PASCO scientific

Physics and Engineering

From **Newton's Laws** to **Ampere's Law**, **PASCO** has what you need.

Newton's Laws Simplified: Using Smart Carts eliminates complicated setup. **pasco.com/smartcart (page 322)**





NEW! Ampere's Law

Verify Ampere's Law by direct measurement. **pasco.com/amperes (page 366)**

www.pasco.com/**physics**

Look to **PASCO** for all your **physics needs.**

Everything from **Introductory** to **Advanced Apparatus**



Mini Launcher
page 133

Zeeman Effect
page 380



Plus **Sensors** and **Interfaces**



Wireless Sensors
pages 8-19

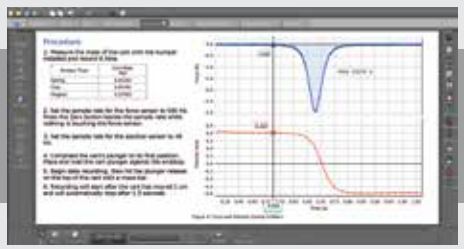
Wired Sensors
pages 31-69



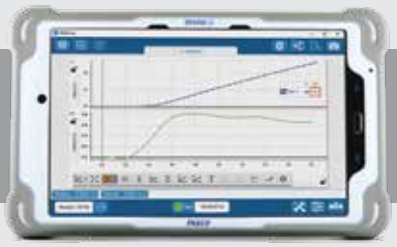
Interfaces
pages 20-30



Plus **Software** for **Data Collection** and **Analysis**



PASCO Capstone
pages 70-73

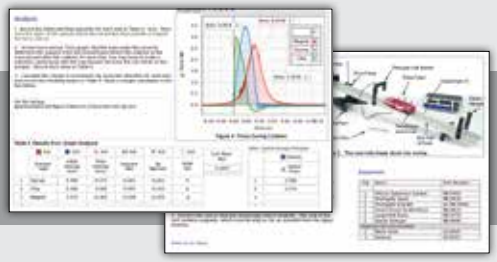


SPARKvue
pages 74-75

Plus **Curriculum** and **Labs**



Essential Physics **Curriculum**
pages 90-95



Experiments with Word® Instructions and Capstone Workbooks
pages 318-380

NEW Products

PASCO's Next GEN Dataloggers

SPARK LX & LXi

SPARK LX
PS-3601
SPARK LXi
PS-3600
See page 20



Wireless Sensors

Wireless 3-Axis Magnetic Field Sensor
PS-3221
See page 13

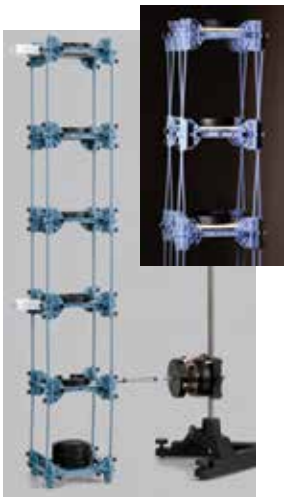


Wireless 3-Axis Accelerometer/Altimeter
PS-3223
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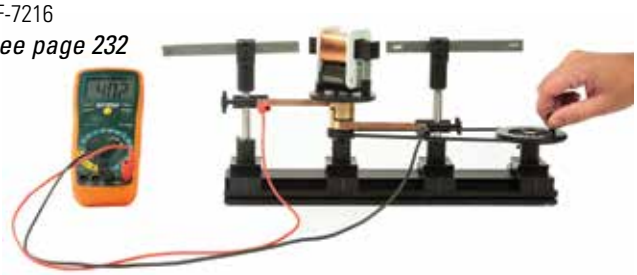


Structures

Shaking Tower
EX-5555
See page 343



Demonstration Motor/Generator Set
SF-7216
See page 232



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Wireless Sensors

Wireless Motion Sensor
PS-3219
See page 9



Wireless Rotary Motion Sensor
PS-3220
See page 9



Wireless Temperature Link
PS-3222
See page 12



Wireless Drop Counter
PS-3214
See page 15



Products

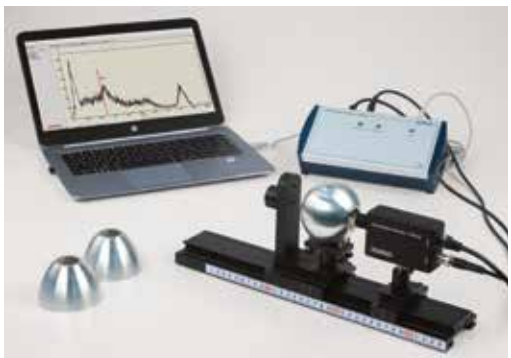
Deflection of Beta Particles
SF-7276
See page 313



Alpha Particle Spark Detector
SF-7219
See page 313



Compton Scattering
SF-7277
See page 312



Speed of Light – Reflector
SF-7203
See page 308



Complete Muon Observatory
SF-7270
See page 315



NEW Experiments

Driven Damped Cart Oscillations

EX-5551

See page 340



Uses Smart Cart

Ampere's Law Experiment

EX-5552

See page 366

Ampere's Law Apparatus



550 Universal Physics System

UI-5830

See page 82

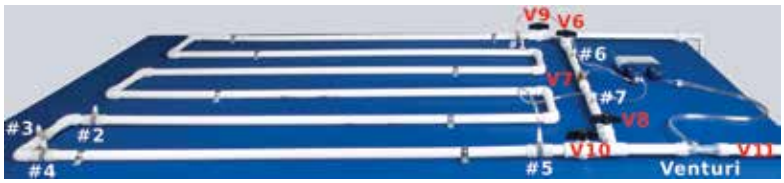


Piping Systems

EX-5553

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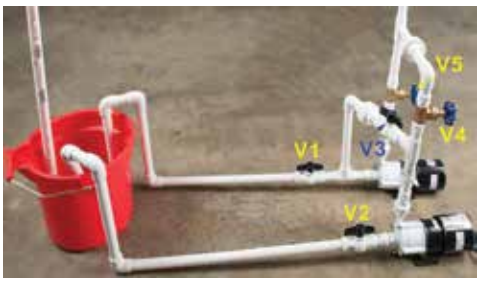
Water Pipe Systems



Pumping Systems

EX-5554

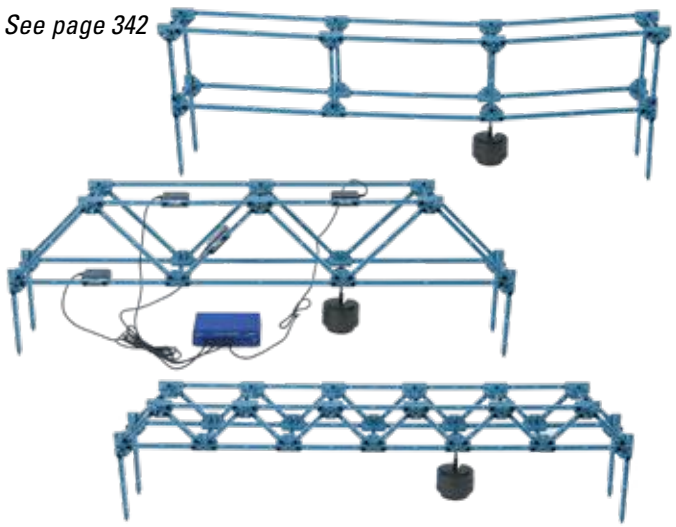
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Basic Bridges

EX-5556

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Tensile Testing Metals

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MTS





3-Point and 4-Point Bending

EX-5559

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Column Buckling

EX-5558

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NEW Products

Smart Cart Rod Stand Adapter
ME-1244
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Conical Pendulum
SF-7206
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Ball Ramp
SE-7596
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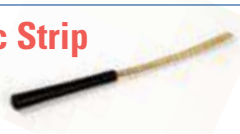
Singing Rods
SE-7301
See page 262



Ball and Ring
SE-7597



Bi-metallic Strip
SE-7598
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Dissectible Leyden Jar
SE-7718
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Colliding Spheres
SE-7303
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PhiTOP
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Loop-the-Loop
SE-7591
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Sound Pipe
SE-7724
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Coated Pith Balls
SE-7719
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UV Beads
SE-7729

