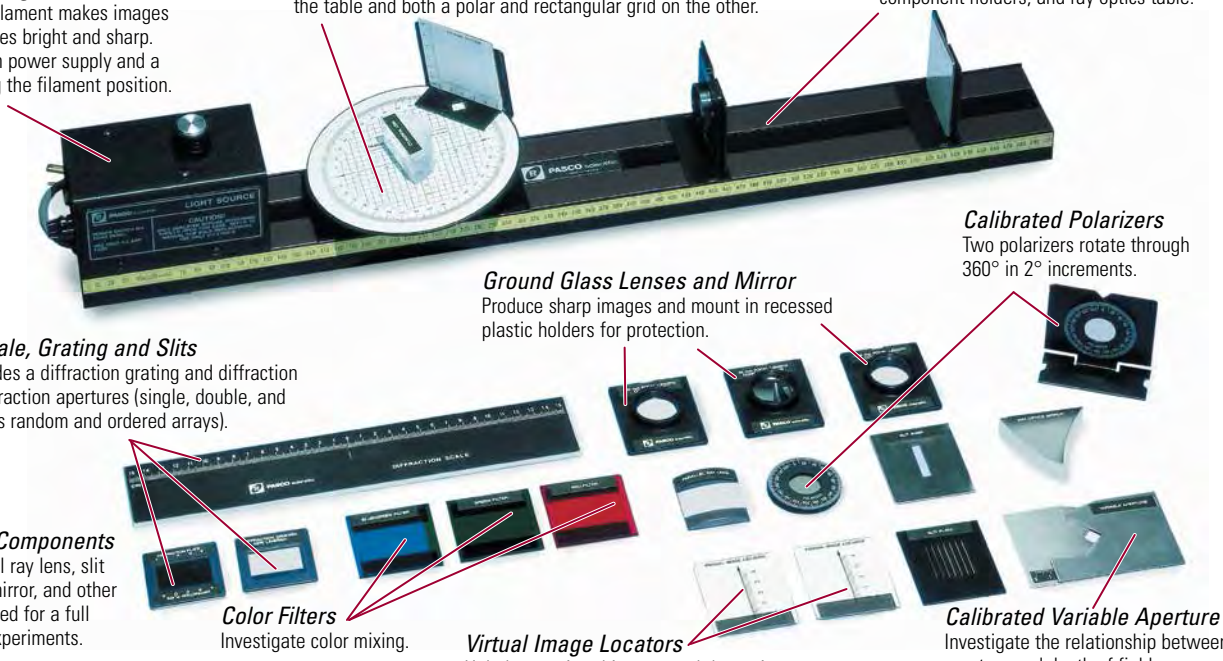
OS-8500

- Complete and comprehensive system
- 22 experiments—from basic ray optics to multiple-slit diffraction
- Easy setup—magnetic mounting

70 cm Optics Bench
This tough aluminum bench has two built-in metric scales, one on each side, and magnetic pads for attaching the light source, component holders, and ray optics table.

Rotating Ray Table
Table mounts magnetically on the bench, at a slight angle, for bright, sharp rays. Measurements are easy: there's a polar grid on one side of the table and both a polar and rectangular grid on the other.

High-Intensity Light Source
The special line filament makes images and diffraction lines bright and sharp. Features a built-in power supply and a knob for adjusting the filament position.



Calibrated Polarizers
Two polarizers rotate through 360° in 2° increments.

Ground Glass Lenses and Mirror
Produce sharp images and mount in recessed plastic holders for protection.

Diffraction Scale, Grating and Slits
The system includes a diffraction grating and diffraction plate with 10 diffraction apertures (single, double, and multiple slits, plus random and ordered arrays).

Full Range of Components
Includes a parallel ray lens, slit mask, universal mirror, and other components needed for a full range of optics experiments.

Color Filters
Investigate color mixing.

Virtual Image Locators
Help locate virtual images and determine their magnification.

Calibrated Variable Aperture
Investigate the relationship between aperture and depth of field.

A Comprehensive and self-contained optics system

This Introductory Optics System includes both a ray table and an optics bench. It includes everything needed for a complete course in introductory optics. It will take students through reflection, thin-lens theory, color theory, polarization, interference, diffraction, and optical instruments. The manual includes 22 quantitative experiments.

Designed for the introductory lab

In many ways, the requirements for a good introductory system are even more stringent than for more advanced equipment. The equipment must be easy-to-use and durable, and the experiments must be substantive, yet conceptually straight-forward. With these requirements in mind, we incorporated the following features into our Introductory Optics System:

Features

Magnetic Mounting: Components mount magnetically to the optics bench and ray table, yet are easily aligned and repositioned.

Fully-Illustrated Manual: The 22 copy-ready experiments provide a thorough and orderly introduction to both elementary and more advanced optics experiments.

Full Range of Components: No improvising or buying additional equipment.

Built-In Scales: Built-in scales are convenient and provide accurate results.

Order Information

Introductory Optics System OS-8500

Typical Experiments

With Teacher's Guide and Sample Data.

1. Introduction to Ray Optics
2. The Law of Reflection
3. Image Formation in a Plane Mirror
4. The Law of Refraction
5. Optical Reversibility
6. Dispersion and Total Internal Reflection
7. Converging Lens—Image and Object Relationships
8. Light and Color
9. Two-Slit Interference
10. Polarization
11. Image Formation: Concave Mirrors
12. Image Formation: Spherical Mirrors
13. Image Formation: Cylindrical Lenses
14. Spherical Lenses: Spherical and Chromatic Aberration, Aperture Size, Depth of Field
15. The Diffraction Grating
16. Single-Slit Diffraction
17. General Diffraction
18. Introduction to Optical Instruments
19. The Projector
20. The Magnifier
21. The Telescope
22. The Compound Microscope

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.



The Introductory Optics System comes in a fitted box for convenient storage.

Component list for Introductory Optics System

The system contains a complete set of the following components:

Optics bench—70 cm extruded aluminum bench with magnetic surface

Incandescent light source—high-intensity; built-in power supply

Instruction and experiment manual—with 22 experiments

The following components are included and can also be purchased separately

Order Information

Diffraction Set—Introductory Optics OS-8480
Diffraction plate (ten patterns)—single slits, double slits, multiple slits, crossed slits, and circular apertures
Diffraction grating
Diffraction scale—for measuring maxima and minima

Color Filter Set—Introductory Optics OS-8481
Color filters—red, green and blue

Polarizer Set—Introductory Optics OS-8482
Polarizers (two)—with degree scales

Mirror Set—Introductory Optics OS-8483
Mirror—front surface, concave (50 mm F.L.)
Mirror—three-sided (plane, concave, and convex)

Slit Set—Introductory Optics OS-8484
Slit plate and mask—for producing up to seven rays
Variable aperture—for investigating depth of field
Virtual image locators (two)

Screen/Target Set—Introductory Optics OS-8485
Crossed arrow target—for determining image orientation and magnification
Viewing screen—with metric scale for measuring images
Virtual image locator

Rotating Base Set—Introductory Optics OS-8486
Ray Table–degree scale, mm grid, and component holder

Component Set—Introductory Optics OS-8487
Component holders (three)—attach magnetically to the bench

75 mm Lens—Introductory Optics OS-8488
Spherical lens—ground glass, mounted in plastic carrier for protection (75 mm F.L.)

150 mm Lens—Introductory Optics OS-8489
Spherical lens—ground glass, mounted in plastic carrier for protection (-150 mm F.L.)

150 mm Lens OS-8490
Spherical lens—ground glass, mounted in plastic carrier for protection (150 mm F.L.)

Cylindrical Lens—Introductory Optics OS-8492
Cylindrical lens—for ray tracing

Lenses and Mirrors



These ground-glass lenses and silver coated front-surface glass mirrors are mounted in recessed plastic holders to protect the optical surfaces.

Order Information

Double-Concave (-22 mm) OS-9131

Double-Convex (+18 mm) OS-9132

Double-Convex (+48 mm) OS-9133

Double-Convex (+127 mm) OS-9134

Plano-Convex (+252 mm) OS-9135

Concave Mirror (-25 mm)–Advanced Optics OS-9137

Component Carrier

OS-9107



Mounts magnetically to the Optics Bench and components mount magnetically to the carrier. The aperture is 22 mm x 22 mm.

Order Information

Component Carrier–Advanced Optics OS-9107

Electroformed Diffraction Slits



These slits are extremely sharp (±5 micron tolerance), producing diffraction patterns superior to those produced by traditional film emulsion slits. Four slides are available, each providing four patterns.

Order Information

Complete Slit Set–Advanced Optics OS-9165
Four slides:
Slide 1–4 single slits: widths 0.02, 0.04, 0.08, 0.16 mm OS-8461
Slide 2–4 sets of double slits: slit widths 0.04 and 0.08 mm; slit spacing 0.25 and 0.5 mm OS-8462
Slide 3–4 sets of multiple slits: 2, 3, 4, 5 slits; all widths 0.04 mm, all spaced 0.125 mm OS-8463
Slide 4–apertures: 2 circular apertures 0.04, 0.08 mm dia.; 1 array of triangular apertures (equilateral); 1 array of square apertures OS-8464

Single/Double Slits–Advanced Optics OS-9179
Slides 1 and 2 only.

Diode Laser – Intro. Optics

OS-8528A



Support bracket automatically aligns laser with Introductory Optics or Advanced Optics components.

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

This versatile, inexpensive Diode Laser can be placed on the Introductory Optics bench. The metal stand adheres to the magnetic strip and automatically aligns the laser beam with each system's diffraction accessories. Easy set-up makes it ideal for diffraction or other general laser experiments.

Specifications

Output Power: <5 mW
Wavelength: 650 nm
Power Supply: 9 VDC, 500 mA adapter (included)

Order Information

Diode Laser – Intro. Optics OS-8528A

High-Precision Diffraction Slits – Intro. Optics

OS-8454



The two sets of interference slits fit the Introductory Optics bench. Perfect for use with the Diode Laser above. Just rotate the disk for a wide range of diffraction patterns. The slit patterns automatically align with the laser.

Single-Slit Disk

4 single slits
- 2 circular apertures
- 1 line/slit comparison
- 4 two-dimensional diffraction patterns
- variable-width slit (0.02-0.20 mm)

-1 opaque line

Multiple-Slit Disk

4 double slits
- 4 multiple slits (2, 3, 4 or 5 slits)
- 4 slit comparisons
- variable double slit (slit separation 0.125-0.75 mm)

See page 265 for more details.

Order Information

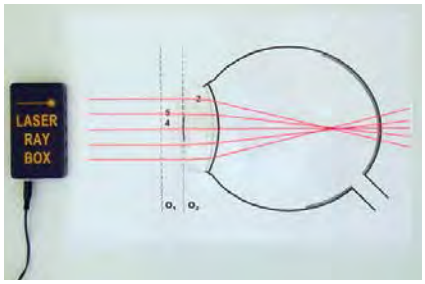
High Precision Diffraction Slits – Intro. Optics OS-8454

Ray Optics Laser System

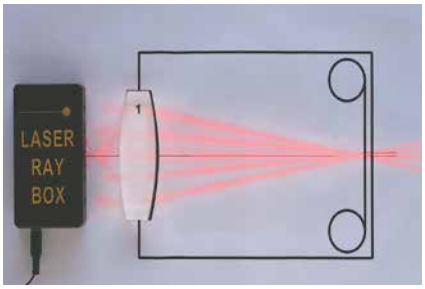
SE-8506

- No need to dim the lights
- Wide variety of optical components
- Templates simulate real-world optical devices

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM



The laser rays are focused in front of the retina by the myopic lens used with the human eye template.



The laser rays are redirected by the converging lens and focused on the "film" of the camera template.

This demonstrations optics set uses a Laser Ray Box that has bright, well-defined rays because it uses lasers rather than an incandescent light source. The Laser Ray Box projects five parallel laser beams onto any flat surface. It contains five 1 mW diode lasers (wavelength 635 nm). The laser beams are spread out into clearly visible lines by cylindrical lenses inside the box.

The ray box has a magnetic back for mounting on any steel board. The unit is powered by an included AC adapter.

This exceptional optics set includes six magnetically-backed templates that have guidelines showing where to put components to perform different demonstrations, including:

- Modeling the human eye and eyeglasses
- How a camera works
- Two types of telescopes
- Spherical aberration
- Refraction and reflection

Each component has a magnetic backing for mounting on any steel board.



Includes

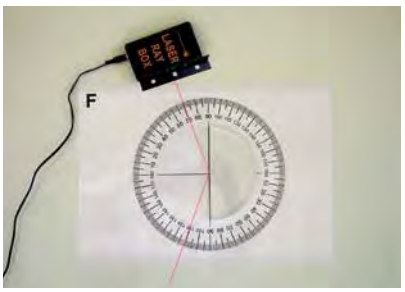
Laser Ray Box
Laser Ray Mask
Double-convex lenses (4)
Double-concave lens
Plano-concave lens
"D" lenses (4.5 cm and 7.5 cm radius) (2)
Plane, convex, and concave mirrors
Right-angle prism
Rectangle (6 cm x 10 cm)
Optical fiber (2 cm x 20 cm)
Templates (6)
Steel whiteboard (56.5 cm x 41.5 cm)
Most components are 10 cm tall and 1.7 cm thick.

Specifications for Laser Ray Box

Dimensions: 11 cm x 6 cm x 2 cm
Laser Ray Separation: 1.8 cm
Power Adapter: 3 VDC, 300 mA (included)
Wavelength: 635 nm

Order Information

Ray Optics Laser System SE-8506
Laser Ray Box (alone) SE-8505



The included protractor template can be used to demonstrate refraction.

Lens Plus Set

SE-7578



Add this additional lens set to extend the use of the Ray Optics Laser System or Laser Ray Box. Components have been chosen to demonstrate the effect of both positive and negative optical devices.

Includes

Biconcave Air Lens
Biconcave Glass Lens
Biconvex Air Lens
Biconvex Glass Lens
Optical Air Prism
Equilateral Optical Glass Prism
Rectangular Optical Glass Prism (2 piece)
Square Glass Planar Parallel Plate
Rectangular Glass Planar Parallel Plate (2 piece)
Planar Mirror (2 piece)

Order Information

Lens Plus Set SE-7578

"Visible Ray" Optics Set

SE-9767



Students can see the light rays as they pass through these unique 20 mm thick acrylic components. Refraction and internal reflection are easily observed.

Set Comes In a Convenient Case and Includes

Double-convex lens: 50 mm focal length
Double-concave lens: 50 mm focal length
Plano-convex lens: 100 mm focal length
Prism: 120°, 90°, 90°, 60°

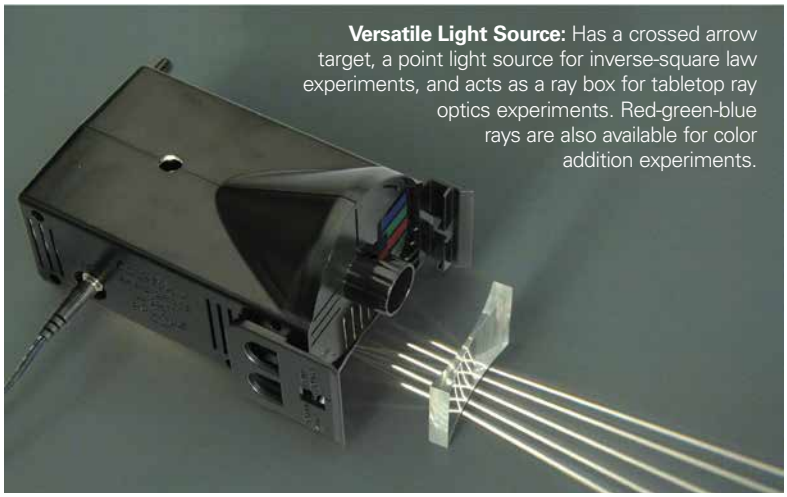
Order Information

Visible Ray Optics Set SE-9767

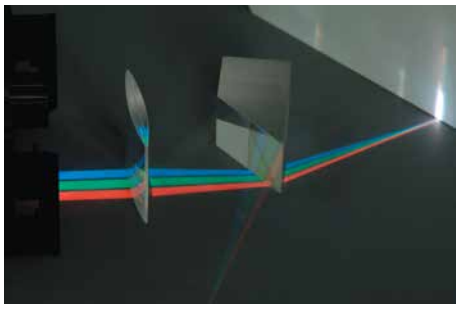
Basic Optics Light Source

OS-8470

- One, three, or five parallel rays
- Three primary color source



Versatile Light Source: Has a crossed arrow target, a point light source for inverse-square law experiments, and acts as a ray box for tabletop ray optics experiments. Red-green-blue rays are also available for color addition experiments.



The primary color mask allows experiments in color addition using components from the Ray Optics Kit.



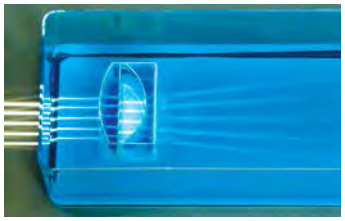
Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.

Order Information

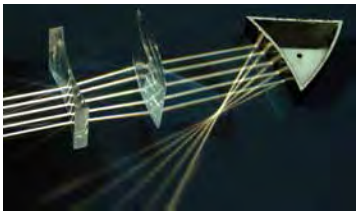
Basic Optics Light Source OS-8470

Ray Optics Kit

OS-8516A



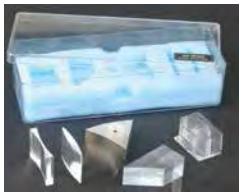
The storage tray is used to create a "hollow" air-filled convex lens. Note that the rays diverge.



Components from the Ray Optics Kit showing Refraction and Reflection.

Includes

Double-Convex Lens, Double-Concave Lens, Rhomboid, Eye-Dropper, Triangular mirror accessory with concave, convex, and plane reflective surfaces and Hollow lens to fill with a liquid or use as an air lens.



Order Information

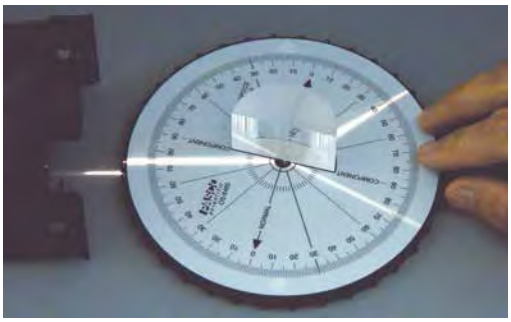
Ray Optics Kit OS-8516A

Ray Table

OS-8465

- Angle of reflection
- Snell's Law
- Total internal reflection

The Ray Table provides an excellent viewing surface for ray optics. The table can be rotated about its axis to quickly change the incident angle of the ray. The resulting angles of reflection and refraction are easily measured directly off the polar grid printed on the table. The (included) acrylic cylindrical D lens simplifies the experiment by having the rays bend at only one surface. Investigate Snell's Law for both cases of rays either entering or leaving the acrylic.



Ray Table in use showing both the Reflected and Refracted rays.

Includes

Table

D-shaped Lens

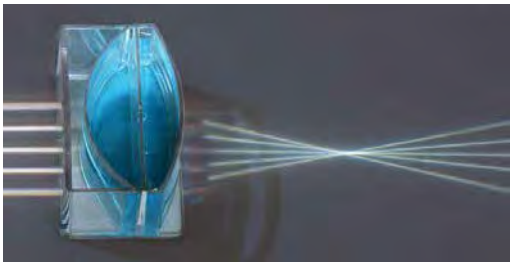


Order Information

Ray Table OS-8465

Hollow Lens

OS-8511



The Hollow Lens allows students to investigate the effect of different liquids on the index of refraction. In addition, students can fill only one or two of the compartments to experiment with compound lenses.

Order Information

Hollow Lens OS-8511

Basic Diffraction Grating Set

SE-9357

For qualitative demonstrations



Three diffraction gratings on a single slide: 100, 300, and 600 lines/mm.

By looking at spectral light sources, students can study the relationship between line spacing and angle of diffraction. The low cost means each student can use one during lecture demonstrations.

Order Information

Basic Diffraction Grating Set SE-9357

Diffraction Gratings

SE-9361



This set of four glass-mounted diffraction replicas are excellent for introductory student work. Four line spacings are provided: 80, 100, 300, and 600 lines/mm. Excellent for quantitatively studying the relationship between line spacing, angle of diffraction, and wavelength.

Each grating is 21 x 35 mm.

Order Information

Diffraction Gratings (set of 4) SE-9361

Prisms

These prisms are made of high quality optical glass.

Equilateral Prism: 30 x 30 mm sides; 50 mm long

Right-Angle Prism: 23 x 32 mm sides; 50 mm long



Equilateral



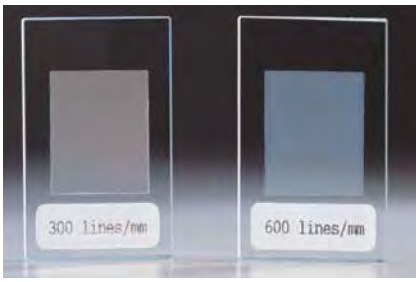
Right-Angle

Order Information

Equilateral Prism SE-9021A
Right-Angle Prism SE-9022A

High-Quality Gratings

300 lines/mm SE-9359
600 lines/mm SE-9358



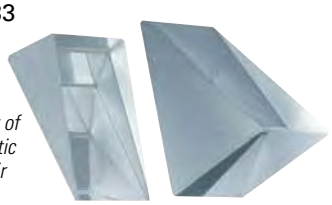
The 300 lines/mm replica grating is strongly blazed in the first through fifth orders, while the 600 lines/mm grating is strongly blazed in the first order. Both have excellent resolving power and produce bright, sharp spectral lines for spectrometer labs or for projecting spectra in lecture demonstrations.

Order Information

High-Quality Gratings
300 lines SE-9359
600 lines SE-9358

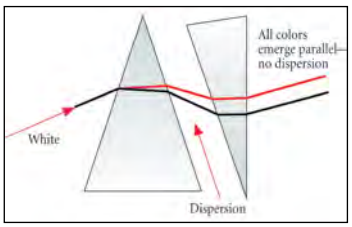
Achromatic Prism Pair

SE-9333



Top View of Achromatic Prism Pair

A beam of white light can be broken up into its constituent colors, and the colored light can be recombined to produce the original white beam of light. Use these prisms to demonstrate dispersion, to show that white light is actually a mixture of colored lights.



Specifications

Material: Optical glass

Shape: Isosceles

Length: 45 mm (long side)

Angles: 20°, 80°, 80° for one, and 40°, 70°, 70° for the other

Order Information

Achromatic Prism Pair SE-9333

Color Filters

SE-9360



Seven filters in glass-covered 35 mm slides. Colors include red, green, blue, magenta, yellow, peacock blue, and purple.

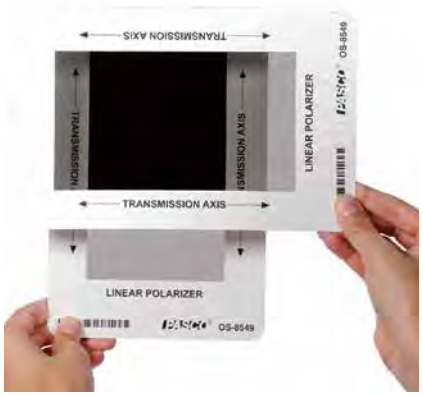
Filters can be used in projectors and ray boxes and are excellent for color mixing and color perception demonstrations.

Order Information

Color Filters (set of 7) SE-9360

Linear Polarizer

OS-8549



This pair of rectangular polarizers are mounted in cardboard frames. The polarizing film dimensions are 3.5" x 6". Includes two polarizers.

Order Information

Linear Polarizer (2 pack) OS-8549

Polarizer

OS-9109



Order Information

Calibrated Polarizer–Advanced Optics OS-9109
(HN-32) calibrated in 2 degree increments

Polarizer Demonstrator

OS-9477A

These two polarizers mounted in tough plastic rings are large enough for classroom demonstrations. Each has a stand which allows the polarizer to be easily rotated. The two stands key into each other to keep them parallel to each other.

Investigate stress patterns by viewing plastic protractors or rulers between crossed polarizers. Use a third polarizer (such as OS-8549) between these crossed polarizers to demonstrate how the direction of polarization of the light is progressively changed as it passes through each polarizer.





The angle of rotation is marked on the edge of each polarizer.



Includes

Two round polarizer discs with stands

Polarizing film 19 cm diameter

Order Information

Polarizer Demonstrator OS-9477A

Polarizer Demonstrator Accessory

NEW

OS-8172

This accessory adds a central platform and diffuser to the Polarizer Demonstrator (OS-9477A). Put sugar water in one of the two supplied square glass bottles and put it on the platform between crossed polarizers. Use a desk lamp or Color Mixer (OS-8496) behind the diffuser and rotate one of the polarizers to see the sugar water change colors because the axis of polarization of different colors are rotated to different angles.



Demo with Karo® corn syrup showing wavelength dependence of optical rotation. The light source used was a compact florescent, not included.



Includes

Square Glass Bottles (2)

Metal Stand for Bottles

Diffusion Screen



Order Information

Polarizer Demonstrator Accessory OS-8172

Required:

Polarizer Demonstrator ..... OS-9477A p. 260

Suggested:

Color Mixer ..... OS-8496 p. 257

Demonstration Mirrors

Convex Mirror SE-7574
Concave Mirror SE-7573

Extra large (60 cm diameter) mirrors are a great way to teach students about image formation. Watch the amazement on their faces as they observe a real image hanging in space before their eyes (produced by the concave mirror). Use the convex mirror to demonstrate why they are used for security purposes in many retail establishments. The plastic mirrors combine large size and a sturdy stand for ease of use during demonstrations. Unique clamp-on stand allows mirror to be adjusted to any angle. Focal lengths are ±75 cm.

Virtual and real images are formed with these large, curved mirrors.





Order Information

Demonstration Convex Mirror SE-7574

Demonstration Concave Mirror SE-7573

Plane Mirror (2 pack)

SE-8804



These mirrors are excellent for many reflection demonstrations. The mirrors are constructed of plastic to avoid chipping on the edges.

Each mirror measures 15 cm x 15 cm.

Includes

Unassembled Mirrors (2)

Wrench



Order Information

Plane Mirror (2 pack) SE-8804

Light and Optics: Spectrophotometer

Educational Spectrophotometer System

OS-8539

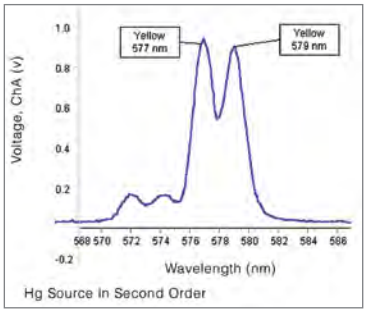
Educational Spectrophotometer Accessory Kit

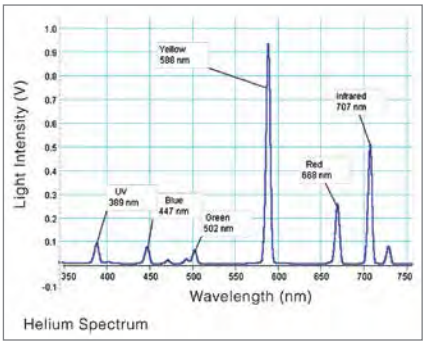
OS-8537

- Analyze and graph spectral lines
- Explore relationship between angle, wavelength, and intensity
- Versatile and inexpensive

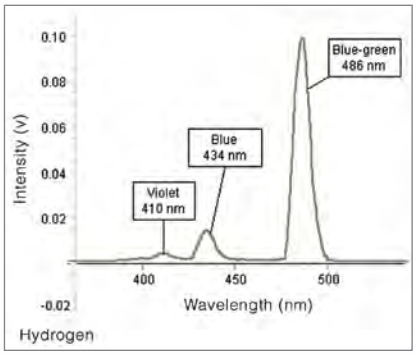
PASCO's Educational Spectrophotometer teaches basic optical principles and allows quantitative measurements rivaling those of more expensive units.

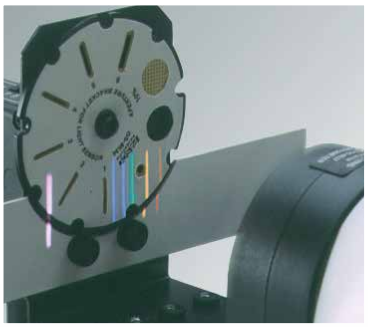
When the Spectrophotometer is used with PASCO's Capstone™ Software, students can explore the relationship between angle, wavelength, and intensity, and graph the spectral lines from discharge tubes. Lines from mercury, sodium, helium, neon, krypton, and argon can be plotted—even the lines of the Balmer series in hydrogen can be detected.

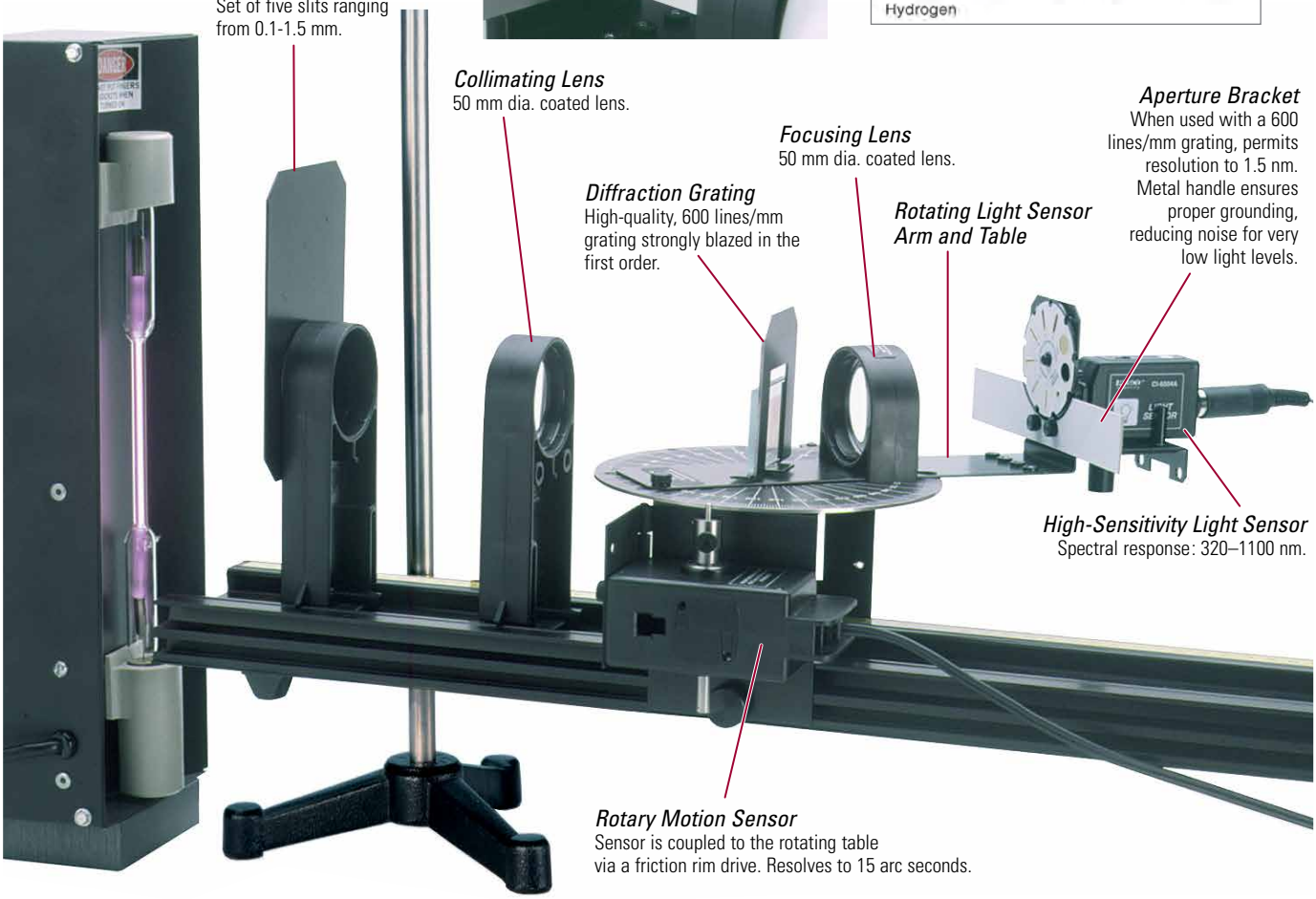




Typical Spectrum Graphs







Educational Spectrophotometer Components

Teachers who already own a PASCO Interface and the Basic Optics System OS-8515C should purchase the Accessory Kit OS-8537 and any additional equipment needed from the list below.

The Spectrophotometer System (OS-8539) includes

1. Optics Bench (60 cm)
2. Rotary Motion Sensor CI-6538
3. High-Sensitivity Light Sensor CI-6604
4. Aperture Bracket OS-8534A
5. Spectrophotometer Table
6. Rotating Arm
7. Collimating Slits and Lens
8. Focusing Lens
9. Diffraction Grating and Holder
10. Optics Bench Rod Clamps (2) ME-9836



The Spectrophotometer Accessory Kit (OS-8537) includes

5. Spectrophotometer Table
6. Rotating Arm
7. Collimating Slits and Lens
8. Focusing Lens
9. Diffraction Grating and Holder
10. Optics Bench Rod Clamps (2) ME-9836

Note: The open design of this spectrophotometer accessory is ideal for education. It is not intended for industrial or research applications.

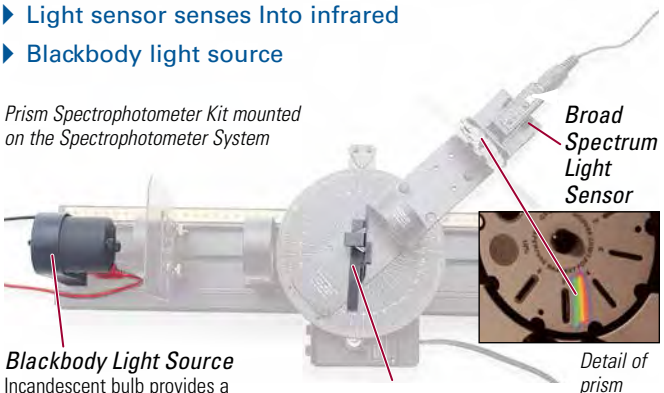
Order Information

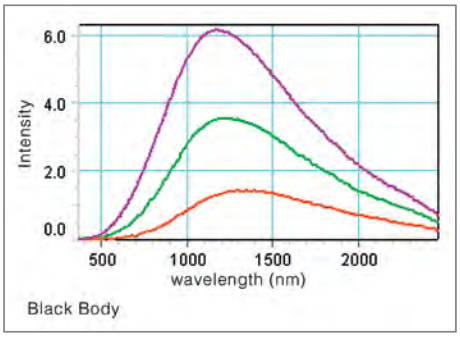
Educational Spectrophotometer System	OS-8539	
Educational Spectrophotometer Accessory Kit	OS-8537	
Required for use with ScienceWorkshop:		
Basic Optics System	OS-8515C	p. 254
Spectral Sources	p. 281	
Rotary Motion Sensor	CI-6538	p. 28
High-Sensitivity Light Sensor	CI-6604	p. 49
Aperture Bracket	OS-8534A	p. 266
For use with PASPORT Sensors, see the Atomic Spectra experiment EX-5546 on page 357.		
For adjusting height of optics bench to your light source:		
Large Rod Stand (2)	ME-8735	p. 170
45 cm Rod (2)	ME-8736	p. 170

Prism Spectrophotometer Kit

OS-8544

- High-quality prism
- Light sensor senses Into infrared
- Blackbody light source





The classic textbook diagram of the intensity versus wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is lowered.

Using this prism spectrophotometer, students can scan the spectrum of a "blackbody", plot the intensity versus wavelength, and change the temperature of the blackbody to see the shift in the peak wavelength.

This spectrophotometer uses a prism to disperse the light instead of a diffraction grating. This allows the infrared to be seen without overlapping the second order visible spectral lines. The sensor has a linear response to all wavelengths within its range, so the actual intensity of the light in the blackbody spectrum is detected. Designed to be used with the Spectrophotometer System described on pages 276-277. See Blackbody Radiation Experiment on page 333.

Includes

Prism, Mount and IR Filter

Blackbody Light Source (OS-8542)

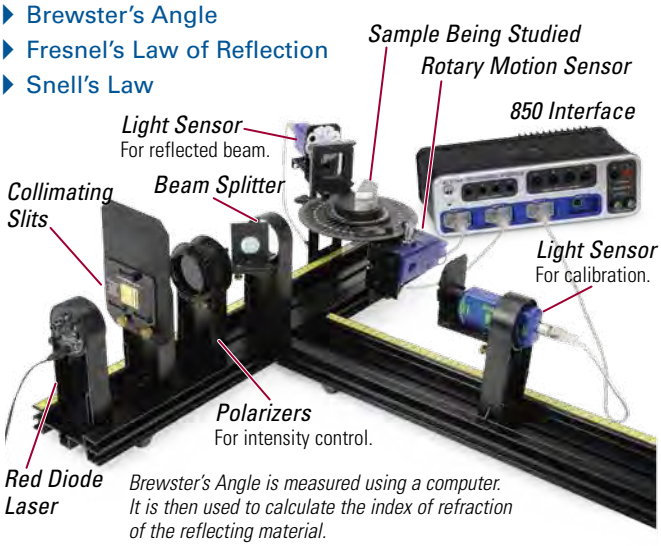
Order Information

Prism Spectrophotometer Kit	OS-8544	
OR components of the system may be ordered separately:		
Blackbody Light Source	OS-8542	
Mounted Prism	OS-8543	
Required for experiment:		
Broad Spectrum Light Sensor	CI-6630	p. 50
Spectrophotometer System	OS-8539	
850 Universal Interface		pp. 14-17
Replacement Supplies:		
Replacement Bulbs (10 pack)	SE-8509	

Brewster's Angle Accessory

OS-8170A

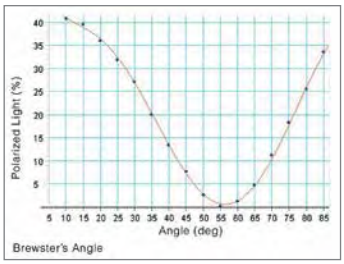
- Polarization by reflection
- Brewster's Angle
- Fresnel's Law of Reflection
- Snell's Law



Brewster's Angle is measured using a computer. It is then used to calculate the index of refraction of the reflecting material.

When light reflects off a nonconducting material, the reflected light is partially polarized. The amount of polarization depends on the incident angle and the index of refraction of the reflecting material. The incident angle that gives maximum polarization is called Brewster's Angle.

Light from a diode laser (wavelength = 650 nm) is reflected off the flat side of an acrylic semi-circular lens. The reflected light passes through a polarizer and is detected by a Light Sensor. The angle of incidence is measured by a Rotary Motion Sensor mounted on the Spectrophotometer table. The intensity of the reflected polarized light versus incident angle is graphed to determine the angle at which the light intensity is a minimum. This is Brewster's Angle, which is used to calculate the index of refraction of acrylic.



The intensity (% of total reflected) of the reflected polarized light as a function of the incident angle. See Brewster's Angle Experiment on page 355.

Developed using original ideas from P.J. Ouseph, Professor of Physics at University of Louisville, KY: "Polarization of Light by Reflection and the Brewster Angle" by P.J. Ouseph, Kevin Driver, and John Conklin, Am. J. Phys. 69, 1166 (2001). This modification to the experiment was suggested by Cristian Bahrim and Wei-Tai Hsu in the American Journal of Physics article: "Precise measurement of the refractive indices for dielectrics using an improved Brewster angle method" Vol. 77, page 337 (2009).

Includes

Acrylic semi-circular lens
Lens platform
Polarizers (2) with holder
Analyzing polarizer
Beam splitter



CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Order Information

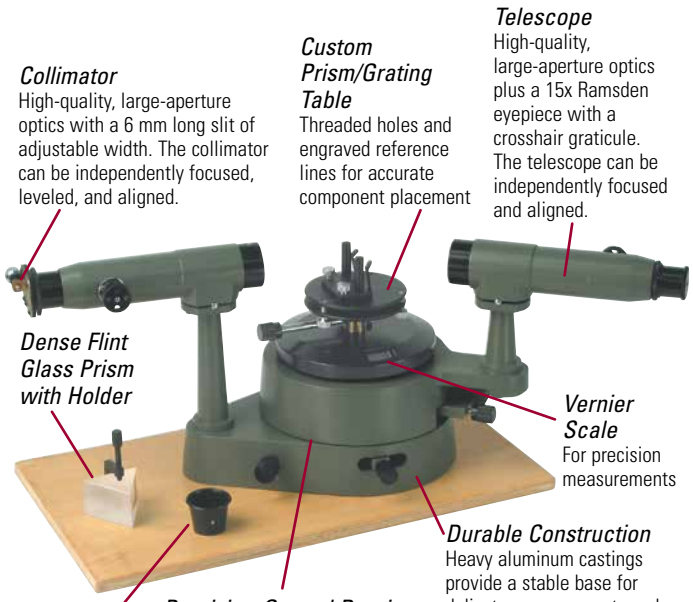
Brewster's Angle Accessory OS-8170A
Beam Splitter (only) OS-8171

For other required equipment, see the Brewster's Angle Accessory experiment EX-5544 on page 355.

Student Spectrometer

SP-9268A

- Wide aperture optics
- Precision Vernier— resolves One Minute of Arc
- Durable and precise



Features

Resolution to 1 Minute of Arc: The 127 mm diameter, precision-engraved degree plate is complemented by two precision-engraved verniers, one on each side of the instrument for convenient reading.

Wider Aperture Optics: 32 mm wide apertures on the telescope and collimator provide more light for brighter and sharper images.

Rack and Pinion Focusing: On both the telescope and the collimator, so focusing is easier and more precise.

Rotatable Table: For greater flexibility in measurements. Turn the table by hand for coarse adjustments. Use the fine lead screw for delicate adjustments.



The Vernier Scale resolves angle measurements within 1 minute of arc.

Order Information

Student Spectrometer SP-9268A

Recommended:
Spectral Light Sources ..... pp. 280-281

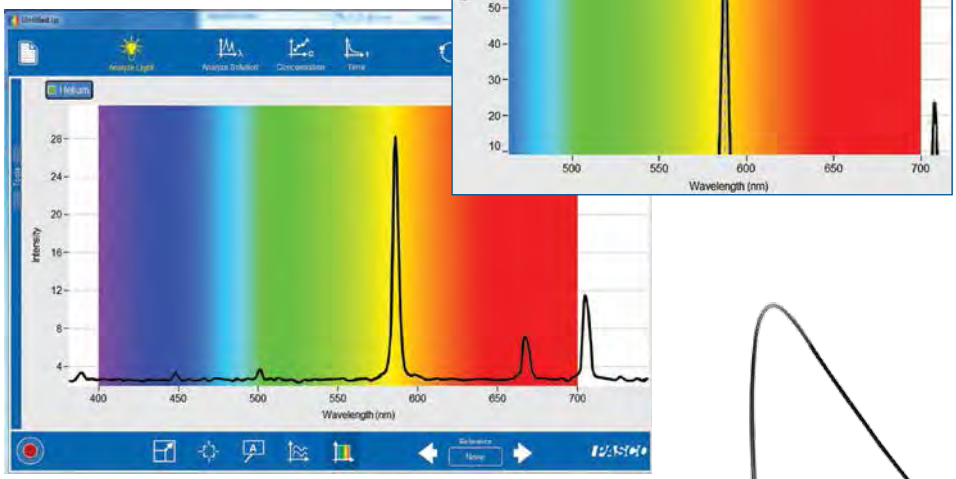
Wireless Spectrometer for iPad®, Tablets, and Computers

PASCO Spectrometer

PS-2600

- Measure intensity, absorbance, transmittance, and fluorescence

The Bluetooth® and USB connectivity enable use with iPad, tablets, and computers, which makes this a powerful and intuitive tool for your spectrometry needs.



Helium Spectrum

Shown using the optional Fiber Optics Cable.

Light from the helium tube is sampled using the fiber optics cable connected to the PASCO Spectrometer. The cursor can be used to measure the wavelengths of the peaks. See page 60 for more applications.

The PASCO Spectrometer comes with **PASCO's new FREE spectrometry software** (PC/Mac version included with purchase, FREE on iTunes).

- PC and Mac versions included with purchase.
- FREE for iOS and Android tablets.
- Designed specifically for spectrometry experiments.

See page 24 for more information.

Specifications

Bluetooth and USB connectivity

2–3 nm FWHM resolution

380–950 nm range

2 fluorescence excitation wavelengths at 405 nm and 500 nm

LED-boosted tungsten light source

Includes

PASCO Spectrometer and 10 cuvettes



Order Information

PASCO Spectrometer PS-2600

Shown in use with:

Spectral Tube Power Supply ..... SE-9460 p. 281

Fiber Optic Cable

PS-2601

Required for External Light Sources



Order Information

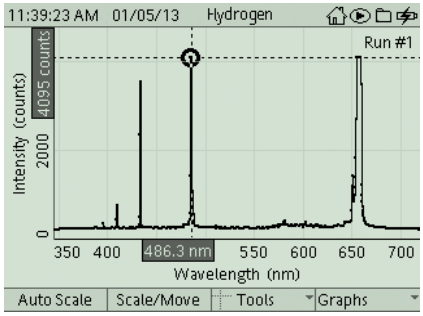
Fiber Optic Cable PS-2601

Emission Spectrometer System for Xplorer GLX

PS-2635

- Uses Ocean Optics™ Red Tide Spectrometer

The Xplorer GLX controls the Ocean Optics Red Tide Spectrometer, which detects the spectrum using a 2048 pixel CCD linear array. The GLX does a full sweep in less than one second.



Spectrum of hydrogen as seen on the Xplorer GLX screen. The Smart Cursor can be used to measure the wavelengths of the peaks.



Light from a hydrogen tube is sampled using the fiber optics cable connected to the Ocean Optics Spectrometer. The Spectrometer is plugged into the USB port on the Xplorer GLX.

Specifications

Range: VIS-NIR, 350-1000 nm

Optical Resolution: 2 nm

Includes

Ocean Optics Red Tide Spectrometer

Fiber Optics Cable, USB Cable

License key for Ocean Optics GLX feature set

Order Information

Emission Spectrometer System for Xplorer GLX PS-2635

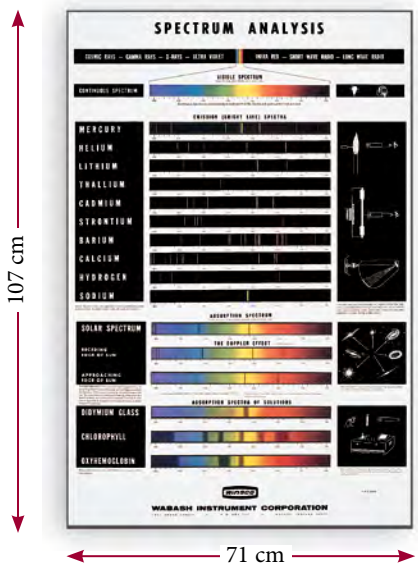
Required:

Xplorer GLX ..... PS-2002 p. 19

Spectrum Chart

SE-7336

The continuous nature of the electromagnetic spectrum is often difficult for students to understand. The Spectrum Chart clearly displays all of the regions of the spectrum, from cosmic rays to long-wave radio. Complete with full-color enumerated examples, the Spectrum Chart visually displays emission or bright line and absorption spectra.



Order Information

Spectrum Chart SE-7336

Spectroscope

SE-8688



The rugged, stainless steel design of this spectroscope means durability. Turn the dial to adjust the slit width and slide the eyepiece back and forth to focus the spectrum.

Order Information

Spectroscope SE-8688

Low-Pressure Sodium Light Source

OS-9287B

- Long lamp life
- Rugged and reliable
- Can be used by two groups simultaneously



This Low-Pressure Sodium Light Source has an output intensity of approximately six candela/cm^2, with better than 99.5% of the visible output concentrated in the 5889 and 5895 angstrom spectral lines. Slight impurities (1% neon and argon) are added to the sodium gas to improve operating efficiency. Lamps provide 10,000+ hours of trouble-free operation. The light ports are 3.2 cm in diameter and are 22.5 cm high.

This light source is supplied fully operational with built-in power supply, housing, and lamp. Operating voltage is 115/220 VAC, 50/60 Hz.

Order Information

Low-Pressure Sodium Light Source OS-9287B

Replacement Supplies:

Replacement Lamp - Low-Pressure Sodium Light Source (for OS-9287B only) 526-034

Mercury Light Source

SE-6608



This bright mercury light source is perfect for studying spectra with the Educational Spectrophotometer (OS-8539). It is also used with the Photoelectric Effect experiment (SE-6609 and EX-5549A) and mounts on the extruded track in that experiment.

Includes

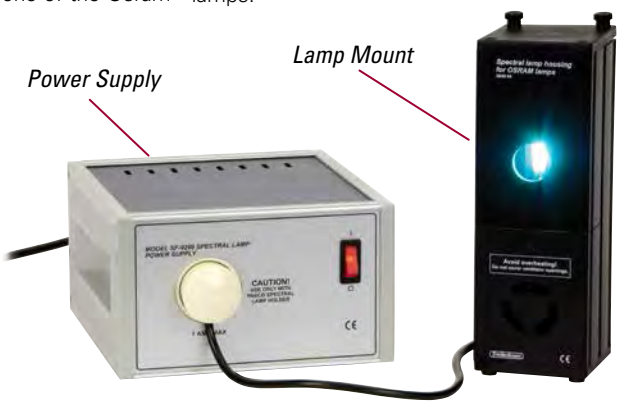
Mercury Light Source Housing
Power Supply
Mercury Lamp (SE-6597)

Order Information

Mercury Light Source	SE-6608
Replacement Supplies:	
Replacement Mercury Lamp	SE-6597

Osram® Spectral Lamps

The SF-9288 Spectral Lamp Power Supply and Lamp Mount is designed for use with Osram® 9-pin DIN spectral lamps. A variety of spectral lamps are available. Changing spectral lamps is easy, so a single power supply and lamp mount are required to power any one of the Osram® lamps.