UV Flashlight
SE-7730
See page 289



Optical Fiber Model
SF-7201
See page 283



Rotational Inertia Accessory
ME-3420
See page 176



Bell Jar
SE-7725
See page 261



Vacuum Pump
SE-7726
See page 261



Circular Motion Apparatus
SF-7205
See page 173



Drop-Shoot Demo
SE-7592
See page 136



Dropper Popper
SE-7304
See page 165



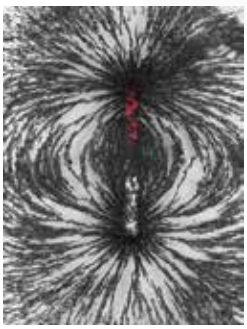
NEW Products

Cow Magnets (Pair)

SE-7722

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Iron Filings

SE-7723

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Mirage

SE-7302

See page 283



Stroboscope

SF-7202

See page 199



Modular Circuits Expansion Kit

EM-3540

See page 220



Resistors for Determining Temperature Coefficient

SF-7213 – Copper
SF-7214 – Constantan
SE-7215 – Nickel

See page 220



Voltaic Cell

SE-7249

See page 229



Laplace Force Demo with Magnet

SF-7279

See page 235



Handheld GM Counter

SF-7220

See page 316



Crooke's Radiometer

SE-7283

See page 211



Measuring with Sensors

In Physics and Engineering, we measure everything in every way we can. Sometimes sensors make it possible to perform measurements that we could not get any other way.

PASCO offers a couple of different ways to go: interface-based sensors or wireless sensors. However, you can use a wireless sensor at the same time you are using sensors connected to an interface. Which way you choose depends on your platform and your purpose.

Which platform do you use?

1. Mac® and/or Windows® Desktop Computers or Laptops

Recommendation:

- **PASCO Capstone Software** (see pages 70-72): This data collection and analysis software is the preferred choice of physics and engineering teachers.
- **550 or 850 Universal Interface:** Choose the 550 if you are teaching high school physics (unless you are one of those high school teachers who has to have the most powerful tools). Choose the 850 if you are teaching college physics or engineering.

PASCO capstone™



850 Universal Interface
UI-5000 (see page 26)

or

550 Universal Interface
UI-5001 (see page 28)





Wireless Force Acceleration Sensor
PS-3202 (see page 11)



PASPORT High Resolution Force Sensor
PS-2189 (see page 37)

2. Tablets (iPad® or Android™) and/or Chromebook™

Recommendation:

- **SPARKvue Software** (see page 74): SPARKvue is our tablet and Chromebook™ software. While PASCO Capstone is very powerful, it is only available for Mac® and Windows®.
- **Wireless Sensors and Wireless AirLink Interface:** Use wireless sensors because tablets may not have a USB port. Whenever a wireless sensor is not available, use the AirLink with a PASPORT sensor.

sparkvue® SPARKvue®



Wireless Force Acceleration Sensor
PS-3202 (see page 11)



AirLink®
PS-3200 (see page 30)

3. Need a Stand-alone Datalogger?

SPARK LXi DATALOGGER NEW

Recommendation:

- **SPARK LXi:** This all-in-one datalogging solution works for classrooms without computers or for outdoor use. The SPARK LXi can be used with wired PASPORT sensors as well as PASCO's wireless sensors. It is battery-powered, has a large color touchscreen, and is loaded with PASCO SPARKvue, MatchGraph, Spectrometry, and Lab Manager software.



SPARK LXi top view



SPARK LXi
PS-3600 (see page 20)

New to sensors? Have sensors already?

1. New to Sensors?

- **PASCO Capstone Software** (see pages 70-72): Unless you are using tablets or Chromebook™, we recommend Capstone for physics and engineering labs.
- **550 Universal Interface:** The 550 Interface is perfect for beginning data acquisition. It has multiple sensor ports to accommodate those experiments that require more than one sensor (as most experiments do). It also has a signal generator and powered output for electronics and speakers.
- **PASPORT Sensors:** Many of these sensors have multiple sensor elements in one sensor, such as the Absolute Pressure/Temperature Sensor (page 48).
- **Wireless Sensors** (see pages 9-19): This is a low-cost solution because no interface is required for the wireless sensors. They are connected via Bluetooth® in PASCO software (Capstone or SPARKvue).



550 Universal Interface
UI-5001 (see page 28)



Wireless Force Acceleration Sensor
PS-3202 (see page 11)



Wireless Smart Cart
ME-1240 (see page 102)

2. Have ScienceWorkshop Sensors?

- **PASCO Capstone Software** (see pages 70-72): Unless you are using tablets or Chromebook™, we recommend Capstone for physics and engineering labs.
- **850 Universal Interface:** The 850 Interface is definitely the right interface for the ScienceWorkshop veteran. It has twice as many sensor ports as the 550 for those more demanding experiments. It also has three signal generators, a high-power output (15 V at 1 A) for speakers and heating elements, and two high-frequency outputs (DC to 500 kHz) for electronics.
- **Use Your Existing ScienceWorkshop Sensors** and add any PASPORT sensors you need: You may want to use the PASPORT 2-Axis Force Platform (page 40) or the Absolute Pressure/Temperature Sensor (page 48).



850 Universal Interface
UI-5000 (see page 26)

3. Have PASPORT Sensors?

- **PASCO Capstone Software** (see pages 70-72): Unless you are using tablets or Chromebook™, we recommend Capstone for physics and engineering labs.
- **550 or 850 Universal Interface:** Choose the 550 if you are teaching high school physics (unless you are one of those high school teachers who has to have the most powerful tools). Choose the 850 if you are teaching college physics or engineering.
- **Use Your Existing PASPORT Sensors** (see pages 31-69) and add the UI-5100 Voltage Sensor (page 54) for high speed sampling of circuits and the UI-5101 Sound Sensor (page 60) to detect sound waves.
- **SPARK LXi:** Choose the SPARK LXi if you want to use your PASPORT sensors without computers or if you need to collect data outside.



550 Universal Interface
UI-5001 (see page 28)



SPARK LXi
PS-3600 (see page 20)

PASCO's Wireless Sensor Family

Our rugged, low-cost wireless sensors connect directly to computers, Chromebooks, and mobile devices to allow students to quickly collect data, leaving more time for analyzing and interpreting data.

In logging mode wireless sensors collect data to their onboard memory for hours, days, weeks or even months at a time without needing to be connected to a computer, tablet, Chromebook or smartphone. When the experiment is concluded, simply connect the sensor to a device running PASCO software and download all the measurements it recorded.

Wireless Physics Sensors

Smart Cart ____ 8
Motion Sensor ____ 9
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3-Axis Acceleration/Altimeter ____ 10
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Wireless Chemistry Sensors

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Wireless Accessories

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Wireless Charging Stations ____ 19
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Bluetooth® Adapter ____ 19

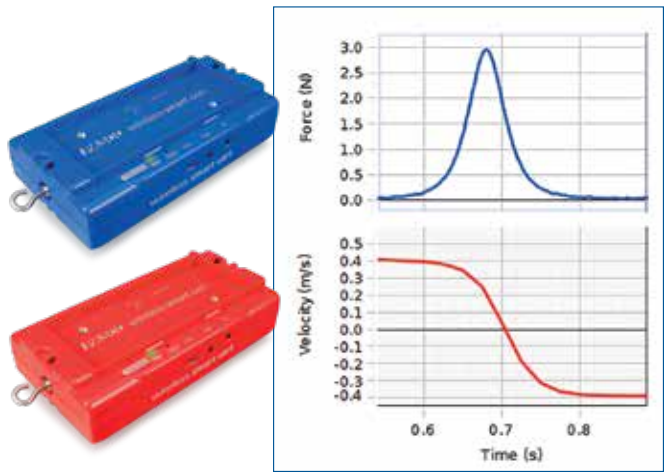
Smart Cart

ME-1240 (red) ME-1241 (blue)

- Your mechanics lab on wheels
- Built-in wireless force, position, and acceleration sensors

The patent-pending Smart Cart is the ultimate tool for studying kinematics, dynamics, Newton's Laws and more. It is based on a durable ABS body with nearly frictionless wheels just like our high quality PAScars. But now we've added built-in sensors that measure force, position, velocity, and acceleration. And the Smart Cart can make these measurements on or off a track and transmit the data wirelessly over Bluetooth®. In essence it is a wireless dynamics cart that combines all the necessary sensors and doesn't require any additional hardware.