Order Information

Spectral Lamp Power Supply and Mount	SF-9288
Mercury Spectral Lamp	SF-9282
Sodium Spectral Lamp	SF-9289
Cadmium Spectral Lamp	SF-9290
Neon Spectral Lamp	SF-9292

Spectral Tube Power Supply and Mount

LAB ESSENTIALS

SE-9460

This system is easy-to-use and inexpensive, with a variety of safety features that make it suitable for beginning labs. Mount any of the eight different spectral tubes into the power supply and turn it on. The 26 cm long tubes are capillary-thin over the middle 10 cm, providing sharp, bright spectra.

Features

Student Safety: The tubes mount from the front of the supply and snap into molded sockets that fully enclose the conductive ends. The all-metal case is electrically grounded.

Spectral Tube Safety: A current limiting transformer protects the tubes. A protective shield also helps safeguard the tubes, while blocking unwanted ambient light for clear viewing.

Power Requirements: 115/220 VAC, 50/60 Hz.



Power Supply and Mount

Order Information

Spectral Tube Power Supply	SE-9460

Spectral Tubes

- Argon
- Carbon Dioxide
- Helium
- Hydrogen
- Krypton
- Mercury
- Neon
- Water Vapor



These spectral tubes are designed for use in the Spectral Tube Power Supply and Mount above.

Order Information

Spectral Tubes:

Argon	SE-9463
Carbon Dioxide	SE-9464
Helium	SE-9462
Hydrogen	SE-9461
Krypton	SE-9465
Mercury	SE-9466
Neon	SE-9467
Water Vapor	SE-9468

Diode Laser – Intro. Optics

OS-8528A



This diode laser adheres to the magnetic strip on the Introductory Optics Bench (OS-8500).

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Specifications

Output Power: <5 mW
Wavelength: 650 nm
Power Supply: 9 VDC, 500 mA adapter (included)

Order Information

Diode Laser – Intro. Optics OS-8528A

Diode Laser – Basic Optics

OS-8525A (Red) OS-8458 (Green)

These diode lasers fit on the Basic Optics Benches (OS-8505 and OS-8541) and the Dynamics Track Optics Carriage (OS-8472).



CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Specifications

Output Power: <1 mW
Wavelength: 650 nm (OS-8525A)
532 nm (OS-8458)
Power Supply: 9-V adapter (included)

Order Information

Diode Laser – Red OS-8525A
Diode Laser – Green OS-8458

Glow String (2 pack)

SE-8690



This stretchy "string" glows in the dark after being exposed to light. Use it to demonstrate wave motion, including resonance and standing wave patterns. Two rolls are included, totaling over 15 meters of string.



Glow String forming a standing wave using PASCO's String Vibrator WA-9857, Sine Wave Generator WA-9867, and a UV Light Source SE-7228.

Order Information

Glow String (2 pack) SE-8690

Red Laser Pointer

SE-9716B

- Push-button switch
- Inexpensive



CLASS IIIa LASER PRODUCT
LASER RADIATION – AVOID DIRECT EYE EXPOSURE

This Red Diode Laser Pointer is an inexpensive, easy-to-use light beam for a multitude of demonstrations and experiments in optics.

Specifications

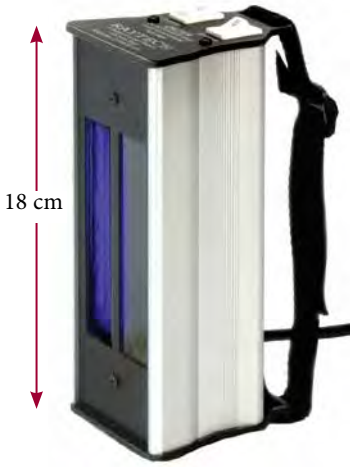
Source: Laser diode
Power: 5 mW max. (class IIIa)
Wavelength: 645 nm (red)
Beam Dia.: Approx. 8 mm at 5 m
Beam Visibility: Up to 50 m
Battery: Alkaline AAA (2 included)
Battery Life: Approx. 1 1/2 hours continuous
Dimensions: 143 mm x 12.7 mm

Order Information

Laser Pointer SE-9716B

UV Light Source

SE-7228



This compact, easy-to-use ultraviolet lamp is ideal for educational use. Two independent lamps are included in one unit. The lamp includes two switches allowing the shortwave and longwave UV to be turned on individually.

Each wavelength produces 4 Watts.

Each lamp window is 10 cm x 2.4 cm.

Order Information

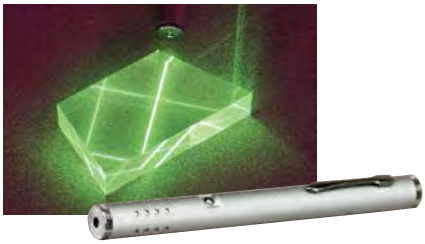
UV Light Source SE-7228

Green Laser Pointer

SE-8805

- Push-button switch
- Brilliant color

CLASS IIIa LASER PRODUCT
LASER RADIATION – AVOID DIRECT EYE EXPOSURE



Use this green diode laser for a wide variety of optics demonstrations and experiments.

Specifications

Source: Laser Diode
Power: 5 mW max (class IIIa)
Wavelength: 532 nm
Beam Dia: Approx. 15 mm at 10 m
Beam Visibility: 500 meters
Battery: Alkaline "AAA" (2 included)
Dimensions: 151 mm x 13.5 mm

Order Information

Green Laser Pointer SE-8805

X-Y Adjustable Diode Laser

OS-8526A



This versatile, inexpensive Diode Laser is designed to mount on a rod stand. The laser assembly can rotate 360 degrees. Easy set-up makes it perfect for refraction investigations or other general laser experiments.



Two knobs allow independent adjustment of horizontal and vertical alignment of the laser beam.

Specifications

Output Power: <1 mW
Wavelength: 650 nm
Power Supply: 9 VDC, 500 mA adapter (included)

Order Information

X-Y Adjustable Diode Laser OS-8526A

Laser Alignment Bench

OS-9172



This Laser Alignment Bench connects to the Optics Bench with the included couplers. It leaves the full one-meter length of the Optics Bench free for experimental work.

Order Information

Laser Alignment Bench OS-9172

Mini Laser w/Bracket

OS-8514



Shown mounted on a PASCO Laser Alignment Bench (see below).

CLASS II LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

This 0.5 mW Helium Neon Laser is ideal for use with the PASCO Advanced Optics System. It includes a mounting bracket that attaches to the PASCO magnetic optics bench and permits adjustment of the laser beam in the *x* and *y* axes.

The aperture has a 15.8 mm (5/8") receptacle for mounting beam spreaders or spatial filters. An AC adapter is included, but the unit can be powered with any power source providing 0.7 A at 12 VDC.

Specifications

Output: 0.5 mW min.
Wavelength: 632.8 nm
Polarization: Random
Power: 115/220 VAC, 50/60 Hz

Order Information

Mini Laser – with Bracket OS-8514

Mini Laser w/o Bracket

SE-9367



CLASS II LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

Order Information

Mini Laser – without Bracket SE-9367

Modulated Laser (1.5 mW)

SE-9449

This Helium Neon Laser has two advantages over the other lasers:

1. **1.5 mW:** The extra power makes laser experiments and demonstrations brighter (and often easier). It's especially useful for holography. A shorter exposure time can be used to minimize problems with vibrations.
2. **Modulation:** Connect a microphone to this laser, and students can transmit voice through the laser beam to a distant receiver. Or use this laser as a laser stroboscope for timing.

Note: Additional equipment, not available from PASCO, is required for laser communication experiments.

For video transmitting, see (SE-8793) page 287.



CLASS IIIa LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM

Specifications

Wavelength: 632.8 nm
Power: 1.5 mW min., 3.5 mW max.
Beam Diameter: 0.49 mm
Beam Divergence: 1.65 mRad
Housing Size: 32.8 x 7.2 x 7.4 cm
Modulation Range: 85-100% of full power
Input Signal Frequency: 50 Hz-600 kHz (±3 dB)

Miniature phone jack accepts audio input signals at 100 mV peak-to-peak and 60 kΩ impedance

Transmission Range: Effective up to several hundred feet; with a good collimator and detector, transmissions up to several thousand feet are possible

Power: 115 VAC, 60 Hz
(not available in 220 V)

Order Information

1.5 mW Modulated Laser SE-9449

Introductory Michelson Interferometer

OS-8501

The Introductory Michelson Interferometer provides precision interferometry at an economical price (laser and screen not included).

- Micrometer-controlled mirror movement
- Precision, front-surface optics
- Good quality, low price

This Introductory Michelson Interferometer is a precision interferometer for the introductory lab. It's easier to use, more compact, and less expensive than PASCO's advanced interferometer (see page 285).

It's capable of measuring the wavelength of monochromatic light with an accuracy of better than 5%. The Michelson Interferometer can also be used for making precise measurements of the index of refraction of air.

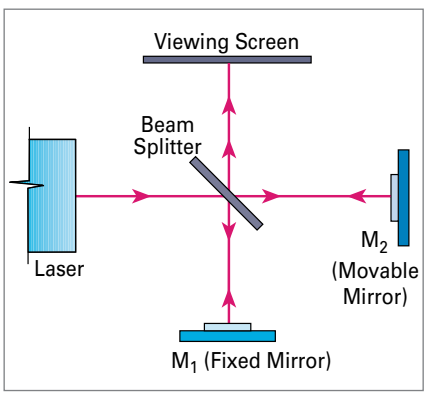
Features

Smooth Mirror Movement:
Uses a taut-band mirror movement similar to PASCO's more expensive interferometer, providing smooth movement with minimal backlash.

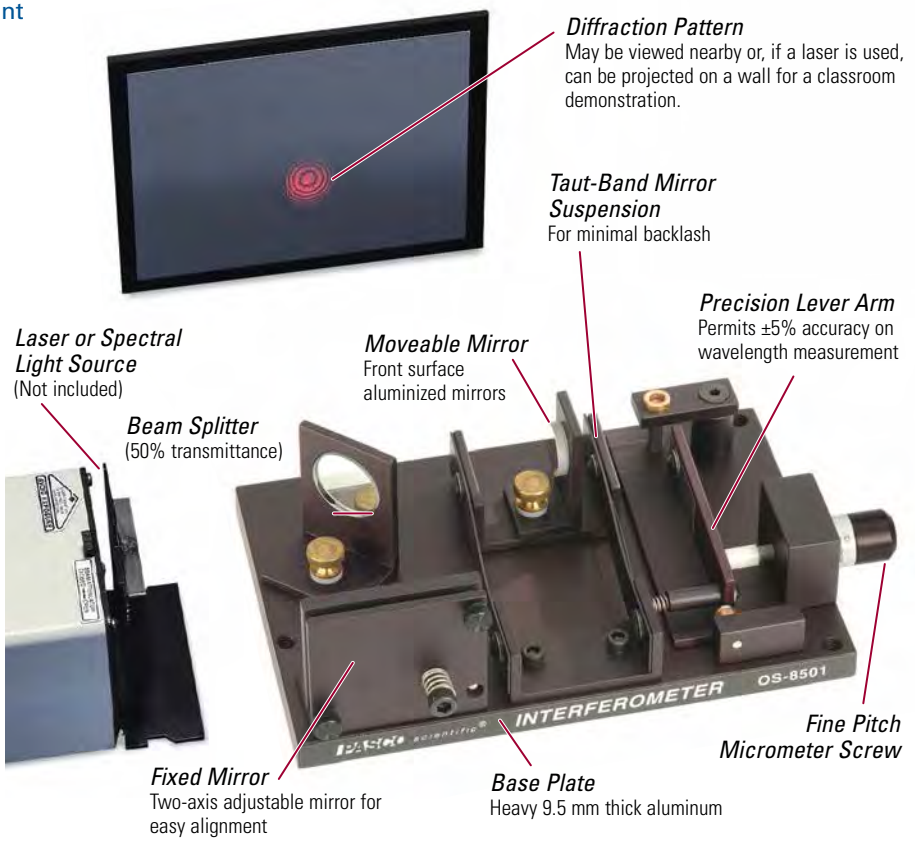
Built-in Micrometer:
Measures mirror movement to a fraction of a micron.

Easy Setup:
Especially easy with a laser and a PASCO Optics Bench. If a laser is unavailable, a spectral light source can be used.

Complete Manual:
Manual includes illustrated set-up instructions, a detailed discussion of basic Michelson interferometry, plus two copy-ready experiments (measure the wavelength of monochromatic light, and measure the index of refraction of air).



Beam-splitting schematic for a basic Michelson Interferometer.



Optics Bench

Note: While the interferometer is designed to be used with the Optics Bench of the Introductory Optics System OS-8500 or the Optics Bench of the Advanced Optics System OS-9103, it can also be used without the PASCO Optics Bench.

Includes

Michelson Interferometer
Gas Cell
Collimating Lens (18.4 mm focal length)
Lens Holder
Storage Case
Manual



Order Information

Introductory Michelson Interferometer OS-8501

Recommended:
Mini Laser w/Bracket ..... OS-8514 p. 283
Hand-Operated Vacuum Pump w/Gauge OS-8502

Hand-Operated Vacuum Pump

OS-8502

This Hand-Operated Vacuum Pump with Gauge is required to measure the index of refraction of air using the Introductory Michelson Interferometer.



Hand-Operated Vacuum Pump with Gauge

Order Information

Hand-Operated Vacuum Pump OS-8502

Complete Interferometer System with Laser

OS-9258B

- Three modes: Michelson, Fabry-Perot, Twyman-Green
- Large precision optics
- 5 kg machined aluminum base

LAB ESSENTIALS

No study of interferometry should overlook the historical importance of the Michelson interferometer. Yet in the laboratory, the Fabry-Perot and Twyman-Green interferometers can be more important tools; the first for high-resolution spectroscopy, the second for testing and producing optical components with aberrations that can be measured in fractions of a wavelength.

The PASCO Interferometer is a high-precision, movable-mirror interferometer that can be used to perform Michelson, Fabry-Perot, and Twyman-Green interferometry. Mirrors are attached with thumbscrews, so it's easy to set up and change configurations.

The PASCO Interferometer can be ordered in a variety of systems. The Precision Interferometer can be operated in either the Michelson or Fabry-Perot modes. The Complete Interferometer Systems also contain components for the Twyman-Green mode and a vacuum pump for the refractive index of air experiment. The Systems Component List shows the contents of each system.

Features

Stable: The massive (5 kg) base is machined from a single block of aluminum, ensuring extremely stable optics.

Smooth Mirror Movement: With the taut-band suspension system, there's no starting or stopping friction and virtually no backlash (less than 0.5 micron).

Precise Measurements: Mirror control is extremely fine—one micron per division of the micrometer head. The mirrors and beam-splitter are flat to 1/4 wavelength to ensure uniform interference patterns.

Larger Optics: The 3.2 cm (1 1/4") diameter optics in the PASCO Interferometer produce larger and sharper interference patterns for better experimental results.

Complete: The Precision Interferometer includes everything necessary to perform basic Michelson and Fabry-Perot interferometry.

Order Information

Complete Interferometer System OS-9258B

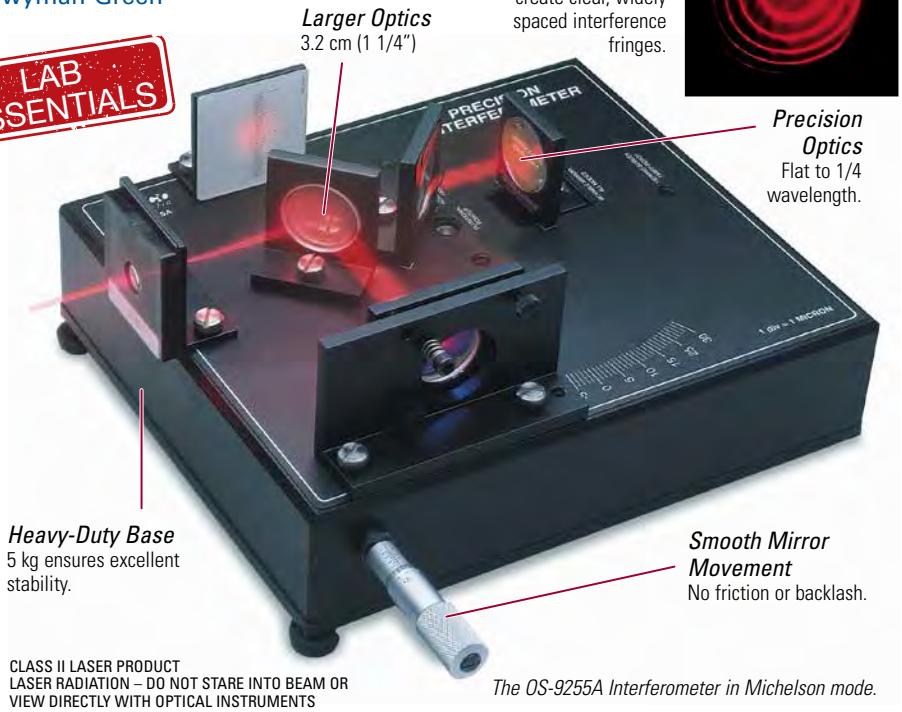
Complete Interferometer System (no laser) OS-9257A

Precision Interferometer OS-9255A

Interferometer Accessories Kit OS-9256A



Fabry-Perot Interferometry: Two parallel, partially reflecting mirrors create clear, widely spaced interference fringes.



The OS-9255A Interferometer in Michelson mode.

Add the Accessories Kit (included in the Complete Interferometer System) to:

Demonstrate that cross-polarized beams will not interfere

Measure lens irregularities in Twyman-Green Mode

Measure the indices of refraction for air and glass. The indices of refraction for user-supplied materials can also be measured.

Note: The fitted case will hold all components and accessories except the 5 kg base, which must be stored separately.

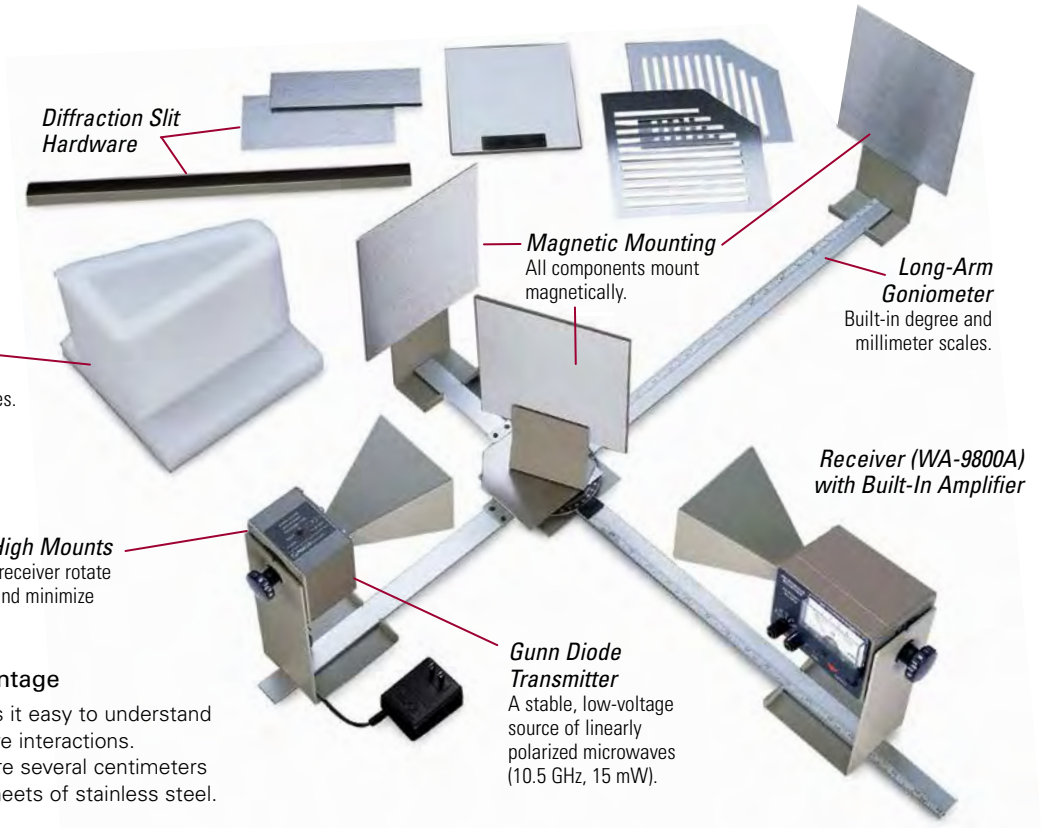
A. OS-9258B Complete Interferometer System with Laser
B. OS-9257A Complete Interferometer System without Laser
C. OS-9255A Precision Interferometer
D. OS-9256A Interferometer Accessories Kit

Systems Component List	***A***	***B***	***C***	***D***
Machined base— 5 kg	1	1	1	
Three-point adjustable mirror	1	1	1	
Mounted beam-splitter	1	1	1	
Mounted movable mirror	1	1	1	
Accessory mounts	3	3	2	1
Viewing screen OS-9138	1	1	1	
Diffuser OS-9120	1	1	1	
Double convex lens (18 mm) OS-9132	1	1	1	
Compensator lens	1	1	1	
Fitted case	1	1	1	
Vacuum pump with gauge OS-8502	1	1		1
Gas cell	1	1		1
Calibrated polarizer OS-9109	2	2		2
Glass plate OS-9128	1	1		1
Rotating component holder	1	1		1
Twyman-Green lenses OS-9133, OS-9132	2	2		2
Mini laser with bracket OS-8514	1			
Laser alignment bench OS-9172	1			
Instruction manual	1	1	1	

Basic System
WA-9314C

Advanced System
WA-9316A

- **Durable construction**
  Parts are made of stainless steel or die-cast aluminum.



GREAT DEMO

The Microwave Optics Advantage

The large 3 cm wavelength makes it easy to understand and visualize electromagnetic wave interactions. Interference and diffraction slits are several centimeters wide, and polarizers are slotted sheets of stainless steel.

The heart of the Microwave Optics System is the Gunn Diode Transmitter and receiver. The transmitter is a low voltage source of linearly polarized microwaves (10.5 GHz, 15 mW). The receiver has a built-in amplifier, as well as a variable sensitivity scale, ensuring accurate data for even the lowest intensity measurements.

The WA-9314C Basic Microwave Optics System Includes

Gunn Diode Transmitter with mounting stand
Receiver with built-in amplifier and mounting stand
Goniometer with fixed and rotatable arms and degree scale
Fixed-arm assembly for interferometer experiments
Component holders: two standard, one rotating
Rotating table
Reflectors: two full reflectors (metal), two partial reflectors (wood)
Polarizers (2)
Diffraction slit hardware
Prism (Ethafoam) with styrene pellets
AC adapter
Laboratory manual with 12 experiments

The WA-9316B Advanced Microwave Optics System Includes

WA-9314C Basic Microwave Optics System
WA-9315 Microwave Accessory Package

Order Information

Basic Microwave Optics System	WA-9314C
Advanced Microwave Optics System	WA-9316A

Recommended:
The microwave transmitter and receiver assemblies may be purchased separately:

Microwave Transmitter	WA-9801
Microwave Receiver	WA-9800A
Microwave Mounting Stand (two needed)	WA-9802

Microwave Detector Probe
WA-9319A



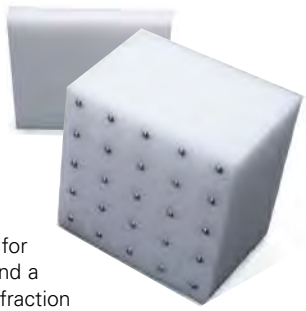
Investigate the nodes and antinodes in standing wave patterns with this microwave probe. It plugs directly into the (WA-9800A) receiver.

Not compatible with older versions of the receiver.

Order Information

Microwave Detector Probe	WA-9319A

Microwave Accessory Package
WA-9315



(included in the WA-9316A Advanced System)

Includes a polyethylene panel for measuring Brewster's angle and a simulated crystal for Bragg diffraction experiments. The crystal is a cubic lattice of 100 metal spheres in a 5 x 5 x 4 array, mounted in plastic foam.

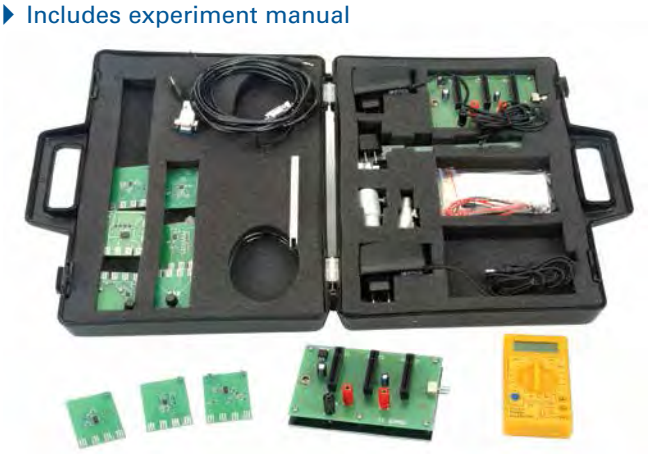
Order Information

Microwave Accessory Package	WA-9315

Fiber Optics Communication Kit

SE-8794

- Demonstrate light propagation in optical fibers
- Transmit and receive optical data
- Includes experiment manual



This kit has transmitter and receiver boards, plus several modules to connect to these boards to transfer optical data through fiber optics cables. The modules included are: analog transmitter and receiver, digital transmitter and receiver, transmitter set with microphone, receiver set with amplifier and speaker, a frequency generator, RS232 signal converter receiver and transmitter. The kit also includes a special holder for the optical fibers, special emery cloths for preparation of the fibers, multimeter, equipment for Tyndall's Light-Guiding experiment, force plates, bending cylinders, jacketed and non-jacketed fibers, power sources, and a user's guide. Also included is a Windows CD user guide and video tutorials.

Order Information

Fiber Optics Communication Kit SE-8794

Red Laser Pointer

SE-9716B

- Push-button switch
- Inexpensive



CLASS IIIa LASER PRODUCT
LASER RADIATION – AVOID DIRECT EYE EXPOSURE

This Red Diode Laser Pointer is an inexpensive, easy-to-use light beam for a multitude of demonstrations and experiments in optics.

Specifications

Source: Laser diode
Power: 5 mW max. (class IIIa)
Wavelength: 645 nm (red)
Beam Dia.: Approx. 8 mm at 5 m
Beam Visibility: Up to 50 m
Battery: Alkaline AAA (2 included)
Battery Life: Approx. 1 1/2 hours continuous
Dimensions: 143 mm x 12.7 mm

Order Information

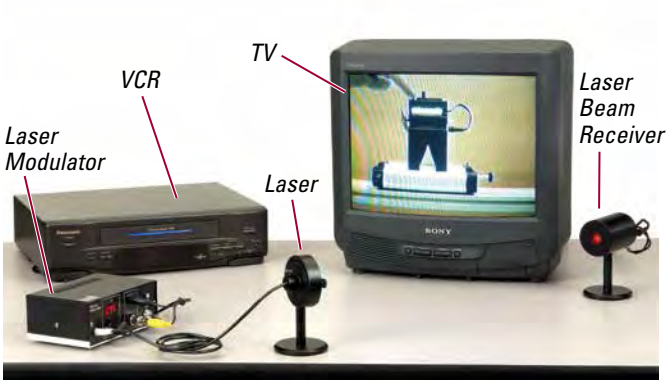
Laser Pointer SE-9716B

Laser Communication Kit

SE-8793

- Transmit both audio and video over laser beam
- Transmit voice using microphone
- Laser included

A laser is modulated by a microphone, audio oscillator, or video player. The modulated beam is received on the other side of the room and the emitted signal comes out of a speaker or television.



Both Video & Audio: *A video tape is played to modulate the laser beam and the laser signal is received and displayed on a television set.*



Speak into a microphone and your words are transmitted over the laser beam to the speakers.

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Includes

Laser Transmitter
(diode laser 635 nm, 1 mW)
Laser Receiver
Microphone
Speaker
Adjustable Transmitter Holder
Adjustable Receiver Holder
Power Source:
230 VAC/110 VAC or 12 VDC
Compact Plastic Case



Order Information

Laser Communication Kit SE-8793

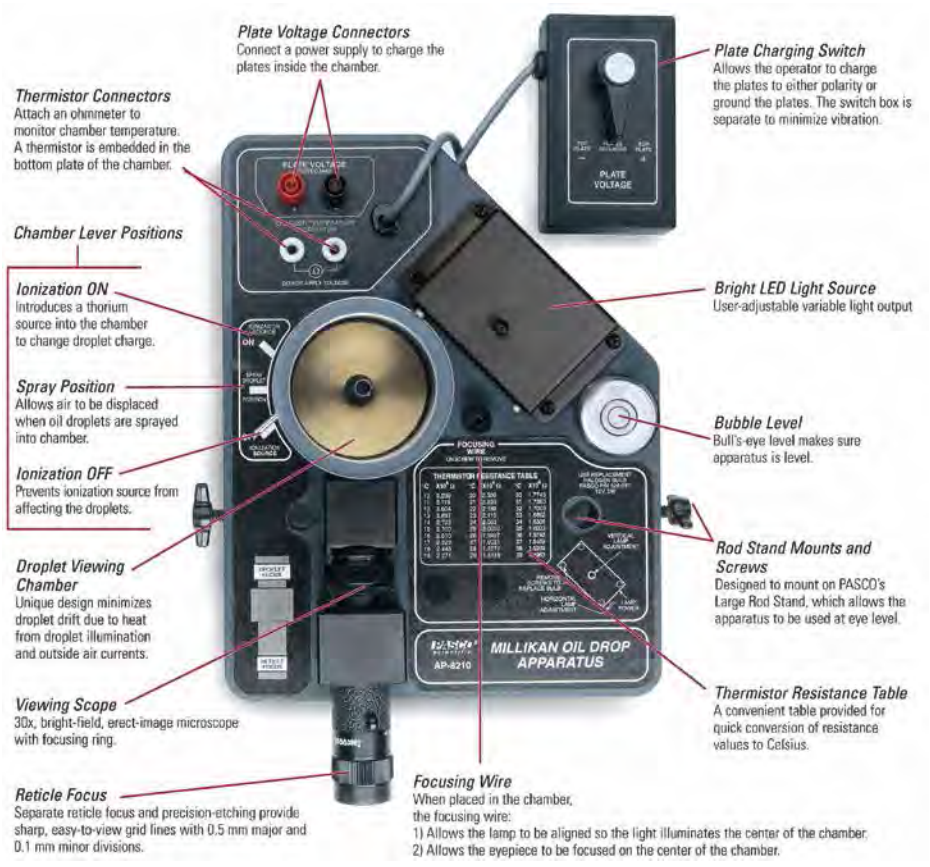
Millikan Oil Drop Apparatus

AP-8210A

- Nobel prize-quality physics in the student lab
- Ionization source for changing droplet charge
- Measures the charge of an electron to within ±3%

The Millikan Oil Drop Experiment is one of the most popular experiments in undergraduate physics for several reasons:

- The experimental principle is straightforward and easy to understand
- It measures a fundamental atomic constant using a method that won its originator, Robert Millikan, the Nobel Prize
- The observation of the effects of one or more electrons upon oil drops in an electric field provides a striking demonstration of the quantized nature of electricity



Clear droplet observation and low droplet drift are essential for success with Millikan's classic experiment. PASCO's apparatus uses a pre-aligned optical system and special condenser to achieve these conditions.

Accuracy in the Oil Drop Experiment depends on the student's ability to precisely measure all the variables involved: plate voltage, plate separation, time and distance of droplet rise and fall, temperature, oil density, etc. Extreme care taken in the design and manufacture of this unit ensures that the student's best efforts will be rewarded with more accurate results. Typically, a careful student can achieve results within 3% or less of the accepted value.



The Millikan Oil Drop Apparatus mounted on a rod stand for easy, eye-level viewing

Specifications

Maximum Plate Voltage:
500 VDC
Light Source: Cool LED
Reticle Line Separation:
0.5 mm major divisions
0.1 mm minor divisions
Plate Spacing— 7.62 mm
Plate Diameter— 60 mm



Includes

Millikan Oil Drop Apparatus with switch
Non-volatile Oil and Atomizer
12 VAC Lamp Power Adapter

Order Information

Millikan Oil Drop Apparatus AP-8210A

Required:

Basic Digital Multimeter (2) ..... SE-9786A p. 239
High Voltage Power Supply ..... SF-9585A p. 233

Recommended:

For mounting unit at eye level on a standard lab table:
Large Rod Base ..... ME-8735 p. 170
45 cm Steel Rod (2) ..... ME-8736 p. 170

Complete System:

Charge of an Electron ..... EX-9929A p. 338
USB Video Flex ..... SE-7235A p. 74

Replacement Part:

4 oz. Bottle Mineral Oil (qty. 4) AP-8211
Millikan LED Light Source AP-8212

Electron Charge-to-Mass Ratio System

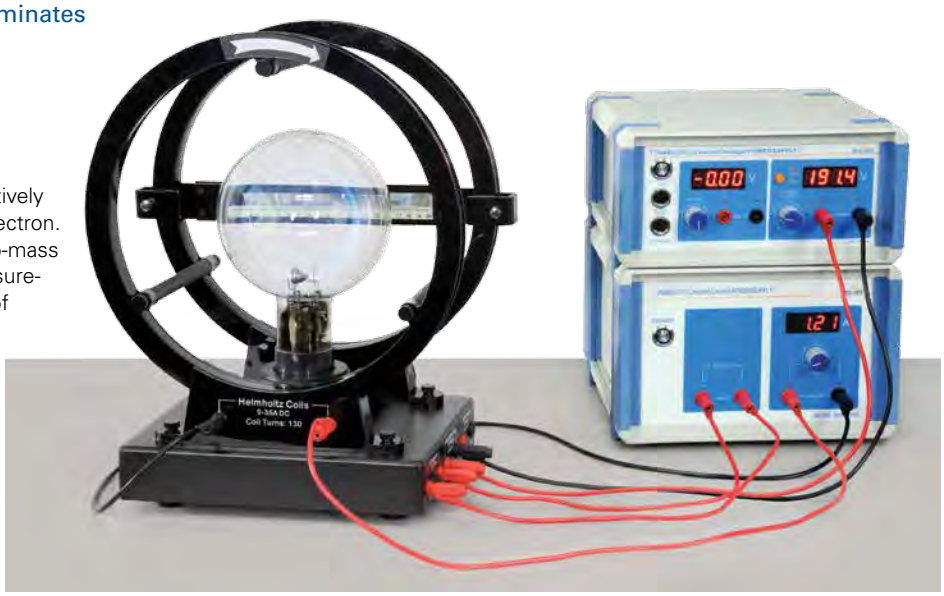
SE-9629

- Sharp, clearly visible electron beam
- Phosphorescent, mirrored scale eliminates parallax errors
- Tube rotates for general study of electrons in a magnetic field

In 1897, J. J. Thomson showed that the mysterious cathode rays were actually negatively charged particles—he had discovered the electron. In the same year he measured the charge-to-mass ratio of the electron, providing the first measurement of one of the fundamental constants of the universe.

The Charge-to-Mass Ratio System reproduces one version of Thomson's landmark experiment, providing an accurate measurement of the charge-to-mass ratio of the electron. And, since the electron tube can be rotated through 90°, students can also make a more general study of the behavior of electrons in a magnetic field.

This apparatus also has deflection plates so students can study the effect of an electric field on moving electrons.



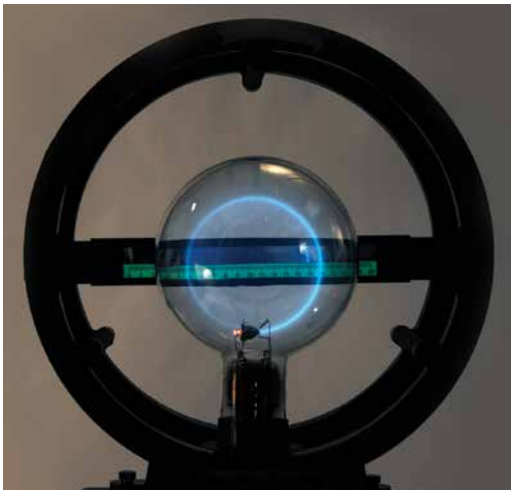
Complete Charge-to-Mass Ratio System includes the power supplies which can also be used in other experiments (such as Franck-Hertz experiment, see page 291).

How It Works

A large, helium-filled electron tube is mounted between a pair of Helmholtz coils. The tube contains an electron gun, which generates a focused beam of electrons. A measured current is applied to the Helmholtz coils so that the magnitude of the magnetic field within the electron tube can be calculated. A measured accelerating potential (V) is then applied to the electron gun. The magnetic field (B) deflects the electron beam in a circular path with a radius (r) that is measured using the illuminated mm scale. From these measured values, the charge-to-mass ratio of the electron is calculated:

$$e/m = 2V/B^2r^2.$$

(The details of the calculations are fully described in the manual.)



Fluorescent scale shows behind the electron beam in a dark room.

Specifications

Hemholtz Coil Radius: 16 cm
Number of Turns: 130
Maximum Current: 3.5 A
Filament Voltage: 6.3 VAC
Acceleration Voltage: 0 - 200 V
Tube Diameter: 15.5 cm

For more information about the power supplies, see page 234.

Electron Charge-to-Mass Ratio System (SE-9629) Includes:

SE-9626 Helmholtz Coils (without tube)
SE-9651 e/m Tube
SE-9622 Tunable DC (Constant Current) Power Supply
SE-9644 Tunable DC (Constant Voltage) Power Supply II
Red and black Patch Cords

Order Information

Electron Charge-to-Mass Ratio System	SE-9629
If you already have power supplies, you will need:	
Helmholtz Coils (without tube)	SE-9626
e/m Tube	SE-9651
Replacement Parts:	
e/m Tube (for SE-9629)	SE-9651

Photoelectric Effect System

SE-6609

- Find Planck's Constant to within 5%
- Verify the stopping voltage is independent of intensity
- Find characteristics of photodiode

The Photoelectric Effect System is used to perform the photoelectric experiment, determining Planck's Constant to within 5%. This apparatus uses the conventional method of determining Planck's Constant. The metal plate in the photodiode is illuminated with various frequencies of light, selected from a mercury lamp using filters. The voltage is then adjusted to stop the photoelectric current. The stopping voltage is plotted versus the frequency and Planck's Constant is determined from the slope of the graph.

The concept that the stopping voltage does not change with light intensity is tested using the various apertures that vary the light intensity by partially blocking the light.

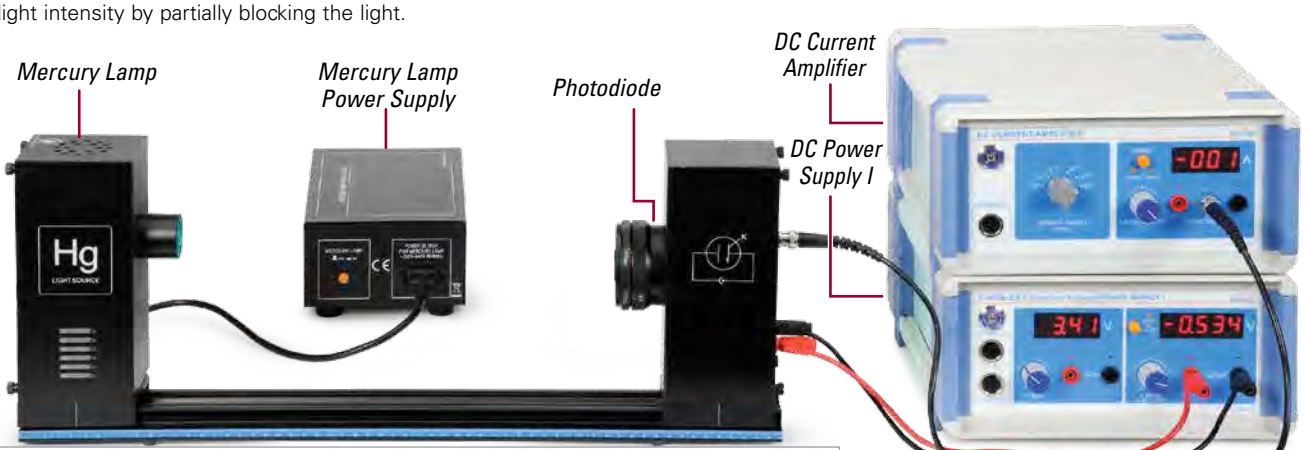
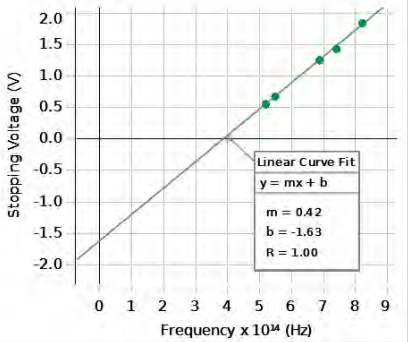


Table I: Photoelectric Effect with 4 mm Aperture

	Run #1	Run #1
	Frequency x 10^{14} (Hz)	Stopping Voltage (V)
1	8.214	1.835
2	7.408	1.428
3	6.879	1.248
4	5.490	0.671
5	5.196	0.551



For the typical sample data shown, the graph of stopping voltage versus frequency gives a slope of 4.2 x 10^{-15} V·s. This results in a value for Planck's Constant of 6.7 x 10^{-34} J·s, which is 1.3% above the accepted value. Graph generated using PASCO Capstone™ Software and 850 Interface.



Can be used with the 850 Interface (UI-5000, see p. 14) and PASCO Capstone

See the complete experiment on page 359.

Power Supply and Current Amplifier specs: See page 234.

The filters and the apertures are built into the front of the photodiode case, making it easy to keep clean and eliminating the need for a separate storage box. To change the aperture size in order to investigate the affect of different light intensities, simply pull outward on the aperture ring and rotate it to a different aperture. The filter wheel rotates independently of the aperture ring to select different frequencies of light. The wheel clicks into place, assuring that the filter is aligned with the aperture.



SE-6609 Includes:

Basic Photoelectric Effect	SE-6614
DC Current Amplifier	SE-6621
DC Power Supply I	SE-6615

SE-6614 Includes:

Mercury Light Source with Hg Tube SE-6608 (see page 281)
Photodiode enclosure with tube and track and cables

Specifications

Current Amplifier
Measuring Range: 10^{-8} to 10^{-13} A, in six ranges
Voltage Output for Photoelectric Tube
Voltage Adjustment: –4.5 V to 0 V and –4.5 V to +30 V (two ranges), 4 digit display.
Photoelectric Tube
Spectral Response Range: 300–700 nm
Anode: nickel ring
Optical Filters
Five Filters with Central Wavelengths: 365.0, 404.7, 435.8, 546.1, and 578.0 nm

Order Information

Photoelectric Effect System SE-6609

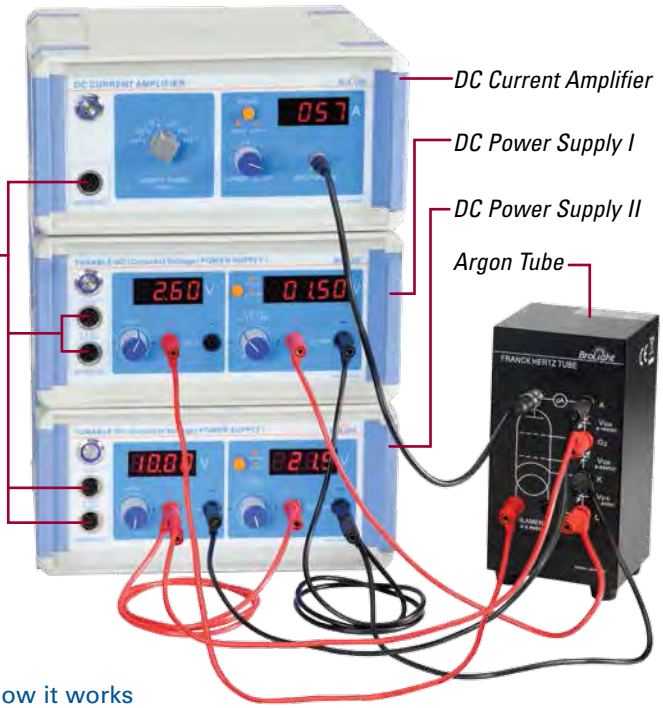
If you already have the Power Supply and Amplifier, you will need:
Basic Photoelectric Effect Apparatus SE-6614

Replacement Parts:
Photoelectric Tube with Box Plate SE-6612

Franck-Hertz Apparatus

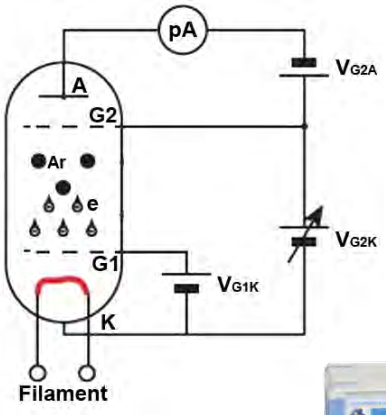
SE-9639

- Uses argon gas so no heating is required
- Digital displays for stand-alone use
- Can be used with the 850 Interface and PASCO Capstone

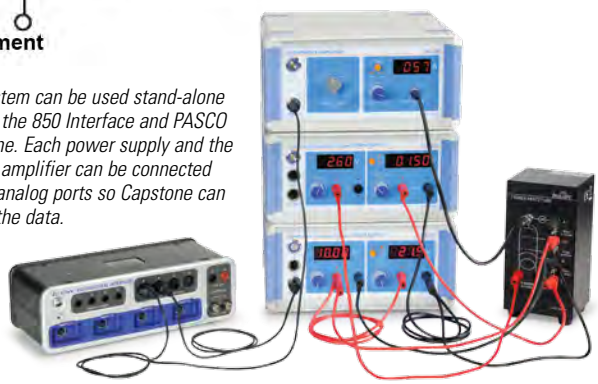


Introduction

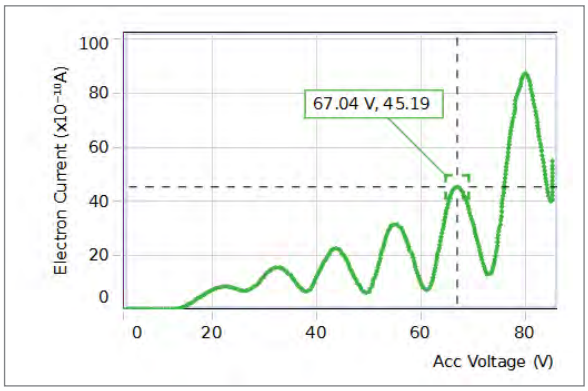
As early as 1914, James Frank and Gustav Hertz discovered in the course of their investigations an energy loss in distinct steps for electrons passing through mercury vapor and a corresponding emission at the ultraviolet line (λ= 254 nm) of mercury. They performed this experiment that has become one of the classic demonstrations of the quantization of atomic energy levels. They were awarded the Nobel Prize for this work in 1925.



This diagram shows the internal structure of the Franck-Hertz tube and the wiring diagram.



The system can be used stand-alone or with the 850 Interface and PASCO Capstone. Each power supply and the current amplifier can be connected to 850 analog ports so Capstone can record the data.



The advantage of using Capstone is that students are able to get many more data points compared to manually taking readings from the digital readouts. The peaks and troughs are easily measured using the coordinate tool.

How it works

Electrons are accelerated by applying a known potential between two grids inside the argon tube. When an electron has sufficient kinetic energy to excite one of argon's outer orbital electrons and has an inelastic collision with an argon atom, the electron loses a specific amount of kinetic energy. This loss of electron kinetic energy causes a decrease in the electron current in the argon tube. The excited argon electron will within a very short time fall from the excited state back into the ground state level, emitting energy in the form of photons.

As the accelerating voltage is increased, the electrons undergo multiple collisions and the excitation energy of the argon atom can be determined by the differences between the accelerating voltages that cause a decrease in the current. Planck's constant can be determined.

Specifications

Filling gas: argon
Filament Voltage: ≤6.3 VDC
Accelerating Voltage: ≤100 VDC
Wave crest(or trough) number: 6
Argon Tube Life span: ≤3000 hrs

Power supply and current amplifier specs: See page 234

Franck-Hertz System (SE-9639) Includes:

SE-9650 Franck-Hertz Tube Enclosure with Argon Tube
SE-6615 Tunable DC (Constant Voltage) Power Supply I
SE-9644 Tunable DC (Constant Voltage) Power Supply II
SE-6621 DC Current Amplifier
Red and black Patch Cords

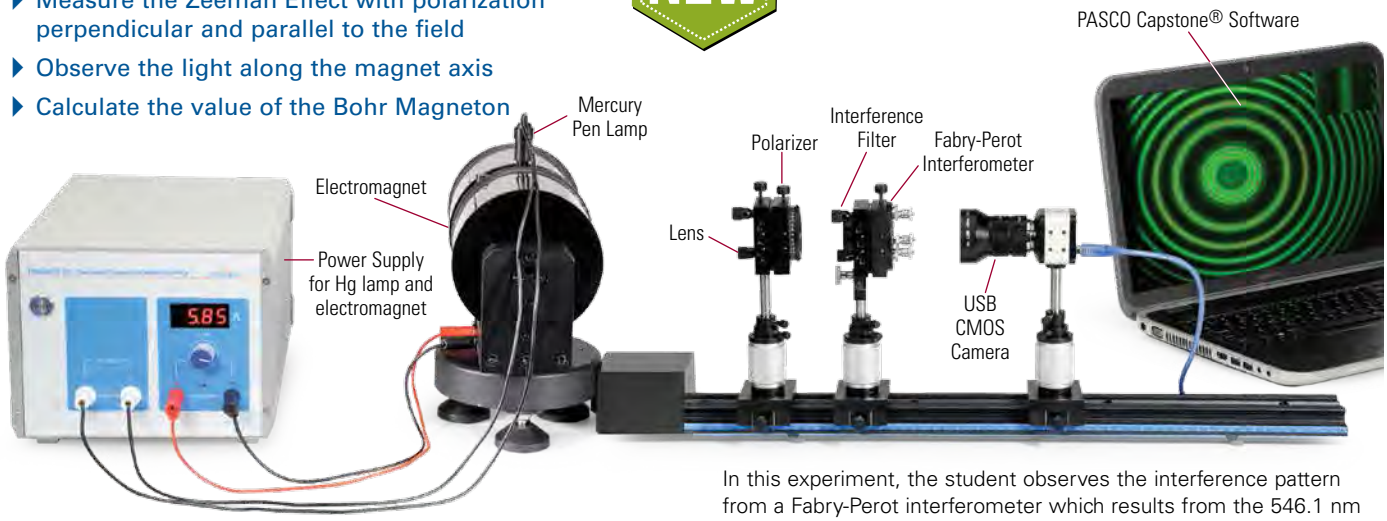
Order Information

Franck-Hertz System SE-9639
If you already have power supplies, you will need:
Franck-Hertz Tube Enclosure with Ar Tube SE-9650
Power supplies and amplifier can be purchased separately – See p. 234
Replacement Parts:
Franck-Hertz Argon Tube SE-9645

Zeeman Effect

SE-9654

- Measure the Zeeman Effect with polarization perpendicular and parallel to the field
- Observe the light along the magnet axis
- Calculate the value of the Bohr Magneton



In this experiment, the student observes the interference pattern from a Fabry-Perot interferometer which results from the 546.1 nm spectral line of a mercury lamp immersed in a uniform magnetic field. The magnetic field is varied from zero to nearly 1 Tesla.

Initially, the light is viewed along an axis perpendicular to the magnetic field axis. A polarizer is used to show the three lines due to light that is polarized parallel to the field axis and to show the six lines that are polarized perpendicular to the field axis. The pattern may also be viewed along the field axis where the light is circularly polarized.

Finally, the pattern that is polarized perpendicular to the field axis is used to calculate the Bohr magneton. All atomic magnetic moments are integral or half-integral multiples of the Bohr magneton.



End view through the axis of the magnet.



Electromagnet produces over one Tesla.



The vertical position can be adjusted precisely with the fine-adjust mechanism.



Lens and polarizer mount can be adjusted vertically and horizontally.



The optics and track come in a alumunum hard case with foam cut-outs for each component.

Specifications

CMOS Camera and Lens	1/3", 2M pixels, f=50 mm, RA=1:4
Fabry-Perot Interferometer	λ=546.1 nm
Collimating Lens	f=125 mm
Mercury Lamp	10A, 3W
Electromagnet	5A, 1.2T, ~ 7.4 mm gap
Tunable DC Power Supply	110V/220V, 6A
Precision Adjustable Optical Mount	Φ45 mm, 2D
Horizontal Optical Mount	Φ45 mm, travel = 36 mm, 2D
Track length	600 mm

Includes

Electromagnet, power supply, optics, and PASCO Capstone Single User License.

Order Information

Zeeman Effect	SE-9654	
May be purchased seperately:		
Electromagnet	SE-9655	
Tunable DC Power Supply 6A	SE-9656	
Optional:		
Tesla Meter	SF-7579	p. 230

Field strength as a function of the current supplied to the magnet is included in a chart. To directly measure field strength, order the optional Tesla Meter (SF-7579).

Gravitational Torsion Balance

AP-8215A

- Measure the universal gravitational constant in a single lab period
- Adjustment and locking mechanisms decrease lab setup time
- Torsion band easily replaced

NEW
Computerized Version:
See the Universal Gravitational Constant experiment (EX-5550) on page 317 for a new video analysis method of tracking the laser beam.

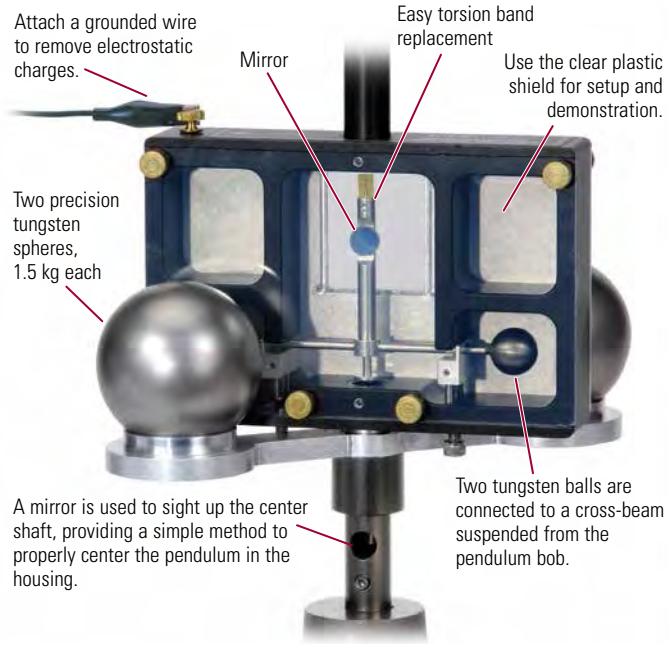
Features

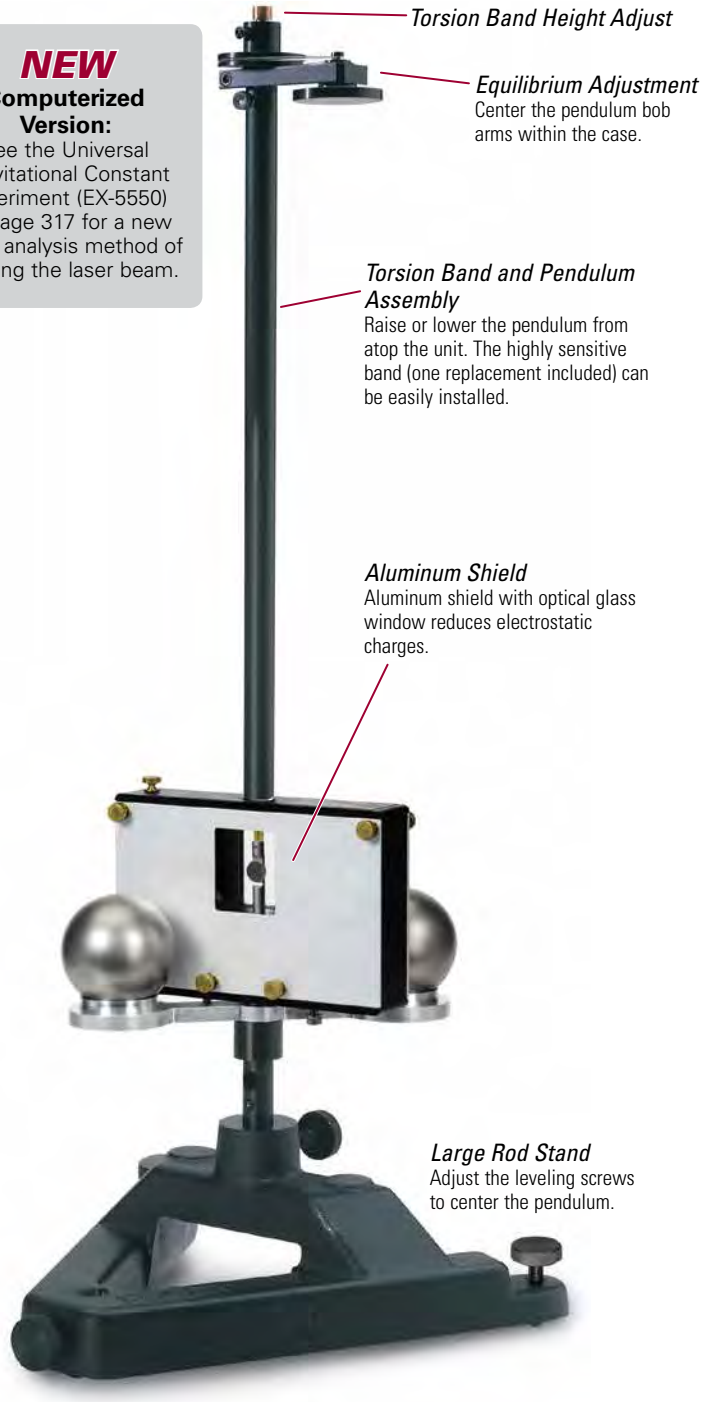
View the pendulum bob's position through a mirror in the unit's central shaft. Use the leveling screws in the cast iron base to accurately center the bob.

A special "U"-shaped groove in the locking mechanism is used to dampen the oscillation of the small lead balls.

Easily adjust pendulum height with a single screw.

The smooth action of the rotating large tungsten ball support ensures that the balls can be moved easily without disturbing the motion of the small tungsten balls.





Specifications

Torsion Band: Beryllium copper ribbon, 36 cm long with a cross section of 0.0178 x 0.15 mm
Small Masses: Two tungsten balls of 38 g each
Large Masses: Two tungsten balls of 1.5 kg each
Period of Oscillation: Eight minutes (approx.)
Accuracy: 5% (approx.)

Includes

Torsion Balance Assembly
Large Rod Base ME-8735
One Extra Torsion Band
Manual

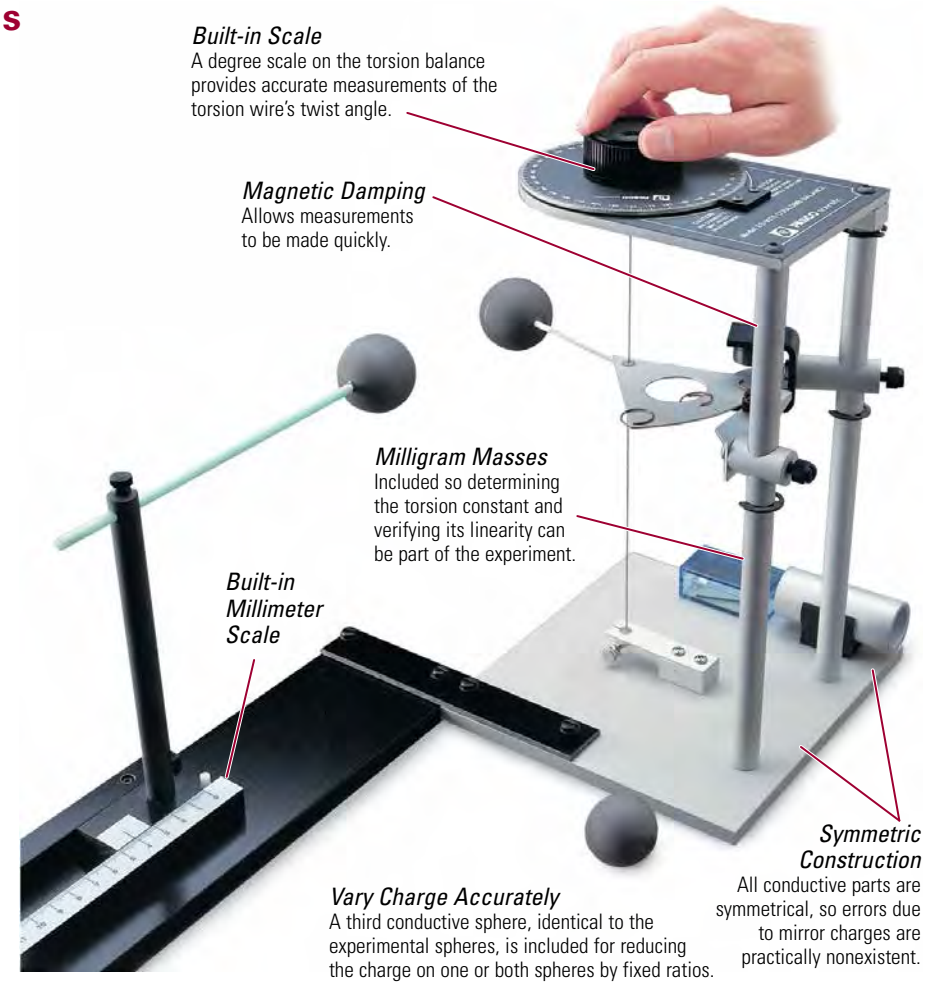
Order Information

Gravitational Torsion Balance	AP-8215A	
Required:		
X-Y Adjustable Diode Laser	OS-8526A	p. 283
45 cm Steel Rod	ME-8736	p. 170
Large Table Clamp	ME-9472	p. 173
Replacement Supplies:		
Torsion Bands (2 pack) – Gravitational Torsion Balance	AP-8218	
Gravitational Balls Replacement Set	AP-8219	

Coulomb's Law Apparatus

ES-9070

- Accurately measure charge, force, and distance
- Symmetric design minimizes stray and mirror charges
- Magnetic damping for quick, accurate measurements



How It Works

A conductive sphere is mounted on the end of an insulating, counterbalanced rod and suspended from a thin torsion wire. An identical sphere is mounted on a calibrated linear track. This second sphere can be positioned at various distances from the first. When the conductive spheres are charged, the force between them is proportional to the twist of the torsion wire that is required to bring the balance back to its equilibrium position. Beginning students can determine the Inverse Square Law in a simple experiment. Advanced students can perform a more sophisticated investigation into all the variables of electrostatic repulsion.

Additional Equipment

To perform a basic experiment, the conductive spheres can be charged with a piezoelectric gun or by contact with a charged rod. This allows the Inverse Square Law to be verified with reasonable accuracy. However, for more accurate and thorough investigations, we strongly recommend the following additional equipment (see ordering information):

- A Kilovolt Power Supply, which provides a fixed and repeatable charge. The charge can be refreshed before each measurement, which practically eliminates errors due to leakage currents.
- A Basic Electrometer and a Faraday Ice Pail, for accurate measurement of the charge on the spheres (required only if you wish to measure the Coulomb Constant).

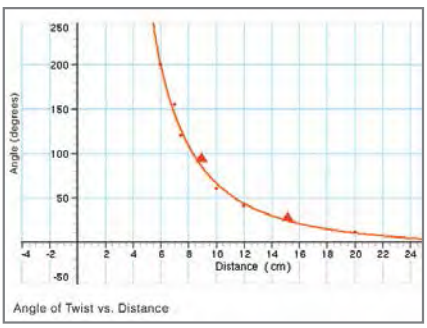
Specifications

Torsion Balance:
Torsion Assembly: 38 mm dia. conductive sphere on 12 cm rod with counterbalance vane
Torsion Wire: equals 10^{-6} Newtons/degree
Degree Plate: 1° increments
Magnetic Damping: dampens oscillations for quick measurements

Calibrated Linear Track:
Sphere: 38 mm dia. conductive sphere
Range of Movement: 350 mm in 1 mm increments
Material: phenolic (to minimize mirror charges)

Miscellaneous Equipment:
Charging Probe: 17 cm long plus 1.5 m cable; banana plug connector; 200 μΩ internal resistance
Calibration Masses: 50 mg (1), 20 mg (2)
Conductive Sphere on Insulating Thread: for reducing charge by fixed ratios
Spare Torsion Wire: 3 m

Shipping Information:
Size: 28 x 38 x 61 cm (11 x 15 x 24 in.)
Weight: 9.5 kg, 21 lbs



Actual data of the angle (force) vs. distance

Order Information

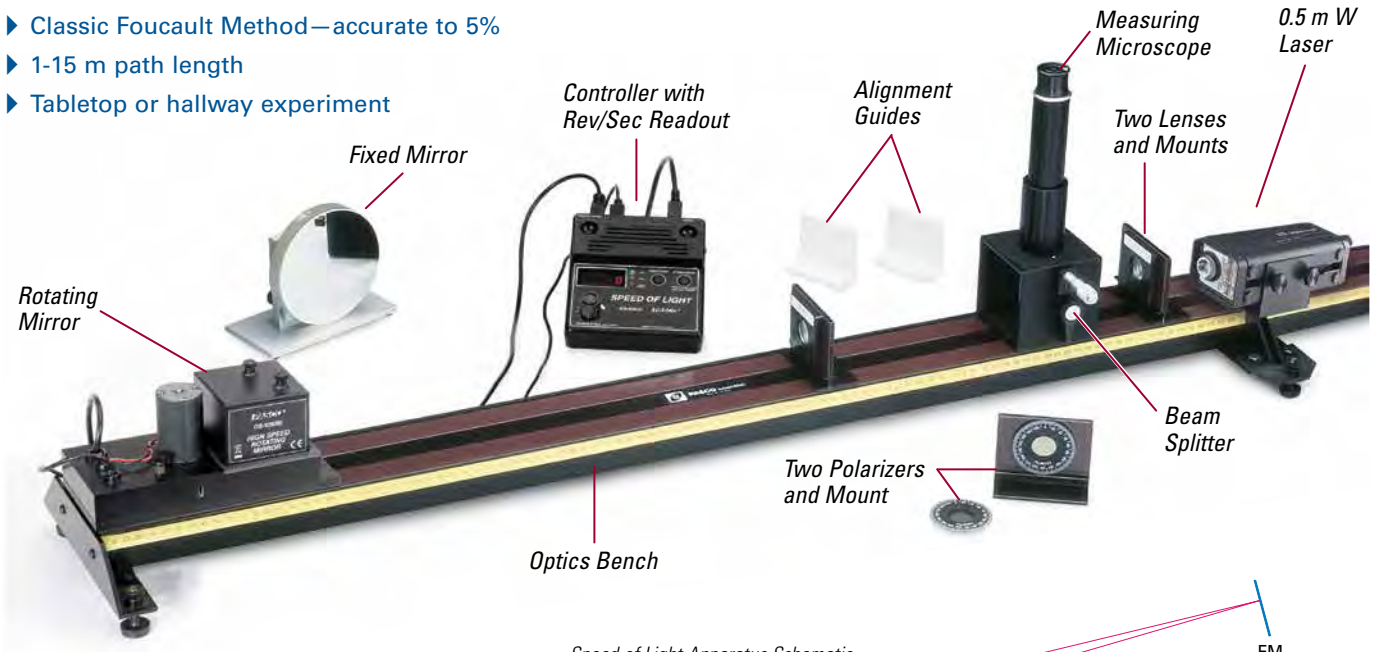
Coulomb's Law Apparatus	ES-9070	
Recommended:		
Kilovolt Power Supply	SF-9586B	p. 233
Basic Electrometer	ES-9078A	p. 206
Faraday Ice Pail	ES-9042A	p. 207
Charge Producers	ES-9057C	p. 207
Complete System:		
Coulomb's Law	EX-9930B	p. 337

Complete Speed of Light Apparatus

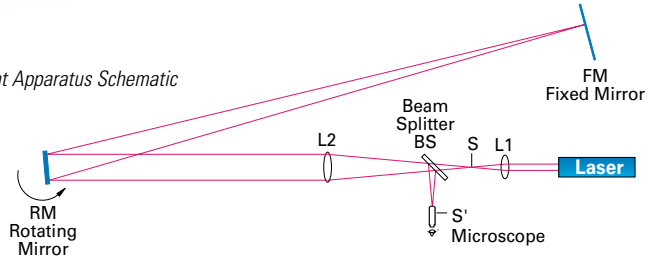
OS-9261B

CLASS II LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

- Classic Foucault Method—accurate to 5%
- 1-15 m path length
- Tabletop or hallway experiment



Speed of Light Apparatus Schematic



How It Works—The Foucault Method

1. The first observation is made when the rotating mirror is not rotating. Light from a He-Ne laser is reflected from the rotating mirror and focused onto the fixed mirror. The fixed mirror reflects the image back onto the rotating mirror, which in turn reflects the light back through the lenses to reform the image, where it can be observed with the microscope.
2. The second observation is made when the rotating mirror is rotating. Since it takes a finite amount of time for the light to traverse the distance between the fixed and rotating mirrors, the rotating mirror is in a slightly different position when the light returns after reflecting off the fixed mirror. This produces a displacement, which can be measured with the microscope.
3. The displacement between the first and second observations is proportional to the transit time of the light to the angular velocity of the rotating mirror. With a very straightforward calculation, the speed of light can be calculated.

OS-9261B Includes

1 m Optics Bench (OS-9103)
Laser Alignment Bench (OS-9172)
Mini Laser with Bracket (OS-8514)
Double Convex Lens, 48 mm F.L. (OS-9133)
Plano Convex Lens, 252 mm F.L. (OS-9135)
Calibrated Polarizer (OS-9109)
Component Carrier (OS-9107)

High Speed Rotating Mirror with Controller

OS-9263B



Order Information

High Speed Rotating Mirror with Controller	OS-9263B

Order Information

Complete Speed of Light Apparatus	OS-9261B	
Parts available separately:		
Optics Bench (1 m)	OS-9103	
Laser Alignment Bench	OS-9172	p. 283
Mini Laser with Bracket	OS-8514	p. 283
Lens, 48 mm F.L.	OS-9133	p. 271
Lens, 252 mm F.L.	OS-9135	p. 271
Calibrated Polarizers (2)	OS-9109	p. 274
Component Carriers (3)	OS-9107	p. 271
Speed of Light Experiment	EX-9932	p. 352

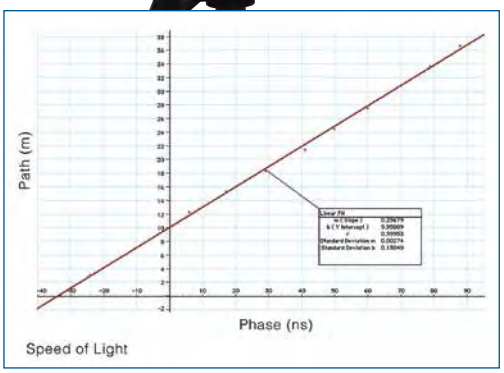
Laser Speed of Light System

AP-8586

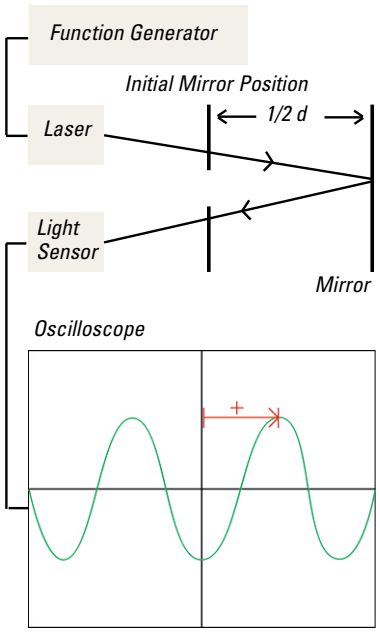
- Easy setup
- Accurate results
- Low cost

The Laser Speed of Light System is a low cost, yet effective method of measuring the speed of light. While it does not duplicate the classic Foucault Method, its ease of use gives every student the opportunity to perform the experiment.





A linear fit is applied to the data, and the slope of the fit represents Δd/Δt, or the speed of light.



How It Works

A function generator is used to modulate the light from the laser at 3 MHz. This light is then reflected from a mirror and focused onto a light receiver. An oscilloscope is used to observe the modulated light, and the phase of the signal is noted as the baseline value for phase.

The mirror is moved back, increasing the distance that the light travels. Since it takes more time for the light to travel from the laser to the sensor, the phase of the signal on the oscilloscope increases. The phase at each successive mirror position is recorded and compared to the baseline value. The mirror is moved back several more times to get a reasonable number of data points. For each mirror position, the additional path length (d) is graphed versus the phase difference (t).

Includes

Diode Laser, Component Carrier (2)
+127 mm Lens
Laser Alignment Bench
Light Receiver
Stainless Steel Mounting Pads (4)
Concave Mirror
Coaxial Cable– RCA male to BNC male
Coaxial Cable– 3.5 mm phone plug to BNC male
Coaxial Cable– BNC male to male

Order Information

Laser Speed of Light System AP-8586
Required:
Wide Range Function Generator SB-9549A
Tape Measure (30 m) SE-8712A
Standard Photo Tripod
60 MHz Oscilloscope SB-9620A

Intermediate Nuclear Laboratory System USB

SN-7900A (Win/Mac)

- Macintosh, Windows, or stand-alone option
- Complete system

PASCO's most sophisticated stand-alone G-M System provides a wide range of experiments with alpha, beta, and gamma radiation. Includes a versatile scaler, a G-M Tube with a mount and trays, and a full set of radioactive sources and absorbers.



Includes

1. SN-7902 Radiation Counter with RADEM and LABLINK software and manual
2. SN-7970A G-M Probe (35 mm) and stand
3. USB Cable
4. SN-8111A Calibrated Absorber Set (20)
5. SN-7972A Radioactive Sources (5)
6. Two CDs with installation instructions and nuclear science experiments

Five Radioactive Sources

1.	Po-210:	0.1 μCi,	138 days,	α
2.	Sr-90:	0.1 μCi,	28.6 years,	β
3.	Co-60:	1 μCi,	5.27 years,	β,γ
4.	Tl-204:	0.25 μCi,	3.78 years,	β,γ
5.	Cs-137:	0.25 μCi,	30.2 years,	β,γ

The five sources are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations. Shown below are the isotopes, activity, half-life, and type of radiation.



Main screen display from LABLINK software

Advanced Scaler/Timer

The Radiation Counter SN-7902 is a versatile, general purpose Scaler/Timer.

Sensitive G-M Probe

- Suitable for alpha, beta, and gamma radiation detection.
- Rugged and versatile mount: made of sturdy plastic for years of rugged use. It comes with one sample holder and 10 shelf positions.

Large Variety of Absorbers

The Absorber Set SN-8111A includes four lead, 10 aluminum sheets, two polyethylene, two plastic, and two aluminum foil absorbers, ranging from 5 mg/cm^2 to 7200 mg/cm^2

Computer Compatibility

The bi-directional LABLINK software allows full control of the Radiation Counter from the computer. LABLINK provides real-time display of a simulated analog rate-meter with auto-ranging, digital ratemeter in CPM or CPS, count, elapsed time, preset count, preset time, acquisition time, and run number. Data is loaded into spreadsheet-compatible files.

Features

Preset Timing and Counting Intervals: (in seconds) 1-9, 10-90, 100-900, 1K-9K, 10K-90K, 100K-900K. Intervals are selected using the Preset switch.

Digital Display: Bright 6-decade digital readout uses extra-large LEDs for clear readout in most ambient light conditions.

Built-in Power Supply: 0 to 1200 V for the G-M Probe.

MAC WINDOWS

Order Information

Intermediate Nuclear Laboratory System, USB.....SN-7900A

Required:

Isotope Generator Kit*.....SN-7995A

***Note:** Purchased Sources are "Non-Cancellable" and "Non-Returnable".*
See Radioactive Source Disclaimer on the Order Information page 384.

Advanced Nuclear Spectroscopy System, USB

SN-7901B (Windows)

- Sophisticated Spectroscopy system
- Multi-channel analysis

Designed for spectroscopy applications, the Universal Computer Spectrometer (1) offers complete support for standard scintillation detectors together with multi-channel scaling for decay and time-related studies. The multi-channel analyzer contains many advanced features, including computer-controlled amplifier and high voltage for G-M tubes, upper- and lower-level discriminators, data memory, and a comprehensive software package.



Includes

1. Universal Computer Spectrometer, USB
2. NaI (Tl) Scintillation Probe
3. Gamma Sources (8)
4. Connection Cables
5. Installation, Instruction, and Experiment CDs (2)

Specifications

Hardware:
Physical: Interface card or box includes pre-amplifier, amplifier, detector high voltage, 1024 channel analyzer with data memory, LLD and ULD

ADC: Wilkinson-type with 80 MHz clock and computer selected conversion gain of 256, 512, or 1024 channels

High Voltage: 0-1280 V, 1 mA maximum

Amplifier: Preamplifier/amplifier combination. Computer controlled coarse/fine gain from x2 to x1000

Modes: MCA for pulse height analysis, or MCS for half-life decay or other time-related studies

Software:
Energy Calibration: 2-point linear or 3-point quadratic converts cursor position reading directly to energy units

Computer Display: Vertical scale adjusts from 32 to 16 M and LOG display. Horizontal 1024 channels with expansion down to 128 channels

ISOMATCH: Isotope library text file with peak markers and labeling for overlaying on spectrum for quick isotope identification. Library may be edited and expanded.

The sources are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations.

WINDOWS

Order Information

Advanced Nuclear Spectroscopy System, USB*.....SN-7901B

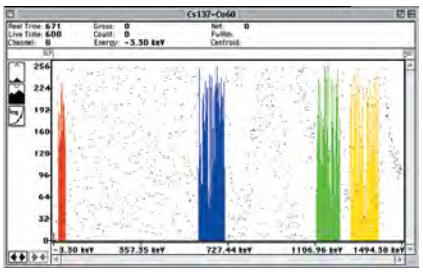
Features

Variable Voltage: A regulated high voltage of 0 to 1280 V is supplied with computer control (1 mA maximum, 5 V increments).

Amplifier: On-board combination preamplifier/amplifier for use with scintillation detectors and PMTs.

Complete Computer Control: When used in MCA mode, the software provides complete computer control of all features including preset live/real-time, preset count, unlimited regions-of-interest, and centroid, gross, and net area calculations.

Multiple Memory Buffers: In addition to on-board hardware data memory, the spectrometer provides three software memory buffers for holding spectra. A background spectrum may be collected over a long counting period and stored in the background buffer.



Main screen display for Universal Computer Spectrometer

***Note:** Purchased Sources are "Non-Cancellable" and "Non-Returnable".*
See Radioactive Source Disclaimer on the Order Information page 384.

High-Sensitivity Gamma Spectrometer System

SE-9764



Includes

Detector and Multi-Channel Analyzer

WinDAS Software

User Guide with Teacher Notes and Eight Experiment Descriptions

Seven Empty Sample Containers

A Complete College-level Gamma Spectrometer System

This system is a complete scintillation spectrometer with a one-inch lead shield and all electronics for connection to any PC with USB interface. The system has been developed for optimal performance in nuclear spectroscopy. Add the Particle Detector to form a complete system for teaching and understanding the different types of nuclear radiation.

Specifications

Hardware:
Detector Unit: 2" x 2" NaI detector with PM-tube (<7.5% resolution), HV-supply and lead shield container
Multi-Channel Analyzer: Amplifier, Discriminator, 1024 channel 50 MHz Wilkinson ADC, Microprocessor with USB interface. Connectors for the Particle Detector, USB and 12VDC power inlet from a wall-adapter.
Complies with the EU EMC directives.

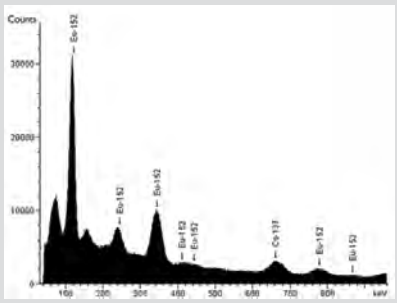
Software:
Data acquisition software for Windows 7, Vista and XP automatic recording and calculation of Cs-134/137 and radon gas activity.

Customer needs to supply approximately 18 kg of lead pellets (1-1.5 mm dia.). Contact PASCO for information about calibration or other radioactive sources.

Typical Experiments

1. Measurement of a Gamma-Ray Spectrum and Basic Training in Gamma Spectroscopy
2. The Absorption of Gamma Radiation by Different Materials
3. The Efficiency of the NaI Detector (Measurement of the Activity of a K-40 Solution)
4. The Half-Life of Pb-214
5. Measurement of Cesium Activity (with the Aid of an Efficiency Curve)
6. Measurement of Cesium Activity (simpler method)
7. Compton Scattering
8. X-ray Fluorescence

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.



Showing peaks belonging to a given nuclide from a nuclide library. The nuclides and energies can be stored in an editable ASCII file that can be controlled directly from the software

High-Sensitivity

A sensitive detector provides a resolution of 1 Bq for a 60 mL Cs-137 sample measured over 1 hour (67% confidence level).

Features

Modes: PHA, MCS, and serial collection of several spectra

Smoothing: Adjustable non-destructive smoothing function

Calibration: Energy calibration manually or from data files

Order Information

High-Sensitivity Gamma Spectrometer System SE-9764

Recommended:

Particle Detector SE-9782

Particle Detector

SE-9782



Includes

Detector Unit

Two GDM sample rods including metal grid, mounting for thin film alpha/beta sources, and lead shield

Two frames for absorbers and light shielding case

This particle detector adds alpha beta detection capability to the High-Sensitivity Gamma Spectrometer System.

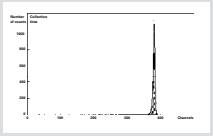
Typical Experiments

1. Stopping Power of Air for Alpha Particles
2. Determination of Thickness of an Aluminum Foil
3. Study of Beta Particles and Conversion Electrons

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

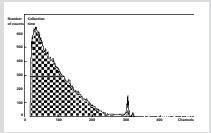
High Resolution

A resolution of <100 keV for 5 MeV alpha particles is obtained without vacuum, using the recommended sources.



Alpha spectrum from a GDM Am-241 source. The source-to-detector distance is about 1 cm.

Beta spectrum from a GDM Cs-137 source



Specifications

Ortec® Ultra silicon detector

Resolution: Alpha <15 keV, beta <7 keV

Panel-mounted switch for alpha or beta mode

Connection: Directly to the Multi-Channel Analyzer of the High-Sensitivity Gamma Spectrometer System.

Order Information

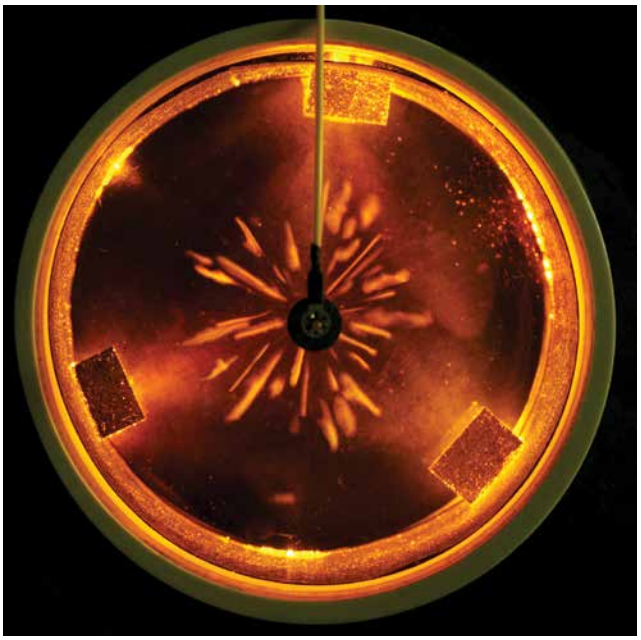
Particle Detector SE-9782

Diffusion Cloud Chamber

SE-7943

- No dry ice required
- View cosmic rays
- Built-in illumination

The Diffusion Cloud Chamber is used to view high energy alpha particles, lower energy beta particles, and electrons produced by gamma rays interacting with gas molecules.





Particle tracks are visible from radioactive particles given off by the Pb-210 source at the center. The dense straight tracks are produced by alpha particles and the fainter, crooked tracks are produced by beta particles.



How It Works

The bottom of the chamber is cooled by circulating ice water through the base and further cooling it to -35°C with a Peltier device. Alcohol placed in the chamber wicks up the inside chamber lining where it evaporates in the warmer region of the chamber and diffuses downward. The alcohol vapor is then cooled near the chamber bottom and becomes super saturated.

As energetic alpha and beta particles from a radioactive source pass through the alcohol vapor, the vapor condenses, forming droplets that appear as tracks in the strong chamber cross-lighting.

Features

Uses ice water instead of dry ice

Water circulation pump

Built-in high voltage (~800 V) power supply for clearing the chamber of unwanted ions

Powered by 12 V DC power adapter

Built-in LED lamps for illuminating the particle trails

Specifications

Diameter: 15 cm

12 VDC Power Adapter (6 A)

Water Circulation Pump: 120 V/ 60 Hz, 3 W, 180 liter/hr

Built-in High Voltage Source: ~800 VDC with 10^8 Ω protection resistor

Rubber Hoses: 0.25" ID (6.4 mm ID), 60 cm long

High Voltage Connection Cable: 22 cm long, Banana plug to ring lug

Eight Amber LEDs

Includes

Cloud Chamber

12 VDC Power Adapter (6 A)

Water Circulation Pump

Two Rubber Hoses

Extraction Pipette

Source Holder and Stopper

High Voltage Connection Cable

SpecTech™ Coupon for Pb-210 Source Needle

Order Information

Diffusion Cloud Chamber	SE-7943
Diffusion Cloud Chamber – No Source	SE-7940

Required:

Ice Water

Recommended:

Pb-210 Replacement Radioactive Needle Source* SE-7945

The Needle Source is USNRC License Exempt (US only).

***Note:** Purchased Sources are "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 384.

G-M Probe with Sample Holder

SN-7970A



The 35 mm diameter window provides excellent photon efficiency for detecting low activity samples. The G-M Probe has a 200 µs dead time. Contains 10 shelf positions and is designed to accommodate the larger G-M Probe. The probe can be removed from the holder and comes with a standard BNC connector cable.

Specifications

Mica Window: ≤ 2 mg/cm^2

Probe Dimensions: 11.25 x 3.5 cm (4.5 x 1.4 in.) OD, excluding connector

Operating Voltage: 900 V, 150 V plateau

Order Information

G-M Probe.....SN-7970A

Radiation Counter

SN-7902 (Win/Mac)



Using a specialized microcontroller, many of the features previously found only in multiple products are now combined in PASCO's Radiation Counter.

The classic nuclear scaler function has been extended to include a timer, preset counter, digital ratemeter with alarm, computer interface, and battery power for field applications. The alarm level may be set to any preselected value.

Features

Preset Scaler/Timer

Large 6-digit LED display

Computer Programs: For Win and Mac computers, LABLINK offers full computer control of all functions including preset count, preset time, count rate in CPM or CPS, alarm level, start, stop, reset, data transfer, and high-voltage setting.

Includes USB Cable

Specifications

High Voltage: 0-1200 V, digitally selectable in 25 V increments

Software:
RADEM: Runs on Win and Mac computers including CGA, EGA, VGA, SVGA, and Hercules
LABLINK: Requires EGA or VGA graphics

Dimensions: 31 x 21 x 12 cm (12 x 8 x 4.5 in.)

Order Information

Radiation Counter, USB.....SN-7902

Nuclear Experiments with a Computer Interface

Geiger-Muller Tube

SN-7927A



A Geiger-Muller Tube is available for use with PASCO interfaces. The Geiger-Muller Tube can also be used with any PASPORT interface with a Digital Adapter. No Digital Adapter is required for use with the 500, 750, or 850. Easy portability makes them ideal alpha, beta, and gamma radiation detectors.

Specifications

Sensitivity: Beta, gamma, alpha

Count Detection: Audio signal

Window Thickness: 1.5 to 2 mg/cm^2, mica

Gas Filling: Neon, Argon, and Halogen

Starting/Operating Voltage for Tube: 450 VDC/500 VDC

Dead Time: 90 µs

Order Information

Geiger-Muller Tube.....SN-7927A

Radioactive Sources and Supplies

The following sources are mounted in 2.5 cm diameter sealed plastic disks. All sources and isotopes on this page are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations. Shown below are the isotopes, activity, half-life, and types of radiation (alpha-α, beta-β, gamma-γ).

Radioactive Sources

SN-8110



***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 384.

1. Po-210	0.1 µCi	138 days	α
2. Sr-90	0.1 µCi	28.6 years	β
3. Co-60	1 µCi	5.27 years	β,γ

Order Information

Radioactive Sources* (set of 3) SN-8110

Radioactive Sources

SN-7972A



***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 384.

1. Po-210	0.1 µCi	138 days	α
2. Sr-90	0.1 µCi	28.6 years	β
3. Tl-204	0.25 µCi	3.78 years	β
4. Co-60	1 µCi	5.27 years	β,γ
5. Cs-137	0.25 µCi	30.2 years	β,γ

Order Information

Radioactive Sources* (set of 5) SN-7972A

Individual Sources



***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 384.

Order Information

Po-210*	0.1 µCi	138 days	α	SN-9085
Sr-90*	0.1 µCi	28.6 years	β	SN-9796
Tl-204*	1 µCi	3.78 years	β	SN-9797
Co-60*	1 µCi	5.27 years	β,γ	SN-9794
Cs-137*	5 µCi	30.2 years	β,γ	SN-9795
Cs-137*	0.25 µCi	30.2 years	β,γ	SN-7942
Tl-204*	0.25 µCi	3.78 years	β	SN-7941

Gamma Sources

SN-7949A



***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 384.

1. Co-60	1 µCi	5.27 years	β,γ
2. Na-22	1 µCi	2.60 years	β+,γ
3. Mn-54	1 µCi	313 days	γ
4. Cs-137	0.25 µCi	30.2 years	β,γ
5. Ba-133	1 µCi	10.5 years	γ
6. Cd-109	1 µCi	464 days	γ
7. Co-57	1 µCi	270 days	γ

8. "UNKNOWN": mixture of Cs-137 and Zn-65 for student testing. Cs-137 is 0.25 µCi or lower.

Order Information

Gamma Sources* (set of 8) SN-7949A

G-M Resolving Time Set

SN-9798



This set is used for determining the resolving time of GM counters. It consists of three half-discs: two of five microcuries of Tl-204, plus a third with no activity. The count-rate of each half-disc plus the blank (to maintain constant geometry) is measured, and then both active half-discs are combined for a measurement with high count-rate. The counting loss is calculated by adding the rates from each half-disc and comparing the result to the count-rate with both.

Order Information

G-M Resolving Time Set* SN-9798

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 384.

Absorbers

SN-8111A



This set of 20 calibrated absorbers includes four lead, two plastic, 10 aluminum sheets, two polyethylene and two aluminum foil absorbers. Absorbers vary in density from 5 mg/cm^2 to 7200 mg/cm^2.

Order Information

Absorbers (set of 20) SN-8111A

Isotope Generator Kit (Barium-137m)

SN-7995A



This Cs-137/Ba-137m Isotope Generator is used to demonstrate the properties of radioactive decay. Based on the original Union Carbide patented design, it offers exceptional performance, ease-of-use, and safe operation.

Each generator contains 10 µCi of Cs-137. The generator can produce up to 1000 small aliquots of the short-lived Ba-137m isotope with a half-life of 2.6 minutes.

Each generator is supplied with 250 mL of eluting solution (0.9% NaCl in 0.04M HCl). The parent isotope Cs-137 with a half-life of 30.1 years beta decays (94.6%) to the metastable state of Ba-137m. This further decays by gamma emission (662 keV) with a half-life of 2.6 min. to the stable Ba-137 element. During elution, the Ba-137m is selectively "milked" from the generator, leaving behind the Cs-137 parent. Regeneration of the Ba-137m occurs as the Cs-137 continues to decay, re-establishing equilibrium in less than 1 hour.

Approximately 30 minutes after elution, the residual activity of the Ba-137m sample has decayed to less than one thousandth of its initial activity, making it safe for disposal. When used with the eluting solution supplied, bleed-through of the parent Cs-137 is less than 50 Bq/mL, affording a long working life. Each kit is supplied with the generator, syringe, tube, 250 mL of solution, and a storage case.

Order Information

Isotope Generator Kit* SN-7995A

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 384.

Planchets

SN-9799

These disposable planchets are useful for holding isotope samples produced by the Isotope Generator.

Order Information

Planchets (100 pack) SN-9799

Experiment List

PASCO Experiments

The following pages present classic experiments in physics performed with PASCO apparatus.

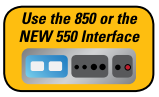
Everything is included in the experiment: apparatus, sensors (when needed), and accessories.

Manuals can be downloaded at www.pasco.com. Interfaces and software, where indicated, should be ordered separately.

Download This Experiment

Each experiment manual and the PASCO Capstone™ workbook files may be downloaded free at **www.pasco.com/CapstoneExperiments**

- Experiment Manual: A detailed experiment manual helps ensure student success. An electronic Word® version is included for modification by the teacher.
- PASCO Capstone Workbook File: PASCO Capstone workbook files are included for each experiment. These files contain workbooks with step-by-step instructions with embedded live data displays. Use these files with students. A file with sample data is also included.



Experiment List	Page No.	PASCO Capstone™ Software: 850 UNIVERSAL INTERFACE	DataStudio® Software: Science Workshop	DataStudio® Software: PASPORT	DataStudio® Software: Xplorer GLX	Interface Not Used
Mechanics						
Atwood's Machine	303	EX-5501				
Projectile Motion	304	EX-5502			EX-9948	
Newton's Laws	305	EX-5503		EX-9941		
Hooke's Law	306	EX-5504		EX-9951		
Centripetal Force on a Pendulum	307	EX-5505A	EX-9974			
Centripetal Force	308	EX-5506	EX-9925	EX-9926		
Motion Graph Matching	309	EX-5507A				
Sliding Friction	310	EX-5508	EX-9938	EX-9939		
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Conservation of Momentum	312	EX-5510A	EX-9901			
Ballistic Pendulum	313	EX-5511A		EX-9959A		
Conservation of Energy	314					EX-9935
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Variable-g Pendulum	324	EX-5519A	EX-9904			
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Electrical Equivalent of Heat	329	EX-5525		EX-9962	EX-9963	
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Ideal Gas Law	331	EX-5527	EX-9950	EX-9954		
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Blackbody Radiation	333	EX-5529A	EX-9920	EX-9971B		
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Magnetic Fields of Coils	347	EX-5540A	EX-9931			
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Waves	350					EX-9952
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Polarization of Light	354	EX-5543A	EX-9917A	EX-9958A		
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Light Intensity vs. Distance	358	EX-5547A				
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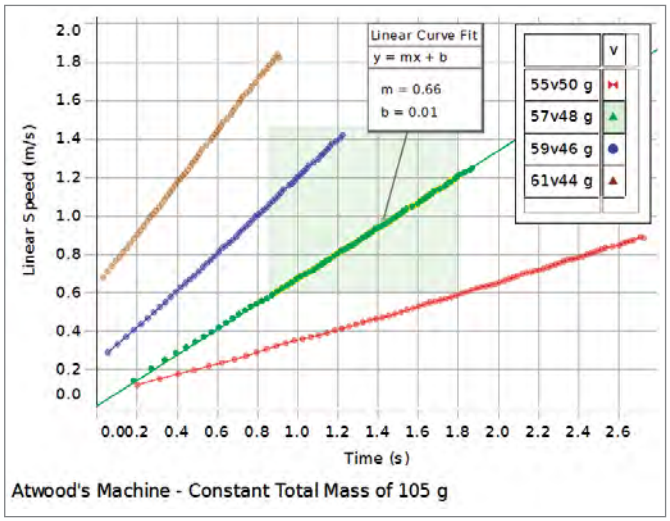
Atwood's Machine

EX-5501

Concepts:

- Newton's Second Law of Motion
- Newton's Second Law of Rotational Motion
- Rotational inertia

In this classic experiment students use a very low mass/low friction pulley and measure the changing velocity of the unbalanced mass system. They interpret the slope of the velocity graph as acceleration. They examine the effect of the rotational inertia of the pulley and estimate the friction forces based on experimental data.



The acceleration of the weights is determined using the slope of the velocity vs. time graph. From this, the acceleration due to gravity can be found.



PASCO Advantage

The Super Pulley/Photogate System makes it easy for students to set up the apparatus and take data. Analysis includes accounting for friction and the rotational inertia of the pulley.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Use the 850 or the NEW 550 Interface

Experiment Includes

Photogate/Pulley System	ME-6838A
Mass and Hanger Set	ME-8979
Universal Table Clamp	ME-9376B
60-cm Long Threaded Rod	ME-8977
Multi Clamp	ME-9507
Braided Physics String	SE-8050

Order Information

Atwood's Machine EX-5501

Required:

550 or 850 Universal Interface		pp. 2-3, 14-17
PASCO Capstone Software		pp. 6-13
Balance or Scale		p. 180
Calipers	SE-8710	p. 176

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces. (Photogates require a Digital Adapter, see page 41.)

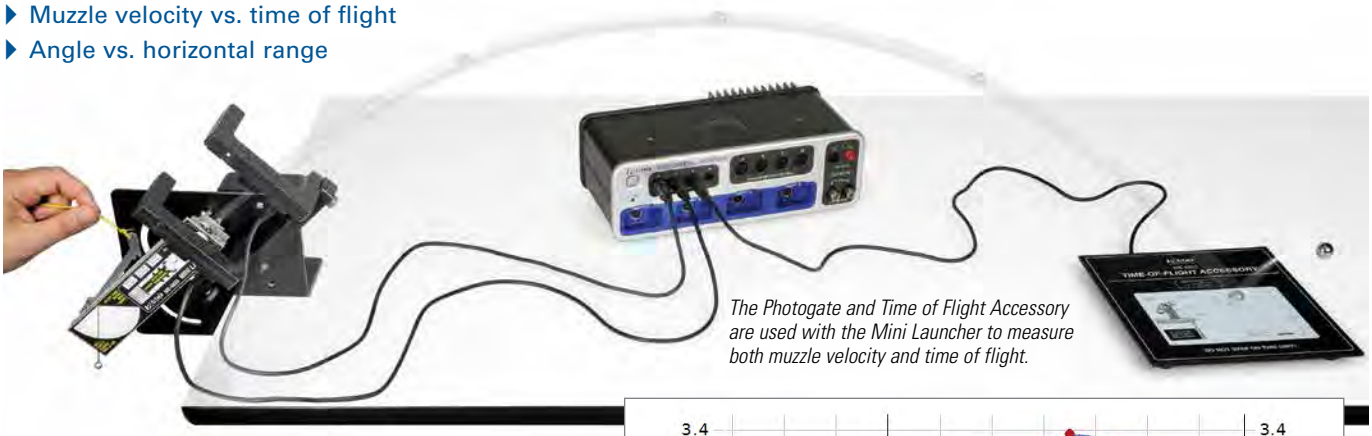
Mechanics

Projectile Motion

EX-5502

Concepts:

- Independence of x- and y-motion
- Muzzle velocity vs. time of flight
- Angle vs. horizontal range



The Photogate and Time of Flight Accessory are used with the Mini Launcher to measure both muzzle velocity and time of flight.