Smart Carts are ideal for studying mechanics (both kinematics and dynamics) and more. For instance, the built-in load cells make a pair of Smart Carts an easy way to visually demonstrate Newton's Third Law. And with measurements of both force and acceleration, Newton's Second Law can be investigated in minutes with no other equipment required. Smart Carts truly are a physics lab on wheels: The most advanced physics cart ever created and all without the hassle and restrictions of cables.



- Built-in ±100 N force sensor
- 3-axis accelerometer
- Motion encoder (measures position and velocity on or off a track)
- Bluetooth® connectivity
- No interface required!
- Rechargeable battery
- Magnetic bumper for force sensor
- 3-position plunger
- Mass tray
- Velcro® tabs
- Force sensor hook and rubber bumper

Order Information

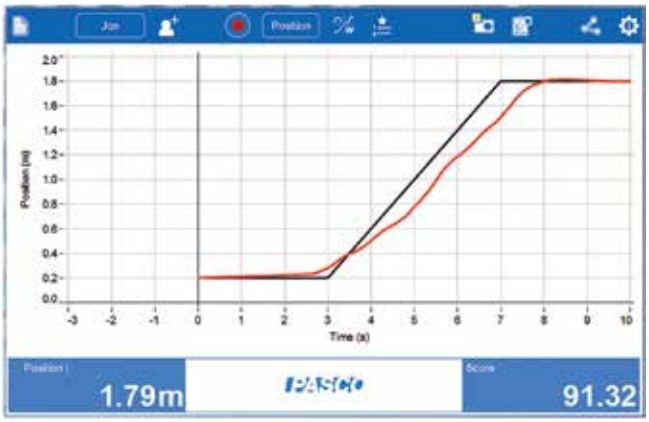
Smart Cart (red).....ME-1240
Smart Cart (blue) ME-1241

Wireless Motion Sensor

PS-3219



The Wireless Motion Sensor measures position, velocity, and acceleration of objects using ultrasound. Students can measure themselves and watch their motion graphed in real time. The Wireless Motion Sensor can detect objects within a range of 15 cm to 4 m away. The fact that the sensor is wireless means no cables to get in the way, which is key for handheld or ceiling-mounted applications. The Wireless Motion Sensor connects directly to your devices via Bluetooth® or USB.



The Wireless Motion Sensor works with our free MatchGraph! software (see page 76). It is an ideal way to teach the concepts of motion graphing, interpreting graphs, and rate of change or slope.

Specifications

Range: 0.15 to 4 m
Resolution: 1 mm
Maximum sample rate: 50 Hz
Transducer rotation range: 180°
Rechargeable battery: Lithium-polymer
Logging: Yes
Connectivity: Direct USB or via Bluetooth® (Bluetooth 4.0)

Order Information

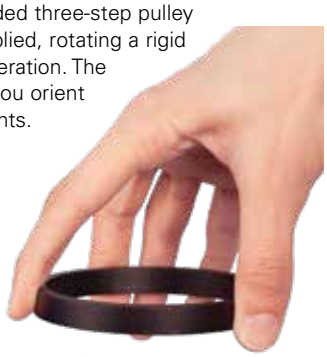
Wireless Motion Sensor PS-3219
Recommended:
MatchGraph! Software ..... See page 76

Wireless Rotary Motion Sensor

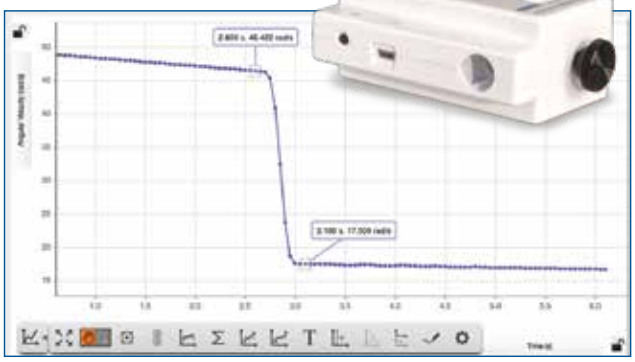
PS-3220



The Wireless Rotary Motion Sensor measures angle, angular velocity, and angular acceleration, as well as their linear equivalents. The included three-step pulley allows different torques to be applied, rotating a rigid system at different rates of acceleration. The included rod-mounting holes let you orient the sensor for different experiments. The Wireless Rotary Motion Sensor connects directly to your devices via Bluetooth® or USB.



Show that angular momentum is conserved: The Wireless Rotary Motion Sensor records the angular velocity as a ring is dropped on a spinning disk.



Specifications

Angle resolution: 0.18° (0.00314 radian)
Linear resolution: 0.0157 mm (with 5 mm pulley radius)
Three-step pulley: 10, 29, and 48 mm diameter
Shaft diameter: 6.35 mm
Maximum rotation rate: 30 revolutions per second
Optical encoder: 2000 divisions/rev, bidirectional
Rechargeable battery: Lithium-polymer
Logging: Yes
Connectivity: Direct USB or via Bluetooth® 4.0

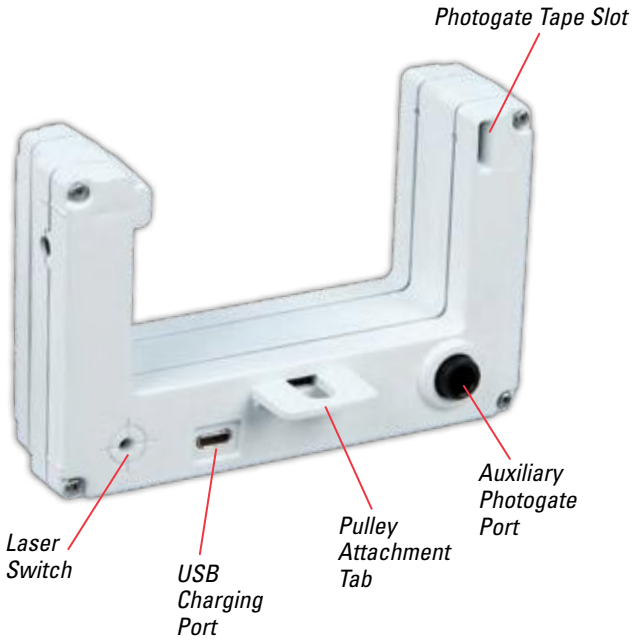
Order Information

Wireless Rotary Motion Sensor PS-3220
Shown in use with:
Rotational Inertia Accessory Kit ME-3420 p.176

Wireless Smart Gate

PS-3225

- Dual photogate beams
- Laser switch
- Photogate tape slot
- Auxiliary photogate/Time-of-Flight port



The Wireless Smart Gate has all the features of the wired Smart Gate. It has dual photogate beams spaced at 1.5 cm to accurately measure speed. The built-in laser switch (when used with any laser) allows you to time objects too large to fit through the standard photogate. Use Photogate Tape passing through the photogate slot to measure movement of objects. The auxiliary port is for adding an additional photogate head or Time-of-Flight Accessory.

We do not recommend using two Wireless Smart Gates in the same experiment unless the measured times are relatively long (greater than one-half second) since synchronization is limited to 2 ms.

Specifications

Logging: Yes
Battery: Rechargeable Lithium-Polymer
Connectivity: Direct USB or via Bluetooth 4.0

Coming soon!
Check pasco.com for availability.