Muzzle Velocity vs. Time of Flight

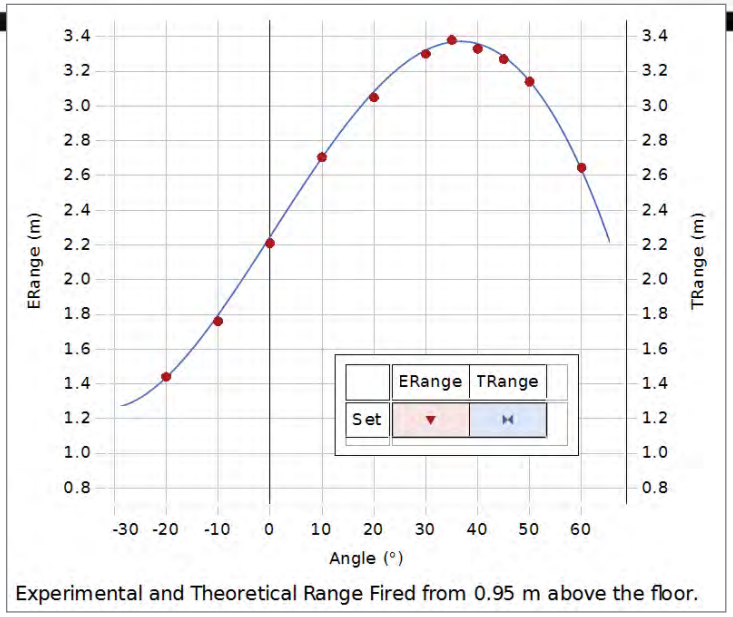
Students fire the projectile at three different velocities from the same height. The Photogate and Time of Flight Accessory are used to measure the time of flight at each muzzle velocity. Students are surprised to find that time of flight is not related to muzzle velocity at 0˚ launch angle.

Angle vs. Horizontal Range

The angle of launch is varied and the horizontal range measured for each angle. Students produce a graph of angle vs. horizontal range. The angle of maximum range can then be found. This experiment is conducted for two cases:

- Projectile is fired from a higher vertical position than its landing position
- Projectile is fired from the same vertical position as its landing position

Students are asked to use the kinematics equations to predict the horizontal range given a launch angle and muzzle velocity. Carbon paper and a bulls-eye can then be used to test their hypothesis.



Students can use their data to determine which launch angle produces the maximum horizontal range.

PASCO Advantage

PASCO projectile launchers are designed for repeatable and accurate launches. In addition, photogates and other accessories are designed to work seamlessly with our projectile launchers. These features allow student predictions and calculations from the kinematics equations to be empirically verified.

Experiment Includes

Mini Launcher	ME-6825A
Time of Flight Accessory	ME-6810
Phone Jack Extender Cable	PI-8117
Photogate Head	ME-9498A
Photogate Bracket	ME-6821A
Carbon Paper	SE-8693
Large "C" Clamp	SE-7285
Plumb Bob (need 1 only)	SE-8728
Metric Measuring Tape	SE-8712A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9948) into the search box at **www.pasco.com**.

Order Information

Projectile Motion EX-5502

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

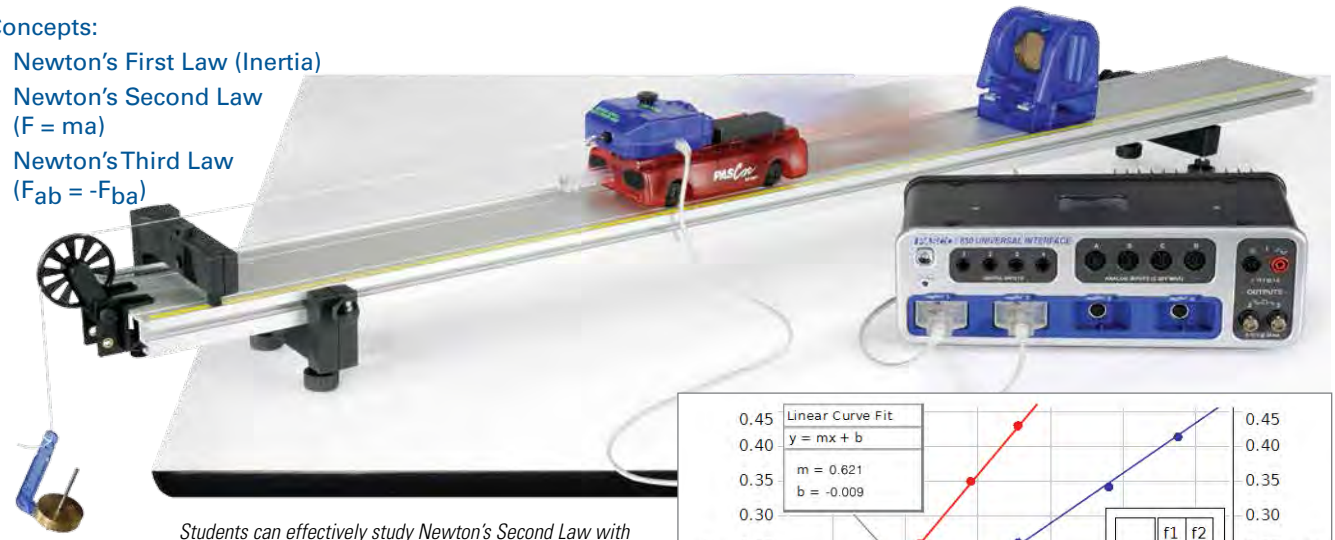
Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces. (Photogates require a Digital Adapter, see page 41.)

Newton's Laws

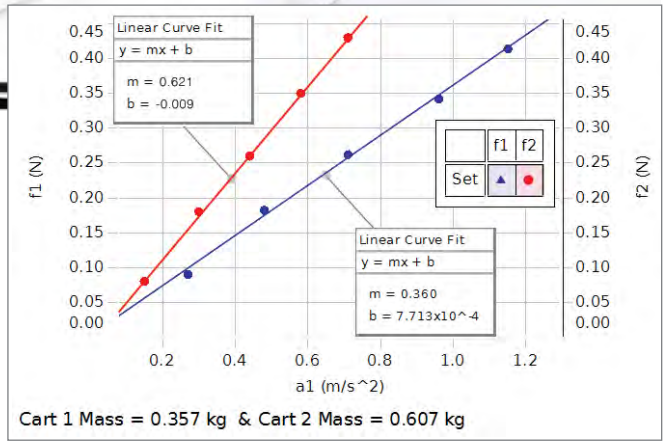
EX-5503

Concepts:

- Newton's First Law (Inertia)
- Newton's Second Law (F = ma)
- Newton's Third Law ($F_{ab} = -F_{ba}$)



Students can effectively study Newton's Second Law with a Dynamics System, Force Sensor, and Motion Sensor.



Cart 1 Mass = 0.357 kg & Cart 2 Mass = 0.607 kg

Force vs. acceleration data for the PAScar as it experiences changing net force

Method

Students use this collection of equipment to discover or experimentally determine all three of Newton's Laws.

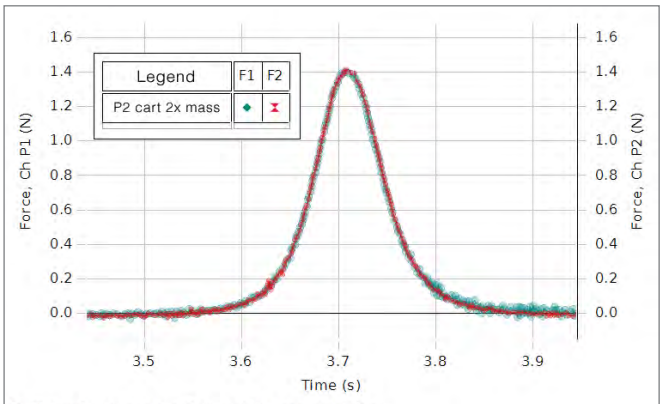
Newton's First Law – Students use a Motion Sensor to collect data for various sliding, rolling, and hovering objects. Using the data and their observations, students better understand that an object's motion will not change unless acted upon by an external net force.

Newton's Second Law – Students use a Force Sensor and Motion Sensor with PASCO's Dynamics System to discover the relationships between force, mass, and acceleration.

Newton's Third Law – Using two Force Sensors, students prove that forces between objects are equal in magnitude yet opposite in direction. These experiments include both tug-of-war exercises and collisions between cars.

PASCO Advantage

Using this set of equipment and probeware, students will better understand all three of Newton's Laws. The integration between the probeware and equipment helps students focus on the physics of each experiment.



Collision between PasCar and 2x mass PasCar

Experiment Includes

PAScar Dynamics System	ME-6955
Motion Sensor	PS-2103A
Hover Puck	SE-7335
Discover Friction Accessory	ME-8574
Physics String	SE-8050
High Resolution Force Sensor (2)	PS-2189
Smart Pulley with Clamp	ME-9448A
Mass and Hanger Set	ME-8979
Magnetic Bumper Set	ME-8979
Magnetic Bumper Set	ME-9885A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9941) into the search box at **www.pasco.com**.

Use the 850 or the NEW 550 Interface

Order Information

Newton's Laws EX-5503

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Mechanics

Hooke's Law and Energy Stored in a Spring

EX-5504A

Concepts:

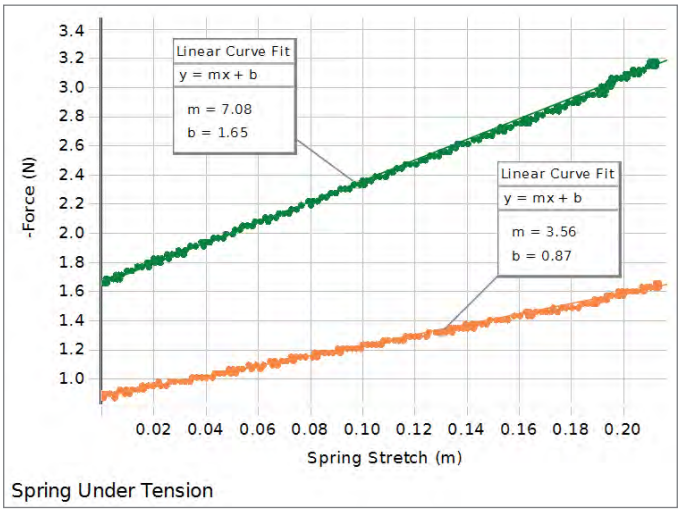
- Relationship between force and spring deformation
- Investigate both spring compression and extension
- Amount of energy stored in a spring

Method

In this experiment, students use a Force Sensor to measure the force exerted to either compress or extend various springs, and a Motion Sensor to measure position and speed.

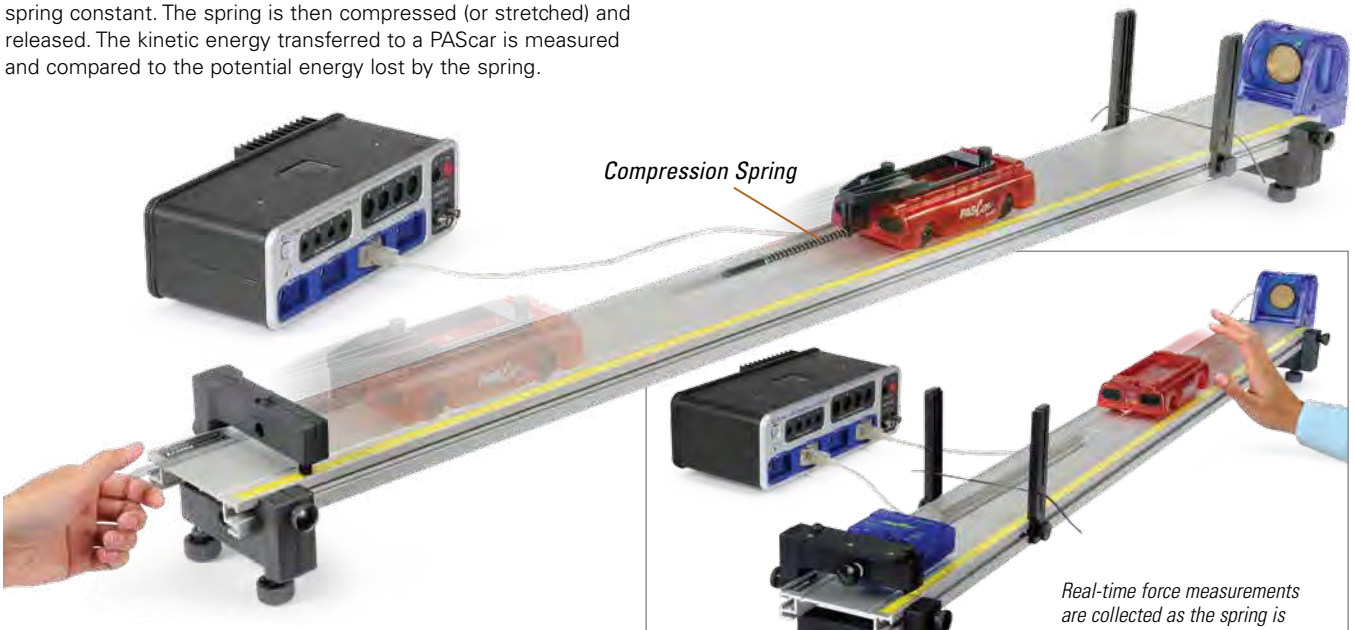
Students create a Force vs. Stretch (or Compression) graph. The slope of this graph is known as the spring constant, while the vertical intercept is the initial loading force.

Various springs of different construction are included, so students can better understand the physical meaning of the spring constant. The spring is then compressed (or stretched) and released. The kinetic energy transferred to a PAScar is measured and compared to the potential energy lost by the spring.



Spring Under Tension

The slope of the Force vs. Stretch graph is known as the spring constant. Various springs of different construction are included, each having a different spring constant.



Real-time force measurements are collected as the spring is stretched and then released.

PASCO Advantage

The Force Sensor allows students to take direct measurements of force for each compression or elongation of the spring. This is superior to using a hanging mass to apply a force, since students don't have to convert from mass to force. In addition, students are applying the forces to the springs and will have a better kinesthetic feel for the amount of force being applied in each case. Energy changes are easily measured and very visual.

Experiment Includes

PAScar Dynamics System	ME-6955
Motion Sensor	PS-2103A
Dynamics Track Spring Set	ME-8999
Force Sensor	PS-2104
Discover Collision Bracket	ME-8973
Spring Cart Launcher	ME-6843
Elastic Bumper	ME-8998
Physics String	SE-8050

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9951) into the search box at **www.pasco.com**.

Order Information

Hooke's Law and Energy Stored in a Spring EX-5504A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13

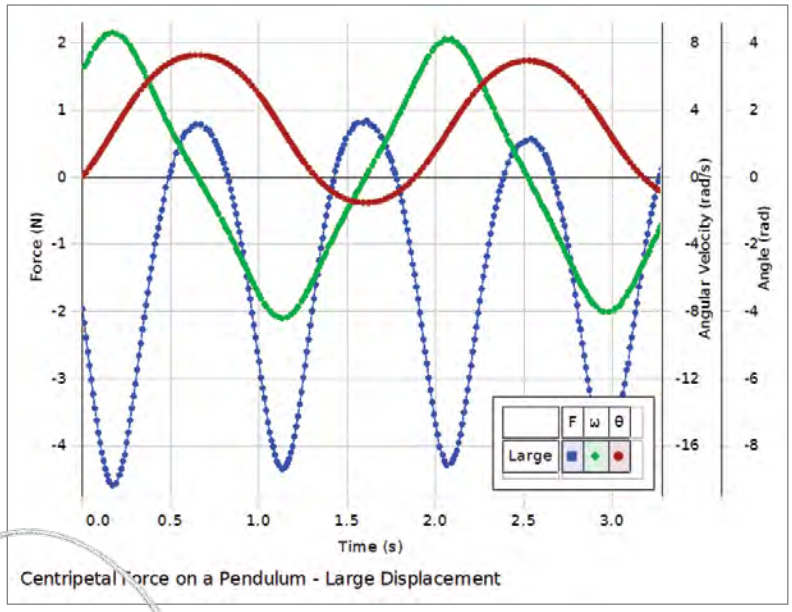
Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Centripetal Force on a Pendulum

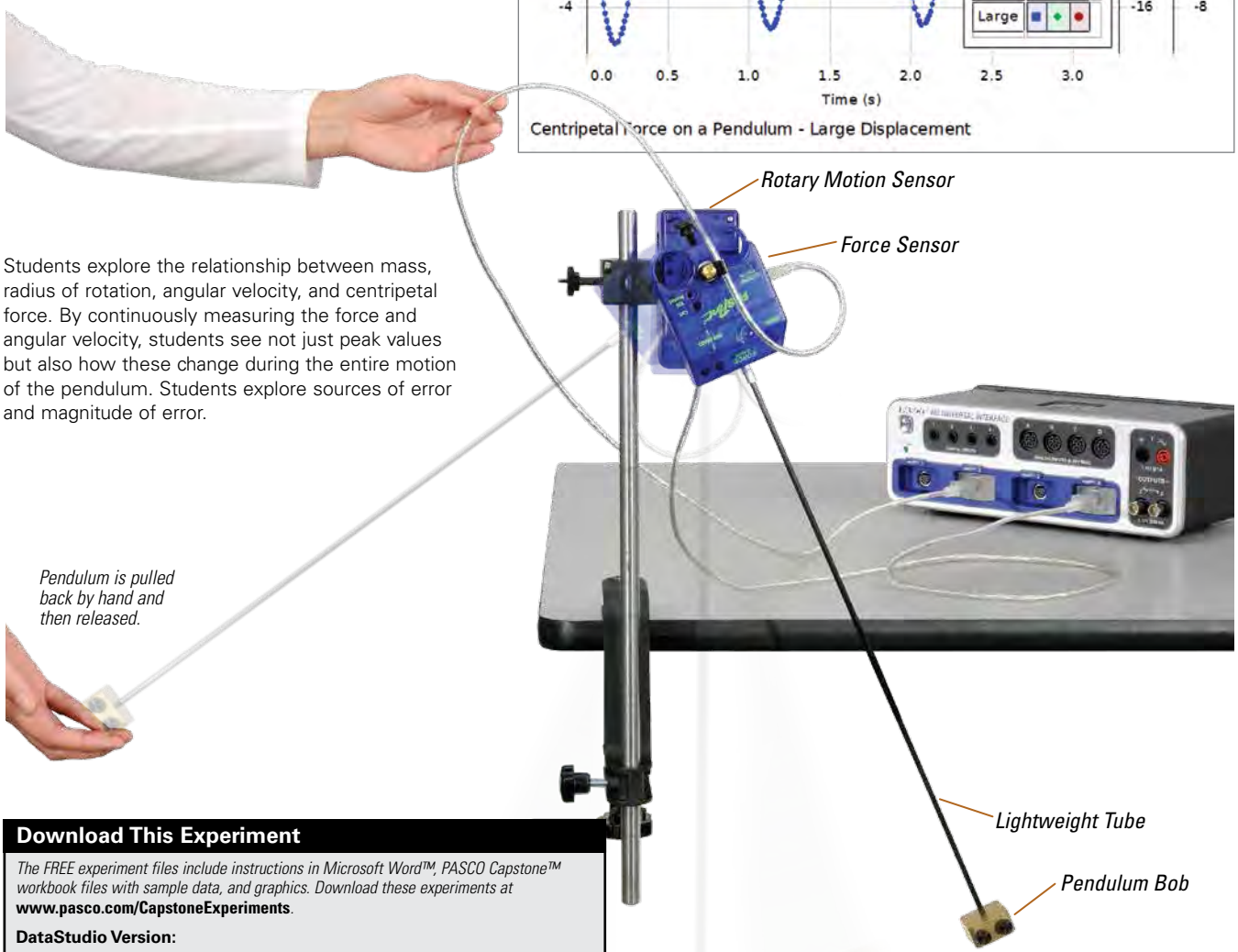
EX-5505A

Concepts:

- Centripetal force
- Angular velocity
- Periodic motion



The force, position, and velocity can be monitored for the entire range of motion. Note that the position and velocity are not sinusoidal for this large amplitude pendulum.



Students explore the relationship between mass, radius of rotation, angular velocity, and centripetal force. By continuously measuring the force and angular velocity, students see not just peak values but also how these change during the entire motion of the pendulum. Students explore sources of error and magnitude of error.

Pendulum is pulled back by hand and then released.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9974) into the search box at **www.pasco.com**.

Experiment Includes

Force Sensor	PS-2104
Rotary Motion Sensor	PS-2120A
Centripetal Force Pendulum	ME-9821
Aluminum Table Clamp	ME-8995
Steel Rod 45 cm	ME-8736

Use the 850 or the NEW 550 Interface

Order Information

Centripetal Force on a Pendulum EX-5505A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13
Balance or Scale ..... p. 180

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Mechanics

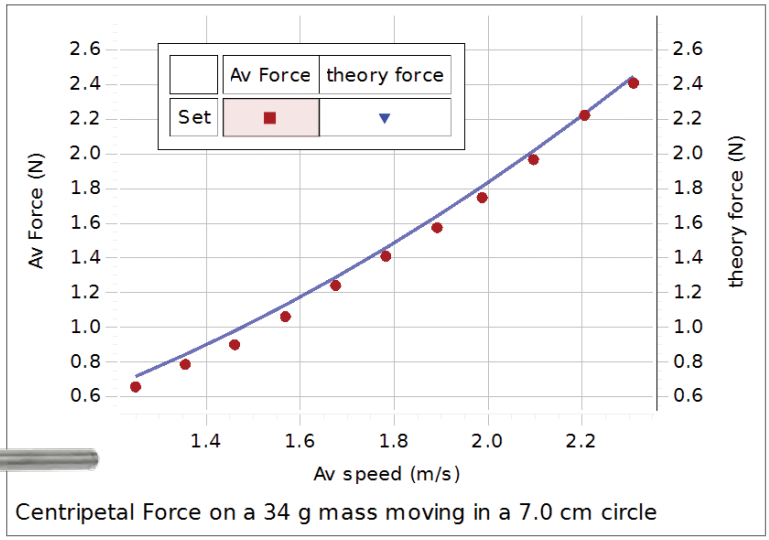
Centripetal Force

EX-5506

Concept:

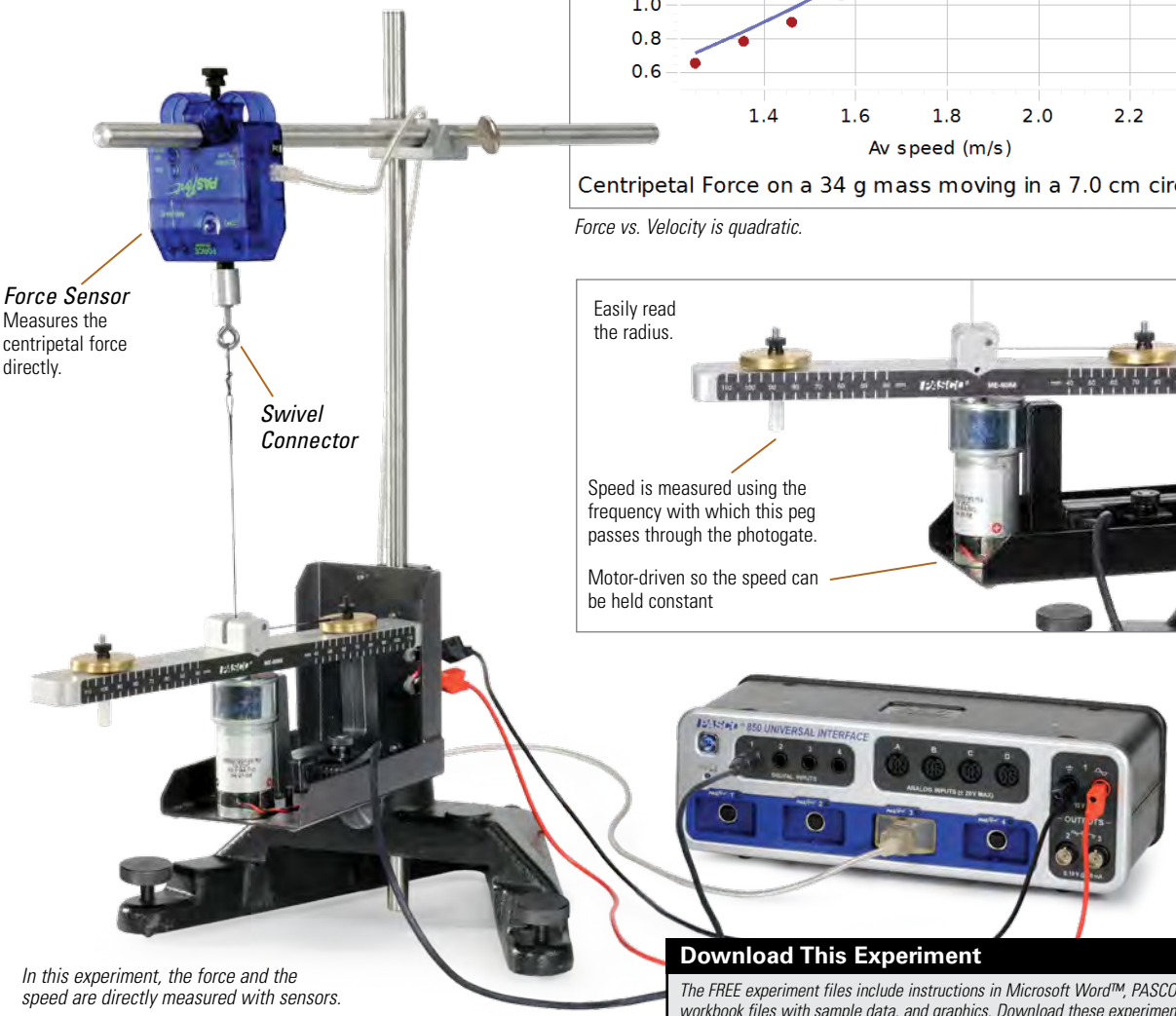
- How centripetal force depends on radius, mass, and speed

Students explore the relationship between mass, radius of rotation, tangential speed, and centripetal force. By continuously measuring the force as the speed is varied, students clearly see the effect of speed on the centripetal force. The effect of changing the mass or radius is also investigated.



Centripetal Force on a 34 g mass moving in a 7.0 cm circle

Force vs. Velocity is quadratic.



In this experiment, the force and the speed are directly measured with sensors.

Experiment Includes

Centripetal Force Apparatus	ME-8088
Force Sensor	PS-2104
Photogate Head	ME-9498A
Large Rod Base	ME-8735
90 cm Steel Rod	ME-8738
Multi-Clamp	ME-9507
45 cm Steel Rod	ME-8736
Banana Plug Cord-Red (5 pack)	SE-9750

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9925 and EX-9926) into the search box at **www.pasco.com**.

Order Information

Centripetal Force EX-5506

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

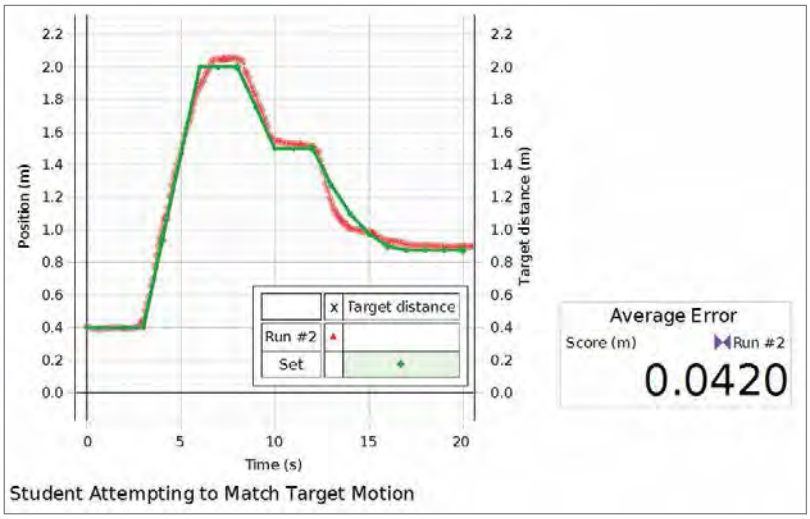
Motion Graph Matching

EX-5507A

Concepts:

- Position vs. time graph
- Velocity vs. time graph
- Meaning of slope and inflection point

Students explore the relationship between their motion walking toward and away from a motion sensor and graphs of position and velocity. They are challenged to match a predetermined graph and explain what the meaning of slope and inflection points on the graph of their movements mean.



Student Attempting to Match Target Motion

On this position versus time graph, the red trace is the motion he is trying to match. He learns to pay attention to the axis values and that the slope reflects the speed. Students have fun trying to minimize the average error, calculated each second during the motion.





Experiment Includes

Motion Sensor	PS-2103A
Motion Sensor Reflector Board	PS-6809

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Motion Graph Matching EX-5507A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Mechanics

Sliding Friction

EX-5508

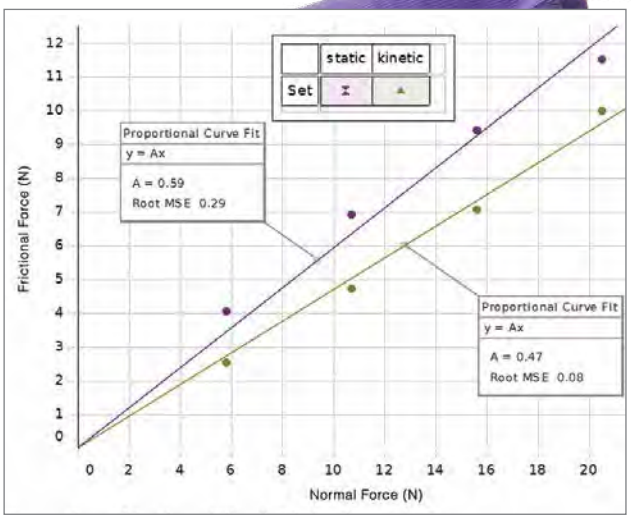
Concepts:

- Relationship between frictional force and normal force
- Coefficients of friction (kinetic and static)

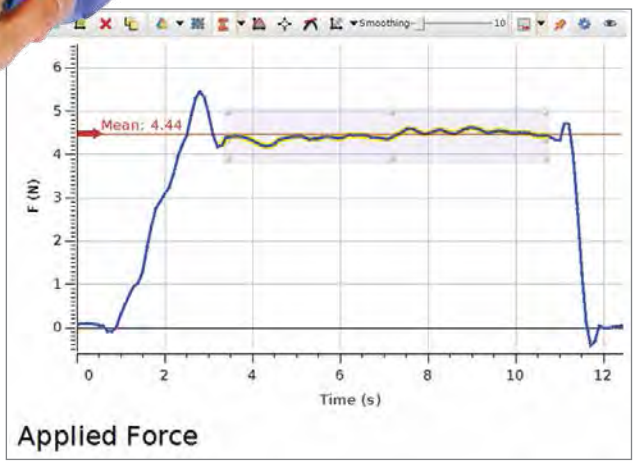


In this experiment, students use a Force Sensor to discover frictional forces and their effect on the motion of an object. In addition, the coefficients of friction for various surface combinations can be empirically determined.

Students pull the friction tray from rest to a constant velocity to measure both static and kinetic friction.



Students create a graph of frictional force vs. normal force to find the coefficients of static and kinetic friction.



The peak of the graph represents the maximum static frictional force. Once the friction tray begins to move, the kinetic frictional force is evident on the graph.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9938 and EX-9939) into the search box at **www.pasco.com**.

Experiment Includes

Discover Friction Accessory	ME-8574
Force Sensor	PS-2104
Motion Sensor	PS-2103A
500 g Cart Masses (4)	ME-6757
Physics String	SE-8050

Use the 850 or the NEW 550 Interface



Order Information

Sliding Friction EX-5508

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Impulse

EX-5509

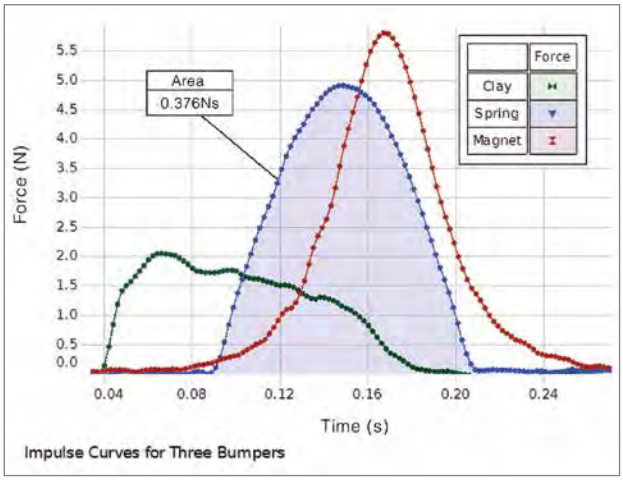
Concepts:

- Impulse: change in momentum
- Impulse: area under a force versus time curve
- Different shaped force curves for elastic and inelastic collisions

In this experiment, the impulse on a cart is determined in two ways: by measuring the change in velocity and by finding the area under a force versus time curve.

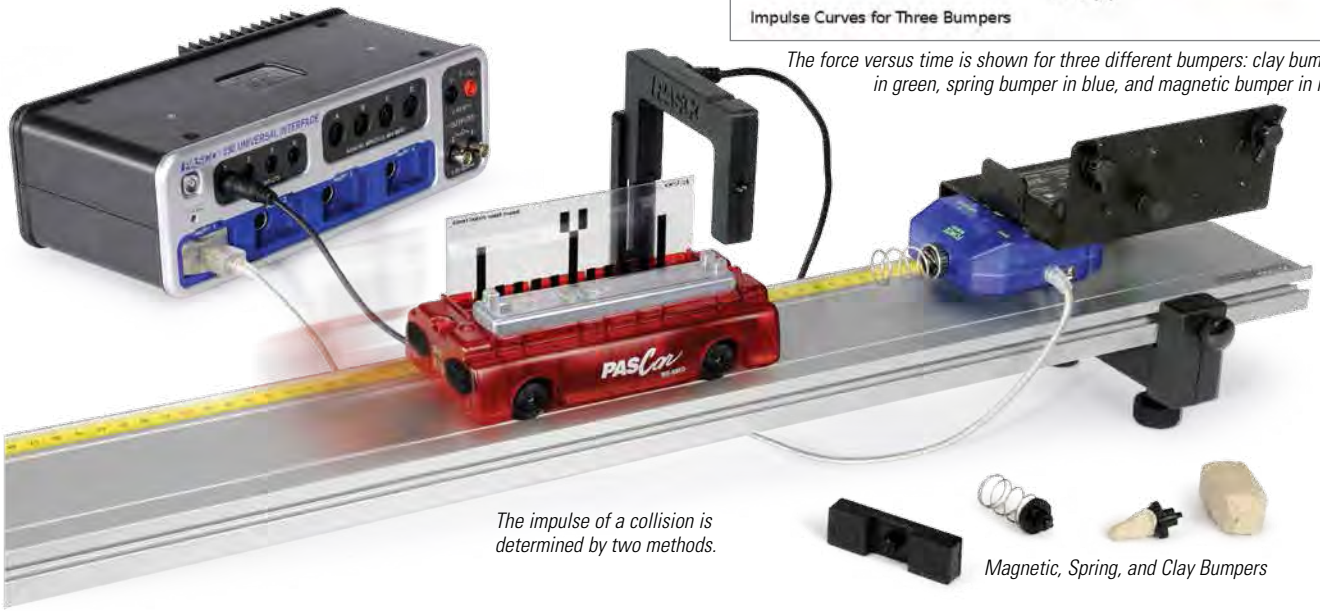
A cart runs down a slightly inclined track and collides with a Force Sensor equipped with either a clay bumper, spring bumper, or magnetic bumper. To determine the change in momentum (impulse), the speeds before and after the collision are recorded with a photogate. The photogate is also used to trigger the beginning of data collection for the Force Sensor. To confirm the impulse, the force versus time is plotted and the impulse is determined by finding the area under the curve.

Different shaped curves of force versus time are obtained for the different bumpers. The spring and magnetic bumpers result in nearly elastic collisions, while the clay produces a completely inelastic collision. The area under the clay force curve is half the area under the spring or magnetic force curves because the cart does not rebound in the clay collision.



Impulse Curves for Three Bumpers

The force versus time is shown for three different bumpers: clay bumper in green, spring bumper in blue, and magnetic bumper in red.



The impulse of a collision is determined by two methods.

Magnetic, Spring, and Clay Bumpers

PASCO Advantage

Since PASCO Capstone™ is capable of having start and stop conditions, force data can be collected at a high rate during the collision, showing the force in great detail without a lot of extraneous data before and after the collision. The data collection starts when the cart passes through the photogate and ends after a set amount of time.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Experiment Includes

1.2 Meter PAScar System	ME-6955
Force Accessory Bracket	CI-6545
IDS Photogate Bracket	ME-9806
Smart Timer Picket Fence (Set of 2)	ME-8933
Photogate Head	ME-9498A
Force Sensor	PS-2104
45 cm Steel Rod	ME-8736
Aluminum Table Clamp	ME-8995

Use the 850 or the NEW 550 Interface



Order Information

Impulse EX-5509

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13
Balance or Scale ..... p. 180

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces. (Photogates require a Digital Adapter, see page 41.)

Mechanics

Conservation of Momentum

EX-5510A

Concepts:

- Conservation of momentum in elastic and inelastic collisions
- Kinetic energy not conserved in inelastic collisions
- Kinetic energy temporarily stored as magnetic potential energy during elastic collisions using magnetic bumpers



Cart velocities are recorded using two Rotary Motion Sensors connected to the carts by string wrapped around pulleys. The moving cart rotates the pulley on the Rotary Motion Sensor, recording the cart's position with a resolution of 0.4 mm.

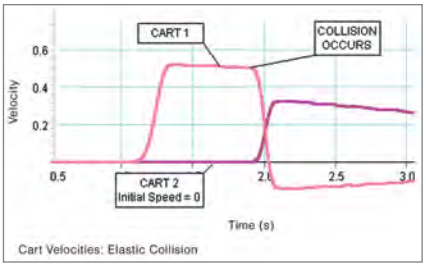
The total momentum and total energy of carts undergoing elastic and inelastic collisions are measured. The values before and after the collisions are compared to verify that momentum is conserved in all collisions, while energy is only conserved in elastic collisions.

Elastic and inelastic collisions are performed with two dynamics carts of different masses. Magnetic bumpers are used in the elastic collision and Velcro® bumpers are used in the completely inelastic collision. In both cases, momentum is conserved.

Cart velocities are recorded using two Rotary Motion Sensors connected to the carts by string wrapped around pulleys. This measurement method adds very little friction to the experiment and, since the velocities are continuously monitored, any deceleration due to friction can be measured.

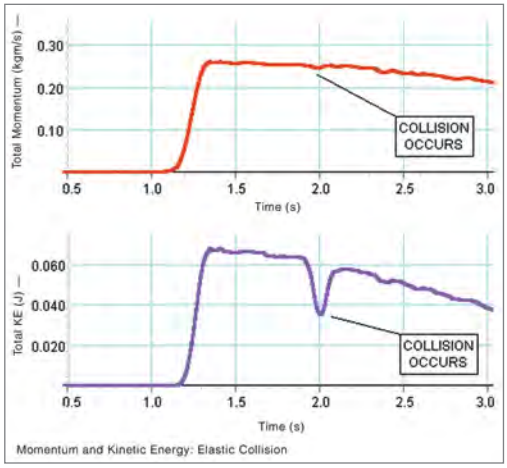
A real-time graph of velocity versus time is obtained for each cart, clearly showing when the collision occurred. This enables the student to determine the cart velocities immediately before and after the collision.

The kinetic energy before and after the collision is also studied. Kinetic energy is not conserved for inelastic collisions. It is also demonstrated that kinetic energy momentarily decreases during the elastic collision and then returns to the original value after the collision.



Cart Velocities: Elastic Collision

A real-time graph of velocity versus time is obtained for each cart, clearly showing when the elastic collision occurred.



Momentum and Kinetic Energy: Elastic Collision

The top graph of the total momentum for the 2-cart system (as calculated in PASCO Capstone™) shows no change throughout the elastic collision. The total kinetic energy, shown in the bottom graph, momentarily decreases during the collision because energy is stored as magnetic potential energy.

PASCO Advantage

The magnitude and direction of the velocity of each cart is recorded continuously throughout the collision, which eliminates the problem in older methods of positioning photogates too close or too far from the point of collision.

Experiment Includes

1.2 m PAScar Dynamics System	ME-6955
Dynamics Track Mount (2)	CI-6692
RMS/IDS Adapters (2)	ME-6569
Rotary Motion Sensors (2)	PS-2120A

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9901) into the search box at **www.pasco.com**.

Order Information

Conservation of Momentum EX-5510A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13
Balance or Scale ..... p. 180

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Ballistic Pendulum

EX-5511A

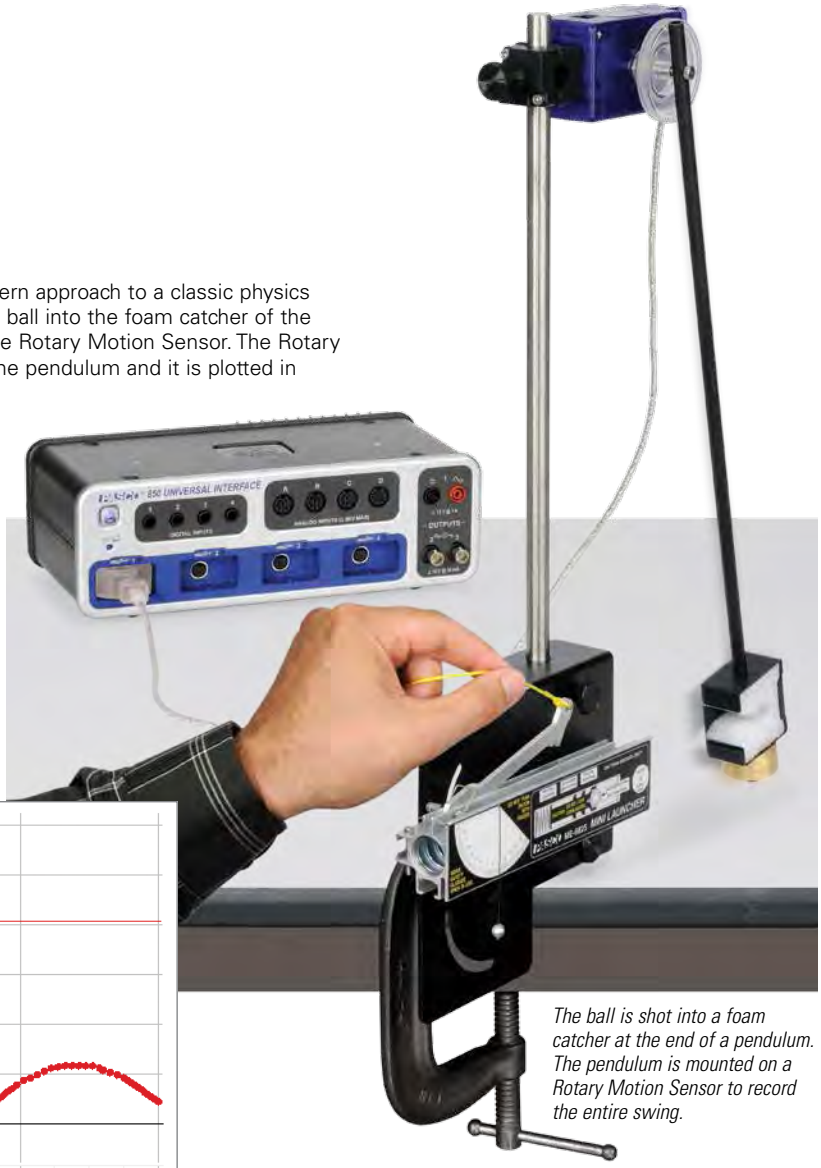
Concepts:

- Modern approach to a classic experiment
- View graph of entire pendulum swing
- Conservation of momentum
- Conservation of energy

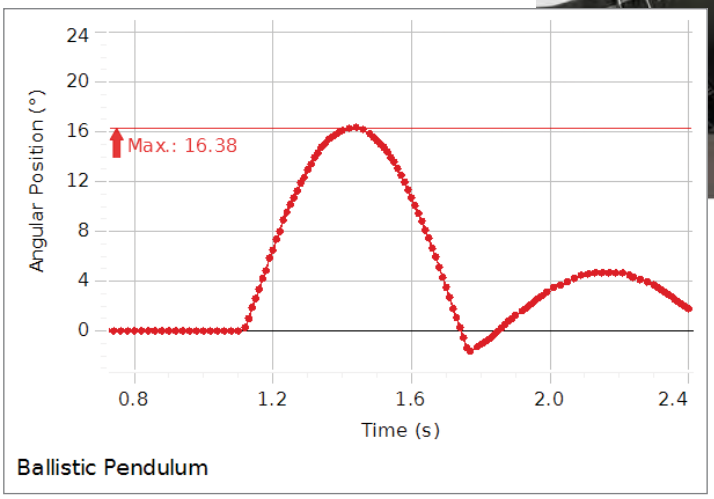
PASCO's Rotary Motion Sensor is the heart of this modern approach to a classic physics experiment. The Mini Launcher (ME-6825A) fires a steel ball into the foam catcher of the Ballistic Pendulum Accessory (ME-6829) mounted on the Rotary Motion Sensor. The Rotary Motion Sensor measures the angular displacement of the pendulum and it is plotted in real-time in PASCO Capstone™.

There is no need to catch the pendulum at its maximum height because the angle is continuously measured. Using the analysis tools in PASCO Capstone, students can find the maximum angle.

Using Conservation of Momentum and Conservation of Energy, students can determine the initial speed of the ball as it leaves the projectile launcher. The initial speed of the ball is confirmed by using two photogates to time the flight of the ball for a short distance.



The ball is shot into a foam catcher at the end of a pendulum. The pendulum is mounted on a Rotary Motion Sensor to record the entire swing.



This graph of the angle of the pendulum versus time is plotted in real-time in PASCO Capstone™. The maximum angle is displayed on the graph.

Experiment Includes

Rotary Motion Sensor	PS-2120A
Mini Launcher	ME-6825A
Photogate Heads (2)	ME-9498A
Photogate Mounting Bracket	ME-6821A
Mini Launcher Ballistic Pendulum	ME-6829
Large "C" Clamp	SE-7285
45 cm Steel Rod	ME-8736

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9959A) into the search box at **www.pasco.com**.

Order Information

Ballistic Pendulum EX-5511A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Mechanics

Conservation of Energy

EX-9935

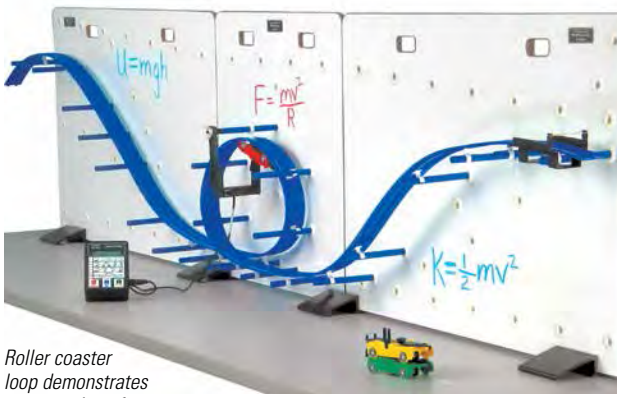
Concepts:

- Conservation of energy
- Centripetal acceleration
- Apparent weight

In this experiment, the Law of Conservation of Energy is verified by measuring the potential and kinetic energies for a car traveling over hills and loops on a curved track.

A car is started from rest on a variety of tracks (hills, valleys, loops, straight track). The speed of the car is measured at various points along the track using a photogate connected to a Smart Timer. The potential energy is calculated from the measured height and the kinetic energy is calculated from the speed. The total energy is calculated for two points on the track and compared.

The height from which the car must be released from rest to just make it over the loop can be predicted from conservation of energy and the centripetal acceleration. Then the prediction can be tested on the roller coaster. If the car is released from the top of the hill so it easily makes it over the top of the loop, the speed of the car can be measured at the top of the loop and the centripetal acceleration as well as the apparent weight (normal force) on the car can be calculated.



Roller coaster loop demonstrates conservation of energy.

Experiment Includes

Complete Roller Coaster System	ME-9812
Photogate Heads (2)	ME-9498A
Smart Timer	ME-8930
Conservation of Energy Experiment Manual	

PASCO Advantage

The Roller Coaster can be configured in many ways. The white board background is convenient for writing calculations or making marks for measuring heights. The PASCO Roller Coaster differs from conventional roller coaster toys in three ways:

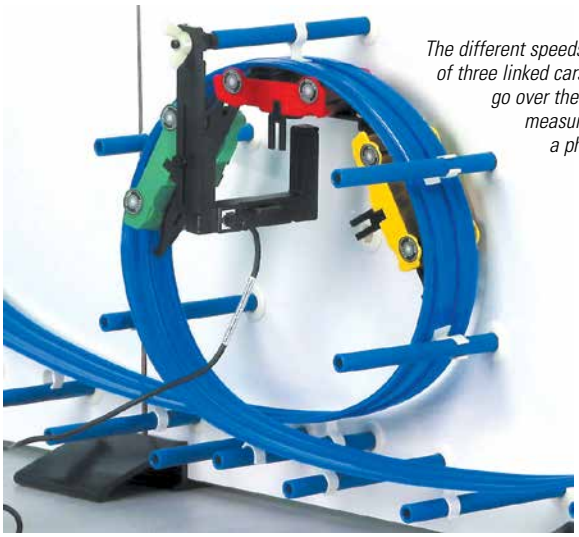
- Speed and height of the Roller Coaster car can be easily measured
- Loss of energy due to friction is generally only about 5%
- Cars will withstand repeated drops to the floor



Conservation of energy for a car going over hills



Conservation of energy shows that the final speeds of these two cars are the same even though the red car takes much less time than the yellow car to reach the end of the track.



The different speeds of each of three linked cars as they go over the loop are measured using a photogate.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Conservation of Energy EX-9935

Conservation of Energy II

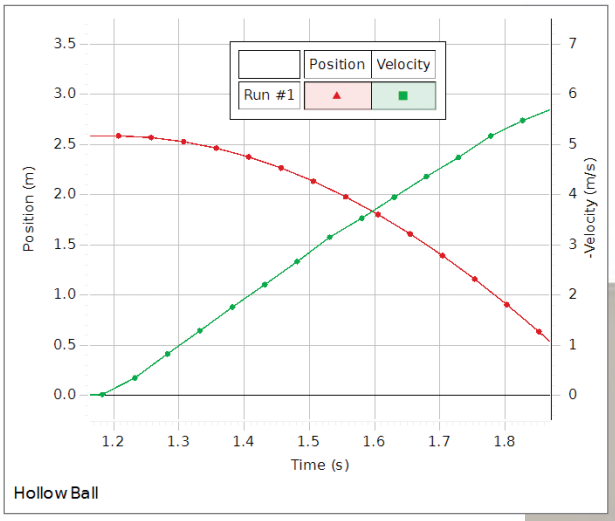
EX-5512

Concepts:

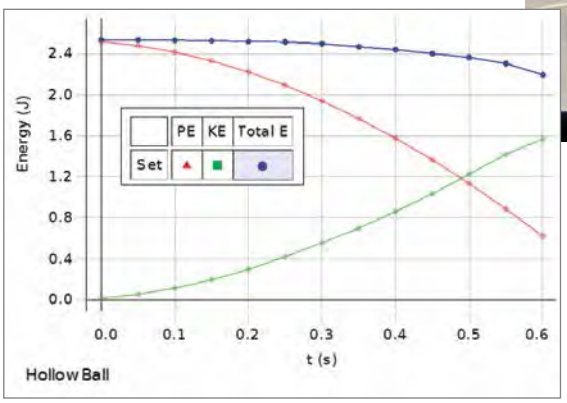
- Potential energy of a falling ball
- Kinetic energy of a falling ball
- Use different size balls to change friction

A ball is dropped from rest and its height and speed are recorded using a Motion Sensor. The ball's potential energy and kinetic energy are calculated at various points during the ball's fall.

The total energy of the ball is examined throughout the fall to determine if there is any change. Balls of different sizes are used to vary the amount of air friction, so that students can see that energy is not conserved when friction is appreciable.



As the ball falls, its height and speed are recorded and displayed in PASCO Capstone™ Software.



The height and speed of the ball at various points during the fall are used to calculate the potential energy and the kinetic energy. Note decrease in total energy for hollow ball near end of fall.



Experiment Includes

Motion Sensor	PS-2103A
Discover Freefall System	ME-9889
Large Rod Base	ME-8735
120 cm Rod	ME-8741
Multi Clamp	ME-9507
45 cm Rod	ME-8736
Motion Sensor Guard	SE-7256

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9961) into the search box at **www.pasco.com**.

Order Information

Conservation of Energy II EX-5512

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces. (Photogates require a Digital Adapter, see page 41.)

Mechanics

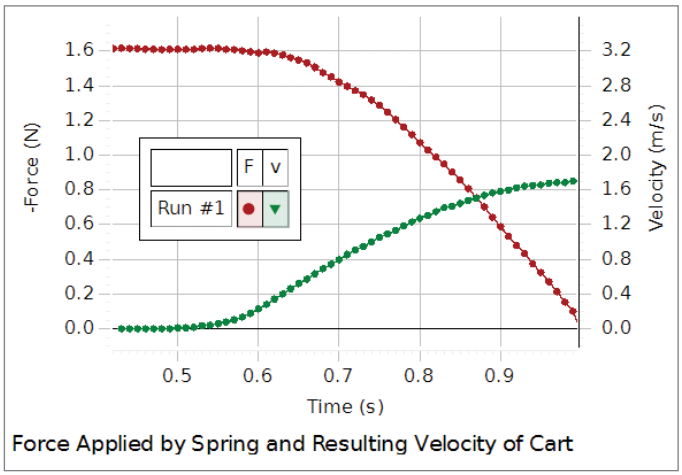
Work Energy Theorem

EX-5513A

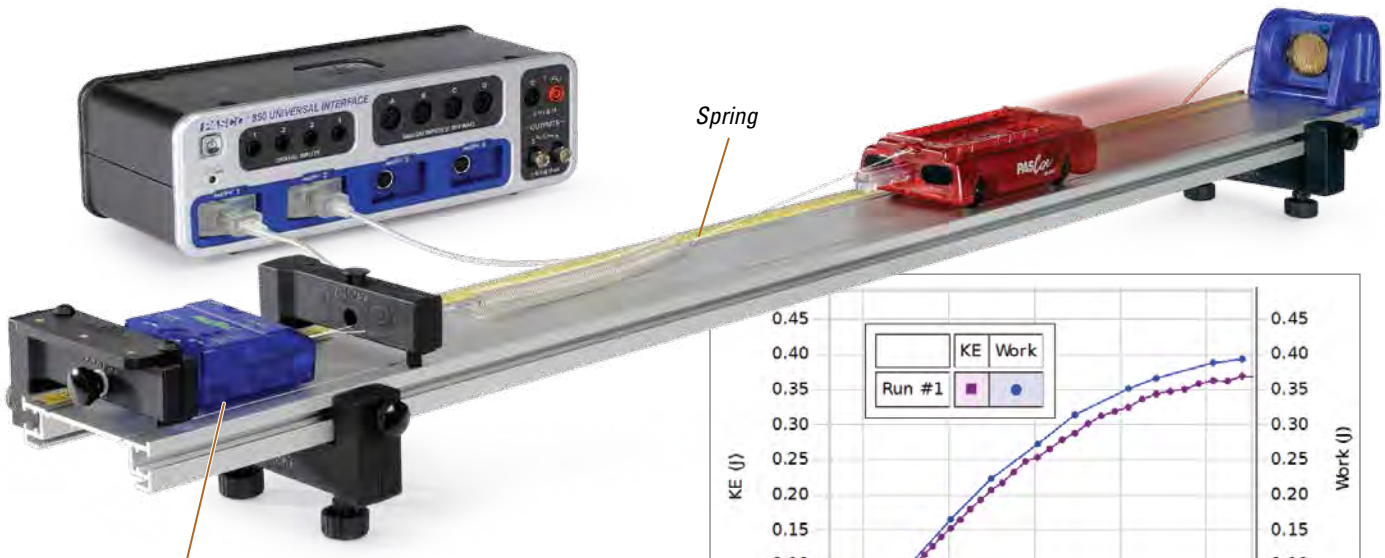
Concepts:

- Kinetic energy
- Potential energy
- Work energy theorem
- Conservation of mechanical energy

The total work done on an object is compared with the change in kinetic energy of the object. Using a Force Sensor and a Motion Sensor, students record and display the force as a function of position. The work done is the area under the force vs. position plot. At any point during the experiment, kinetic energy is calculated from the velocity measured with the Motion Sensor. Students explore the meaning of dissipative forces.



Force Applied by Spring and Resulting Velocity of Cart



Force Sensor
measures the force exerted by the spring on the cart.

Work done by friction and ignoring the rotational kinetic energy of the wheels cause the cart kinetic energy to be approximately 5% low.

Work done by a spring vs Kinetic Energy gained by cart.

PASCO Advantage

Instead of just focusing on the end points, real-time measurements of force, position, and velocity allow students to continuously examine the work done and the resulting kinetic energy of the cart during its entire trip down the track.

Experiment Includes

High Resolution Force Sensor	PS-2189
1.2 m PASCar Dynamics System	ME-6955
Motion Sensor	PS-2103A
Discover Collision Bracket	ME-8973
Dynamics Track Spring Set	ME-8999
Braided Physics String	SE-8050

Use the 850 or the NEW 550 Interface

Order Information

Work Energy Theorem EX-5513A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13
Balance or Scale ..... p. 180

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

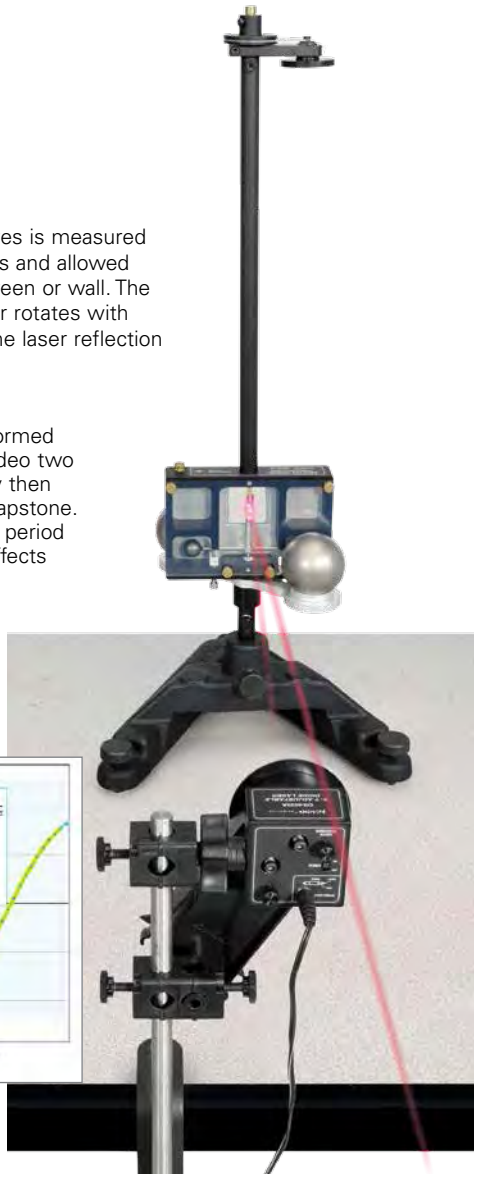
Universal Gravitational Constant

EX-5550

Concepts:

- Measure the Universal Gravitational Constant in less than three hours!
- Recreate Cavendish's historical experiment
- Uses PASCO Capstone Video Analysis

The attraction between a pair of small tungsten spheres and a pair of larger tungsten spheres is measured by the torsion of a beryllium ribbon. The large spheres are placed close to the small spheres and allowed to equilibrate. A laser is reflected from a mirror on the beryllium ribbon and shown on a screen or wall. The large spheres are then rotated through an angle to produce torque on the ribbon. The mirror rotates with the ribbon, so the laser reflection on the screen or wall is displaced. The displacement of the laser reflection is measured to find "G".

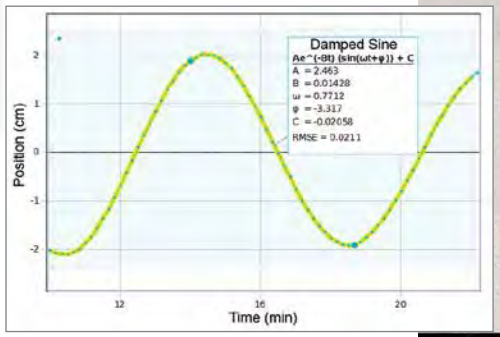


PASCO Advantage

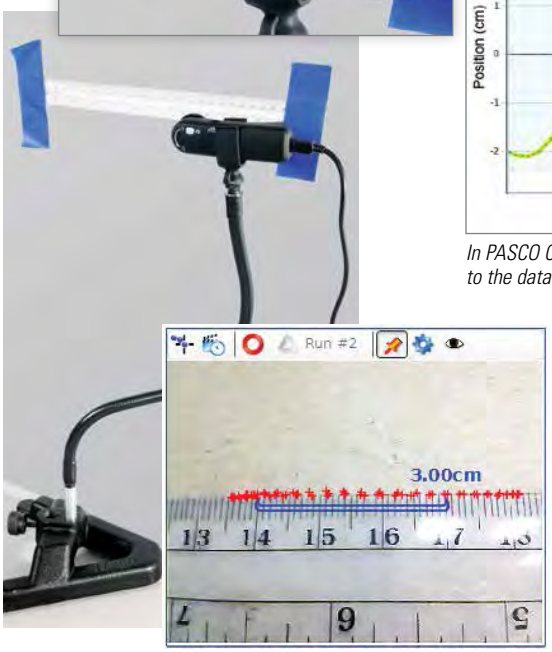
For the first time, the measurement of G using the Cavendish Balance can actually be performed in a 3-hour lower division physics laboratory! Data collection is done using a webcam to video two periods of the oscillation for both ball positions in less than 45 minutes. The video data may then be transferred to the lab groups for analysis using the video analysis capability of PASCO Capstone. Fitting a damped sine curve to the video data allows an extremely precise determination of period of oscillation and where the final equilibrium positions would be. When analysis of small effects inherent in the method is included, an accuracy of better than 2% is possible.



At left, the USB Camera Microscope records the oscillation of the laser beam.



In PASCO Capstone, a damped sine fit is applied to the data to determine the equilibrium point.



This is a screenshot of the video analysis points (red plus signs) in PASCO Capstone.

Experiment Includes

Gravitational Torsion Balance	AP-8215A
X-Y Adjustable Diode Laser	OS-8526A
Large Rod Base	ME-9735
USB Camera Microscope	PS-2343
Polarizer Set	OS-8473
Digital Calipers	SE-8710
Rods and Clamps	

Needed but not included:

Transparent ruler and Meter Stick

PASCO Capstone See pages 6-7

NOTE: *No interface is required.*

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Universal Gravitational Constant	EX-5550
Gravitational Torsion Balance Replacement Spheres	AP-8219

Mechanics

Archimedes' Principle

EX-9909

Concepts:

- Archimedes' Principle
- Density
- Buoyant force

Archimedes' Principle states that the buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object.

The buoyant force on several objects is measured by weighing the water displaced by a submerged object. The buoyant force is also determined by measuring the difference between the object's weight in air and its apparent weight in water.

Some of the objects have the same density, some have the same volume, and some have the same mass. The density of each object is measured and the dependence of the buoyant force on density, mass, and volume is explored.



The buoyant force is measured by weighing the water displaced by the object.





The mass and volume are measured to determine the dependence of the buoyant force on mass, volume, and density.

Experiment Includes

Density Set	ME-8569
Overflow Can	SE-8568
Rod Base	ME-8735
45 cm Steel Rod	ME-8736
Physics String	SE-8050
Triple-Beam Balance	SE-8707
Stainless Steel Calipers	SF-8711
1000 ml Beaker	
100 ml Beaker	
50 ml Graduated Cylinder	
Archimedes' Principle Experiment Manual	

PASCO Advantage

The provided objects have related volumes, masses, and densities to demonstrate that only the volume of water displaced affects the buoyant force.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Archimedes' Principle EX-9909

Materials Stress Strain

EX-5515A

Concepts:

- Stress
- Strain
- Young's Modulus
- Yield Point



Method

In this experiment, students test a variety of materials by stretching them until failure under the tensile load. The sample is placed in the holder and firmly held on both ends. By turning the hand crank, the sample is stretched in one dimension. During the stretching, the Force Sensor measures the applied force through the 5 to 1 lever arm. This allows the maximum allowable force in the experiment to be 250 N. Simultaneously, the Rotary Motion Sensor measures the stretch of the sample real-time. Using PASCO Capstone™ software, the stress and strain can be calculated and graphed versus one another. The slope of the stress-strain graph in the elastic region is known as Young's Modulus. The transition between elastic and plastic deformation is known as the Yield Point; this point can be easily determined from the PASCO Capstone graph.

PASCO Advantage

Students experience the tensile failure of various materials and collect critical measurements real-time with PASCO probeware. PASCO Capstone graphs and calculations are created to extend student understanding of materials science. The compact size of the Stress-Strain Apparatus makes it ideal for any laboratory or classroom setting.

Included Test Coupons

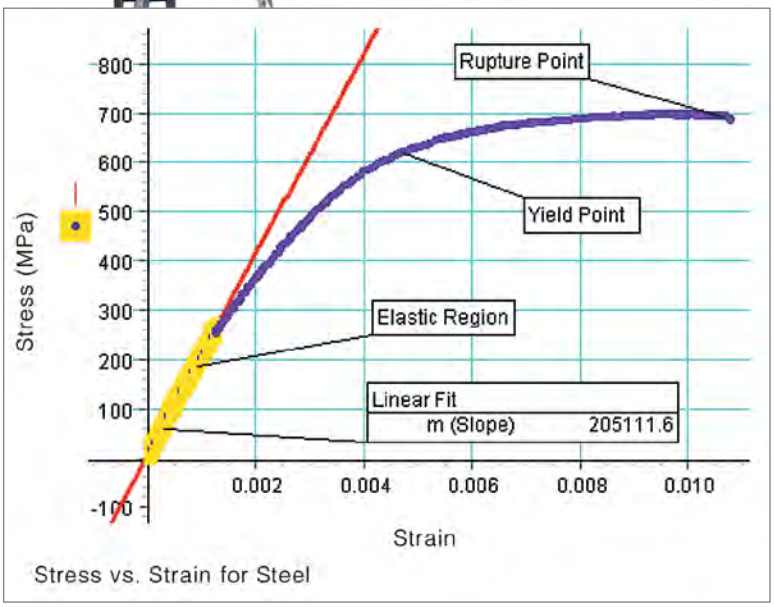
The set of test coupons included with the Stress/Strain Apparatus contains: steel, annealed steel, aluminum, two thicknesses of brass, and four different types of plastic. Ten test coupons of each material come with the unit.



Plastic Coupons



Metal Coupons



Young's Modulus for steel is determined using a linear curve fit on the elastic portion of the curve.

Experiment Includes

Stress-Strain Apparatus	AP-8214A
Force Sensor	PS-2104
Rotary Motion Sensor	PS-2120A
Calipers	SF-8711

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9928A) into the search box at **www.pasco.com**.

Order Information

Materials Stress-Strain EX-5515A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Mechanics

Rotational Inertia

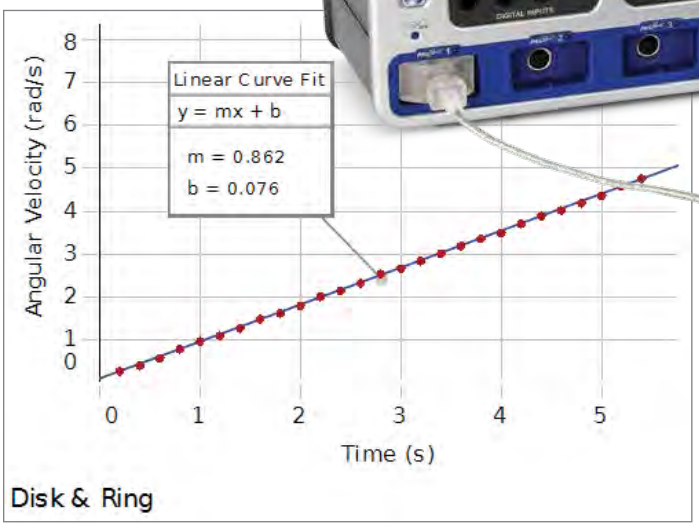
EX-5516A

Concepts:

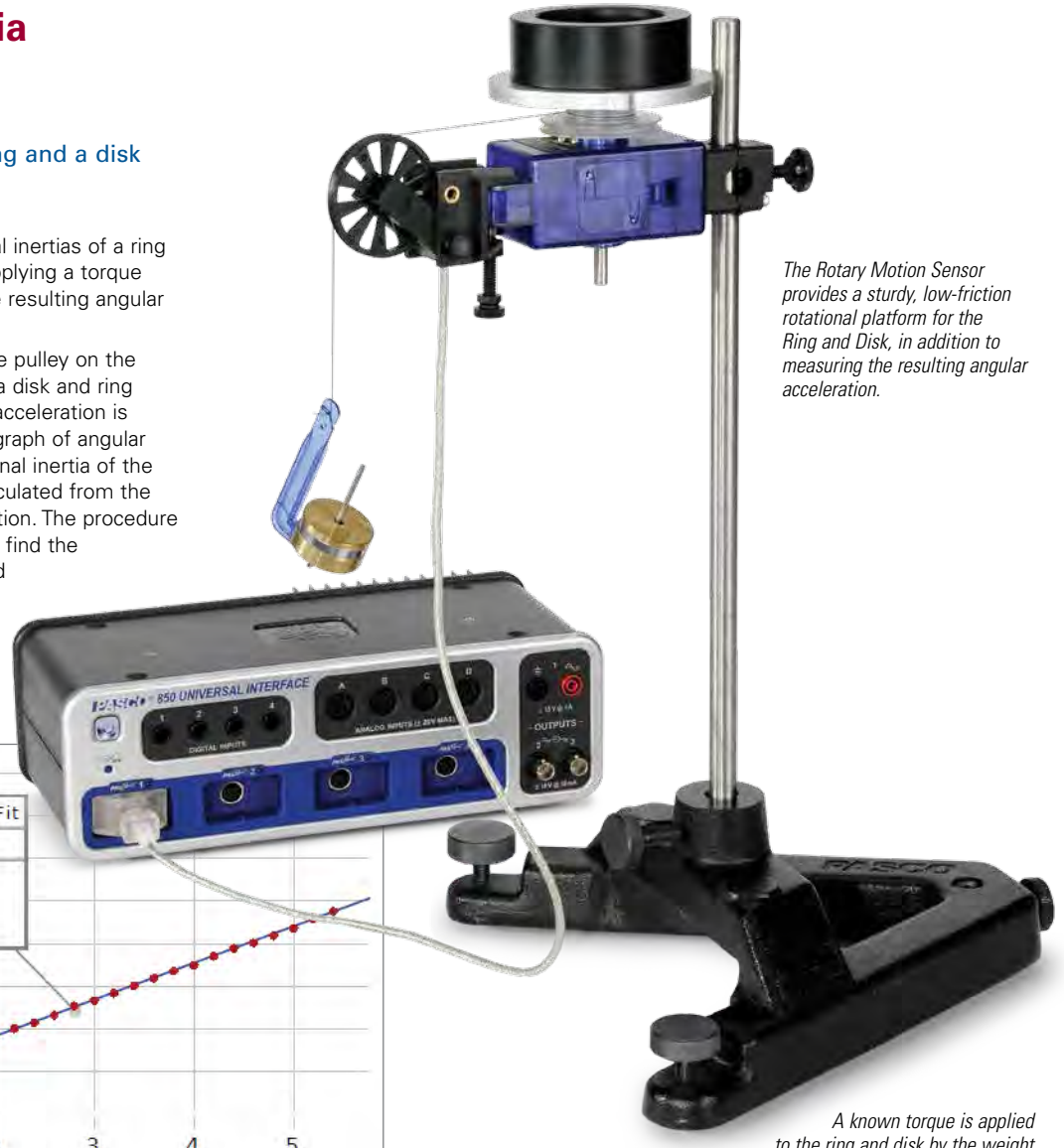
- Rotational inertia of a ring and a disk
- Torque

In this experiment, the rotational inertias of a ring and a disk are determined by applying a torque to the object and measuring the resulting angular acceleration.

A known torque is applied to the pulley on the Rotary Motion Sensor, causing a disk and ring to rotate. The resulting angular acceleration is measured using the slope of a graph of angular velocity versus time. The rotational inertia of the disk and ring combination is calculated from the torque and the angular acceleration. The procedure is repeated for the disk alone to find the rotational inertias of the ring and disk separately.



The rotational inertia of the ring and disk is calculated from the angular acceleration obtained from the slope of this angular velocity versus time graph.



The Rotary Motion Sensor provides a sturdy, low-friction rotational platform for the Ring and Disk, in addition to measuring the resulting angular acceleration.

A known torque is applied to the ring and disk by the weight hanging over the pulley. The rotational inertia of the ring and disk are determined from the resulting angular acceleration. The procedure is repeated for the disk alone.

Experiment Includes

Large Rod Stand	ME-8735
90 cm Long Steel Rod	ME-8738
Mini-Rotational Accessory	CI-6691
Mass Set (5 g resolution)	ME-8979
Rotary Motion Sensor	PS-2120A

PASCO Advantage

Friction can be neglected in this compact setup. The Rotary Motion Sensor is a versatile tool that can be used in a variety of other experiments.

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9936 and EX-9942A) into the search box at **www.pasco.com**.

Order Information

Rotational Inertia EX-5516A

Required:

550 or 850 Universal Interface		pp. 2-3, 14-17
PASCO Capstone Software		pp. 6-13
Balance or Scale		p. 180
Calipers	SE-8710	p. 176

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Physical Pendulum

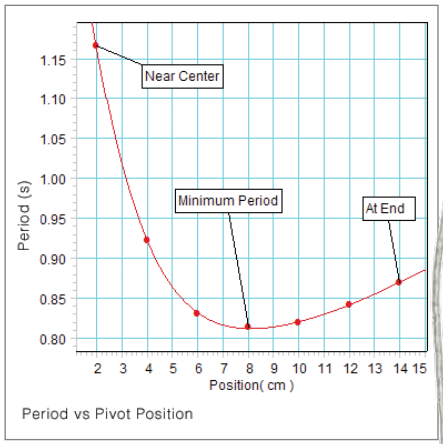
EX-5518A

Concepts:

- Parallel Axis Theorem
- Period of a physical pendulum
- Computer modeling of a system
- Rotational inertia

In this experiment, the period of a physical pendulum, a narrow bar, is determined as a function of the distance of the pivot from the center of mass. A computer model of the system is developed, which allows the student to vary the physical parameters of the model (gravity, length, c.m. position) to match the data. This makes it possible to obtain values for the physical parameters without direct measurement.

A second experiment verifies the parallel axis theorem. It also uses superposition to find the rotational inertia of a disk with an off axis circular hole.



The Pendulum Bar has holes spaced at 2 cm intervals. A graph of oscillation period vs. pivot hole position shows that there is a unique placement that gives a minimum period. This location can be verified using calculus.







Apply a known torque and measure the angular acceleration to calculate the moment of inertia of the object. Multiple holes in the plate allow investigation of the Parallel Axis Theorem.



Unique design allows pivot exactly at the edge. Measure the period of the thick ring oscillating at either the inner or outer radius.



Experiment Includes

Large Rod Stand	ME-8735
45 cm Long Steel Rod	ME-8736
Physical Pendulum Set	ME-9833
Rotary Motion Sensor	PS-2120A

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Physical Pendulum EX-5518A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Mechanics

Conservation of Angular Momentum

EX-5517A

Concepts:

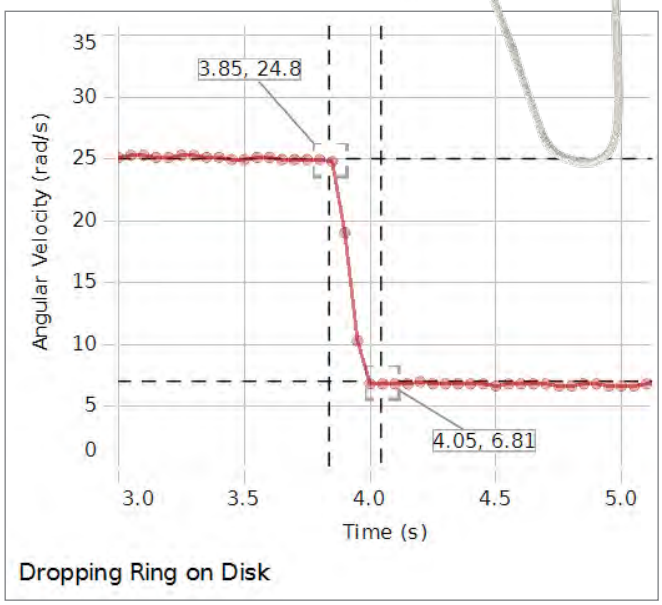
- Conservation of angular momentum during collisions
- Easy determination of before and after points
- Calculation of energy lost during collision

The study of conservation of angular momentum during collisions is easy and fast using this system based on the Rotary Motion Sensor. The angular velocity of the spinning disk is graphed in real-time as a non-rotating ring is dropped onto it.



The Rotary Motion Sensor provides a sturdy, low-friction rotational platform for the Ring and Disk, in addition to measuring the resulting change in angular velocity.

As a non-rotating ring is dropped onto a rotating disk, the angular velocity decreases to about 1/6th of its initial value since the ring has a large rotational inertia compared to the disk.



PASCO Advantage

It is easy to measure the rotational speeds just before and after the collision since the entire collision is visible in the graph.

The rotational inertias of the ring and disk are calculated using the mass and dimensions of each. Then the total angular momentum before the collision is compared to the total angular momentum after the collision to show that it does not change.

The total kinetic energy before and after the collision is calculated to show the amount of energy lost during the inelastic collision.

Experiment Includes

Rotary Motion Sensor	PS-2120A
Rotational Accessory	CI-6691
Calipers	SF-8711
Large Rod Stand	ME-8735
45 cm Long Steel Rod	ME-8736

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9960A) into the search box at **www.pasco.com**.

Order Information

Conservation of Angular Momentum EX-5517A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13
Balance or Scale ..... p. 180

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Large Amplitude Pendulum

EX-5520A

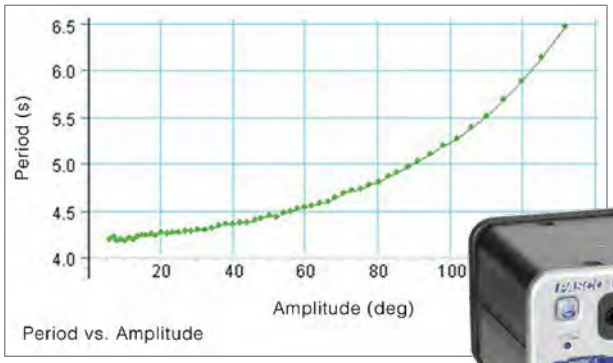
Concepts:

- Low amplitude approximation for the pendulum period
- Large amplitude period
- Shape of displacement, velocity, and acceleration curves for large amplitude

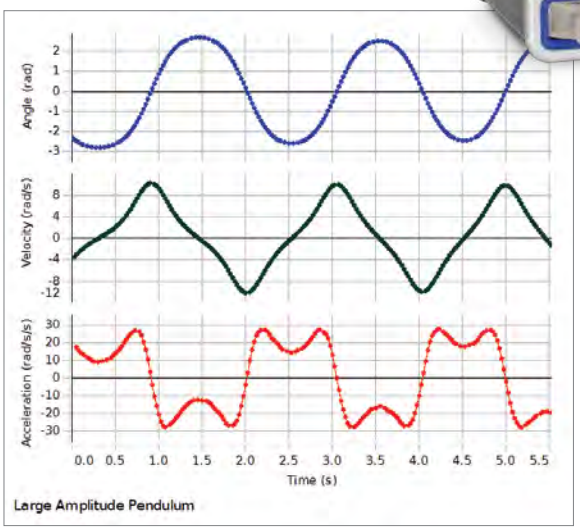
This experiment explores the dependence of the period of a simple pendulum on the amplitude of the oscillation. Also, the displacement, velocity, and acceleration for large amplitude are plotted versus time to show the difference from the sinusoidal motion of low amplitude oscillations.

A rigid pendulum consists of a 35 cm long lightweight (28 g) aluminum tube with a 75 g mass on each end. The center of the tube is mounted on a Rotary Motion Sensor. One of the masses is slightly closer to the center than the other mass, so the pendulum will oscillate slowly. Students will have time to view the motion of the pendulum, while also watching the real-time graph of displacement, velocity, and acceleration versus time.

The period is measured as a function of the amplitude of the pendulum and compared to theory.



The pendulum period is plotted versus amplitude.



Graphs of angular displacement, velocity, and acceleration versus time are displayed for a pendulum oscillating with large amplitude.



The rigid pendulum can be displaced 180 degrees and has a long period because of the offset masses.

PASCO Advantage

PASCO Capstone™ has a period function that can be plotted versus the amplitude in real-time as the pendulum's oscillation damps out. The pendulum is initially displaced almost 180 degrees and then, as the amplitude decreases because of friction, the period is automatically recorded as a function of amplitude.

Experiment Includes

Small "A" Base	ME-8976
25 cm Long Threaded Steel Rod	ME-8988
Pendulum Accessory	ME-8969
Rotary Motion Sensor	PS-2120A

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9905) into the search box at **www.pasco.com**.

Order Information

Large Amplitude Pendulum EX-5520A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Oscillation

Variable-g Pendulum

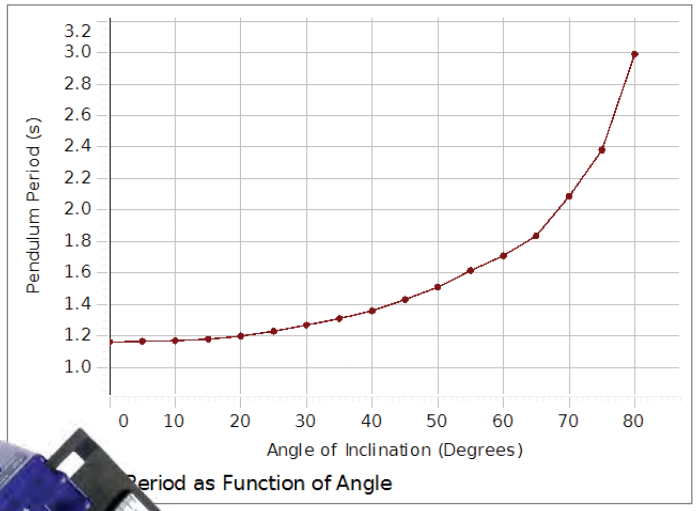
EX-5519A

Concepts:

- Period of a simple pendulum
- Effect of decreasing "g" on the pendulum period
- Large amplitude period
- Shape of displacement, velocity, and acceleration curves for large amplitude

This experiment explores the dependence of the period of a simple pendulum on the acceleration due to gravity and on the length and amplitude of the pendulum.

A simple rigid pendulum consists of a 35 cm long lightweight aluminum tube with masses at the end, mounted on a Rotary Motion Sensor. The pendulum is constrained to oscillate in a plane tilted at an angle from the vertical. This effectively reduces the acceleration due to gravity because the restoring force is decreased.



The period of the Variable-g Pendulum is plotted as a function of the angle of inclination to show the dependence of the period on g.



The Adjustable Angle Clamp makes it easy to adjust the angle from zero to 90 degrees, thus varying "g" from 9.8 m/s^2 to zero.

The period is measured for varying angles, simulating changing the acceleration due to gravity for the pendulum.

Experiment Includes

Large Rod Stand	ME-8735
45 cm Long Steel Rod	ME-8736
Angle Indicator	ME-9495A
Adjustable Angle Clamp	ME-8744
Pendulum Accessory	ME-8969
Rotary Motion Sensor	PS-2120A

PASCO Advantage

The rigid pendulum can be assumed to be a simple pendulum: the actual period is approximately 99% of the period of a simple pendulum of the same length.

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9904) into the search box at **www.pasco.com**.

Order Information

Variable-g Pendulum EX-5519A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

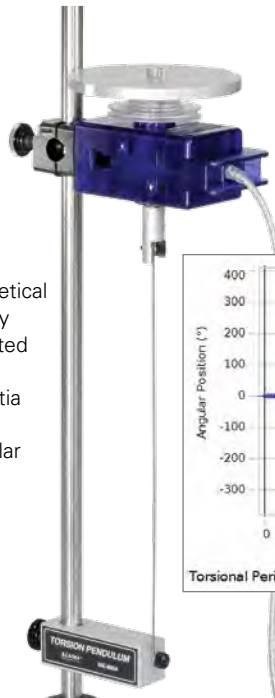
Torsional Pendulum

EX-5521A

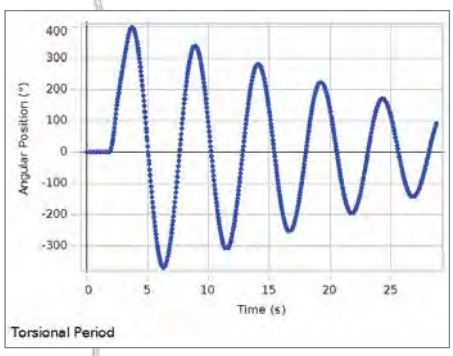
Concepts:

- Period of a torsional pendulum
- Rotational inertias of a disk, ring, and point masses
- Torque
- Torsional spring constant

The period of a Torsional Pendulum is measured and compared to the theoretical value. The torsional pendulum consists of a torsion wire attached to a Rotary Motion Sensor with an object (a disk, ring, or rod with point masses) mounted on top of it. The period of oscillation is measured from a plot of the angular displacement versus time. To calculate theoretical period, the rotational inertia is determined by measuring the dimensions of the object. The torsional spring constant is determined from the slope of a plot of force versus angular displacement.

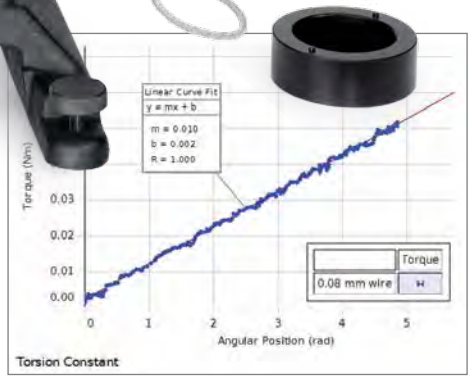


The torsional pendulum uses a Rotary Motion Sensor to record the oscillations.



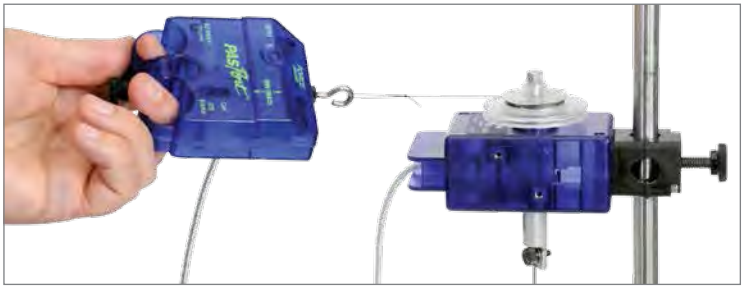
The period of the torsional pendulum is determined from a plot of angular displacement versus time.





The torsional spring constant is determined from a plot of torque versus angular displacement.

To determine the torsional spring constant, a torque is applied by pulling with a Force Sensor.



PASCO Advantage

To determine the torsional spring constant, the force versus angular displacement graph is quickly and easily obtained by pulling with a Force Sensor on a string wrapped around the Rotary Motion Sensor pulley.

Experiment Includes

Torsion Pendulum Accessory	ME-6694
Large Rod Stand	ME-8735
60 cm Long Steel Rod	ME-8977
Mini-Rotational Accessory	CI-6691
Rotary Motion Sensor	PS-2120A
Force Sensor	PS-2104

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9903 and EX-9943A) into the search box at **www.pasco.com**.

Order Information

Torsional Pendulum EX-5521A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Oscillation

Driven Damped Harmonic Oscillator

EX-5522A

Concepts:

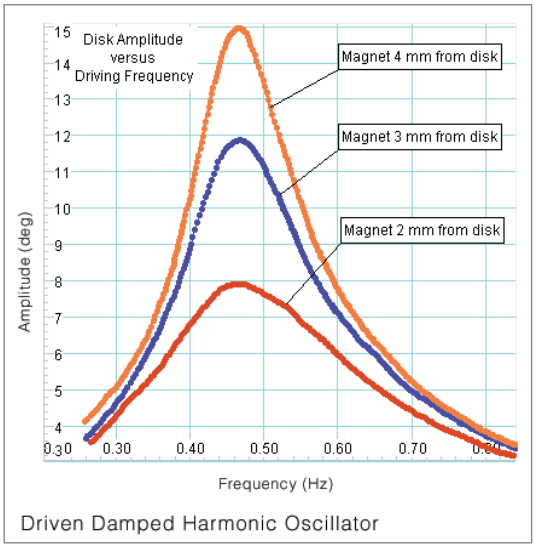
- Resonance curves for an oscillator: amplitude vs. frequency
- Resonant frequency
- Period of a pendulum
- Effect of magnetic damping on shape of resonance curve
- Phase difference between oscillator and driver at low, resonant, and high frequencies

In this experiment, the resonance of a driven damped harmonic oscillator is examined by plotting the oscillation amplitude versus frequency for various amounts of damping.

The oscillator consists of an aluminum disk with a pulley connected to two springs by a string. The angular positions and velocities of the disk and the driver are recorded as a function of time using two Rotary Motion Sensors. The amplitude of the oscillation is plotted versus the driving frequency for different amounts of magnetic damping. Increased damping is provided by moving an adjustable magnet closer to the aluminum disk.

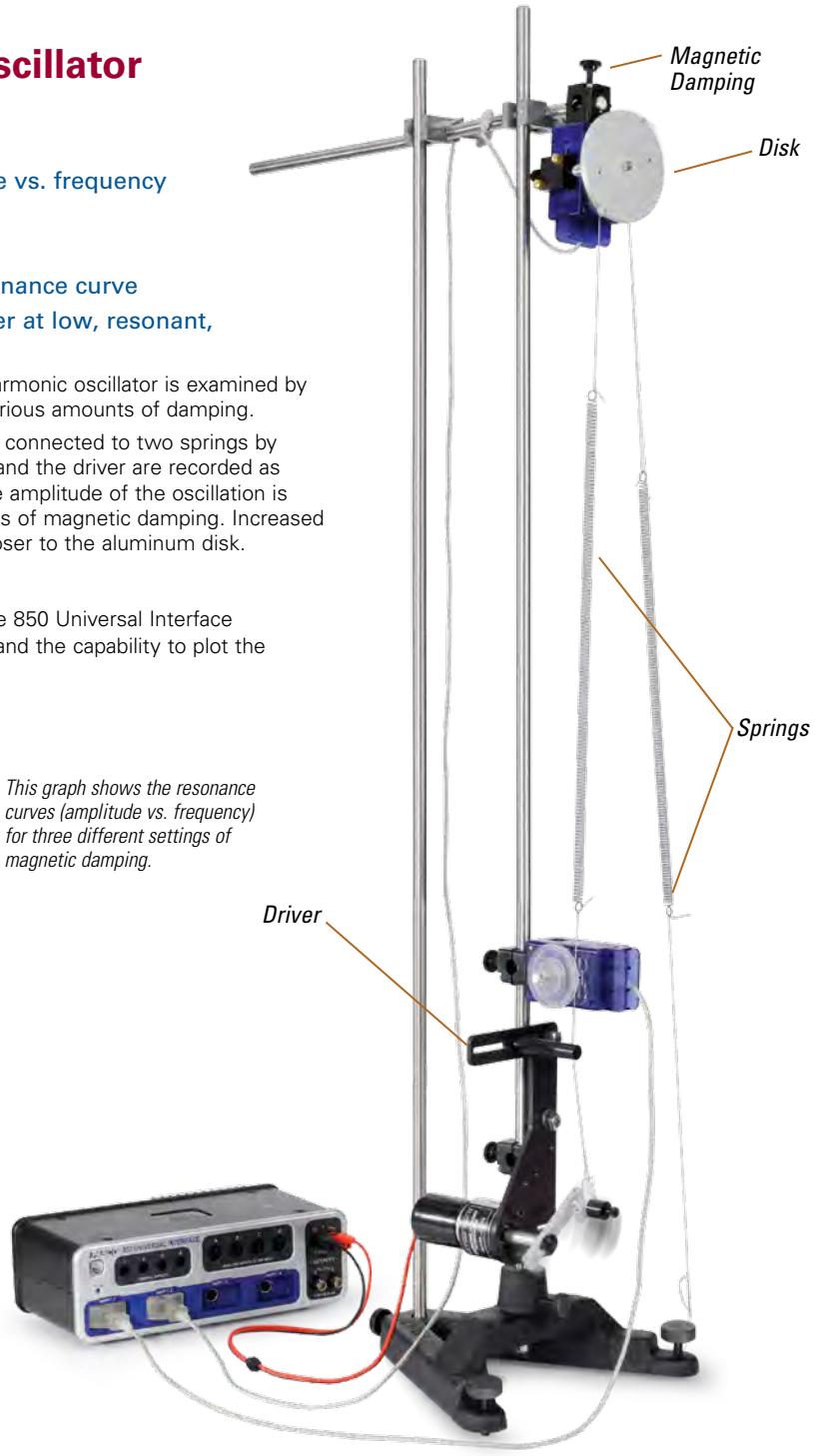
PASCO Advantage

The combination of PASCO Capstone™ Software and the 850 Universal Interface has the power to sweep through the driver frequencies and the capability to plot the amplitude versus the driver frequency in real-time.



Driven Damped Harmonic Oscillator

This graph shows the resonance curves (amplitude vs. frequency) for three different settings of magnetic damping.



The magnetically damped oscillator is driven by a sinusoidal mechanical driver.

Experiment Includes

Motion Sensor (2)	PS-2120A
Mechanical Oscillator/Driver	ME-8750
Chaos/Driven Harmonic Accessory	CI-6689A
Large Rod Stand	ME-8735
120-cm Long Steel Rod (2)	ME-8741
45-cm Long Steel Rod	ME-8736
Multi-Clamps (2)	ME-9507
Physics String	SE-8050

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9906 and EX-9970B) into the search box at **www.pasco.com**.

Order Information

Driven Damped Harmonic Oscillator EX-5522A

Required:

850 Universal Interface		pp. 14-17
PASCO Capstone Software		pp. 6-13
Hooked Mass Set		p. 181
Calipers	SE-8710	p. 176

Chaos

EX-5523A

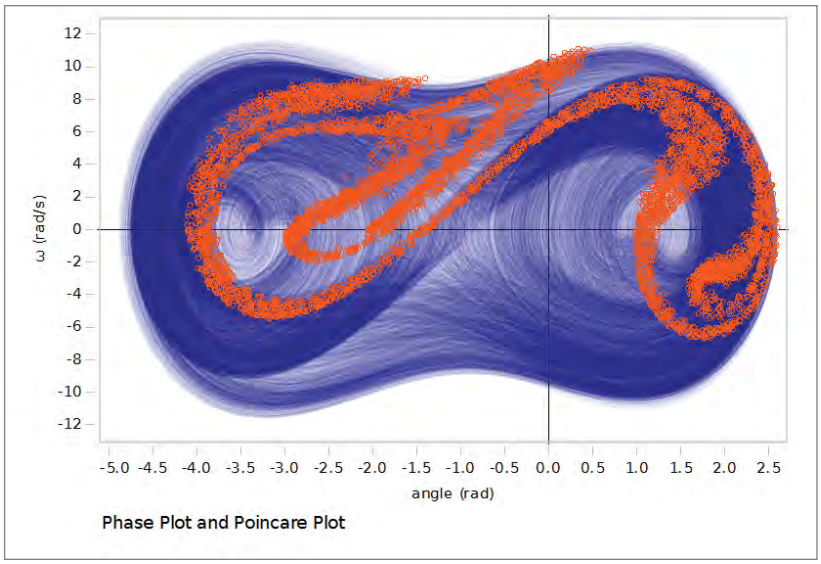
Concepts:

- Nonlinear oscillator
- Chaotic motion
- Phase space
- Poincare plot

The chaotic behavior of a driven nonlinear pendulum is explored by graphing its motion in phase space and by making a Poincare plot. These plots are compared to the motion of the pendulum when it is not chaotic.

The oscillator consists of an aluminum disk connected to two springs. A point mass on the edge of the aluminum disk makes the oscillator nonlinear. The frequency of the sinusoidal driver can be varied to investigate the progression from predictable motion to chaotic motion. Magnetic damping can be adjusted to change the character of the chaotic motion. The angular position and velocity of the disk are recorded as a function of time using a Rotary Motion Sensor. A real-time phase plot is made by graphing the angular velocity versus the displacement angle of the oscillation.

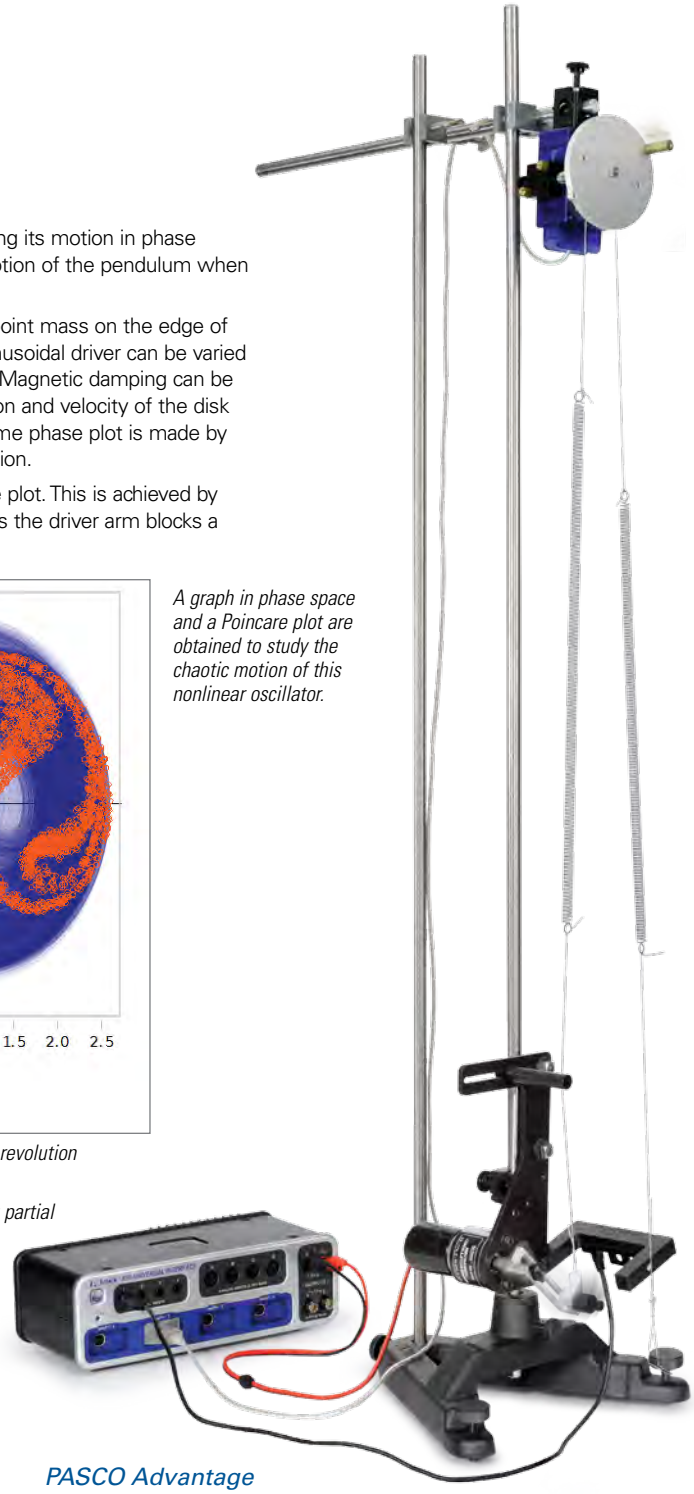
The Poincare plot is also graphed in real-time, superimposed on the phase plot. This is achieved by recording the point on the phase plot once every cycle of the driver arm as the driver arm blocks a photogate.