Order Information

Wireless Smart Gate PS-3225

Wireless 3-Axis Acceleration/Altimeter

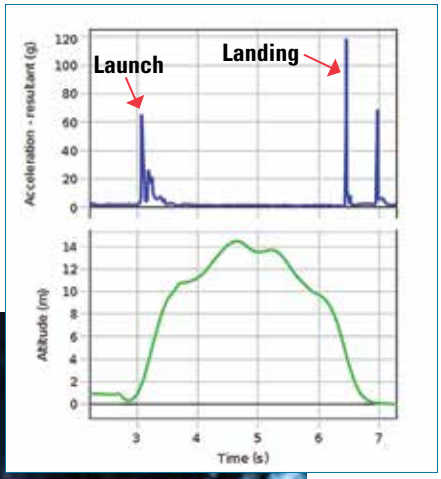
PS-3223

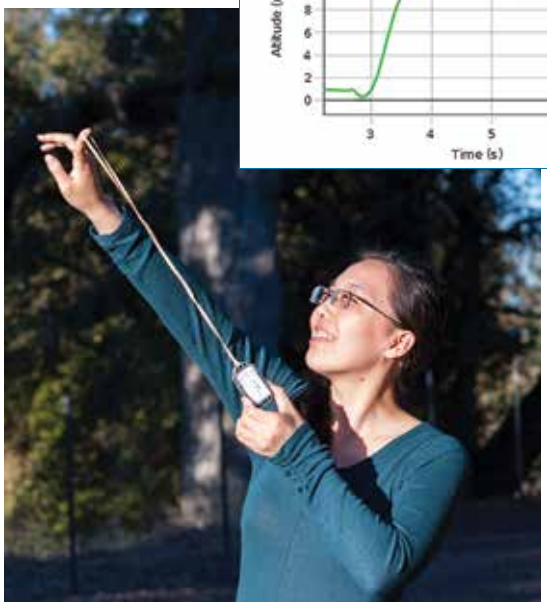
- 3-axis accelerometer
- 3-axis gyroscope
- Altimeter
- Rubberized case



The Wireless 3-Axis Acceleration/Altimeter can remotely log acceleration in three dimensions and altitude, making it ideal for recording roller coaster rides.

The Wireless 3-Axis Acceleration/Altimeter is launched by a stretched rubber band that is connected to one of many attachment holes in the rubberized case. The graph shows the resultant acceleration (measured in g's) and the altitude for the four-second flight.





Specifications

Accelerometer
Ranges: ±16 g, ±100 g, ±200 g, ±400 g
Measurements: Acceleration (3 axes and resultant); Altitude; Angular velocity (3 axes)
Logging: Yes
Battery: Coin Cell
Connectivity: Bluetooth 4.0

Coming soon!
Check pasco.com for availability.

Order Information

Wireless 3-Axis Acceleration/Altimeter PS-3223

Wireless Force Acceleration Sensor

PS-3202

- Freedom from wires
- Measure force, acceleration, and rotation



The Wireless Force Acceleration Sensor permits live data collection in a moving frame of reference. You can mount the sensor on a rotating platform or on a moving cart to measure forces and accelerations of the constantly changing dynamic system. The wireless design offers improved measurements without a cable affecting the experiment outcome.

Features

- Bluetooth® and USB connectivity
- Logging
- ±50 N
- 3-axis accelerometer
- 3-axis gyroscope
- Finger-holes
- Built-in rod clamp

Specifications

Force Range: ±50 N
Force Resolution: 0.03 N
Accuracy: 0.1 N
Acceleration Range: ±16 g
Battery: Rechargeable lithium-polymer
Logging: Yes
Bluetooth: BT 4.0



Includes (1 each)

- Eye bolt
- Thumb screw
- Bumper
- Rechargeable lithium-polymer battery
- USB connector

Order Information

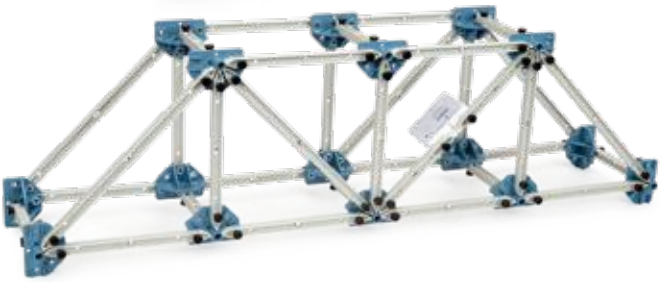
Wireless Force Acceleration Sensor.....PS-3202

Wireless Load Cell

PS-3216

- Measures loads in structures
- Built-in 3-axis accelerometer measures bridge vibrations





The Wireless Load Cell and Accelerometer is designed to measure loads in all PASCO Structures Systems. It is particularly useful for measuring vibrations because it includes an accelerometer and has no wires to impede movement.

Specifications

Load Cell
- **Range:** ±50 N
- **Resolution:** 0.05 N
- **Accuracy:** 0.1 N
- **Maximum Sample Rate:** 2 kHz

Acceleration
- **Range:** ± 6 g (three axis)
- **Maximum Sample Rate:** 500 Hz

Measurements: Force; Acceleration (3 axes and resultant)
Logging: Yes
Battery: Rechargeable Lithium-Polymer
Connectivity: Direct USB or via Bluetooth 4.0

Order Information

Wireless Load Cell/Accelerometer.....PS-3216
Shown in use with:
Building Better Bridges Kit (includes PS-3216).....ME-3581

Wireless Pressure Sensor

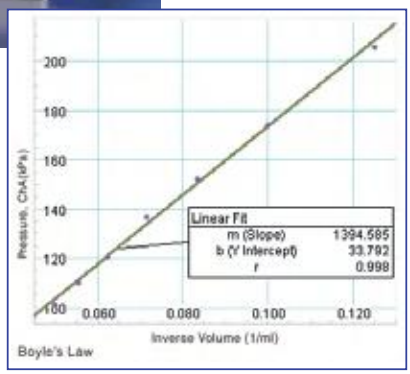
PS-3203

With the new Wireless Pressure Sensor you can make accurate and consistent measurements of gas pressure, regardless of ambient conditions, and explore how chemical reactions affect gas pressure. In combination with a wireless Temperature Sensor, you can study the empirical gas laws.





A test tube, piece of steel wool, and a Wireless Pressure Sensor are all you need to have your students calculate the amount of oxygen in the air.



With these sensors, students can easily study gas laws.

Specifications

Range: 0-400 kPa
Resolution: 0.1 kPa
Accuracy: ±1 kPa
Battery: Rechargeable lithium-polymer included
Logging: Yes
Bluetooth: BT 4.0
USB cable for charging

Includes

- 2 feet of polyurethane plastic tubing
- 1 tube connector
- 2 male barbed luer locks
- 1 female barbed luer lock
- 1 60 cc syringe
- USB connector

Wireless sensors connect directly to most classroom devices.

Order Information

Wireless Pressure Sensor PS-3203

Wireless Temperature Sensor

PS-3201

Welcome to the modern thermometer. Students can access instant temperature readings but also continuously monitor, log, and plot temperature data.



Features

- Simplicity: just pair and go, no cables and adapters to manage
- Variable sampling rate for capturing small fast changes or experiments that run for hours, days, or weeks
- Features convenient Bluetooth® wireless connectivity and long-lasting coin cell battery
- Logs temperature data directly onto the sensor for long-term experiments.



Specifications

Range: -40°C to 125°C
Resolution: 0.01°C
Accuracy: 0.5°C
Displays: °C, K, and °F
Battery: Coin cell included
Logging: Yes
Bluetooth: BT 4.0

The versatile Wireless Temperature Sensor works well, both in the lab and outside.

Order Information

Wireless Temperature Sensor PS-3201
Recommended:
Coin Cell Battery Pack (US only) PS-3504

Wireless Temperature Link

NEW

PS-3222

- Accepts three types of thermistor temperature probes
- Includes Fast Response Temperature Probe



Specifications

Compatible Temperature Probes: Skin/Surface (PS-2131); Fast Response (PS-2135); Stainless Steel (PS-2153)
Range with included probe: -30°C to 105°C
Jack: 3.5 mm stereo
Logging: Yes
Battery: Coin cell
Connectivity: Bluetooth 4.0

Includes

- Wireless Temperature Link
- Fast-Response Temp Probe

Coming soon!
Check pasco.com for availability.

Order Information

Wireless Temperature Link PS-3222
Compatible Temperature Probes:
Skin/Surface PS-2131
Fast Response (3-pack) PS-2135
Stainless Steel PS-2153

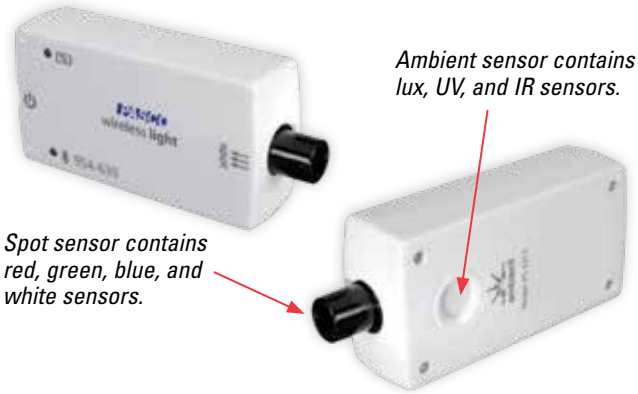
Wireless Light

PS-3213



- Four sensors in one
- Ambient lux
- Ultraviolet and infrared
- Detect RGB colors separately
- Bluetooth 4.0 wireless
- New enhanced features measure PAR and irradient light!

This wireless sensor is four light sensors in one: It has UV and IR sensors, as well as light level in lux and individual detectors for red, green, and blue. The "spot" detector located inside the sensor tube consists of several very small light detectors: red, green, blue, and white. The "ambient" detector (located on the back side of the sensor) consists of three more detectors: ultraviolet, infrared, and a lux meter that sees light the way the human eye does.





Use the ultraviolet sensor on the back side to measure the amount of UVA and UVB radiation that makes it through sunglasses.

Specifications

Light Level Range: 0 to 131,000 lux
Ultraviolet Range: 300 nm to 400 nm (UVA and UVB)
Infrared Range: 700 nm to 1050 nm
Maximum Sample Rate: 2 Hz (ambient); 20 Hz (spot)
Battery: Coin cell
Bluetooth 4.0
Datalogging: Yes

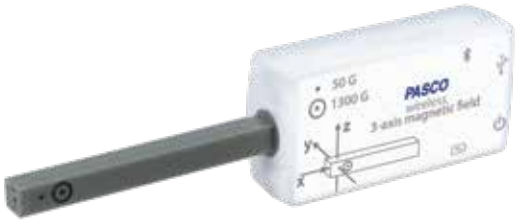
Order Information

Wireless Light Sensor PS-3213

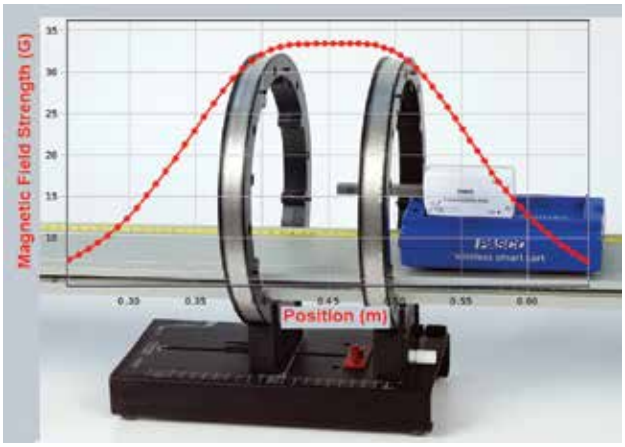
Wireless 3-Axis Magnetic Field Sensor

PS-3221

- Simultaneous measurements on three axes
- Dual range: ±50 G and ±1300 G
- Sensitive enough to measure the Earth's magnetic field
- Measure fields from bar magnets and coils



This 3-Axis Magnetic Field Sensor can sense the Earth's magnetic field and fields from coils and bar magnets. There are two ranges: ±50 gauss and ±1300 gauss. This sensor is primarily for static fields.



A graph of Magnetic Field Strength vs. Position (from PASCO Capstone) is superimposed on a picture of a 3-Axis Magnetic Field Sensor riding on a Smart Cart through Helmholtz coils.

Specifications

Ranges: ±50 G and ±1300 G
Resolution: ±0.01 G (50 G range); ±2 G (1300 G range)
Maximum Sample Rate: 100 Hz
Measurements: Magnetic Field Strength (3 axes and resultant)
Logging: Yes
Battery: Rechargeable Lithium-Polymer
Connectivity: Direct USB or via Bluetooth 4.0

Includes

- 3-Axis Magnetic Field Sensor
- Sensor Mounting Rod
- USB Charging Cable

Coming soon!
Check pasco.com for availability.

Order Information

Wireless 3-Axis Magnetic Field Sensor PS-3221
Recommended:
Zero Gauss Chamber ..... EM-8652 p. 58

Wireless Chemistry Sensors

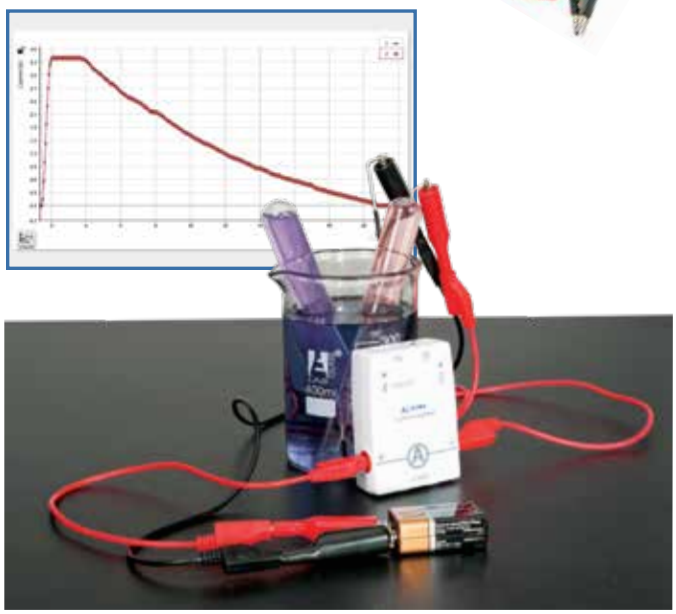
Wireless Current

PS-3212





This sensor's wide current range allows for introductory and advanced explorations of the fundamental concepts of electricity and basic circuits.



Features

- **Two Ranges:** ±1A, ±0.1A
- **Resolution:** 0.2mA (±1A range); 0.02mA (±0.1A range)
- **Bluetooth® sampling rate of 1 kHz**
- **Higher speed sampling via USB**
- **Includes remote logging**

Includes

- Rechargeable battery and USB cable
- 1 red and 1 black shrouded, banana-to-alligator-clip test leads

Order Information

Wireless Current Sensor PS-3212

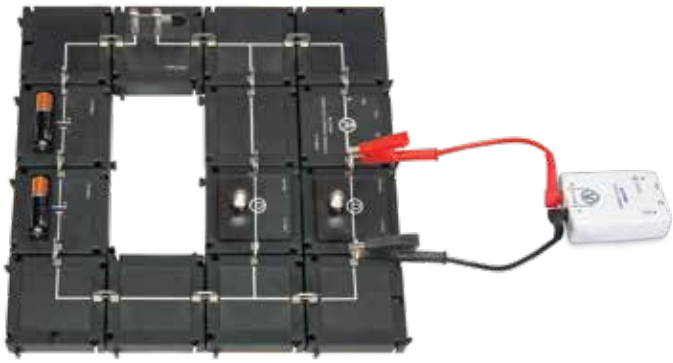
Wireless Voltage

PS-3211



Explore energy and energy transformations with this sensor. Use it to:

- Measure the voltage of student-constructed batteries and see how chemical energy can turn into electrical energy.
- Look at renewable energy by connecting to a wind turbine.
- Track the flow of energy by creating simple circuits.



Features

- **Two Ranges:** ±15 V, ±5 V
- **Resolution:** 7 mV (±15 V range); 2 mV (±5 V range)
- **Bluetooth® sampling rate of 1 kHz**
- **Higher speed sampling via USB**
- **Includes remote logging**

Includes

- Rechargeable battery and USB cable
- 1 red and 1 black shrouded, banana-to-alligator-clip test leads

Order Information

Wireless Voltage Sensor PS-3211

Wireless Current Sensor Module

EM-3534



Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components.

Wireless Current Sensor Module EM-3534 Specifications *(included in EM-3536 on page 219)*

- **Two ranges:** ±1A, ±0.1A
- **Resolution:** 0.2mA (±1A range); 0.02mA (±0.1A range)
- **Bluetooth® sampling rate of 1 kHz**
- **Higher speed sampling via USB**
- **Includes remote logging**

Order Information

Wireless Current Sensor Module EM-3534
Required:
Modular Circuits ..... pp. 218-219

Wireless pH Sensor

PS-3204



Here's the best tool for measuring pH since litmus paper. Students can quickly obtain accurate pH readings but also log data to their connected device and even program the sensor to collect data autonomously for hours or weeks. Use the sensor to study water quality, environmental monitoring, testing solutions, and chemical reactions.