A graph in phase space and a Poincare plot are obtained to study the chaotic motion of this nonlinear oscillator.

The Poincare plot (in orange) shows the pendulum's velocity versus position once per revolution of the driver. The purple background is the phase plot.

This phase plot (angular velocity versus angle) is graphed in PASCO Capstone™ using partial opacity, so the trace gets darker as it traces back over itself.



Experiment Includes

Large Rod Stand	ME-8735
120 cm Long Steel Rod (2)	ME-8741
45 cm Long Steel Rod	ME-8736
Multi Clamps (2)	ME-9507
Chaos/Driven Harmonic Accessory	CI-6689A
Mechanical Oscillator/Driver	ME-8750
Rotary Motion Sensor	PS-2120
Photogate Head	ME-9498A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9907) into the search box at **www.pasco.com**.

PASCO Advantage

PASCO Capstone can graph the motion in phase space and superimpose the Poincare plot in real-time, showing students how the motion in phase space relates to actual motion of the oscillator.

Order Information

Chaos EX-5523A

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Thermodynamics

Specific Heat

EX-5524

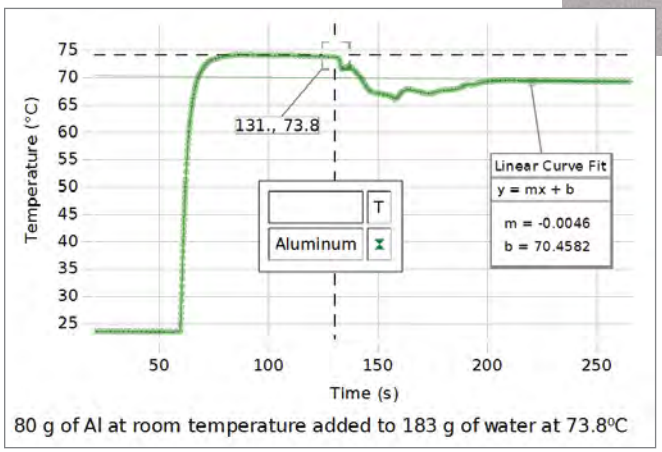
Concepts:

- Thermal energy
- Equilibrium temperature
- Specific heat

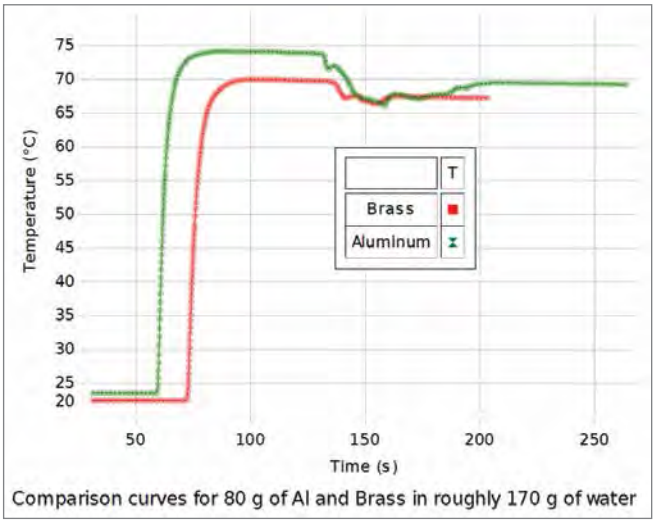
Students learn that materials can be identified using specific heat as a measurable characteristic. A known mass of water is used and the unknown material is placed in the water. The initial temperature of the water and the unknown material are measured. The equilibrium temperature is found and from this the specific heat of the unknown material is derived.

By performing this experiment in two ways (water warming, water cooling) students explore how experiment design may alter results. Finally students explore sources of error and magnitude of error.





Room temperature A1 is added to hot water. After 210 s, the system has come to equilibrium and is slowly cooling. A linear fit to the cooling curve allows extrapolation back to find the equilibrium temperature that would have occurred at 131 s when the A1 was added if the system had come to equilibrium instantaneously. This allows measurement of the specific heat within approximately 10%.



Comparison of similar system shows that A1 causes about twice the drop in water temperature as does brass. The cooling slopes before and after support Newton's Law of Cooling.

Experiment Includes

Temperature Sensor	PS-2125
Set of Calorimetry Cups	TD-8825A
Specific Heat Set	SE-6849
Balance	SE-8723
Hot Plate	SE-8830
Graduated Cylinder, 50 mL	
1000-mL Beaker	
Braided Physics String	SE-8050

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9977) into the search box at **www.pasco.com**.

Order Information

Specific Heat EX-5524

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Electrical Equivalent of Heat

EX-5525

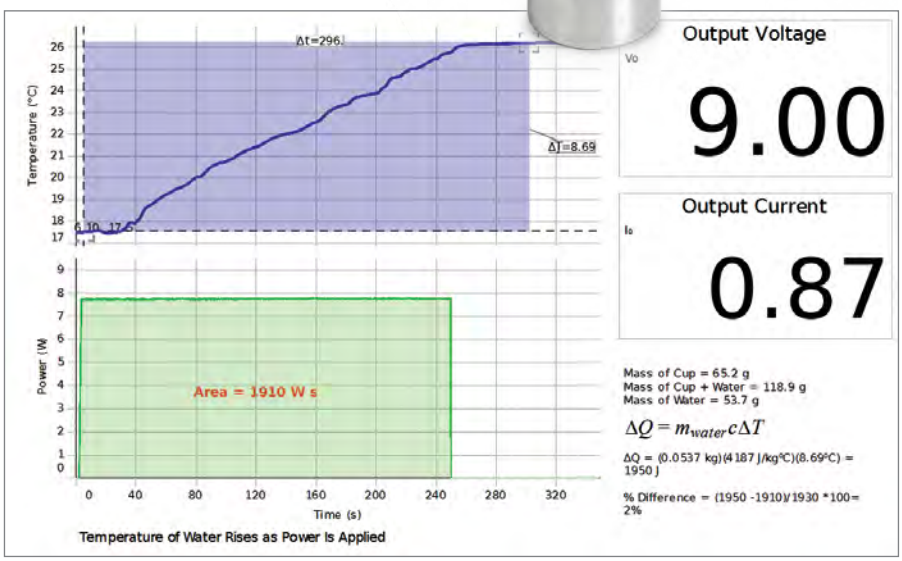
Concept:

- Compare electrical energy input to changes in internal energy

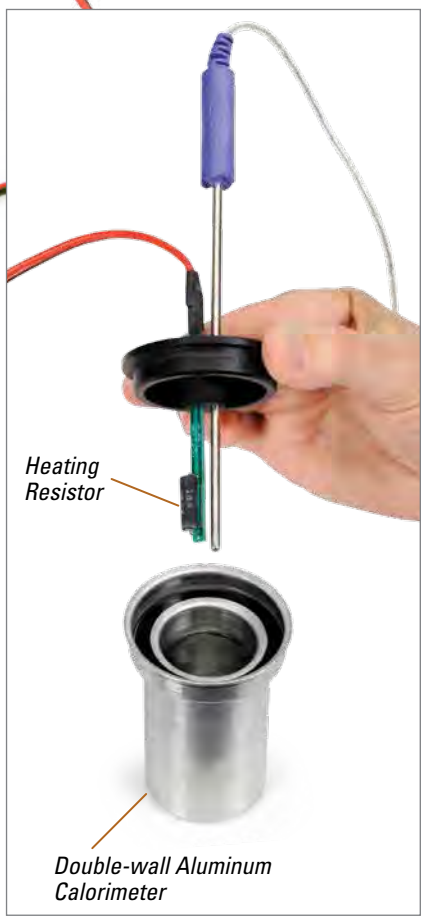
The double wall of the aluminum Calorimeter Cup ensures good insulation. Energy is added to the system using the 10 Ω Heating Resistor, powered by the 850 Universal Interface. The voltage, current, power, and resulting increase in temperature are monitored and displayed continuously.

The amount of electrical energy used to heat the water (and the inner cup) is equal to the area under the power versus time curve. The amount of heat delivered to the water (and the inner cup) can be calculated using the increase in temperature and the mass of the water. The comparison of the electrical energy to the heat results in a value for the number of Joules in a calorie.





The top graph displays the power output from the generator and the bottom graph the increase in temperature. The amount of electrical energy used to heat to the water is determined by finding the area under the power versus time curve.



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9962 and EX-9963) into the search box at **www.pasco.com**.

Experiment Includes

Energy Transfer-Calorimeter	ET-8499
Temperature Sensor	PS-2125
Mass Scale	SE-8707

Order Information

Electrical Equivalent of Heat EX-5525

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Thermodynamics

Frictional Energy Transfer

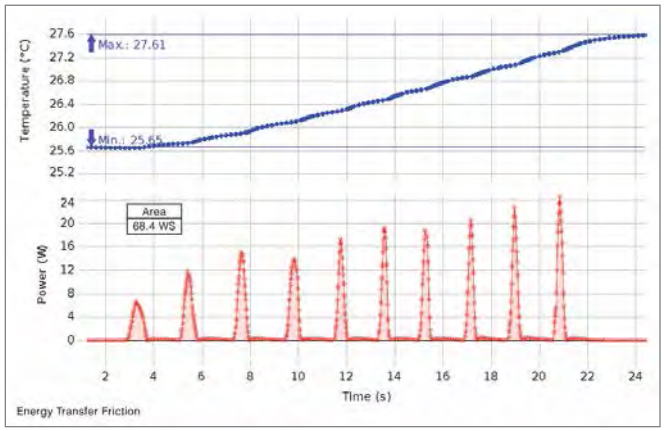
EX-5526A

Concepts:

- Conservation of Energy
- Specific Heat of a Solid
- Power and Work

This experiment is similar to a traditional mechanical equivalent of heat design. However, the objective is somewhat different. The purpose of this experiment is to facilitate a discussion among students about the types of energy in the system and the energy transfer that takes place throughout the process. Students use a Force Sensor to measure the force as the hanging mass is raised and lowered. The string connecting the sensor and the hanging mass is wrapped around a meter cylinder (brass or aluminum) in a spiral pattern. The sliding friction between the string and metal cylinder causes the cylinder to heat up. Each metal cylinder has a built-in thermistor that is used to monitor the real-time temperature of the cylinder.

Using the equation Q = mc ΔT, the change in thermal energy can be calculated. In addition, the string passes over the large pulley on the Rotary Motion Sensor for measurement of the string velocity as it is pulled. A power-time graph is created, since power is simply the product of the force and velocity. By integrating the power-time graph, the energy input can be determined. Next students compare the energy input to the increase in thermal energy in the metal cylinder. Then they discuss other types of energy that are present in the system.



Students use the change in temperature of the cylinder to calculate the heat transferred, and compare this to the work done (area under curve.)

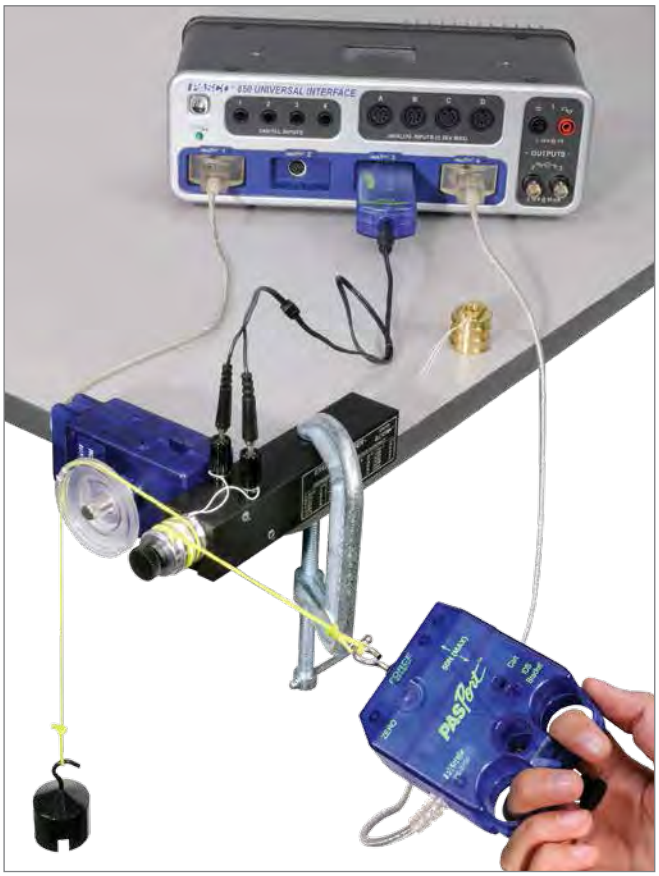
PASCO Advantage

The three sensors used in the experiment (Force, Temperature, and Rotary Motion) allow students to measure everything needed to complete their energy analysis of the system. In addition, all measurements and calculations can be viewed real-time as the energy is being put into the system. Students will then understand how their work translates into the heating of the metal cylinder.

Experiment Includes

Energy Transfer-Friction	ET-8770
Large "C" Clamp	SE-7285
Hooked Mass Set	SE-8759
Temperature Sensor	PS-2125
Force Sensor	PS-2104
Rotary Motion Sensor	PS-2120A

Use the 850 or the NEW 550 Interface



The work done is measured using a Force Sensor and a Rotary Motion Sensor. The amount of thermal energy transferred to the cylinder is measured using a Temperature Sensor.



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9937A) into the search box at **www.pasco.com**.

Order Information

Frictional Energy Transfer EX-5526A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Ideal Gas Law

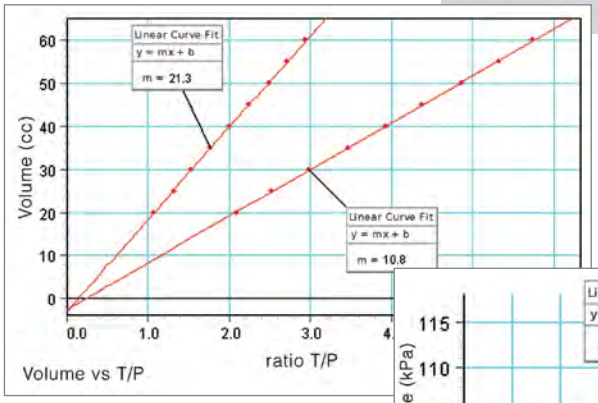
EX-5527

Concepts:

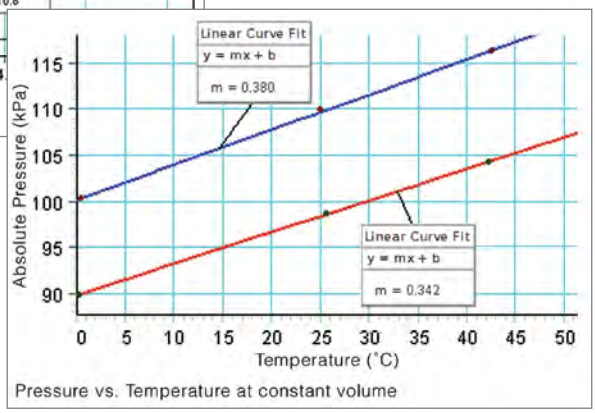
- Ideal gas Law
- Boyle's Law
- Gay-Lussac's Law

The temperature, volume, and pressure of a gas are measured simultaneously to show that they change according to the Ideal Gas Law. Two special cases of the Ideal Gas Law are also examined: constant volume (Gay-Lussac's Law) and constant temperature (Boyle's Law). A syringe is used to vary the volume at constant temperature. A sphere of constant volume is immersed in different temperature water baths to show the change in pressure.





For the Ideal Gas Syringe (shown above) the Slope of the Volume vs. $\frac{T}{P}$ graph equals nR.



For the Absolute Zero Apparatus (shown at right) which has constant volume, the pressure versus temperature graphs have different slopes corresponding to different number of moles in the container.



PASCO Advantage

The Ideal Gas Syringe and Absolute Zero Sphere have a thermistor with small mass that responds quickly to temperature changes.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9950 and EX-9954) into the search box at **www.pasco.com**.

Experiment Includes

Ideal Gas Law Syringe	TD-8596A
Pressure/Temperature Sensor	PS-2146
Absolute Zero Apparatus	TD-8595
Plastic Containers (2)	740-183

Use the 850 or the NEW 550 Interface

Order Information

Ideal Gas Law EX-5527

Required:

550 or 850 Universal Interface		pp. 2-3, 14-17
PASCO Capstone Software		pp. 6-13
Calipers	SE-8710	p. 176

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

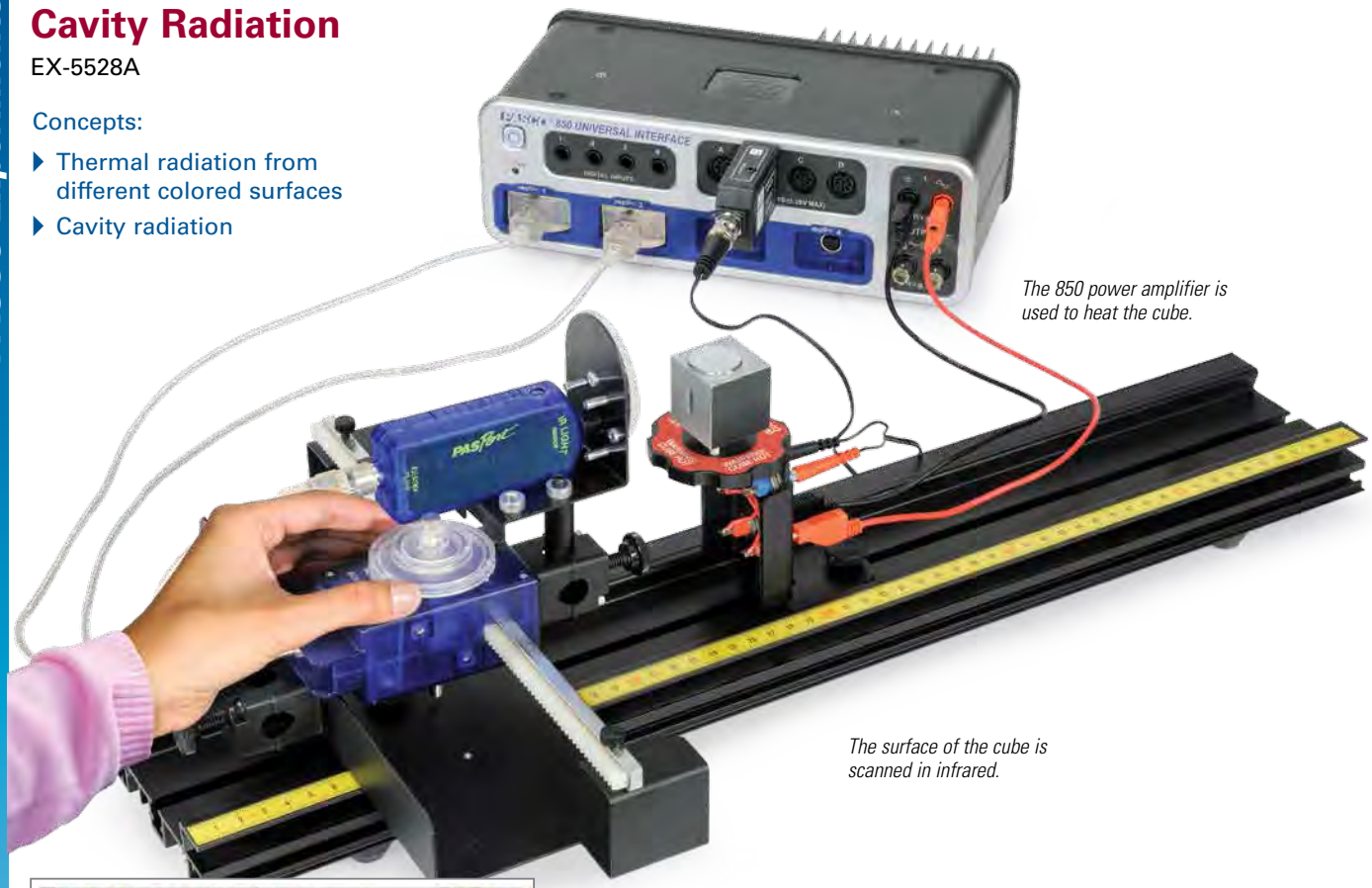
Thermodynamics

Cavity Radiation

EX-5528A

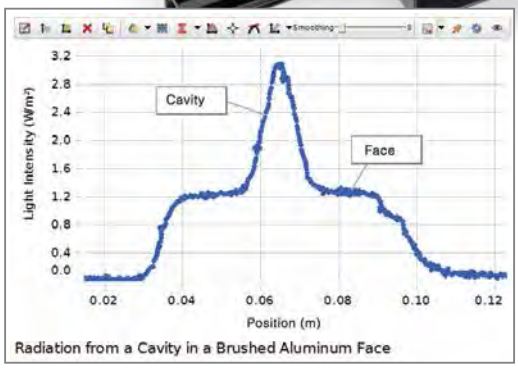
Concepts:

- Thermal radiation from different colored surfaces
- Cavity radiation



The 850 power amplifier is used to heat the cube.

The surface of the cube is scanned in infrared.



Radiation from a Cavity in a Brushed Aluminum Face

In the infrared part of the spectrum, the hot cavity is brighter than the surrounding matte aluminum surface.

In this experiment the amounts of thermal radiation from different colored surfaces and a cavity, all at the same temperature, are compared.

An aluminum cube has sides that are black, white, polished aluminum, and matte aluminum with a hole. The cube is heated to approximately 90°C and an Infrared Light Sensor is moved across the face with the hole in it which shows that the hole emits more infrared radiation than the surrounding surface. A Rotary Motion Sensor on a Linear Translator keeps track of the light sensor position and the light intensity versus position is plotted. The scan in the visible spectrum is made with a Light Sensor to confirm that the hole is darker than the surrounding surface. Also, the intensity of radiation from the different colored surfaces is compared.

PASCO Advantage

The temperature of the cavity is controlled by the 850 Interface and measured using a Thermistor Temperature Sensor, which reads in degrees rather than resistance, eliminating confusion about the resistance decreasing as the temperature increases. The temperature is used to calculate the theoretical wavelength of maximum intensity emitted by the cavity.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9912) into the search box at **www.pasco.com**.

Experiment Includes

Thermal Cavity	TD-8580A
Patch Cords	SE-9750
60 cm Optics Bench	OS-8541
Linear Translator	OS-8535
Aperture Bracket	OS-8534A
Rotary Motion Sensor	PS-2120A
Infrared Sensor	PS-2148
Thermistor Temperature Sensor	CI-6527A

Order Information

Cavity Radiation EX-5528A

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Blackbody Radiation

EX-5529A



The continuous blackbody spectrum is scanned using a prism spectrophotometer.

Concepts:

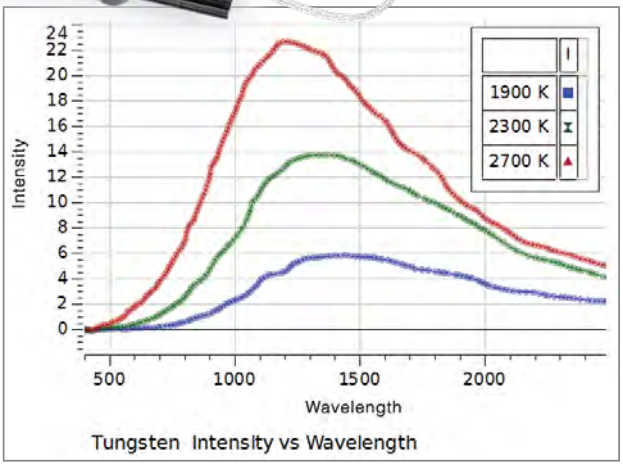
- Blackbody spectrum
- Peak wavelength versus temperature

The classic blackbody spectrum of light intensity versus wavelength is obtained for a light bulb and the shift in the peak wavelength is demonstrated for different bulb temperatures.

The spectrum of an incandescent light bulb is scanned by hand using a prism spectrophotometer, which measures relative light intensity as a function of angle. A Broad Spectrum Light Sensor is used with a prism, so the entire spectrum from approximately 400 nm to 2500 nm can be scanned without the overlapping orders caused by a grating. The wavelengths corresponding to the angles are calculated using the equations for a prism spectrophotometer. The relative light intensity can then be plotted as a function of wavelength as the spectrum is scanned, resulting in the characteristic blackbody curve. The intensity of the light bulb is reduced, reducing the temperature, and the scan is repeated to show how the curves nest with a shift in the peak wavelength.

The temperature of the bulb's filament can then be measured indirectly by determining the resistance of the bulb from the measured voltage and current. From the temperature, the theoretical peak wavelength can be calculated and compared to the measured peak wavelength.

Note: Results are qualitative and suitable for introductory classes only.



Classic textbook diagram of the intensity versus wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is decreased.

PASCO Advantage

All the complex calculations for the angle-to-wavelength conversion are stored in the set-up file supplied for PASCO Capstone™.

Experiment Includes

Prism Spectrophotometer Kit	OS-8544
Optics Bench (60 cm)	OS-8541
Spectrophotometer Accessory Kit	OS-8537
Aperture Bracket	OS-8534A
Broad Spectrum Light Sensor	PS-2150
Rotary Motion Sensor	PS-2120A
Voltage Sensor	UI-5100
Replacement Bulb (10 pk)	SE-8509
Banana Plug Cord-Black (5 pack)	SE-9751

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9920 and EX-9971B) into the search box at **www.pasco.com**.

Order Information

Blackbody Radiation EX-5529A

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Thermodynamics

Heat Engine Cycle

EX-5530A

Concepts:

- Heat engine efficiency
- Isobaric processes
- Isothermal processes
- Ideal gas law

A P-V diagram is generated as a heat engine is taken through a cycle. From this diagram, the heat added to the gas and the work done by the engine are measured to determine the efficiency of the engine. This actual efficiency is compared to the theoretical maximum efficiency.

The heat engine consists of air inside a cylinder that expands when an attached can is immersed in hot water. The expanding air pushes on a piston and does work by lifting a weight. The heat engine cycle is completed by immersing the can in cold water, which returns the air pressure and volume to the starting values.



Figure 1: P-V Diagram for Heat Engine Cycle

The PASCO Capstone™ graph shows an isobaric/isothermal heat engine cycle operating between a cold water bath at 1.5°C and a hot water bath at 41.8°C.

The actual efficiency is determined for a heat engine that lifts a weight as heat is added to the gas.

PASCO Advantage

This operating heat engine shows how a difference in temperature can be used to do work. Each part of the cycle is easily identifiable, and the actual efficiency as well as the maximum possible efficiency can be easily determined.

The cycle is performed as follows:

1. With the can in the cold bath, the 200 g mass is placed on the platform.
2. The can is moved from the cold bath to the hot bath.
3. The 200 g mass is removed from the platform.
4. The can is moved from the hot bath to the cold bath.

The change in pressure is measured with a Low Pressure Sensor. The change in piston height is measured by the attached string over the Rotary Motion Sensor pulley. The change in volume is calculated by multiplying the change in piston height by the piston cross-sectional area.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9911 and EX-9972A) into the search box at **www.pasco.com**.

Experiment Includes

Heat Engine/Gas Law Apparatus	TD-8572
Large Rod Stand	ME-8735
Slotted Mass (200 g)	SE-8811
Mass & Hanger Set	ME-8979
Plastic containers (2)	ME-7559
Thread	
90 cm Long Steel Rod	ME-8738
Rotary Motion Sensor	PS-2120A
Quad Temperature Sensor	PS-2143
Dual Pressure Sensor	PS-2181

Use the 850 or the NEW 550 Interface

Order Information

Heat Engine Cycle EX-5530A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Ratio of Specific Heats

EX-5531

Concepts:

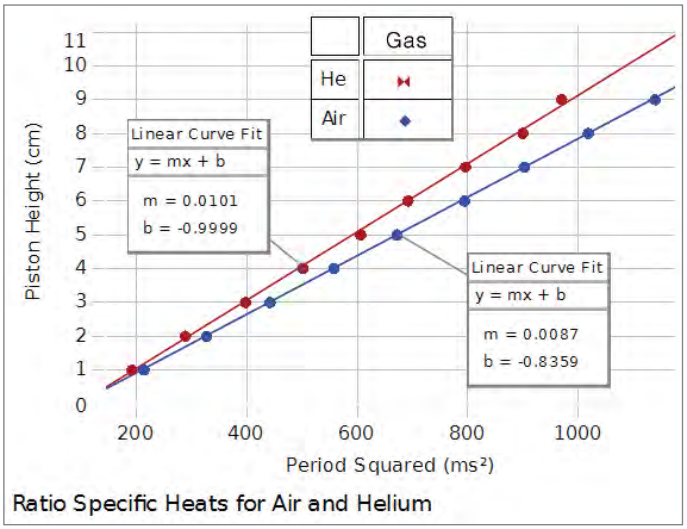
- C_p/C_V for a gas
- Ruchhardt's method of measuring the ratio of specific heats
- Adiabatic process

In this experiment, the ratio of specific heat capacities for air is determined using Ruchhardt's Method of measuring the period of oscillation of the piston in a cylinder filled with air.

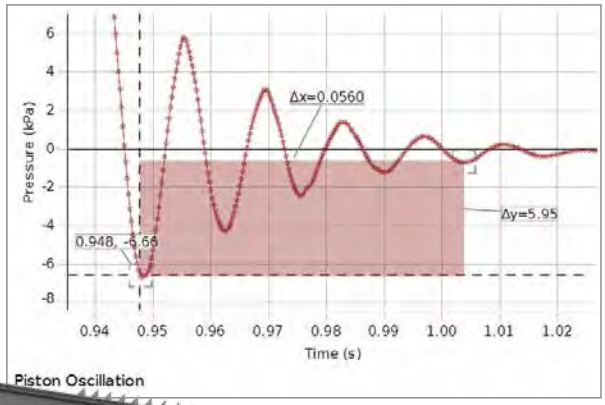
A cylinder is filled with air and a Pressure Sensor is attached. The piston is plucked by hand and allowed to oscillate. The oscillating pressure is recorded as a function of time and the period is determined. The ratio of specific heat capacities is calculated using the period of oscillation, according to Ruchhardt's method.

PASCO Advantage

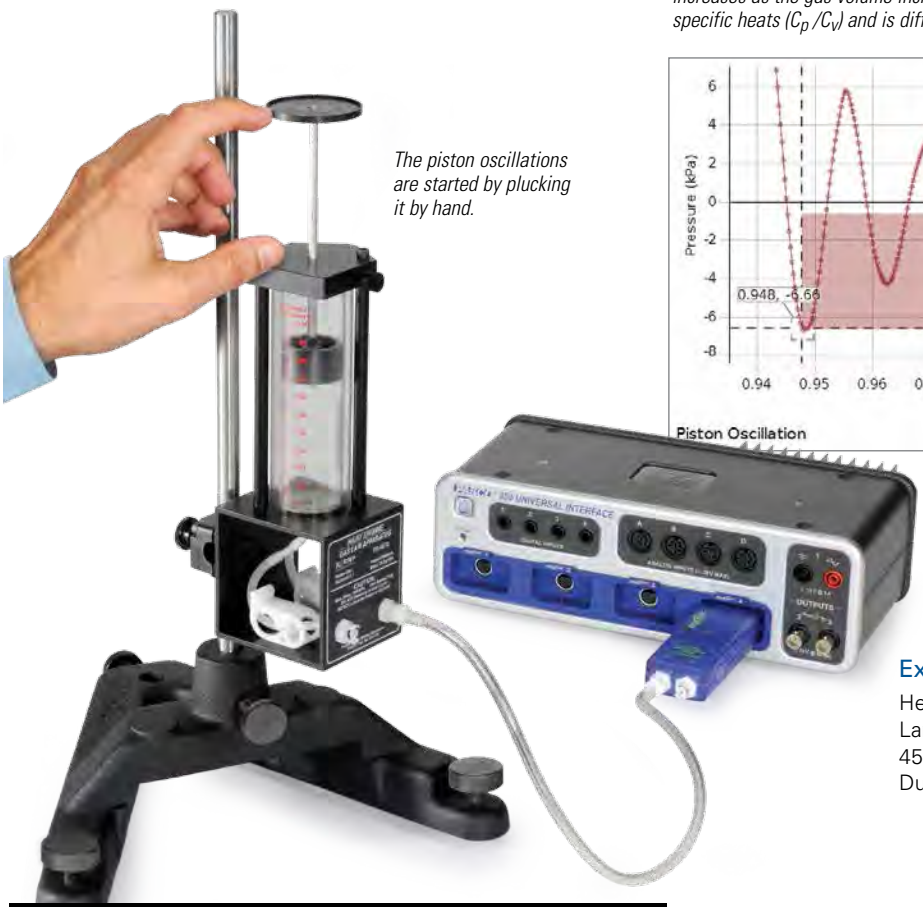
Since the oscillations are plotted, it is easy to accurately measure the period of oscillation.



A plot of the position of piston versus the square of the period shows that the period increases as the gas volume increases. The slope of the line is related to the ratio of specific heats (C_p/C_V) and is different for the two gases.



The pressure oscillates after the piston is plucked by hand.



The piston oscillations are started by plucking it by hand.

Experiment Includes

Heat Engine/Gas Law Apparatus	TD-8572
Large Rod Stand	ME-8735
45 cm Long Steel Rod	ME-8736
Dual Pressure Sensor	PS-2181

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9910 and EX-9969) into the search box at **www.pasco.com**.

Order Information

Ratio of Specific Heats EX-5531

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Electromagnetism

Electrostatic Charge

EX-5532

Concepts:

- Methods of charging
- Charge distribution
- Conservation of charge

Using classic equipment, a Faraday Ice Pail and Conductive Spheres, students learn to charge objects by direct contact and by induction. The charge is measured using a high impedance electrometer.

Students explore the distribution of charge on different shaped conductive shapes. A sphere with a hole in it is provided to show that no charge resides on the inner surface of the conductor when it is charged.



Use the ball end to sample inside the hollow sphere.



New Digital Readout



Experiment Includes

Basic Electrometer	ES-9078A
Charge Producers and Proof Plane	ES-9057C
Faraday Ice Pail and Shield	ES-9042A
Conductive Spheres, 13 cm	ES-9059C
Conductive Shapes	ES-9061
Electrostatics Voltage Source	ES-9077

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9978) into the search box at **www.pasco.com**.

Order Information

Electrostatic Charge EX-5532

Required:

PASCO Capstone Software ..... pp. 6-13

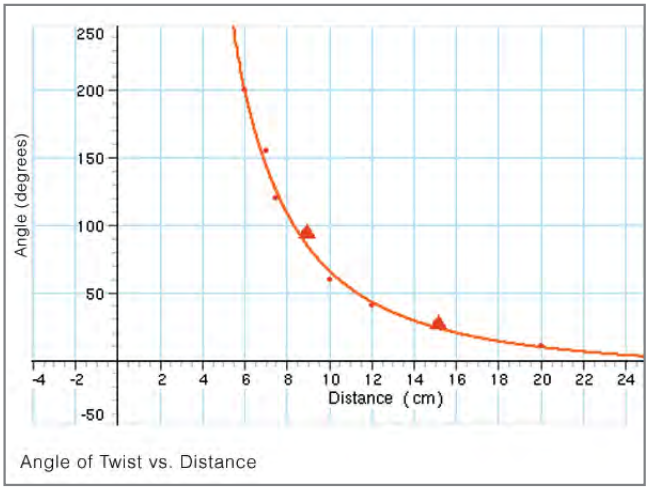
Coulomb's Law

EX-9930B

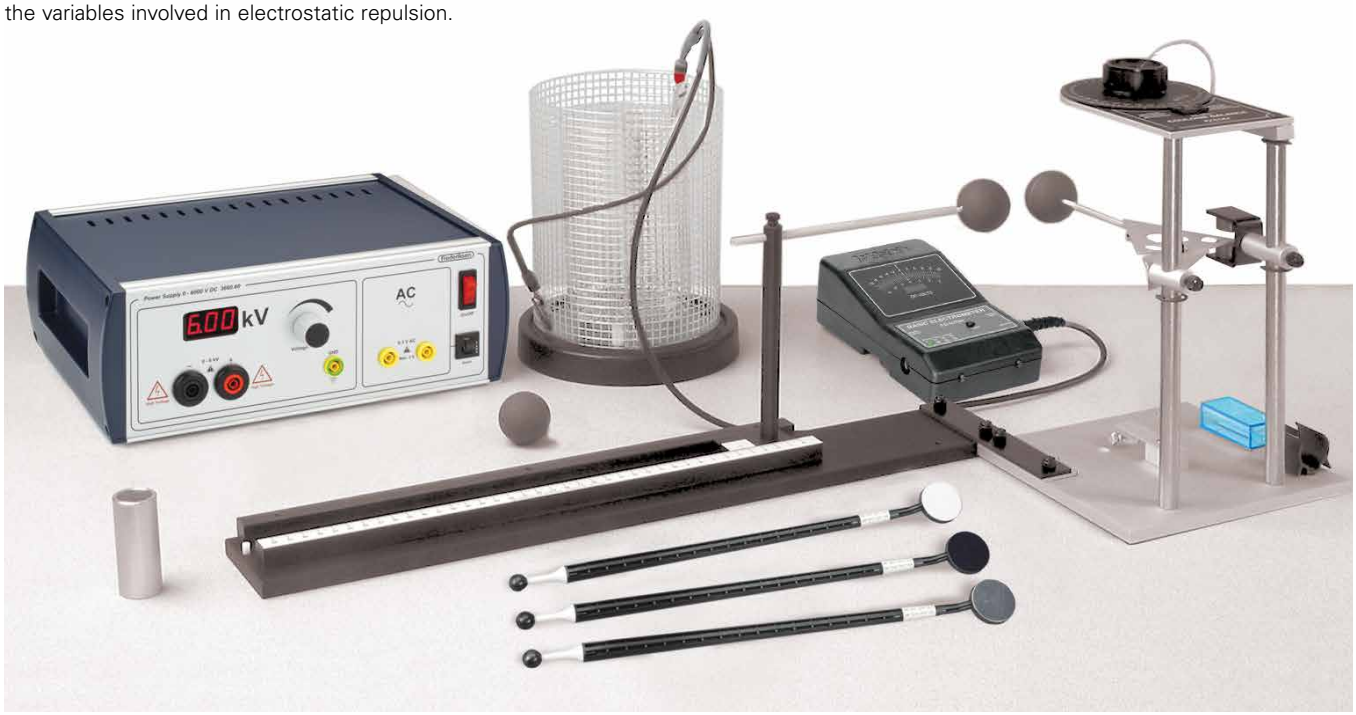
Concepts:

- Verify the Inverse Square Law: $F \sim 1/R^2$
- Verify the Force/Charge Relationship: $F \sim q_1 q_2$
- Determine Coulomb's Constant: $k = 9.0 \times 10^9\ Nm^2/C^2$

A conductive sphere is mounted on the end of an insulating, counterbalanced rod and suspended from a very thin torsion wire. An identical sphere is mounted on a calibrated linear track and can be positioned at various distances from the first sphere. When the conductive spheres are charged, the force between them is proportional to the twist of the torsion wire that is required to bring the balance back to its equilibrium position. Introductory physics students can determine the Inverse Square Law in a simple experiment, while advanced students can perform investigations into all the variables involved in electrostatic repulsion.



Electrostatic force is directly proportional to the angle of twist.



When an electrostatic force is applied, the torsion wire is twisted to return the balance to equilibrium. The twist of the wire is proportional to the electrostatic repulsion force.

Experiment Includes

Coulomb's Law Apparatus	ES-9070
Kilovolt Power Supply	SF-9586B
Basic Electrometer	ES-9078A
Faraday Ice Pail	ES-9042A
Charge Producers and Proof Plane	ES-9057C
Coulomb's Law Experiment Manual	

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Coulomb's Law EX-9930B

Electromagnetism

Charge of an Electron

EX-9929A

Concepts:

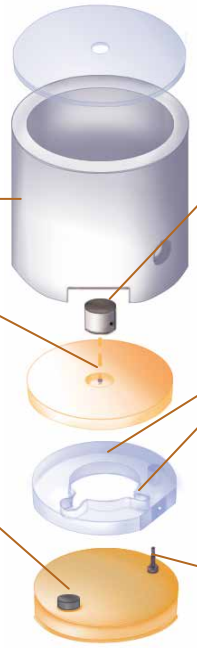
- Accurately measure the charge of a single electron
- Recreate Robert Millikan's historical experiment

Small droplets of oil are introduced into a chamber where an electric field of known strength is present. Using the viewing scope and a stopwatch, the velocity of a falling oil droplet is measured and recorded. Next, the electric field in the chamber is increased, causing the oil droplet to move upward. This allows the measurement of the force on the droplet and, ultimately, the charge of the droplet. By measuring the charge of several different oil droplets, the smallest difference in charge between them can be equated to the charge of an electron.



PASCO Advantage

PASCO's Charge of an Electron Experiment features a 30x, bright-field, erect-image microscope for clear viewing of the oil droplets. The droplet viewing chamber utilizes a special condenser to minimize droplet drift typically caused by droplet illumination and outside air currents. An ionization source allows the droplet charge to be changed.



Easy Cleaning
The condenser system easily disassembles for cleaning and inspection.

Condenser Housing

Minimum Electric Field Distortion
A 0.5 mm diameter droplet entry hole in the top capacitor plate has a negligible effect on the electric field.

Ionization Source
The thorium-232 alpha source can be activated by the switch on the side of the chamber. The source allows the charge on the oil droplets to be changed.

Droplet Hole Cover
Prevents additional droplets from entering the chamber once the experiment has started.

Polished Surfaces
Polished surfaces on the plate spacer minimize absorption of light (and heat) through the chamber walls.

Electrical Connection
Electrical connection to the top plate

Condenser Assembly

Experiment Includes

Millikan Oil Drop Apparatus	AP-8210
Basic Digital Multimeter	SE-9786A
High Voltage Power Supply	SF-9585A
Large Rod Base	ME-8735
45 cm Steel Rod (2)	ME-8736
Banana Plug Cord-Red (5 Pack)	SE-9750
Banana Plug Cord-Black (5 Pack)	SE-9751
Charge of an Electron Experiment Manual	

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Charge of an Electron EX-9929A

Capacitance

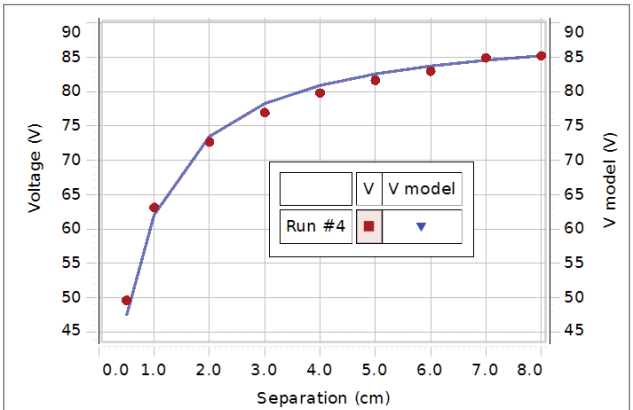
EX-5533

Concepts:

- Capacitance
- Parallel plate capacitor
- Factors affecting capacitance

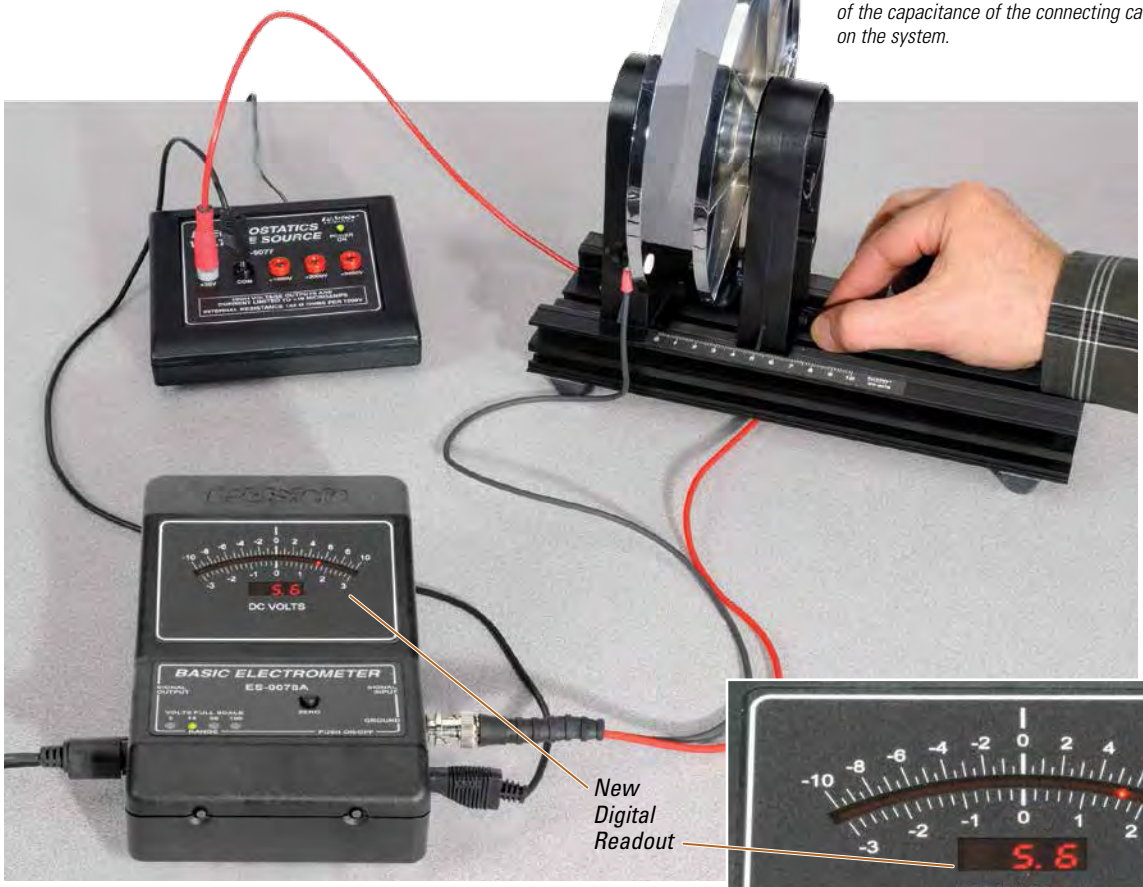
This lab explores the effect of varying the plate distance and insulating dielectric materials in a variable flat plate capacitor.

The Electrometer used in this experiment makes it possible to measure the voltage across the capacitor plates without discharging the capacitor, since it has an internal resistance of 10^{14} ohms.



Graph is non-linear due to capacitance of the connecting cables.

Manipulation of the computer model allows measurement of the capacitance of the connecting cables and the charge on the system.



Experiment Includes

Basic Electrometer	ES–9078A
Basic Variable Capacitor	ES–9079
Electrostatics Voltage Source	ES–9077

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9985) into the search box at **www.pasco.com**.

Order Information

Capacitance EX-5533

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Electromagnetism

Resistivity

EX-5534

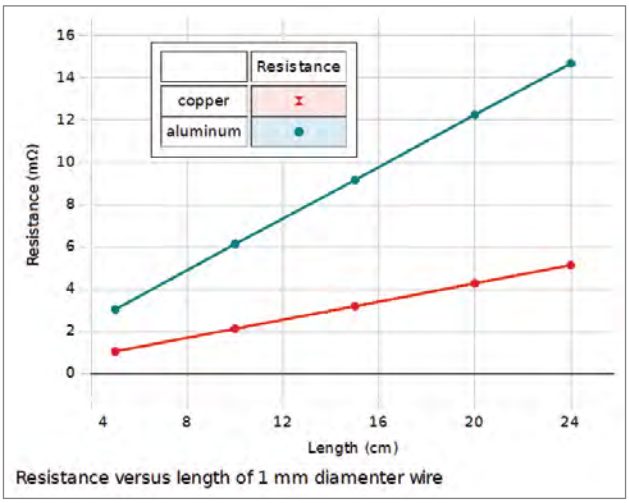
Concepts:

- Relate resistance to wire length
- Determine resistivity of different materials

Discover the relationship between the resistance of a wire and its length, diameter, and the resistivity of the metal.

The current is measured directly by the 850 Universal Interface, and the voltage drop over the selected section of wire is measured by the Voltage Sensor. This allows easy calculation of the resistance of the length of wire. The resistance is plotted versus the length of the wire, and the slope of the resulting straight line is used to determine the resistivity.

Using wires of the same diameter made of different materials allows examination of the effect of resistivity. Using brass wires with various diameters allows examination of the effect diameter has on resistance.



Resistance versus length of 1 mm diamenter wire

Since both wires have the same diameter, the resistivity is directly proportional to the slope. The graph shows that the resistivity of copper is about one-third that of aluminum.



The Resistance Apparatus has a slide wire probe to easily change the measured length of the wire, and it utilizes a four wire hook-up to accurately measure the voltage drop. It comes with four different brass wire diameters and four other wire materials.

PASCO Advantage

The Resistance Apparatus has a slide-wire probe to easily change the measured length of the wire. It utilizes a four-wire hook-up to accurately measure the voltage drop.

The 850 Universal Interface Power Amplifier makes it possible to scan the voltages, allowing more time to examine wires made of different metals and with different diameters.