With the Wireless pH Sensor, students can collect data anywhere!



Easily measure and compare the pH of common acids and bases.

Teaching Advantage

- Simplicity: just pair and go, no cables and adapters to manage.
- Compatible with ion-selective electrodes (ISE) and oxidation reduction probe (ORP).
- Features Bluetooth® wireless connectivity and long-lasting coin cell battery.
- Logs pH data directly onto the sensor for long-term experiments.

Includes

- 1 coin cell battery and a direct-connect pH probe with storage bottle

Specifications

Range: 0-14 pH
Resolution: 0.02 pH
Accuracy: ±0.1 pH
Battery: Coin cell included
Logging: Yes
Bluetooth: BT 4.0

Order Information

Wireless pH Sensor.....PS-3204
Recommended:
Coin Cell Battery Pack.....PS-3504
(US only)

Flat pH Probe

PS-3514



This pH probe gives you the freedom to measure what you want, where you want. Study pH levels in different kinds of foods, investigate the pH of common skin and hair care products, and easily collect pH data when doing soil analysis.

Includes

- Soaker bottle

Order Information

Flat pH Probe.....PS-3514
Requires:
Wireless pH Sensor.....PS-3204

Get even more measurements out of the Wireless pH Sensor by using these ORP or ISE electrodes.

Oxidation Reduction Potential Probe

PS-3515





Probes and Electrodes



Includes

- Cable



Order Information

Oxidation Reduction Potential Probe.....PS-3515

Ion Selective Electrodes
Ammonium.....PS-3516
Carbon Dioxide.....PS-3517
Calcium.....PS-3518
Chloride.....PS-3519
Potassium.....PS-3520
Nitrate.....PS-3521

Wireless Conductivity

PS-3210



Use the Wireless Conductivity Sensor to measure the electrical conductivity of a water solution. With this wireless sensor you can investigate the properties of solutions, as well as model and measure water quality.

Features

- Measure both conductivity and total dissolved solids
- Automatic temperature compensation
- Dust- and sand-proof and water-resistant
- Battery life >1 year



Includes

- 1 coin cell battery

Order Information

Wireless Conductivity.....PS-3210

Wireless Drop Counter

PS-3214

NEW

The Wireless Drop Counter has a wider (18 x 13 mm) drop window for better drop detection and easier alignment with burettes. It works equally well with large or small, fast or slow drops.

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



Includes

- Wireless Drop Counter
- Micro Stir Bar
- Drop Dispenser with Stopcock
- Plastic Dispenser Rod Clamp

Coming soon!
Check pasco.com for availability.

Order Information

Wireless Drop Counter.....PS-3214

Wireless Exercise Heart Rate Sensor

PS-3207



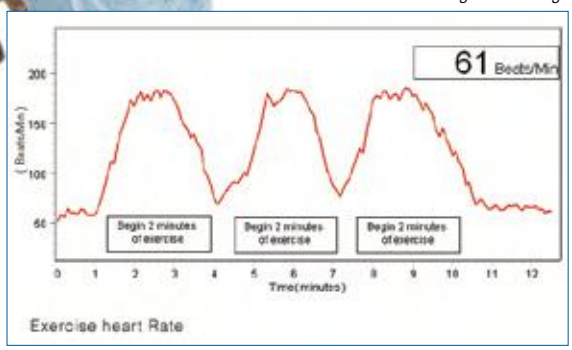
The Wireless Exercise Heart Rate Sensor has a chest strap and will transmit data wirelessly up to 10 m away! The electrode belt fits around the ribcage (worn against the skin for best results, but can be worn over a shirt if saline solution is applied under the electrodes) and wirelessly transmits the cardiac signal to the sensor.

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



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



Includes

- Bluetooth® Heart Rate Module
- Coin-cell battery (1)
- Chest strap (M-XXL)

Order Information

Wireless Exercise Heart Rate Sensor..... PS-3207

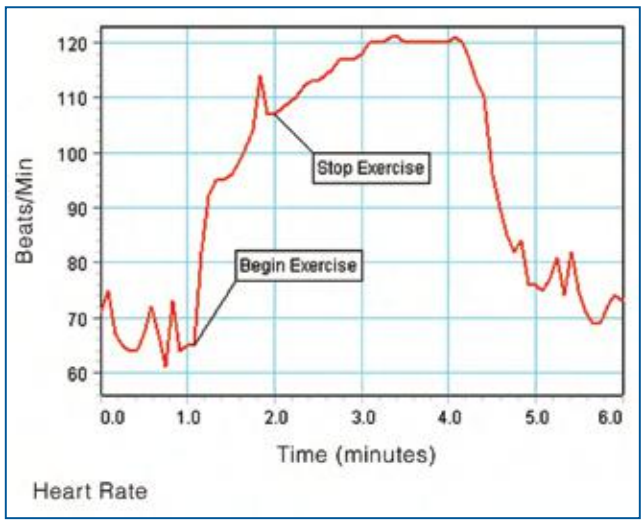
Wireless Hand-Grip Heart Rate Sensor

PS-3206



With these wireless hand grips, conducting physiology labs on the cardiovascular system or homeostasis is easier than ever before. Continuously monitor heart rate during exercise, or use the sensor to take initial and final measurements with fast and reliable heart-rate detection.





Includes

- Hand-grips
- Bluetooth® Heart Rate Module
- Coin-cell battery (1)

Order Information

Wireless Hand-Grip Heart Rate Sensor..... PS-3206

Wireless Blood Pressure Sensor

PS-3218



PASCO's Wireless Blood Pressure Sensor allows students to quickly and easily measure both systolic and diastolic arterial blood pressure (mmHg) as well as heart rate (pulse in bpm). Comparing the digits display for systolic and diastolic pressure with the display of blood pressure from the real-time graph helps students gain a contextual understanding of the physiology of blood pressure.

Typical Applications

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

Specifications

Heart Rate

- Units: beats per minute (bpm)
- Range: 36 to 200 bpm
- Accuracy: ±1 bpm
- Resolution: 1 bpm

Blood Pressure

- Units: millimeters of mercury (mmHg)
- Range: 0 to 375 mmHg
- Accuracy: ±3 mmHg
- Resolution: 0.05 mmHg

Gauge Pressure

- Units: mmHg, N/m2, kPa, atm, psi
- Range: 0 to 375 mmHg
- Accuracy: ±3 mmHg
- Resolution: 0.05 mmHg



Includes

- Wireless Blood Pressure Sensor
- Standard-size arm cuff
- Bladder and pressure release valve

Order Information

Wireless Blood Pressure Sensor PS-3218

Wireless CO_2 Sensor

PS-3208



Use this wireless sensor to measure the concentration of CO_2 gas in a closed system or open environment. Study core topics (including photosynthesis, respiration, and carbon cycling) with this versatile probe. CO_2 data can be logged directly on the device for long-term life science and environmental science studies.



Directly compare separate controlled environments.

Specifications

Range: 0 to 100,000 ppm
Resolution: 2 ppm
Connection: Bluetooth® 4.0 or USB
Battery life: ≥18 hours of continuous use
Accuracy: 0 to 1k: ±100ppm
1 to 10k: ±5% of reading ±100 ppm
10k to 50k: ±10% of reading
50k to 100k: ±15% of reading
Warm-up time: 3 min
Response time: 90% in 30 sec

Includes

- 250-ml sampling bottle
- USB charging cable

(See pasco.com for the latest specs.)

Order Information

Wireless CO_2 Sensor PS-3208

Dissolved CO_2 Waterproof Sleeve

PS-3545

The Wireless CO_2 Sensor can be equipped for aqueous measurements using this semipermeable sleeve. The sleeve is waterproof but allows CO_2 gas to pass through the membrane, creating a headspace around the sensor. Monitor photosynthesis and respiration of aquatic plants or animals with the sample bottle or with other chambers. (Please note: Improper use will void sensor warranty.)

Includes

- Sleeves (5)
- O-rings (5)



Order Information

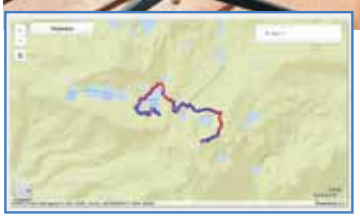
Dissolved CO_2 Waterproof Sleeve PS-3545

Wireless Weather Sensor with GPS

PS-3209

The Wireless Weather Sensor is an all-in-one instrument for monitoring environmental conditions. By incorporating several sensing elements into a single unit, the sensor provides up to **19 different measurements!** Use the sensor in logging mode with the Weather Vane Accessory for long-term monitoring, or use it as a handheld instrument to study microclimates and record ambient conditions relevant to many biological and environmental phenomena.





This sensor can measure latitude, longitude, and other GPS functions!



Measurements

Weather
1. Ambient Temperature
2. Barometric Pressure
3. Wind Speed
4. Wind Direction (true)
5. Relative Humidity
6. Absolute Humidity
7. Dew Point
8. Wind Chill
9. Heat Stress Index

Light
10. Ambient Light (lux)
11. UV Index
12. PAR
13. Irradiance

GPS
14. Latitude
15. Longitude
16. Altitude
17. Speed
18. Magnetic Direction
19. True Direction

Specifications

Battery: Rechargeable
Water-resistance: IP-64 splash-proof
(Please see pasco.com for detailed specifications.)

Includes

- USB charging cable

Order Information

Wireless Weather Sensor with GPS PS-3209
Suggested:
Weather Vane Accessory PS-3533

Weather Vane Accessory

PS-3553

Equip your Wireless Weather Sensor for extended environmental monitoring with the Weather Vane Accessory. Once deployed the sensor will freely rotate to capture wind speed and direction, whether you are monitoring data in real time or using the sensor in logging mode to capture hours (or days!) of data for later analysis.



Includes

- Tripod
- Tripod adapter
- Weather vane

Order Information

Weather Vane Accessory PS-3553

Wireless Colorimeter and Turbidity

PS-3215

The Wireless Colorimeter simultaneously measures the absorbance and transmittance of six different wavelengths. The sensor can be used to study enzyme activity, photosynthesis, and the rates of chemical reactions. By using the accessory cuvettes and a calibration standard, the colorimeter also functions as a turbidimeter for water quality analysis.



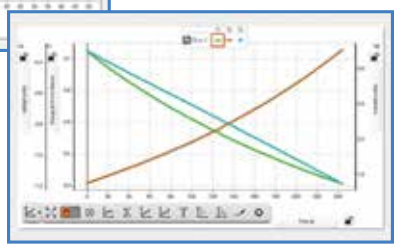


Simultaneously measure the absorbance and transmittance of a solution at six different wavelengths.



Create Beer's Law plots to help students understand the relationship between absorbance and concentration.

Graphically analyze how a reaction changes over time.



Specifications

Color detection/peak wavelengths detected: 650 nm (red), 600 nm (orange), 570 nm (yellow), 550 nm (green), 500 nm (blue), 450 nm (violet)
Detector ranges: ±25 nm from peak
Absorbance: 0-3 Abs units; useful range (0.05 -1.5 Abs)
Transmittance: 0-100%
Turbidity range: 0-400 NTU
Accuracy: ±5% NTU

Includes

- USB charging cable
- Cuvettes (9)
- 100 NTU Calibration Cuvette (1)
- Cuvette racks (2)

WARNING! This product can expose you to chemicals including Formaldehyde, which is known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Order Information

Wireless Colorimeter and Turbidity Sensor PS-3215
Also available:
Replacement Cuvettes/Caps (6 each) SE-8739
100 NTU Cal Standard SC-3512
Cuvette Rack EC-3590

Charging Stations

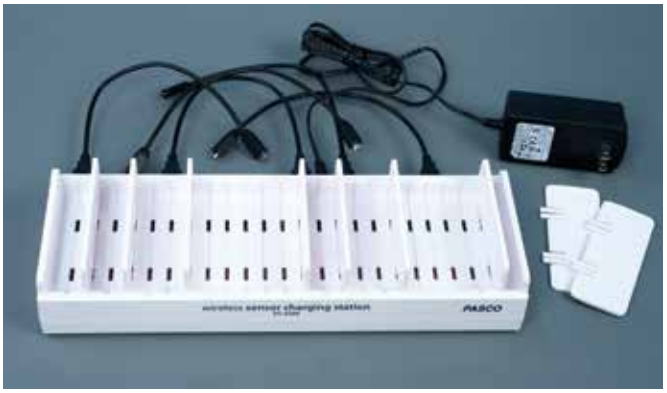
Wireless Sensor Charging Station

PS-3599

- Charge all types of PASCO wireless sensors
- Remove partitions to resize sensor bays



This versatile charging station can be configured to fit any size sensor by adding or removing partitions.



Includes

- Wireless Sensor Charging Station (13 cm x 35 cm)
- Power Adapter
- 10 USB Charging Cables
- 9 Removable Partitions

Coming soon!
Check pasco.com for availability.

Order Information

Wireless Sensor Charging Station PS-3599

Does your Bluetooth need a boost?

USB Bluetooth 4.0 Adapter

PS-3500



If you are using our wireless sensors and working on an older Mac® (without Bluetooth® 4.0 connectivity) or if you are using some Windows® computers and Chromebooks™, you will need a USB Adapter.

Order Information

USB Bluetooth 4.0 Adapter PS-3500

See pasco.com/compatibility if you have questions about Bluetooth connectivity.

Wireless Sensor Storage Trays

Each tray can store up to 10 wireless sensors.

Wireless Temperature, pH and Conductivity Sensors Storage Tray

PS-3585



Wireless Pressure Sensor Storage Tray

PS-3586

Wireless Colorimeter and Turbidity Sensor Storage Tray

PS-3587



Wireless Voltage and Current Sensors Storage Tray

PS-3588

Wireless Light Sensor and AirLink Storage Tray

PS-3594

Wireless Force Sensor Storage Tray

PS-3595

Wireless Weather Sensor Storage Tray

PS-3596

Wireless Hand-Grip Sensor Storage Tray

PS-3597

Wireless CO_2 Sensor Storage Tray

PS-3598

Order Information

Wireless Temperature, pH and Conductivity Sensors Storage Tray PS-3585
Wireless Pressure Sensor Storage Tray PS-3586
Wireless Colorimeter and Turbidity Sensor Storage Tray PS-3587
Wireless Voltage and Current Sensors Storage Tray PS-3588
Wireless Light Sensor and AirLink Storage Tray PS-3594
Wireless Force Sensor Storage Tray PS-3595
Wireless Weather Sensor Storage Tray PS-3596
Wireless Hand-Grip Sensor Storage Tray PS-3597
Wireless CO_2 Sensor Storage Tray PS-3598

Make any PASPORT sensor wireless by connecting to an AirLink®

AirLink®

PS-3200



Connect one PASPORT sensor via Bluetooth® or through a USB connection. USB cable included.

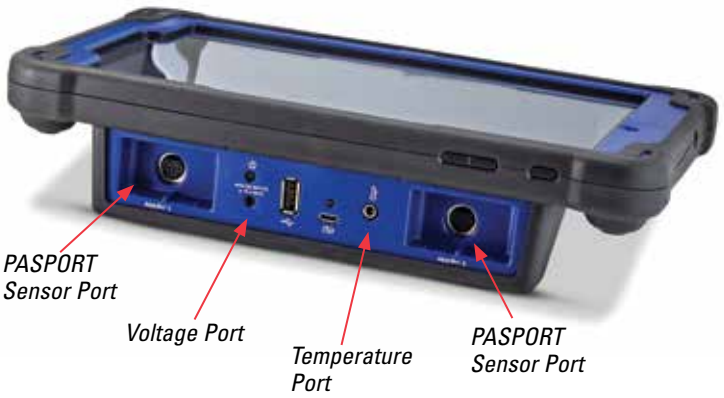
Order Information

AirLink PS-3200

Introducing PASCO's New SPARK LXi Datalogger



SPARK LXi
PS-3600





Built for Student Use
- Portable
- Shock-absorbing ruggedized case
- See all the detail in your data: 9.6" Color Capacitive Touchscreen (1280 x 800 pixels)
- 2 GHz Quad Core Processor, 1.5 GB RAM, 16 GB Memory

Built-in Features
- Built-in voltage and temperature sensor ports (probes included), accelerometer, microphone
- Speakers and GPS
- Two cameras
- Loaded with PASCO software: SPARKvue® for data collection and analysis, MatchGraph, and Spectroscopy

Connections
- Wi-Fi enabled
- New wireless sensors and Smart Carts* connect via Bluetooth®
- Connect to AirLink, SPARKlink Air, or 550 Universal Interface via USB or Bluetooth
- Connect blue sensors via two PASPORT sensor ports (SPARK LXi only)

**Patent pending*



Choose from Two Models: SPARK LX & LXi

SPARK LXi

PS-3600



Designed for use with wired and wireless sensors, the SPARK LXi can simultaneously accommodate up to five wireless sensors and also includes two ports for blue PASPORT sensors, plus two ports for the included Fast Response Temperature Probe and the Voltage Probe. The SPARK LXi can also connect via Bluetooth to the following interfaces: AirLink, SPARKlink® Air, and 550 Universal Interface.