Experiment Includes

Resistance Apparatus	EM-8812
Voltage Sensor	UI-5100
Patch cords (set of 5)	SE-9750

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Resistivity EX-5534

Required:

850 Universal Interface ..... pp. 14-17
PASCO Capstone Software ..... pp. 6-13
Micrometer ..... p. 176

Ohm's Law

EX-5535

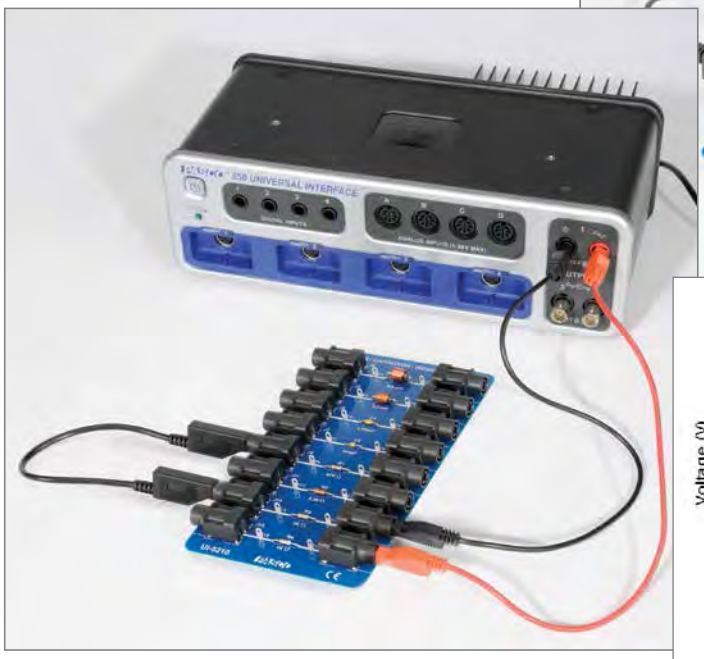
Concepts:

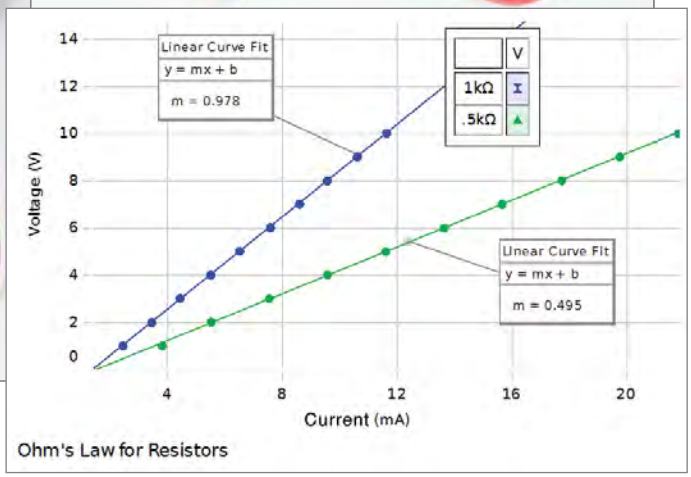
- Relationship between voltage and current

Method

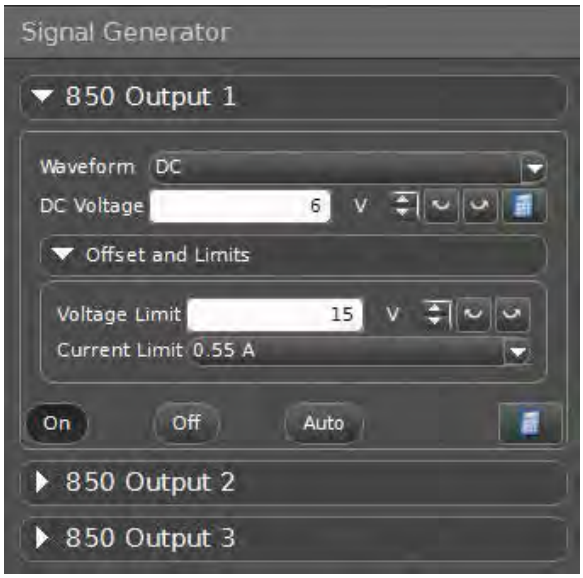
In this experiment, students simultaneously measure both current and voltage for a simple DC circuit. The relationship between current and voltage is explored for different resistors in parallel. Voltage is graphed versus current to verify Ohm's Law and recognize the physical meaning of slope.







The relationship between voltage and current varies for different circuit resistance.



Students control output from the 850 signal generators directly from the user interface in PASCO Capstone™.

Experiment Includes

Resistive/Capacitive/Inductive Network	UI-5210
Short Patch Cords (set of 8)	SE-7123

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9949 and EX-9953) into the search box at **www.pasco.com**.

Order Information

Ohm's Law EX-5535

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Electromagnetism

RC Circuit

EX-5536

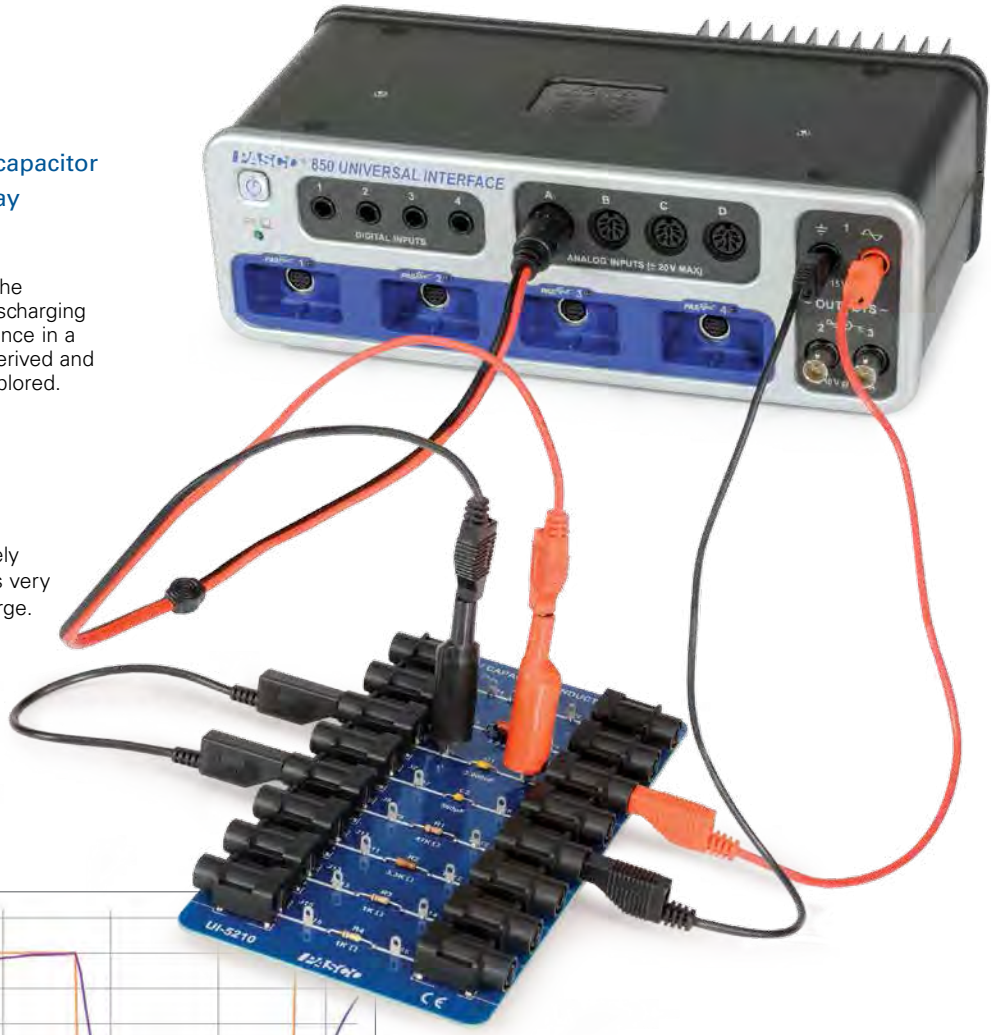
Concepts:

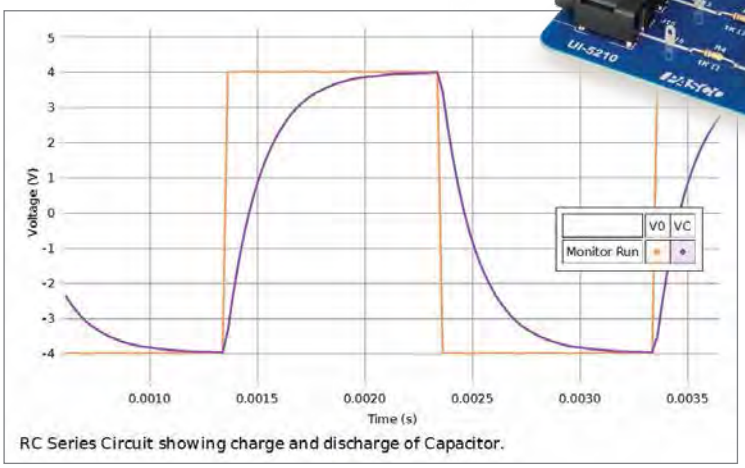
- Charging and discharging a capacitor
- Exponential growth and decay
- Time constants

Students collect data to understand the relationship between charging and discharging rates and the capacitance and resistance in a simple circuit. The time constant is derived and exponential growth and decay are explored.

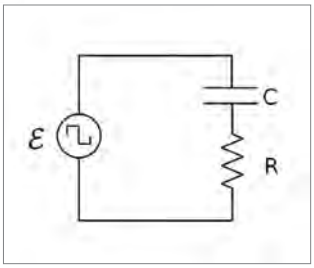
PASCO Advantage

The RC Circuit experiment is extremely simple and transparent to set up. It is very easy to measure the time to half charge. It is also easy to verify that the curve is exponential using the curve-fitting capability of PASCO Capstone™ Software.





The actual capacitance is determined from the charge/discharge curve.



The 850 Universal Interface provides a very clean square wave to the series RC circuit.

Experiment Includes

Resistive/Capacitive/Inductive Network	UI-5210
Voltage Sensor	UI-5100
Short Patch Cords (set of 8)	SE-7123

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9986) into the search box at **www.pasco.com**.

Order Information

RC Circuit EX-5536

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13

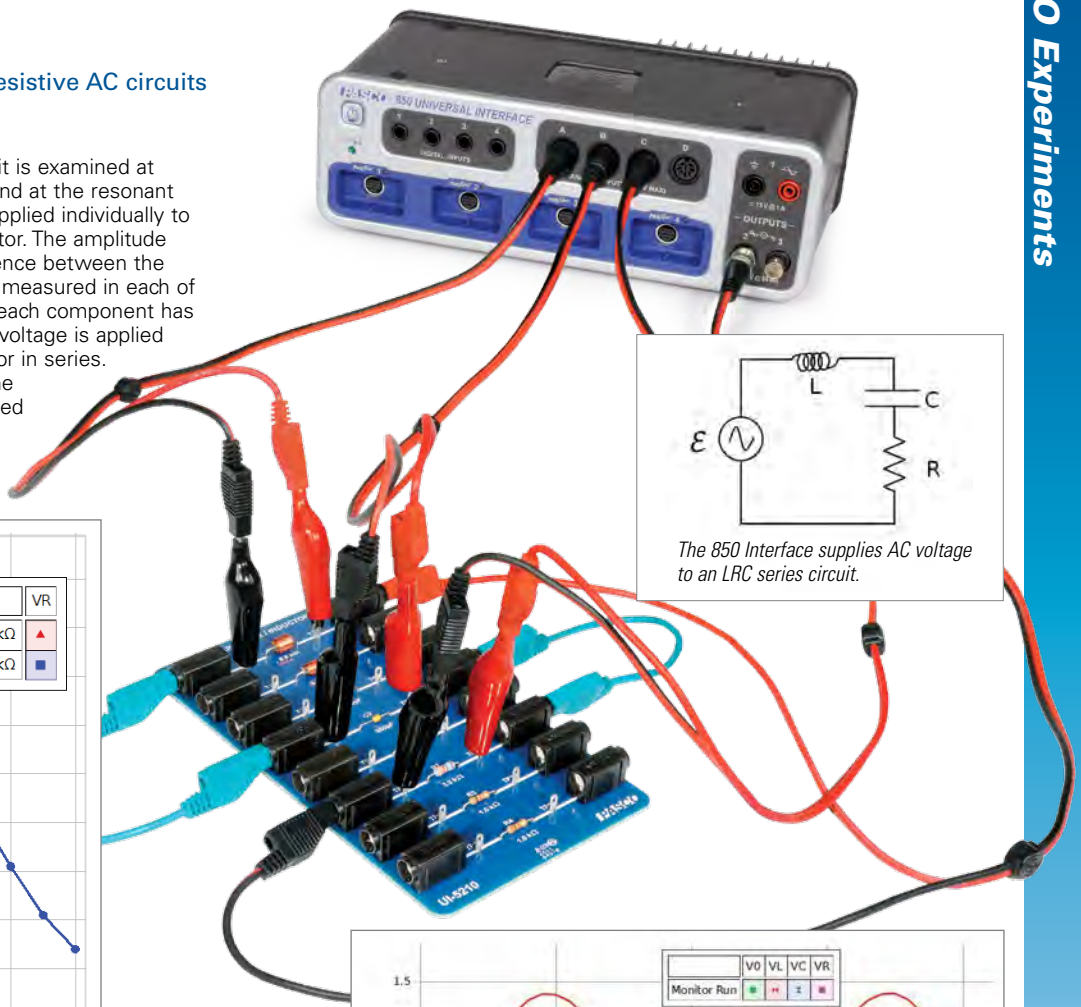
LRC Circuit

EX-5537

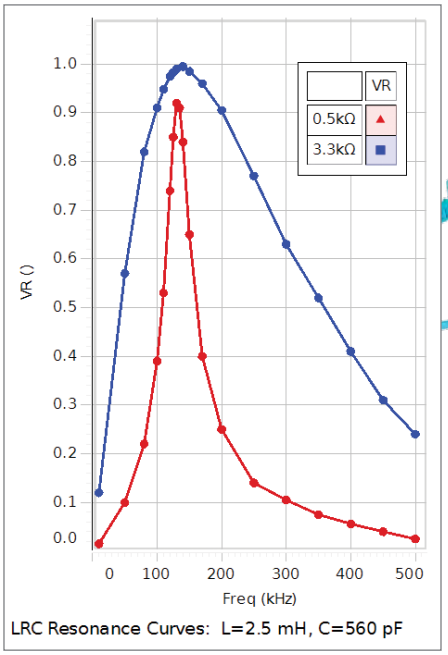
Concepts:

- LC oscillations
- Inductive, capacitive, and resistive AC circuits
- LRC resonant frequency

The response of a series LRC circuit is examined at driving frequencies above, below, and at the resonant frequency. A sinusoidal voltage is applied individually to a resistor, a capacitor, and an inductor. The amplitude of the current and the phase difference between the applied voltage and the current are measured in each of the three circuits to see the effect each component has on the current. Finally, a sinusoidal voltage is applied to an inductor, resistor, and capacitor in series. The amplitude of the current and the phase difference between the applied voltage and the current are measured and compared to theory.

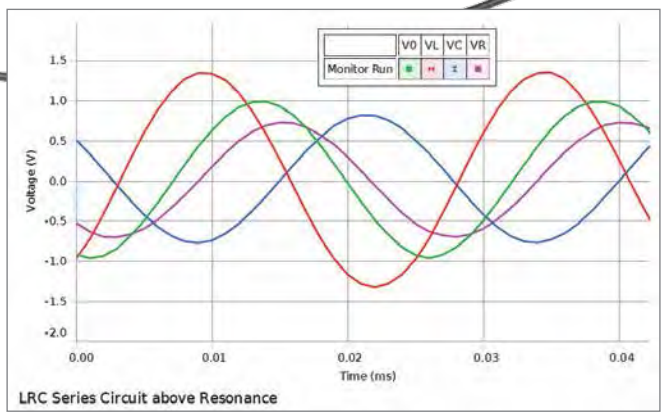


The 850 Interface supplies AC voltage to an LRC series circuit.



LRC Resonance Curves: L=2.5 mH, C=560 pF

The effect of circuit resistance on peak width is clear and leads to an understanding of how to design a filter for a circuit.



LRC Series Circuit above Resonance

The oscilloscope display in PASCO Capstone™ is used to simultaneously display the voltages across the inductor, capacitor, and resistor, as well as the source voltage.

Experiment Includes

Resistive/Capacitive/Inductive Network	UI-5210
Voltage Sensors (3)	UI-5100
Short Patch Cords (set of 8)	SE-7123
BNC to Banana Output Cable	UI-5119

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9915 and EX-9967) into the search box at **www.pasco.com**.

Order Information

LRC Circuit EX-5537

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Electromagnetism

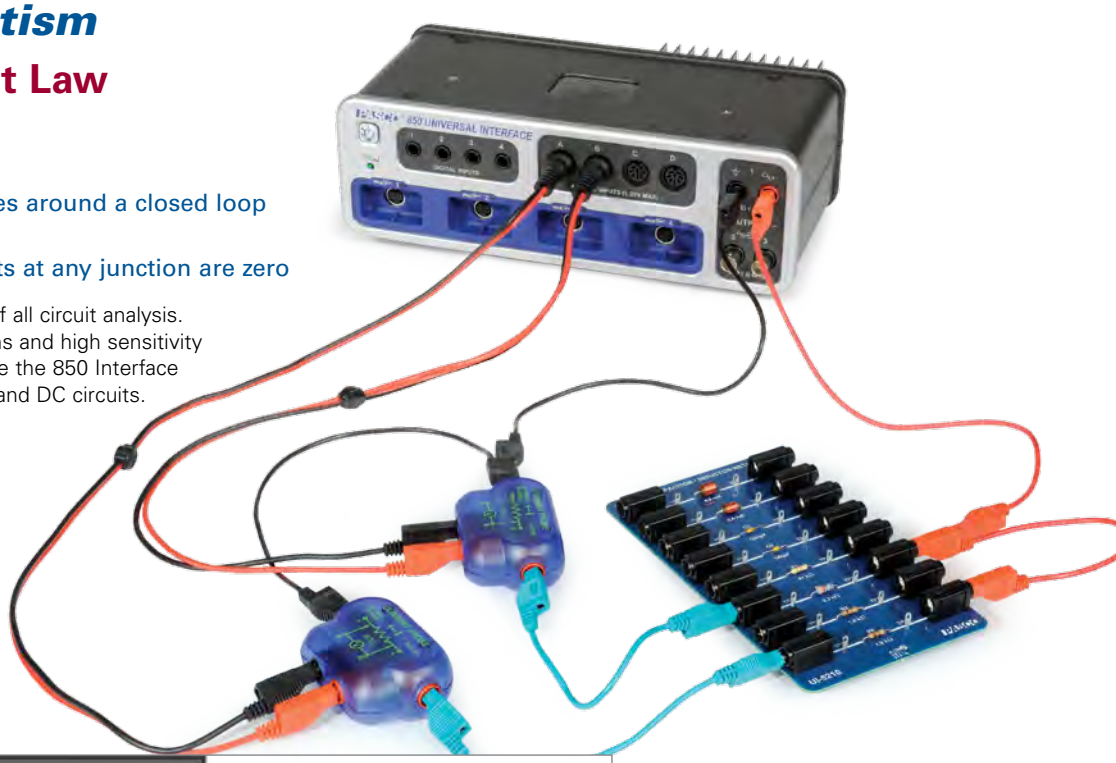
Kirchhoff's Circuit Law

EX-5538

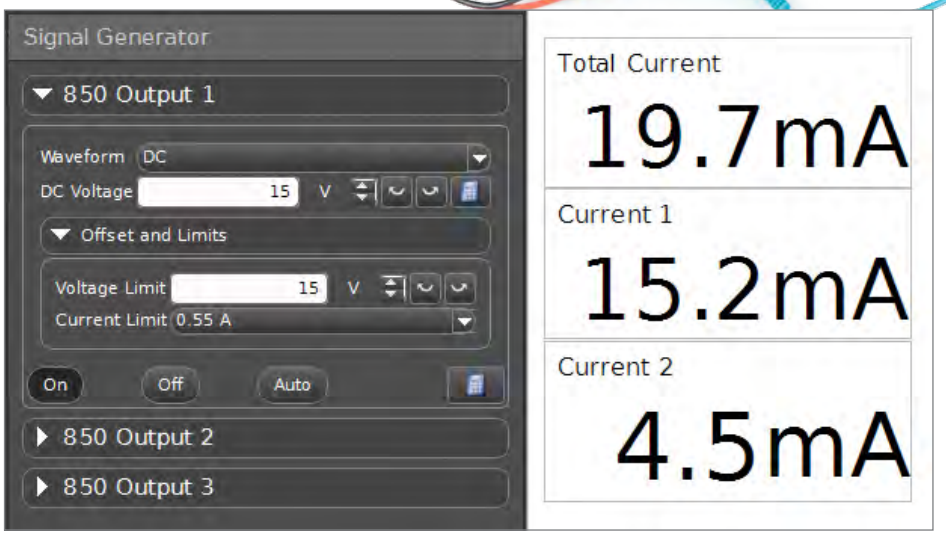
Concepts:

- Summation of the voltages around a closed loop are zero at any instant
- Summation of the currents at any junction are zero

Kirchhoff's Laws form the basis of all circuit analysis. The high speed for AC applications and high sensitivity (0.1 mA) for DC applications make the 850 Interface an ideal tool for investigating AC and DC circuits.

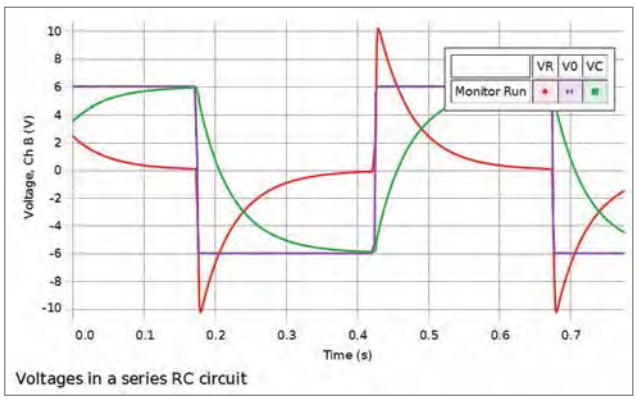


Students control output from the 850 signal generators directly from the user interface in PASCO Capstone™.



Measurement of voltages and currents in series-parallel DC circuits demonstrates the validity of Kirchhoff's Laws. The use of multiple current probes avoids student confusion that can arise when rearranging the circuit to measure currents at different points.

Students compare the current flow through each resistor to the total current output from the 850.



The high speed of the 850 Universal Interface, in scope mode, allows the examination of time varying voltages in an RC circuit to verify that Kirchhoff's loop theorem holds even when voltage is not constant.

Experiment Includes

Resistive/Capacitive/Inductive Network	UI-5210
Voltage Sensors (3)	UI-5100
Current Probe (2)	PS-2184
Short Patch Cords (set of 8)	SE-7123

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Kirchhoff's Circuit Law EX-5538

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Earth's Magnetic Field

EX-5539A

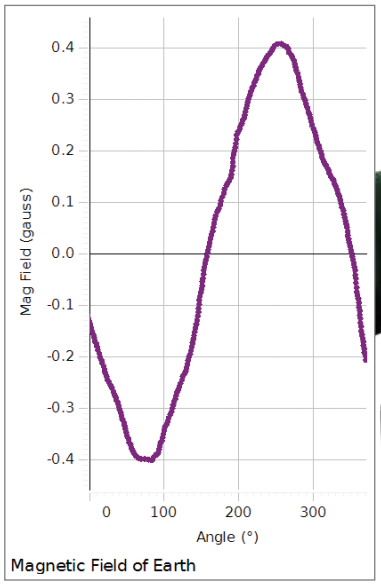
Concepts:

- Magnitude of the earth's magnetic field
- Direction of earth's magnetic field
- Dip angle

The magnitude and direction of the Earth's magnetic field are measured using a Magnetic Field Sensor mounted on a Rotary Motion Sensor. The Magnetic Field Sensor is rotated through 360 degrees by rotating the Rotary Motion Sensor pulley by hand. The Magnetic Field Sensor is zeroed using the Zero Gauss Chamber, the walls of which are made of a highly permeable material that redirects the magnetic field around the chamber.



The Magnetic Field Sensor is mounted on a Rotary Motion Sensor to measure the magnitude and direction of the Earth's magnetic field.



The Earth's magnetic field is measured as the Magnetic Field Sensor is rotated 360 degrees in the Earth's field.

PASCO Advantage

The sensitive Magnetic Field Sensor combined with the Rotary Motion Sensor enables the measurement of the magnetic field strength as a function of angle from North. It is essentially a computerized compass that can measure both the direction and the magnitude of the field.

Experiment Includes

2-Axis Magnetic Field Sensor	PS-2162
Zero Gauss Chamber	EM-8652
Rotary Motion Sensor	PS-2120A
Dip Needle	SF-8619
Aluminum Table Clamp	ME-8995
25 cm Stainless Steel Rod (threaded)	ME-8988
Adjustable Angle Clamp	ME-8744
Angle Indicator	ME-9495A

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9913 and EX-9968A) into the search box at **www.pasco.com**.

Order Information

Earth's Magnetic Field EX-5539A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13

Electromagnetism

Magnetic Forces on Wires

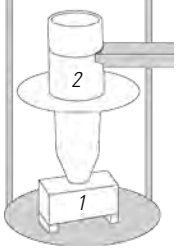
EX-9933

Concepts:

- Relationship between:
  force and current, force and length of wire,
  force and magnetic field strength, force and angle

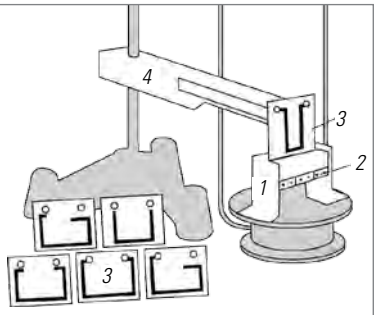


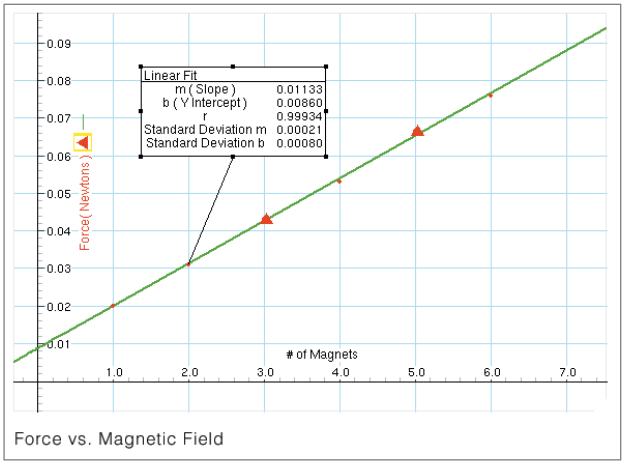




1. *Fixed Magnet with Yoke*
2. *10-turn Rectangular Coil (with a built-in degree scale)*

1. *Iron Yoke (holds magnets)*
2. *Removable Magnets (six)*
3. *Six Conductors (1, 2, 3, 4, 6 and 8 cm in length)*
4. *Mount (for holding/positioning conductors)*





Force vs. Magnetic Field

Graph illustrates the direct relationship between magnetic field and magnetic force.

Magnets are mounted on an iron yoke and placed on a balance (resolution of at least 0.01 g). One of the conducting paths is suspended between the magnets. The balance is used to measure the mass of the magnets and yoke prior to any current passing through the conducting path. Current is then passed through the conducting path, producing a force. The change in reading on the balance can be converted to find the magnetic force between the conductor and magnetic field.

Conductors of different lengths are included to measure the effect of length on magnetic force. Magnetic field can be varied by changing the number of magnets in the yoke. The power source is used to change the current supplied to the conductor. The Current Balance Accessory includes all the components needed to test the effect of angle on magnetic force.

PASCO Advantage

PASCO's Magnetic Force in Wires Experiment allows students to study the key variables (conductor length, current, magnetic field strength, and angle) that affect magnetic force.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Experiment Includes

Basic Current Balance	SF-8607
Current Balance Accessory	SF-8608
Ohaus Cent-o-Gram Balance	SE-8725
Low Voltage AC/DC Power Supply	SF-9584B
Large Base and Support Rod	ME-9355
Banana Plug Cord-Red (5 pack)	SE-9750
Banana Plug Cord-Black (5 pack)	SE-9751
Magnetic Forces on Wires Experiment Manual	

Order Information

Magnetic Forces on Wires EX-9933

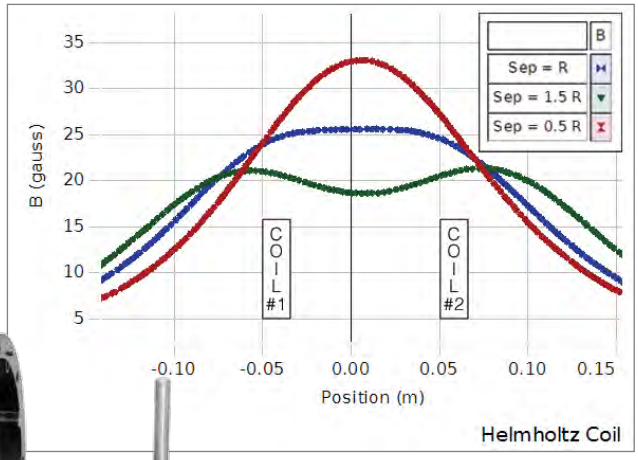
Magnetic Fields of Coils

EX-5540

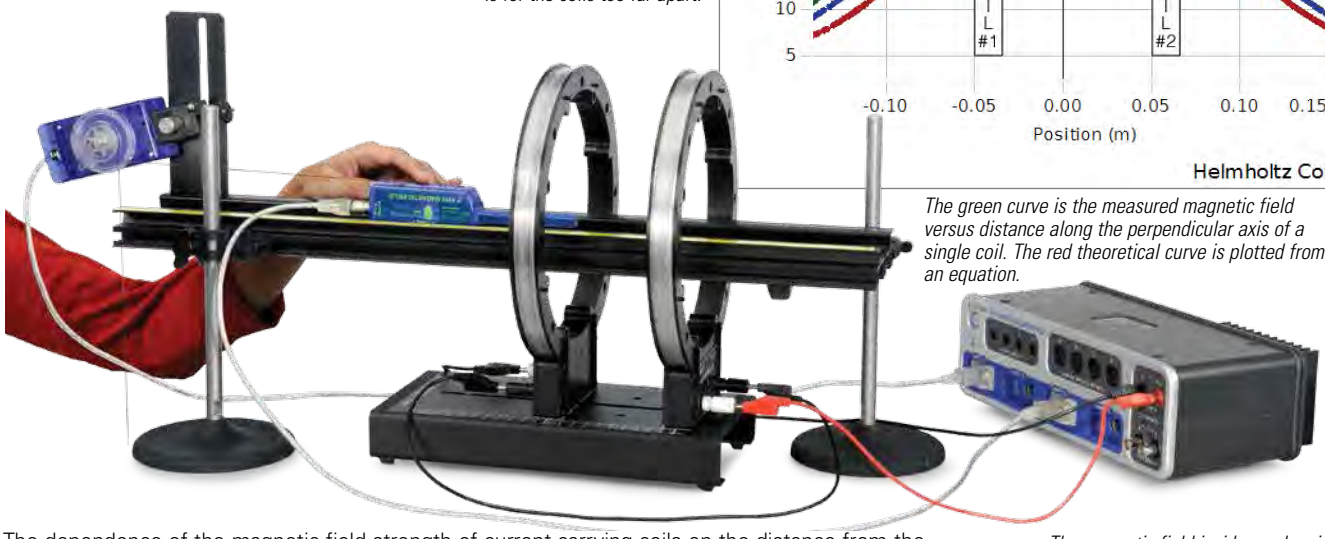
Concepts:

- Magnetic fields of:
  - single coil
  - Helmholtz coils
  - inside a solenoid

This plot shows the magnetic field strength along the axis of Helmholtz coils for three different coil separations. The green data is for coils with the proper separation (the coil radius), the red data is for the coils too close together, and the blue data is for the coils too far apart.



The green curve is the measured magnetic field versus distance along the perpendicular axis of a single coil. The red theoretical curve is plotted from an equation.



The magnetic field inside a solenoid is measured in the radial and axial directions.

The magnetic field of Helmholtz coils is measured as a function of distance along the perpendicular axis.

The dependence of the magnetic field strength of current-carrying coils on the distance from the coil along the perpendicular axis is determined and compared to the theoretical curve. In addition, the effect of varying the coil separation on the shape of the magnetic field between the Helmholtz coils is examined.

The magnetic fields of various coils are plotted versus position as the Magnetic Field Sensor is passed through the coils, guided by a track. The position is recorded by a string attached to the Magnetic Field Sensor that passes over the Rotary Motion Sensor pulley to a hanging mass.

It is particularly interesting to compare the field from Helmholtz coils at the proper separation of the coil radius to the field from coils separated at less than or more than the coil radius.

The magnetic field inside a solenoid can be examined in both the radial and axial directions.



PASCO Advantage

Using the PASCO Capstone™ curve fit, the theoretical equation for the magnetic field can be plotted on the same graph.

Experiment Includes

Helmholtz Coil Base	EM-6715
Field Coil (2) (500 turn)	EM-6723
Primary and Secondary Coils	SE-8653
Patch Cords-red (set of 5)	SE-9750
Patch Cords-black (set of 5)	SE-9751
60 cm Optics Bench	OS-8541
Dynamics Track Mount	CI-6692
20 g hooked mass (Hooked Mass Set)	SE-8759
Small Round Base (set of 2)	ME-8974A
25 cm Steel Rod (2)	ME-8988
Optics Bench Rod Clamps (set of 2)	OS-8479
2-Axis Magnetic Field Sensor	PS-2162
Rotary Motion Sensor	PS-2120A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9931) into the search box at **www.pasco.com**.

Order Information

Magnetic Fields of Coils EX-5540A

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Electromagnetism

Faraday's Law of Induction

EX-5541A

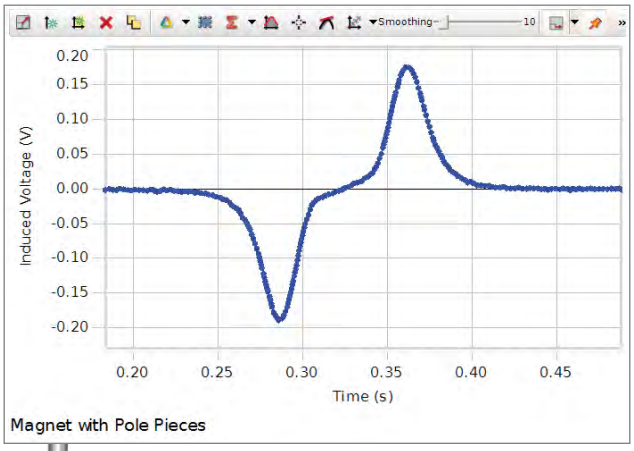
Concepts:

- Magnetic flux
- Faraday's Law of Induction
- Lenz's Law
- Conservation of energy
- Electrical power

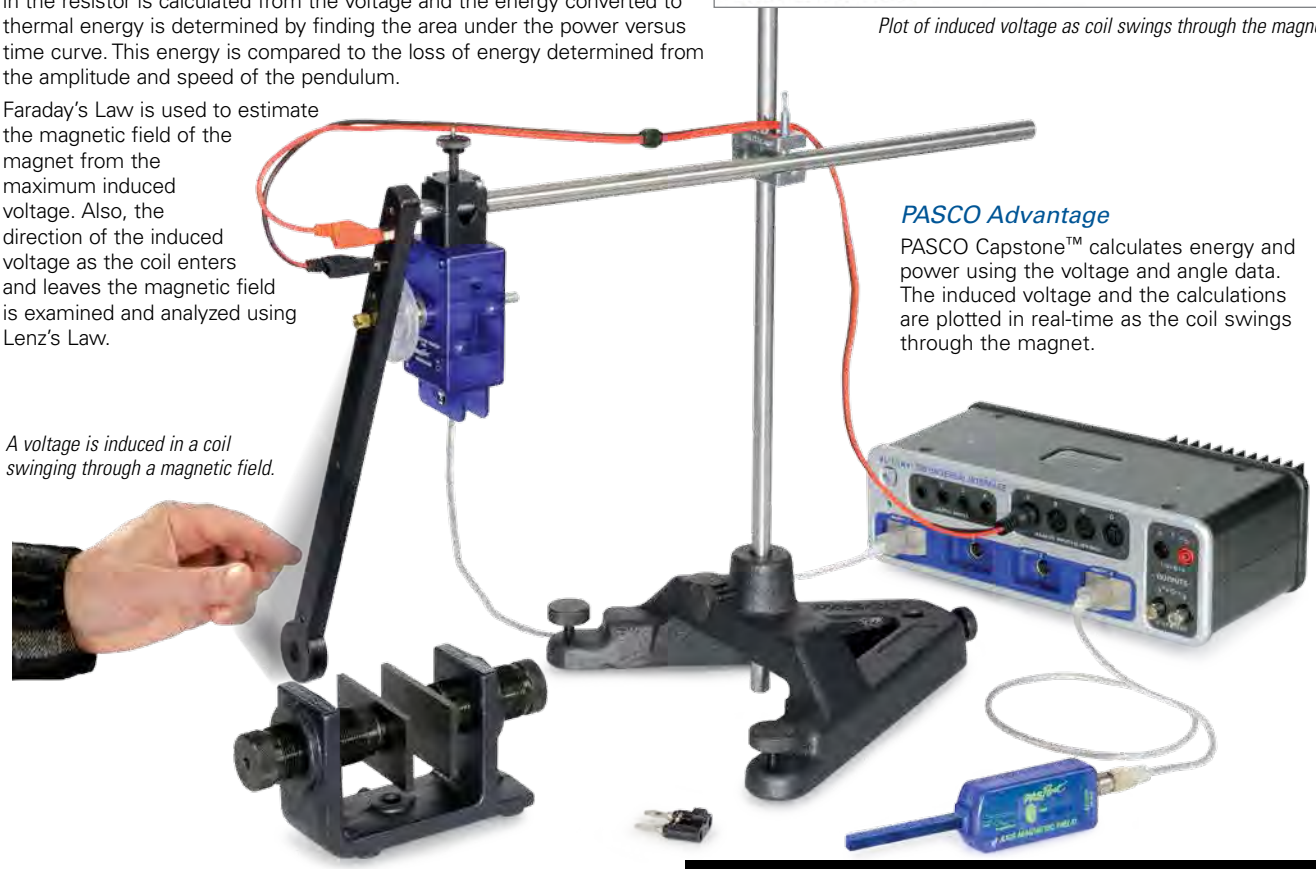
A voltage is induced in a coil swinging through a magnetic field. Faraday's Law and Lenz's Law are examined and the energy dissipated in a load resistor is compared to the loss of energy of the coil pendulum.

A rigid pendulum with a coil at its end swings through a horseshoe magnet. A resistive load is connected across the coil and the induced voltage is recorded using a Voltage Sensor. The angle is measured with a Rotary Motion Sensor, which also acts as a pivot for the pendulum. The induced voltage is plotted versus time and angle. The power dissipated in the resistor is calculated from the voltage and the energy converted to thermal energy is determined by finding the area under the power versus time curve. This energy is compared to the loss of energy determined from the amplitude and speed of the pendulum.

Faraday's Law is used to estimate the magnetic field of the magnet from the maximum induced voltage. Also, the direction of the induced voltage as the coil enters and leaves the magnetic field is examined and analyzed using Lenz's Law.



Plot of induced voltage as coil swings through the magnet



A voltage is induced in a coil swinging through a magnetic field.

PASCO Advantage

PASCO Capstone™ calculates energy and power using the voltage and angle data. The induced voltage and the calculations are plotted in real-time as the coil swings through the magnet.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9914 and EX-9957B) into the search box at **www.pasco.com**.

Experiment Includes

Induction Wand	EM-8099
Variable Gap Lab Magnet	EM-8641
Large Rod Base	ME-8735
45 cm Steel Rod (2)	ME-8736
Multi Clamp	ME-9507
Voltage Sensor	UI-5100
2-Axis Magnetic Field Sensor	PS-2162
Rotary Motion Sensor	PS-2120A

Use the 850 or the NEW 550 Interface



Order Information

Faraday's Law of Induction EX-5541A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13

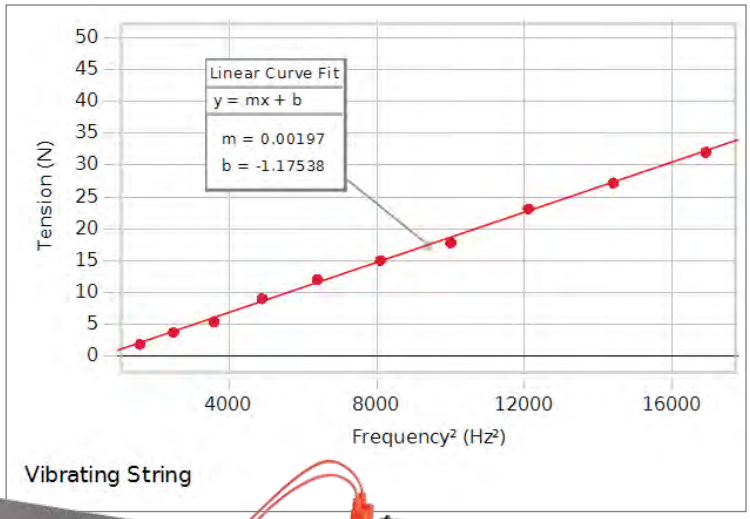
Vibrating String

EX-5542

Concepts:

- Investigate standing waves
- Pull string to adjust number of segments
- Vary frequency of vibration

Study standing waves in a string by varying the driver frequency and keeping the number of segments constant. The String Vibrator is powered by the 850 Universal Interface. Students vary both the frequency and amplitude.



A graph of force vs. the square of the frequency shows a linear relationship. The slope of this line is related to the length and density of the string.



The string tension is measured directly with a Force Sensor, enabling students to feel the force required to obtain a certain number of segments.

PASCO Advantage

The unusual approach in this version of the experiment is that the students actually provide the tension in the string by pulling directly on the force sensor. This is particularly instructive because the students get a feel for how the tension must change to vary the number of segments. Rather than hanging more weight over a pulley, the students must pull harder to achieve a smaller number of segments. This helps them remember the relationship between tension and wavelength.

The 850 Universal Interface controls the frequency and amplitude of the sine waves applied to the String Vibrator. As the frequency is gradually increased (in 10 Hz increments), the student pulls on the Force Sensor to adjust the tension for resonance with the string vibrating in two segments.

Experiment Includes

String Vibrator	WA-9857
Physics String	SE-8050
Force Sensor	PS-2104
Large "C" Clamp	SE-7285
Patch Cords (set of 5)	SE-9750
Tape Measure	SE-8712A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9964) into the search box at **www.pasco.com**.

Order Information

Vibrating String EX-5542

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

Waves and Optics

Waves

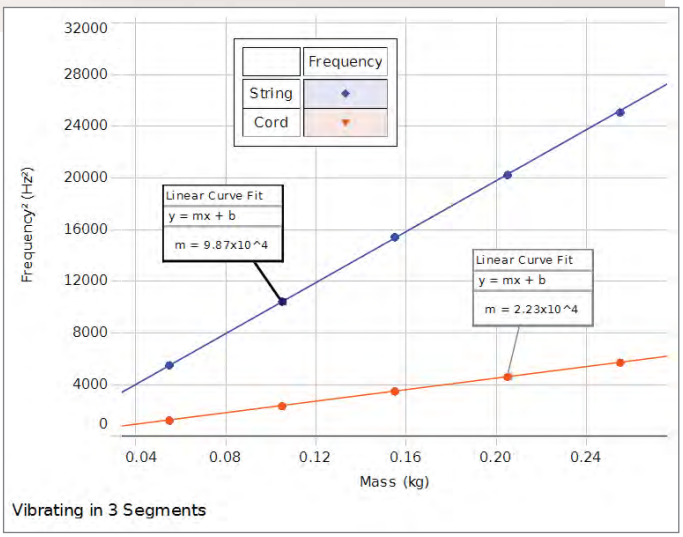
EX-9952

Concepts:

- Speed of waves in a string
- Speed of sound in air
- Resonance in strings and air columns
- Harmonics



Standing waves in strings and air columns are studied. Using a sine wave generator to drive a string vibrator, the driving frequency, length, density, and tension of the string are varied to explore standing waves in strings and to determine the speed of the wave. For the sound waves in the air column, a speaker is used to drive a resonance tube. The driving frequency and the length of the tube are varied for both open and closed tubes. The relationship between resonant frequency modes and tube length is determined for closed versus open tubes.



Graphs of the square of the frequency versus the hanging mass for two different types of strings have different slopes corresponding to different string densities.

Experiment Includes

String Vibrator	WA-9857
Sine Wave Generator	WA-9867
Open Speaker	WA-9900
Economy Resonance Tube	WA-9495
Elastic Wave Cord	SE-9409
Physics String	SE-8050
Yellow Braided Cord	699-067
Mass and Hanger Set	ME-8979
Universal Table Clamp (2)	ME-9376B
Adjustable Angle Clamp	ME-8744
Super Pulley	ME-9450
Pulley Mounting Rod	SA-9242
45 cm Rod (2)	ME-8736
Banana Plug Cord Set, Red	SE-9750
Waves Experiment Manual	

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

PASCO Advantage

The frequency of the vibration of the string is not limited to the line frequency, so the frequency can be varied as well as the length and the tension.

Order Information

Waves EX-9952

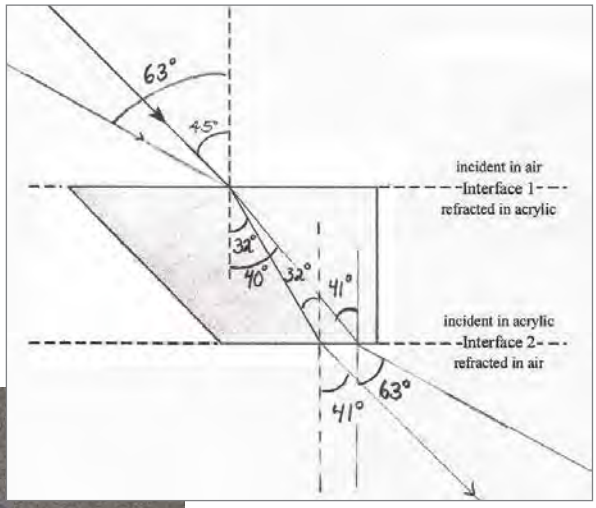
Reflection and Refraction

EX-9987

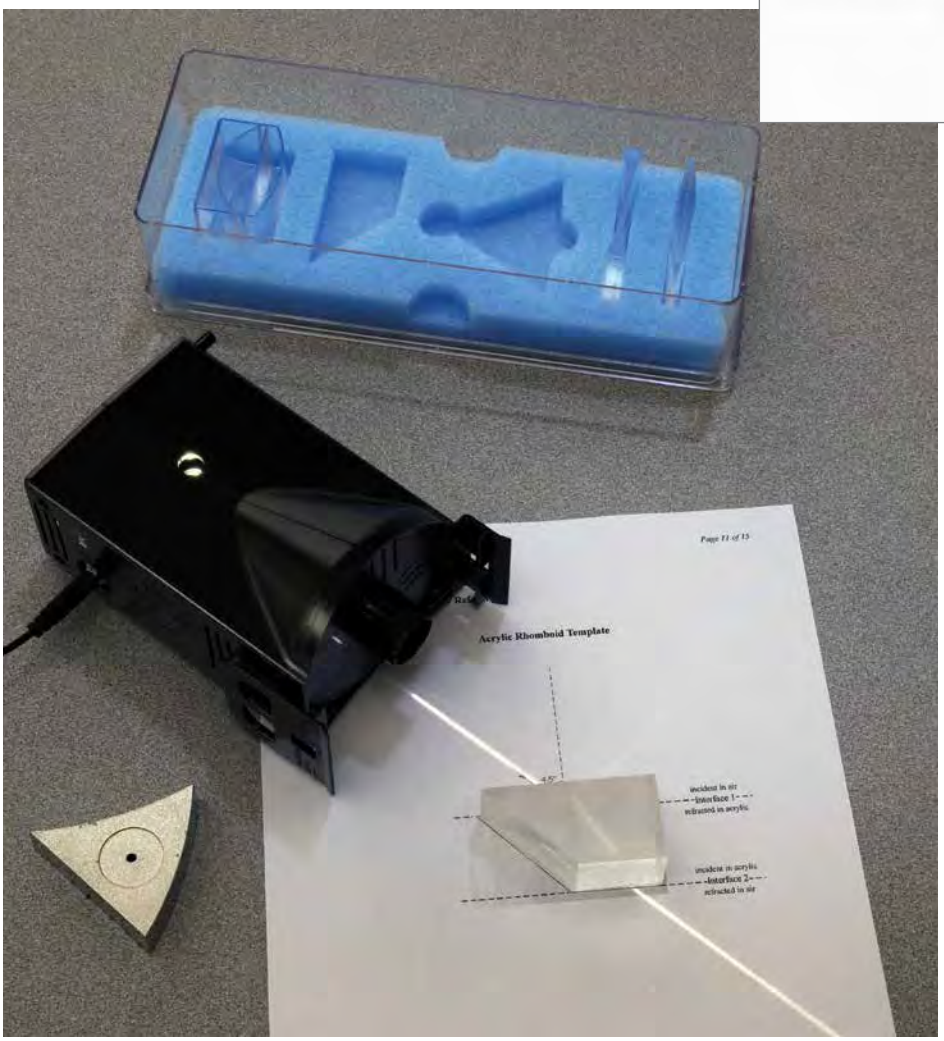
Concepts:

- Reflection and refraction
- Index of refraction

Students experimentally derive the Law of Reflection for curved and flat mirrors. Snell's Law is explored and the index of refraction for a piece of acrylic material is found.



Sample of student work, showing the path of two different rays passing through the acrylic rhomboid.



PASCO Advantage

Students trace the rays on the provided templates and make angle measurements directly from their drawing. This reinforces the connection between the real rays they can see in the lab and the type of ray diagrams seen in the classroom.

Experiment Includes

Ray Optics Kit	OS-8516A
Basic Optics Light Source	OS-8470
Reflection and Refraction Experiment Manual	

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Reflection and Refraction EX-9987

Required:
Protractor and Ruler

Waves and Optics

Speed of Light

EX-9932A

CLASS II LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM OR
VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

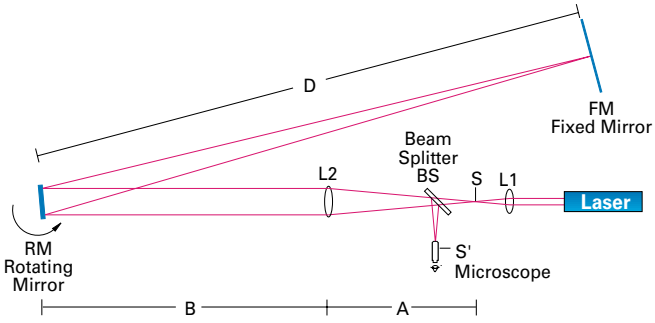
Concepts:

- Determine the Speed of Light in Air
- Recreate Foucault's Historical Experiment



The Speed of Light Experiment uses laser light and a high-speed rotating mirror to determine this fundamental constant using the Foucault method.

Laser light passes through a series of lenses to produce an image of the light source at a measured position. The light is then directed to a rotating mirror, which reflects the light to a fixed mirror at a known distance from the rotating mirror. The laser light is reflected back through its original path and a new image is formed at a slightly different position. The difference between final/initial positions, angular velocity of the rotating mirror, and distance traveled by the light are then used to calculate the speed of light in air.



PASCO Advantage

PASCO's Speed of Light Experiment allows students to experimentally measure the speed of light within 5% of the accepted value. In addition, the experiment can be performed on a desktop or in a hallway.

Experiment Includes

Complete Speed of Light Apparatus	OS-9261B
Speed of Light Experiment Manual	

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Speed of Light EX-9932A

Telescope/Microscope

EX-9988

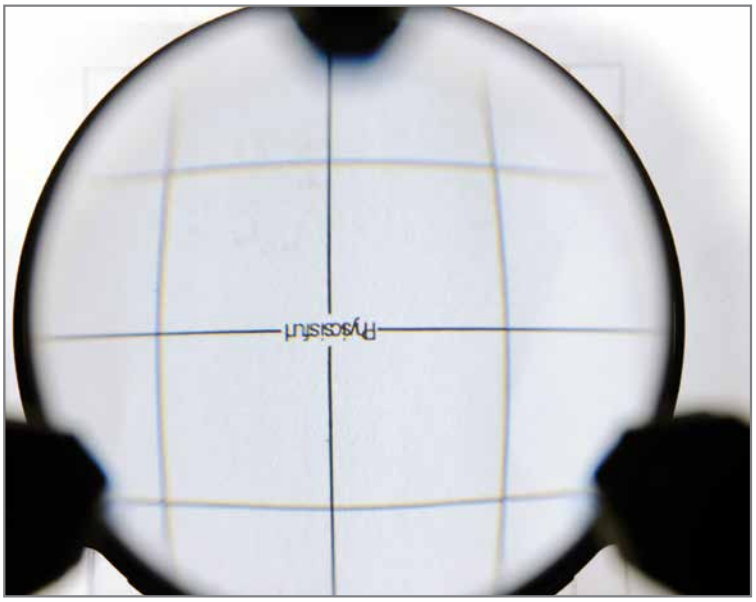
Concepts:

- Multiple lens systems
- Magnification
- Parallax
- Description of images

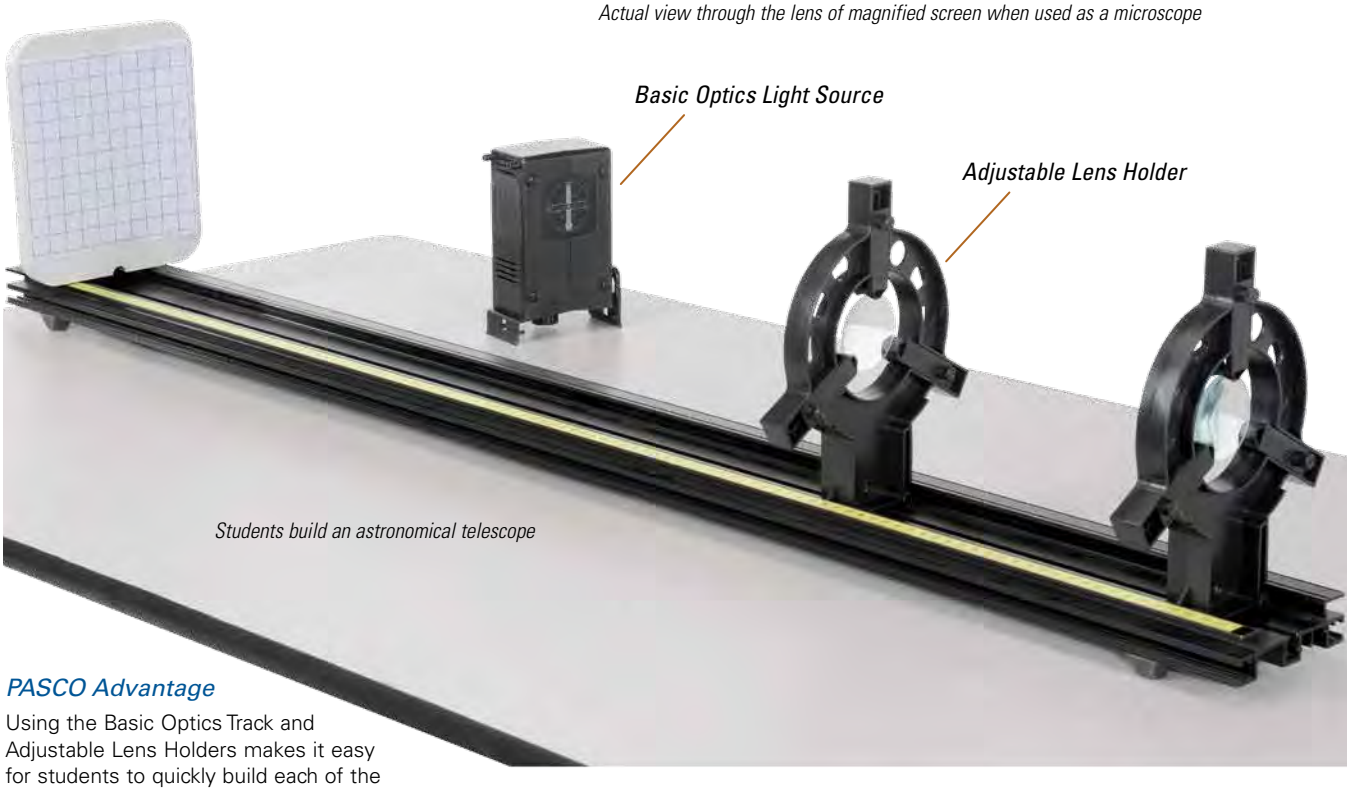
Students construct an astronomical telescope, a Galilean telescope, and a compound microscope on the optical bench. Using a viewing screen with grid, they find and describe the ways in which images are changed by the multiple lens systems.

The parallax method is used to locate virtual images. Students draw ray diagrams and measure the magnification of the instruments.

Cross-hatched screen pattern from provided template allows students to easily observe and measure the resulting magnification.



Actual view through the lens of magnified screen when used as a microscope



Students build an astronomical telescope

PASCO Advantage

Using the Basic Optics Track and Adjustable Lens Holders makes it easy for students to quickly build each of the instruments. Open construction means that all students can see the location and types of lenses used.

Experiment Includes

Beginning Optics System	OS-8459
Includes:	
Basic Optics Light Source	OS-8470
Adjustable Lens Holders (2)	OS-8474
Geometric Lens Set	OS-8466A
Viewing Screen	OS-8460
1.2 m Optics Bench	OS-8508

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Telescope and Microscope EX-9988

Required:

Rubber Bands and Ruler

Waves and Optics

Polarization of Light

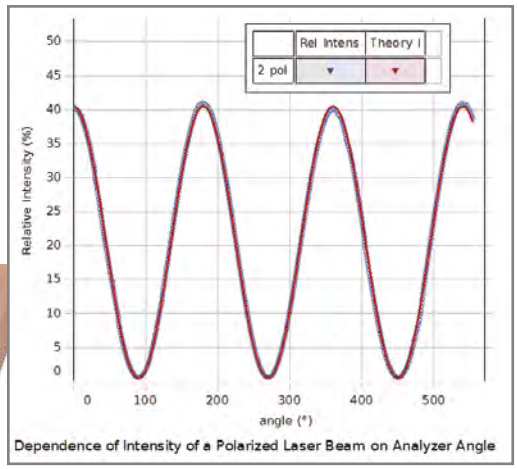
CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

EX-5543A

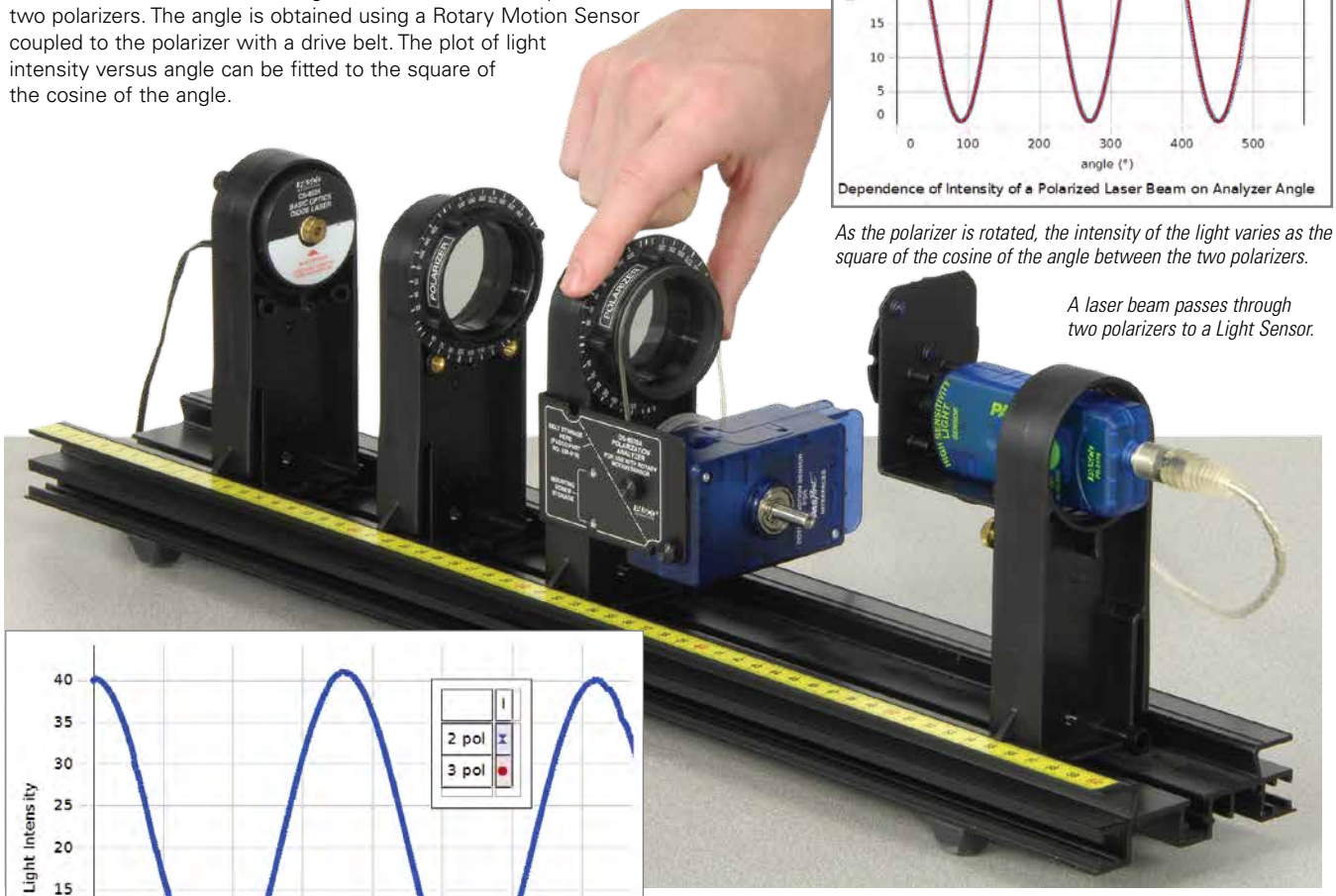
Malus' Law of Polarization

In this experiment, Malus' Law of Polarization is verified by showing that the intensity of light passed through two polarizers depends on the square of the cosine of the angle between the two polarization axes.

Laser light (peak wavelength = 650 nm) is passed through two polarizers. As the second polarizer (the analyzer) is rotated by hand, the relative light intensity is recorded as a function of the angle between the axes of polarization of the two polarizers. The angle is obtained using a Rotary Motion Sensor coupled to the polarizer with a drive belt. The plot of light intensity versus angle can be fitted to the square of the cosine of the angle.



As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.



A laser beam passes through two polarizers to a Light Sensor.

A three polarizer system can be produced using the fact that the laser is polarized. The data (red trace) at left shows that there are four oscillations per full rotation for a three polarizer system.

PASCO Advantage

Laser light is used in this experiment because its wavelength is more completely extinguished by the crossed polarizers.

Experiment Includes

Polarization Analyzer	OS-8533A
Basic Optics Bench (60 cm)	OS-8541
Red Diode Laser	OS-8525A
High Sensitivity Light Sensor	PS-2176
Rotary Motion Sensor	PS-2120A

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9917A and EX-9958) into the search box at **www.pasco.com**.

Order Information

Polarization of Light EX-5543A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13

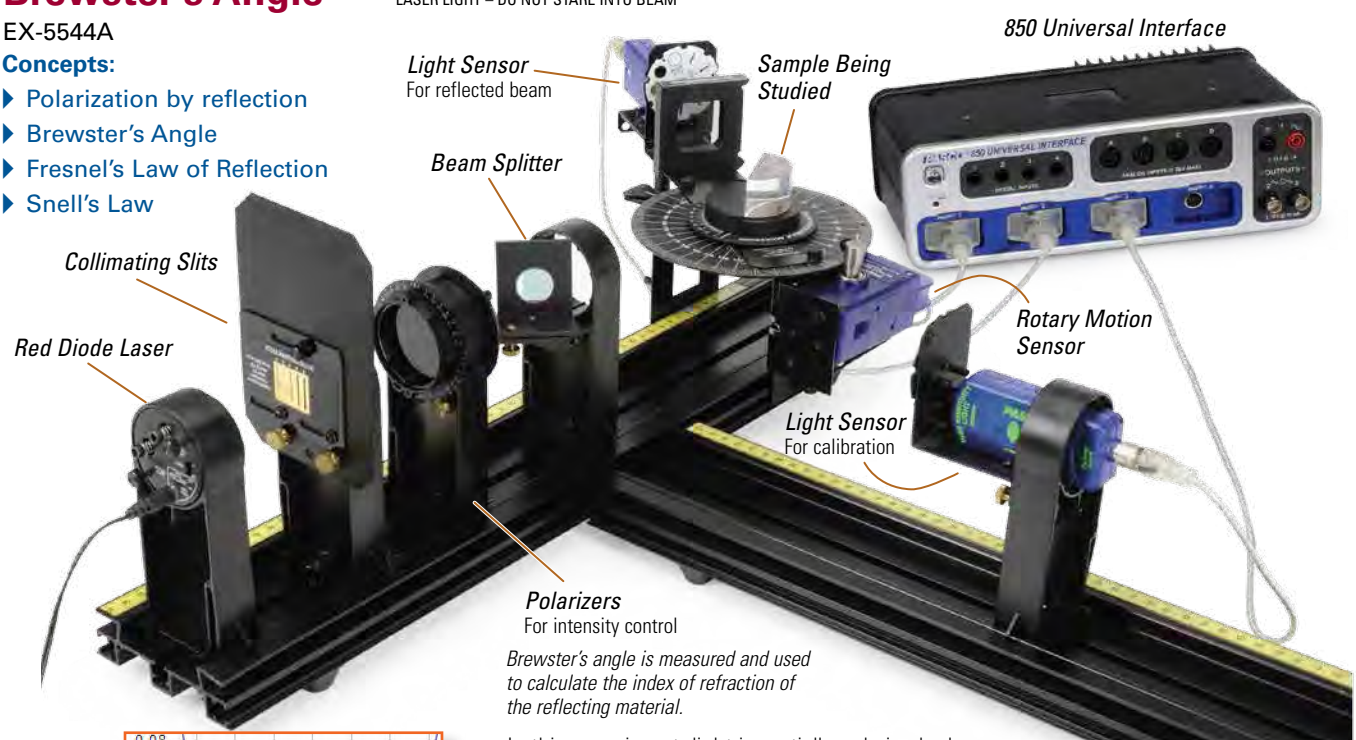
Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Brewster's Angle

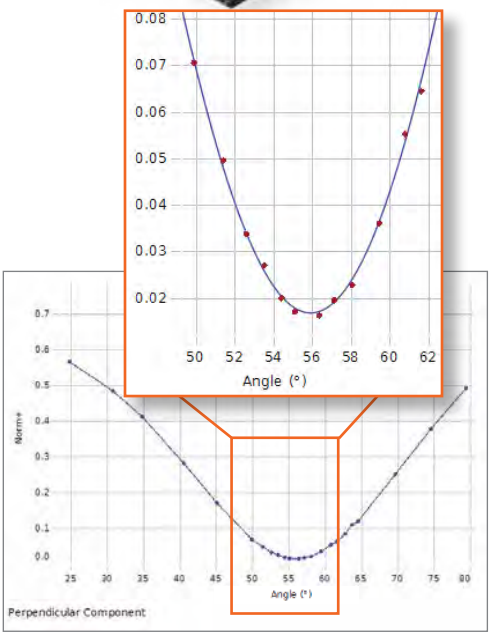
EX-5544A

Concepts:

- Polarization by reflection
- Brewster's Angle
- Fresnel's Law of Reflection
- Snell's Law



Brewster's angle is measured and used to calculate the index of refraction of the reflecting material.



Brewster's Angle is determined by finding the angle at which no light is transmitted through the analyzing polarizer.

In this experiment, light is partially polarized when reflected off a nonconducting surface and Brewster's Angle is measured. Light from a diode laser is reflected off the flat side of an acrylic semicircular lens. The reflected light passes through a polarizer and is detected by a Light Sensor. The angle of reflection is measured by a Rotary Motion Sensor mounted on the Spectrophotometer table. The intensity of the reflected polarized light versus reflected angle is graphed to determine the angle at which the light intensity is a minimum. This is Brewster's Angle, which is used to calculate the index of refraction of acrylic.

PASCO Advantage

It is possible to determine the difference in index of refraction for different wavelengths of light. This is accomplished by using a beam-splitter and a second light sensor to compensate for the variation of the laser intensity. The reflected beam intensity is normalized by the intensity of the laser. This modification to the experiment was suggested by Cristian Bahrim and Wei-Tai Hsu in the American Journal of Physics article: "Precise Measurement of the Refractive Indices for Dielectrics Using an Improved Brewster Angle Method", Vol. 77, page 337 (2009).

Developed using original ideas from P.J. Ouseph, Professor of Physics at University of Louisville, KY. "Polarization of Light by Reflection and the Brewster Angle" by P.J. Ouseph, Kevin Driver, and John Conklin, Am. J. Phys. 69, 1166 (2001).

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9919A and EX-9965A) into the search box at **www.pasco.com**.

Experiment Includes

Brewster's Angle Accessory	OS-8170A
Spectrophotometer Accessory Kit	OS-8537
Optics Bench (60 cm) (2)	OS-8541
Rotary Motion Sensor	PS-2120A
High Sensitivity Light Sensor (2)	PS-2176
Aperture Bracket for Light Sensor (2)	OS-8534A
Red Diode Laser	OS-8525A
Polarizer Set	OS-8473

Use the 850 or the NEW 550 Interface



Order Information

Brewster's Angle EX-5544A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Waves and Optics

Interference and Diffraction of Light

EX-5545A

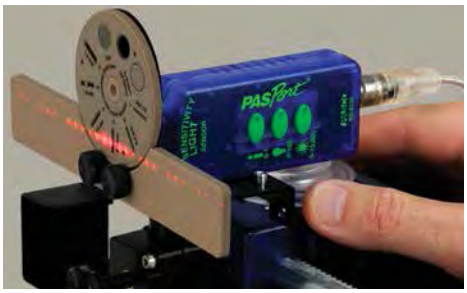
CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Concepts:

- Two-slit interference
- Single-slit diffraction
- Multiple-slit minor maxima
- Slit versus line diffraction

Interference and diffraction patterns from laser light passing through various single-slits and multiple-slits are scanned and plotted in real-time. These patterns are then examined for similarities and differences.

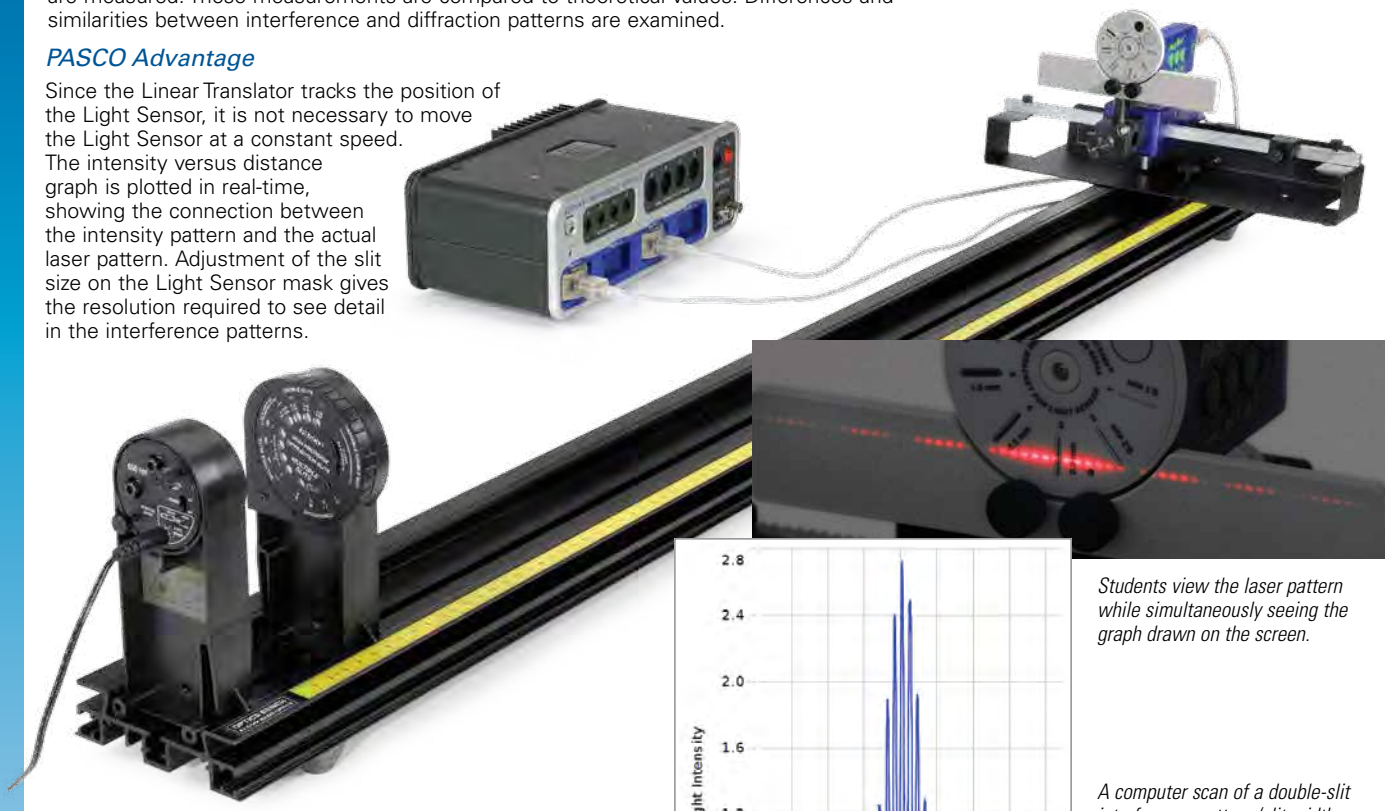
The distances between the central maximum and the diffraction minima for a single slit are measured by scanning the laser pattern with a Light Sensor and plotting light intensity versus distance. Also, the distances between interference maxima for two or more slits are measured. These measurements are compared to theoretical values. Differences and similarities between interference and diffraction patterns are examined.



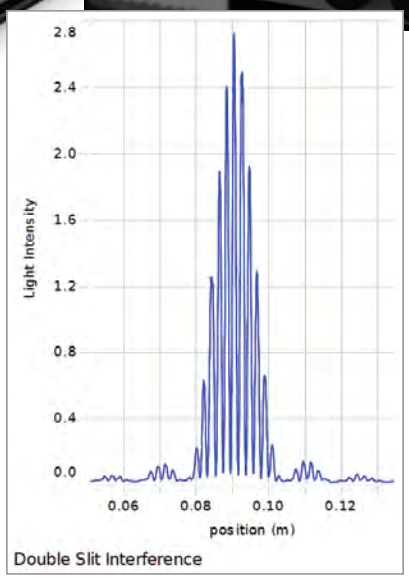
The laser interference pattern is scanned by hand with a Light Sensor on a Linear Translator.

PASCO Advantage

Since the Linear Translator tracks the position of the Light Sensor, it is not necessary to move the Light Sensor at a constant speed. The intensity versus distance graph is plotted in real-time, showing the connection between the intensity pattern and the actual laser pattern. Adjustment of the slit size on the Light Sensor mask gives the resolution required to see detail in the interference patterns.



Students view the laser pattern while simultaneously seeing the graph drawn on the screen.



A computer scan of a double-slit interference pattern (slit width 0.08 mm and slit separation 0.50 mm) is shown at left. A photograph of the actual laser pattern is shown above.

Experiment Includes

Basic Optics Track, 1.2 m	OS-8508
High Precision Diffraction Slits	OS-8453
Basic Optics Diode Laser	OS-8525A
Aperture Bracket	OS-8534A
Linear Translator	OS-8535
High Sensitivity Light Sensor	PS-2176
Rotary Motion Sensor	PS-2120A

Use the 850 or the NEW 550 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9918, and EX-9956A) into the search box at **www.pasco.com**.

Order Information

Interference and Diffraction of Light EX-5545A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Atomic Spectra

EX-5546A

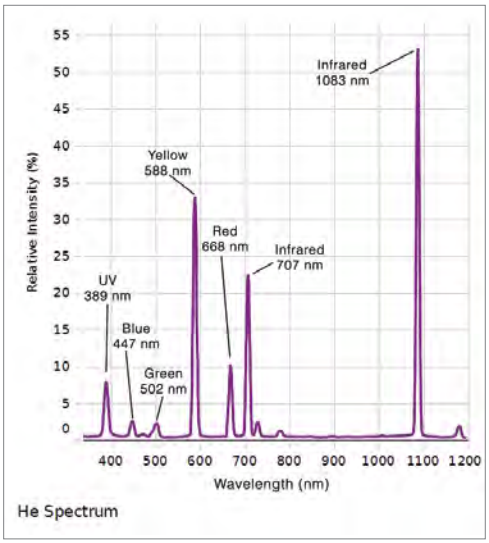
Concepts:

- Hydrogen balmer series
- Helium spectrum
- Mercury doublet

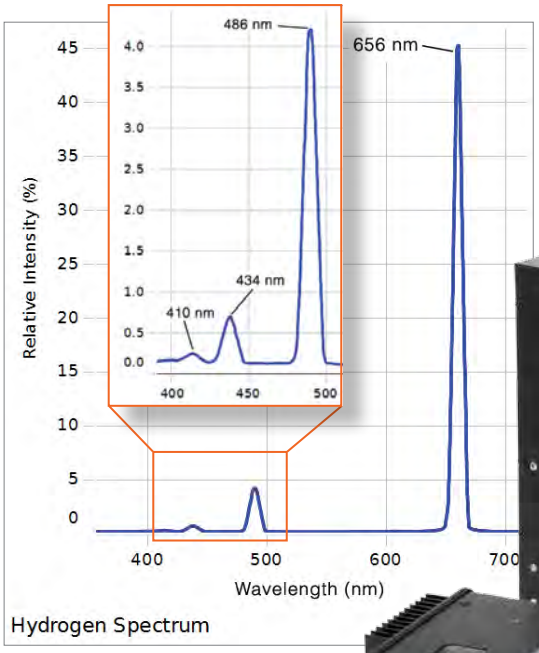
The wavelengths of the discrete lines of the atomic spectra of various gases are measured using a grating spectrophotometer.

The atomic spectra of hydrogen, helium, and mercury are scanned by hand using a grating spectrophotometer, which measures relative light intensity as a function of angle. From the resulting graph, the wavelengths of the spectral lines are determined by measuring the angle from the central maximum to each line. First and second order lines are examined. The spectrum of sodium (the sodium doublet cannot be resolved) is used to calibrate the diffraction grating.

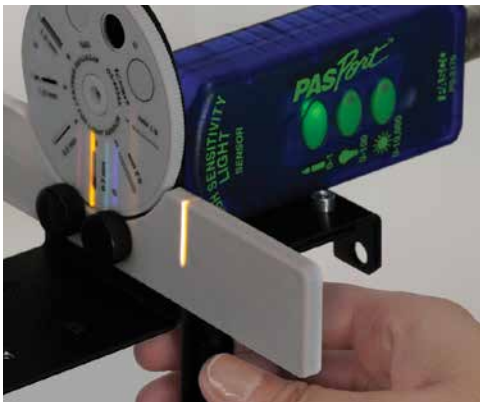
The wavelengths of the spectral lines are compared to the accepted values and, in the case of hydrogen, the electron orbit transitions corresponding to the lines are identified.



The spectral lines of helium are scanned.



The four brightest lines of the Balmer series for hydrogen.



PASCO Advantage

The open construction of the spectrophotometer allows the entire spectrum to be seen, while the intensity versus angle is graphed in real-time.

Experiment Includes

Spectrophotometer Accessory Kit	OS-8537
60 cm Optics Bench	OS-8541
Aperture Bracket	OS-8534A
High Sensitivity Light Sensor	PS-2176
Rotary Motion Sensor	PS-2120A
Small Round Base (set of 2)	ME-8974A
25 cm Steel Rod (2)	ME-8988
Low Pressure Sodium Light Source	OS-9287B
Spectral Tube Power Supply and Mount	SE-9460
Hydrogen Spectral Tube	SE-9461
Helium Spectral Tube	SE-9462
Mercury Spectral Tube	SE-9466

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

DataStudio Version:

The DataStudio experiment is also available to purchase. For order information and downloads, type the model number (EX-9921) into the search box at **www.pasco.com**.

Order Information

Atomic Spectra EX-5546A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Optics

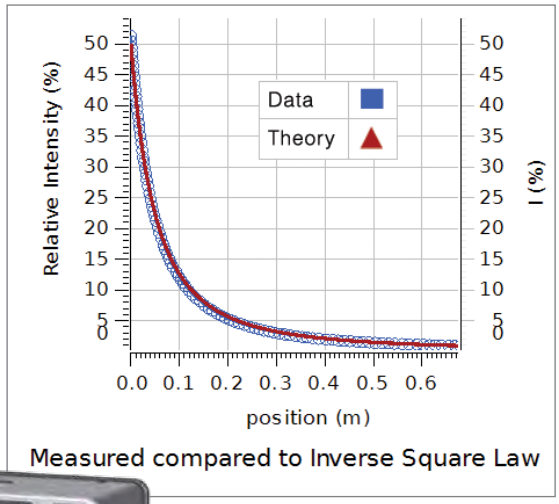
Light Intensity vs. Distance

EX-5547A

In this experiment the student measures intensity as a function of distance from a point of source and from an extended (5 cm x 5 cm) source. Manipulation of a computer model verifies that for the point source, the intensity drops off like an inverse square. But for the extended source the data cannot be fit by an inverse square relationship

PASCO Advantage

As the student slides the light sensor away from the Light Source, the Optics Track keeps everything aligned. The Rotary Motion Sensor measures the position, allowing the intensity vs. distance graph to be plotted in real-time. Students immediately see the relationship between distance and intensity of light.

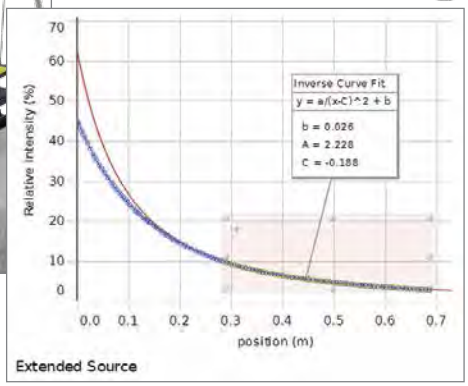


Measured compared to Inverse Square Law





String over Rotary Motion Sensor Pulley allows measurement of the position of the Light Sensor.



Extended Source

Students learn that only a point source falls off as the inverse square of distance. The light source's large crossed arrow target (on back side) doesn't start to look like a point source until the light detector is about 0.5 m away.

Experiment Includes

120 cm Optics Bench	OS-8508
Basic Optics Light Source	OS-8470
Aperture Bracket	OS-8534A
20 g hooked mass (Hooked Mass Set)	SE-8759
Thread	699-011
High Sensitivity Light Sensor	PS-2176
Rotary Motion Sensor	PS-2120A
Dynamics Track Mount	CI-6692

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Light Intensity vs. Distance EX-5547A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17

PASCO Capstone Software ..... pp. 6-13

Use Any PASPORT Interface: This experiment can be performed using any combination of PASPORT Interfaces.

Photoelectric Effect

EX-5549A

- Connects to the 850 Universal Interface for data collection in PASCO Capstone
- Find Planck's Constant to within 5%
- Verify that stopping voltage is independent of intensity
- Find characteristics of the photodiode

The Photoelectric Effect System is used to perform the photoelectric experiment, determining Planck's Constant to within 5%. This apparatus uses the conventional method of determining Planck's Constant. The metal plate in the photodiode is illuminated with various frequencies of light, selected from a mercury lamp using filters. The voltage is then adjusted to stop the photoelectric current. The stopping voltage is plotted versus the frequency, and Planck's Constant is determined from the slope of the graph.

The concept that the stopping voltage does not change with light intensity is tested using the various apertures that change the light intensity by partially blocking the light.

Uses the 850 Universal Interface and PASCO Capstone to collect and analyze the data.

Both the picoammeter and the power supply for the stopping voltage have sensor ports on the front that connect to the analog sensor ports of the 850 Universal Interface. PASCO Capstone automatically recognizes these instruments and can read the current and the voltage. During the experiment, each time a different filter is applied, the user clicks "Keep" in PASCO Capstone and the value of the stopping voltage for that frequency is recorded and automatically graphed versus frequency.

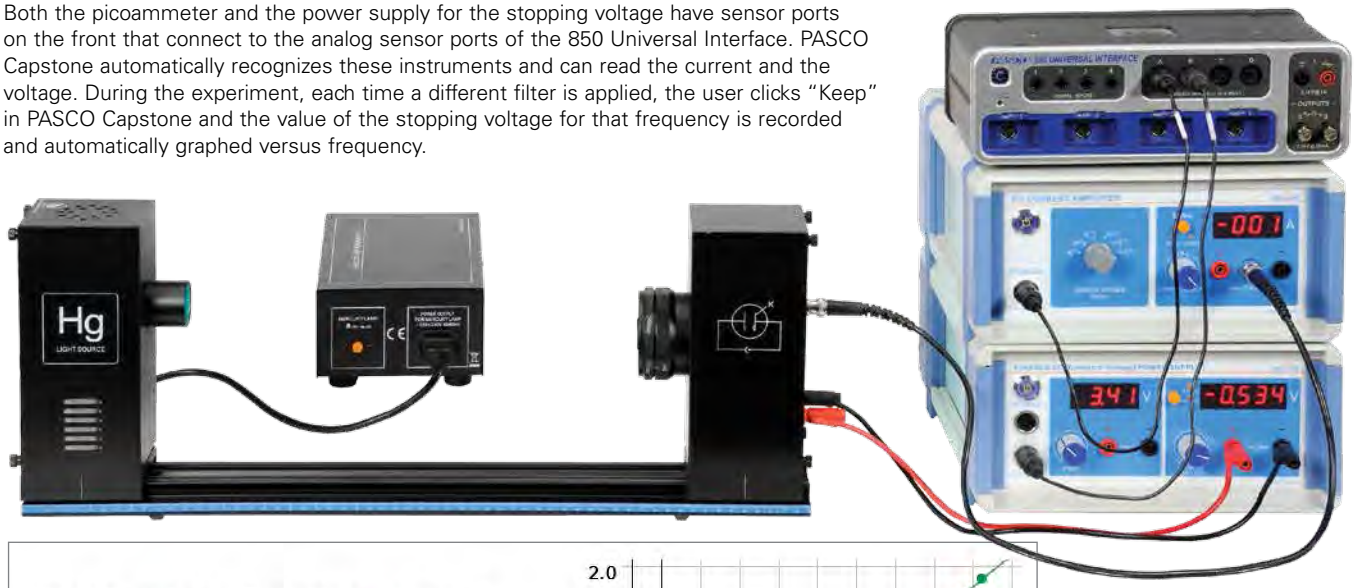
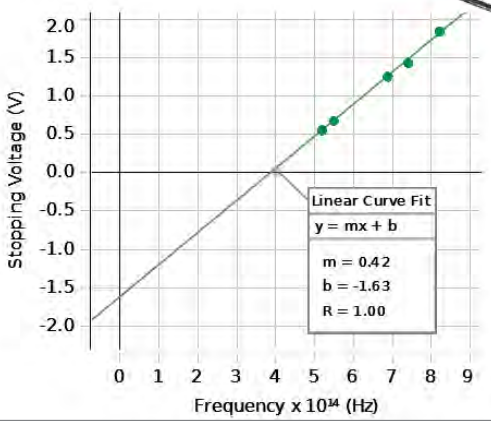


Table I: Photoelectric Effect with 4 mm Aperture

	▲ Run #1	■ Run #1
	Frequency x 10^{14} (Hz)	Stopping Voltage (V)
1	8.214	1.835
2	7.408	1.428
3	6.879	1.248
4	5.490	0.671
5	5.196	0.551



For the typical sample data shown, the graph of stopping voltage versus frequency gives a slope of 4.2 x 10^{-15} V·s. This results in a value for Planck's Constant of 6.7 x 10^{-34} J·s, which is 1.3% above the accepted value. Graph generated using PASCO Capstone™ Software.

Experiment Includes

Photoelectric Effect Apparatus
DC Current Amplifier
Tunable DC Power Supply
Cables for 850 Interface

Use the 850 or the NEW 550 Interface



Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Photoelectric Effect EX-5549A

Required:

550 or 850 Universal Interface ..... pp. 2-3, 14-17
PASCO Capstone Software ..... pp. 6-13

Oscillations

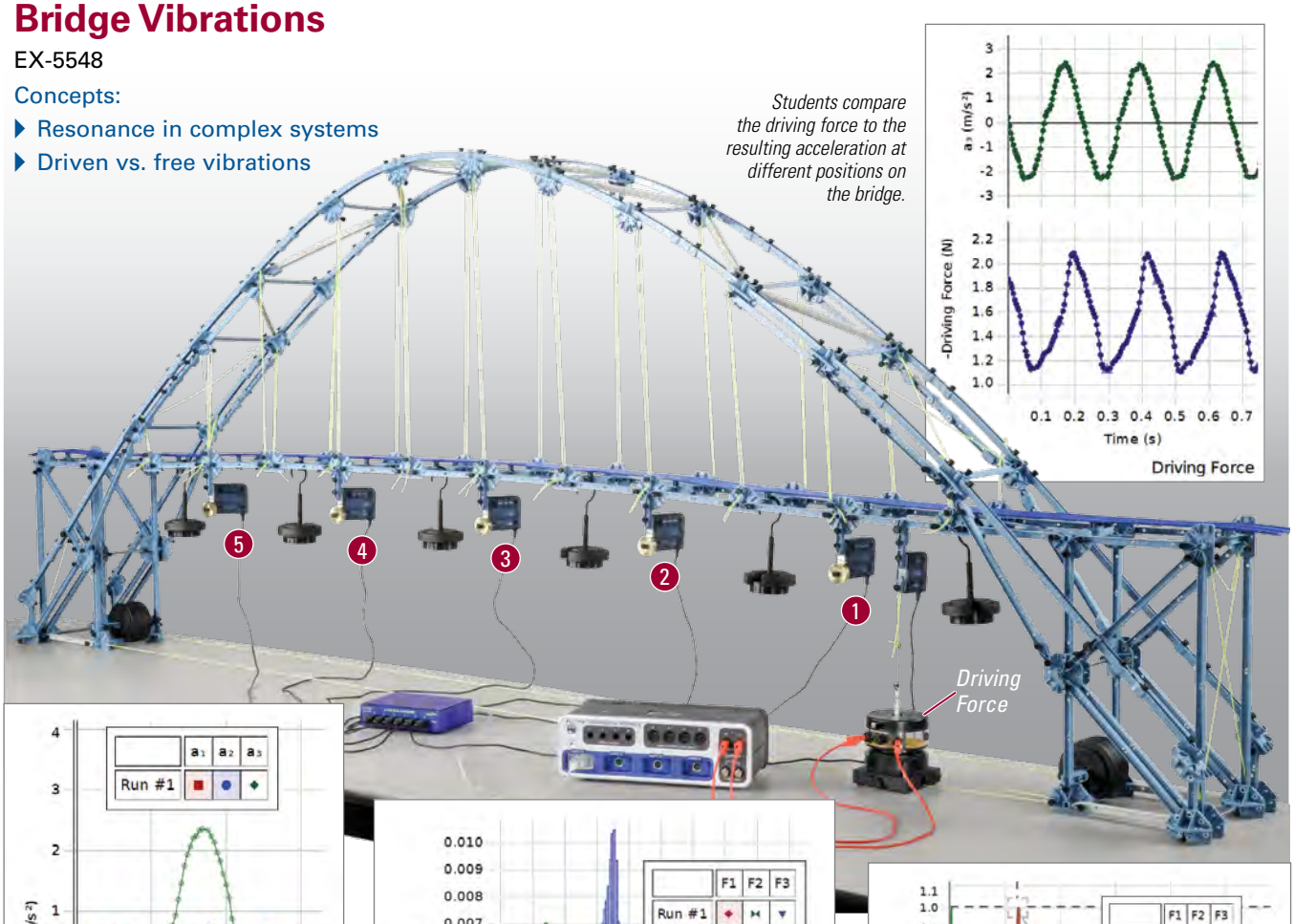
Bridge Vibrations

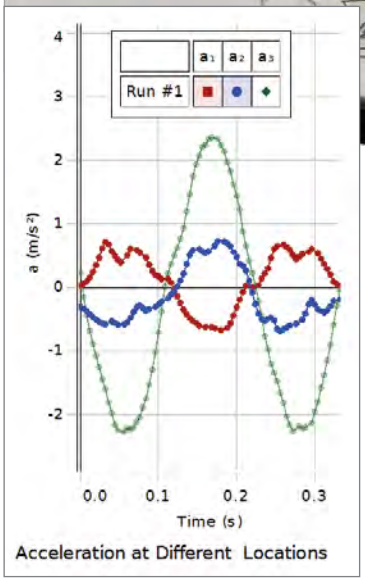
EX-5548

Concepts:

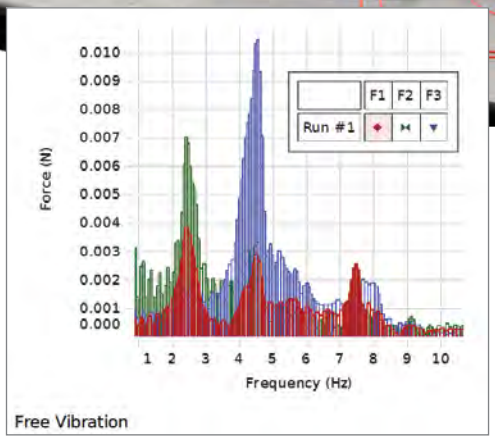
- Resonance in complex systems
- Driven vs. free vibrations

Students compare the driving force to the resulting acceleration at different positions on the bridge.

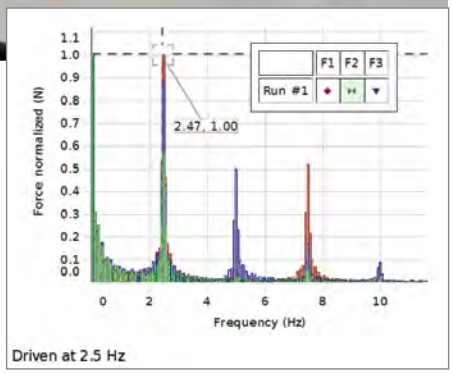




The 5 N Load Cells are used to measure the oscillations of the bridge at several different positions.



The bridge is struck by hand and allowed to freely oscillate. The FFT (using PASCO Capstone™) shows that there are several resonant frequencies. Note how different the amplitudes are at different locations on the bridge.



The resonance of the bridge is characterized by driving the bridge at different resonant frequencies. Note how different the amplitudes are at different locations on the bridge.

Experiment Includes

Large Structures Set	ME-7003
Load Cell Amplifier	PS-2198
100 N Load Cell	PS-2200
5 N Load Cell (5)	PS-2201
Mechanical Wave Driver	SF-9324
4 mm Banana Plug Cords-Red	SE-9750
Rubber Cord	ME-8986
Large Slotted Mass Set (4)	ME-7589
Short Mass Hanger (2)	ME-7590
20 g Masses (3 sets of 6)	ME-8983

Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments**.

Order Information

Bridge Vibrations EX-5548

Required:

850 Universal Interface ..... pp. 14-17

PASCO Capstone Software ..... pp. 6-13

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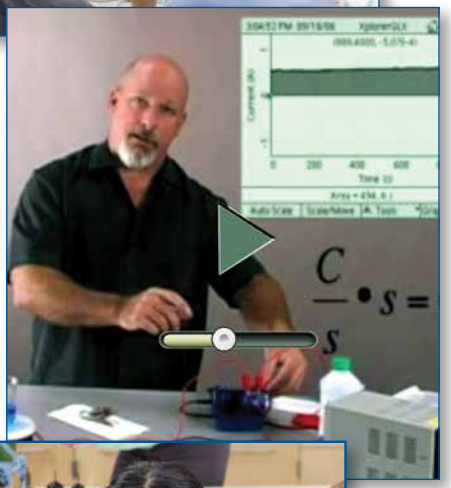


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- *Inquiry-based learning that leads to science literacy*

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Melissa Pytlak



Melissa has been fascinated with science since a young age. She earned a BS in Biology from State University of New York Geneseo and an MS in Plant Biology from University of California Davis where she discovered her passion for teaching. Her specialties include biology with a focus on genetics, molecular biology, and botany.

Scott Sukrapanna



Scott is the most experienced member of our Teacher Support team. He earned a BS in Physics and an MS in Plant Biology from University of California Davis. His specialty is physics and plant physiology. He is also an automotive aficionado.

Danny Hur



Danny's love and intrigue for mathematics started early in his life and led him to study physics. He earned his BS in Physics from California State University, Sacramento. Prior to joining PASCO, Danny worked as an international procurement agent, a land development planner, and as a sushi chef. Danny enjoys his free time reading and learning to play electric guitar.

Steven Meschia



Steven brings a wealth of experience in university level physics, with a BS from University of Chicago and Ph.D. from Montana State University. He is an avid recumbent bicycle commuter.

Mike Paskowitz



Mike fell in love with science as a child by watching metal workers at a craft fair. He earned his BS in Mechanical Engineering and Materials Science from UC Davis, as well as his MS in Chemical Engineering and Materials Science. Mike has taught physics, chemistry, and math to high school students in Sacramento and Davis. Mike's specialties include materials science and engineering. Mike enjoys spending time swimming and bicycling with his family.

Jonathan Hanna



Jonathan brings seven years experience in teaching high school Physics and AP Physics. He earned a BS in Physics from UC Santa Cruz and a Teaching Credential from San Jose State University. In his spare time, Jonathan enjoys reading about the history of science, playing the piano and spending time outdoors with his family.

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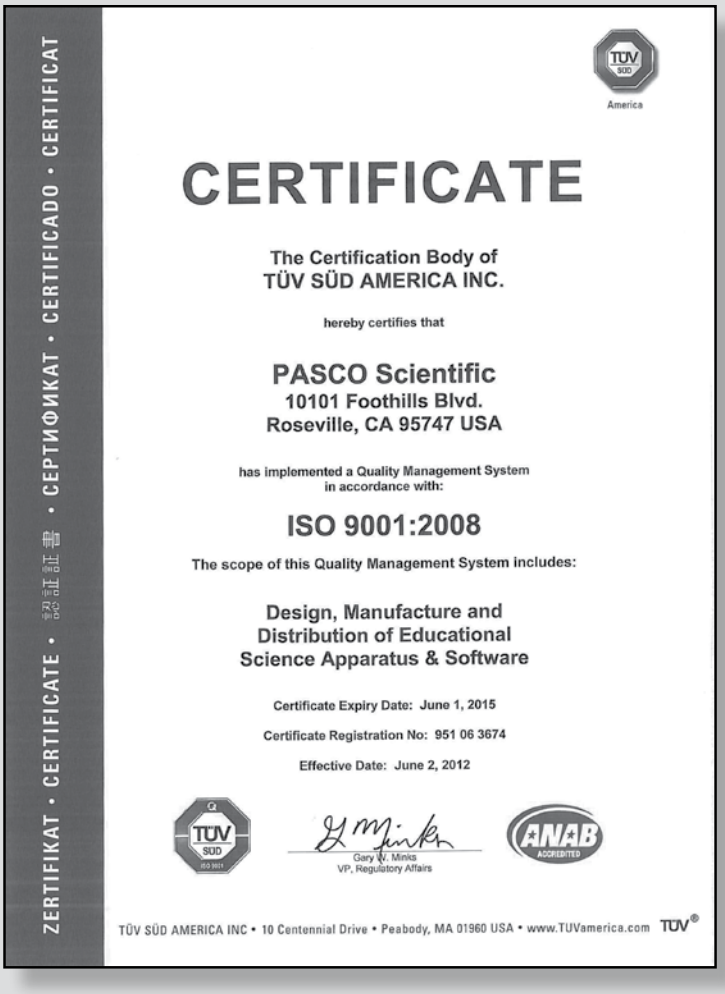
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