SPARK LX

PS-3601



Designed for use with PASCO Wireless sensors, the SPARK LX can also connect via Bluetooth to the following interfaces: AirLink, SPARKlink® Air, and 550 Universal Interface. The SPARK LX can simultaneously connect up to five wireless sensors.

Feature	SPARK LXi (PS-3600)	SPARK LX (PS-3601)
Ruggedized case for indoor/outdoor and wet/dry lab use	✔	✔
9.6" full-color capacitive touchscreen (1280 x 800 pixels)	✔	✔
Simultaneously connects up to 5 PASCO Wireless Sensors	✔	✔
SPARKvue® in-app proximity pairing	✔	✔
Includes 2 PASPORT ports	✔	
Includes Voltage Probe and port	✔	
Includes Fast Response Temperature Probe and port	✔	
Can connect more PASPORT sensors with the AirLink, SPARKlink Air, and 550 Universal Interface	✔	
Installed software: PASCO SPARKvue, MatchGraph, and Spectrometry; Microsoft Office Suite; Google Suite	✔	✔
PASCO Lab Manager application	✔	✔
Hands-free retractable stand		✔
1.2 GHz quad-core processor	✔	✔
1.5 GB RAM, 16 GB memory	✔	✔
Android operating system	✔	✔
Wi-Fi, Bluetooth, and USB connections	✔	✔
Can export data to third-party apps	✔	✔
Operates online or offline	✔	✔
Front and back cameras	✔	✔
Accelerometer	✔	✔
Microphone and speaker	✔	✔
GPS	✔	✔

Order Information

SPARK LXi PS-3600
Recommended:
SPARK LXi Charging Station ..... PS-3602 p. 23
Replacement Parts:
Voltage Probe PS-2165
Fast Response Temperature Probe (3 pack) PS-2135

Order Information

SPARK LX PS-3601
Recommended:
SPARK LX Charging Station ..... PS-3603 p. 23

SPARK LXi and SPARK LX come loaded with useful software!



SPARKvue for data collection

SPARKvue is the software for data collection and analysis. It allows the SPARK LX/LXi dataloggers to connect to PASCO sensors and record data. Data can be displayed on graphs, meter displays, digits displays, and in tables.

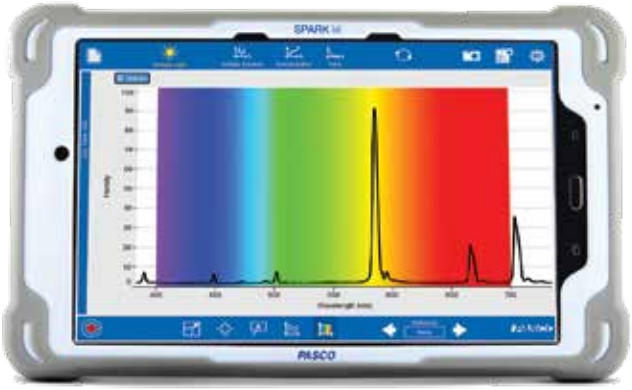
Analysis tools include curve fits, statistics, and finding the area under the graph.

MatchGraph! for learning how to interpret motion graphs



Use a Wireless Motion Sensor with the SPARK LXi or SPARK LX with MatchGraph software. It is an ideal way to teach the concepts of motion graphing, interpreting graphs, and rate of change or slope. See page 76 for details.





Spectrometry

Use a PASCO Wireless Spectrometer (PS-2600) with this Spectrometry software on a SPARK LX or LXi to analyze light spectra in physics and chemistry experiments. See page 77 for details.



Plus more!

- Microsoft Word®
- Microsoft Excel®
- Microsoft PowerPoint®
- Google Science Journal
- Scientific Calculator
- Periodic Table

Lab Manager

NEW

With Lab Manager on the new SPARK dataloggers, PASCO delivers a comprehensive lab management experience. Teachers have visibility and control over student lab devices, which ensures greater efficiency and student engagement.





With Lab Manager teachers can:

- Monitor student screens (or lock student screens to get students' attention).
- Broadcast teacher or student screens to class.
- Control student devices for guidance.
- Quiz students and view responses in real time.
- Message all student devices.
- Easily send and collect any file to and from student devices.

SPARK LXi/LX Charging Stations

SPARK LXi Charging Station

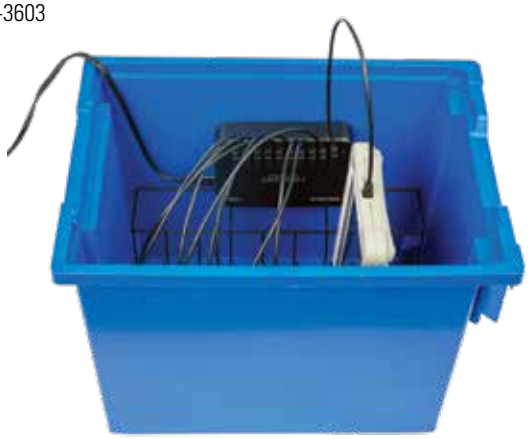
NEW

PS-3602



SPARK LX Charging Station

PS-3603



These convenient charging stations have a wire rack to hold the dataloggers and multiple charging cables, so a complete set of SPARK LXi/LX dataloggers can be charged from one power connection to the wall. The charging station is built into a Gratnells® case (size F3).

- PS-3602 can simultaneously charge up to six SPARK LXi dataloggers.
- PS-3603 can simultaneously charge up to nine SPARK LX dataloggers.

Dimensions: 312 x 427 x 300 mm

Coming soon!
Check pasco.com for availability.

Order Information

SPARK LXi Charging Station PS-3602
SPARK LX Charging Station PS-3603

Interfaces

Use an interface to connect sensors to your computers or mobile devices running PASCO software.

AirLink®

PS-3200



The AirLink is the most cost-effective way to connect sensors.

Connect one PASPORT sensor via Bluetooth® or through a USB connection. USB cable included.

Order Information

AirLink PS-3200

SPARKlink® Air

PS-2011



Connect two PASPORT sensors via Bluetooth® or through a USB connection. Also includes dedicated ports for the included temperature and voltage probes. USB cable included.

Order Information

SPARKlink Air PS-2011

SPARK LXi

PS-3600



Designed for use with wired and wireless sensors, the SPARK LXi can simultaneously accommodate up to five wireless sensors. It also includes two ports for blue PASPORT sensors, plus two ports for the included Fast Response Temp Probe and the Voltage Probe.

Order Information

SPARK LXi PS-3600

550 Universal Interface

UI-5001



The 550 Universal Interface is fast, flexible, and powerful while staying affordable. The 550 has half the ports and many of the great features of our 850 Universal Interface in a smaller package with Bluetooth® and USB connectivity.

Order Information

550 Universal Interface UI-5001

850 Universal Interface

UI-5000



The 850 Universal Interface is the most powerful science education lab interface in the world, with the most ports, highest sampling rates, and the most powerful functionality and future expandability. It can also replace several pieces of lab instrumentation, which represents great value.

Order Information

850 Universal Interface UI-5000

Interface Comparison

Compare the features and capabilities and see which interface works best in your lab.







	AirLink PS-3200	SPARKlink Air PS-2011	SPARK LXi PS-3600	550 Universal Interface UI-5001	850 Universal Interface UI-5000
PASPORT Ports	1	2	2	2	4
Built-in Temp and Voltage	No	Yes	Yes	No	No
Analog Inputs	0	0	0	2 (±10 V, optional gain voltage 10x, 100x)	4 (±20 V, optional gain voltage 10x, 100x, 1000x)
Digital Inputs	0	0	0	2	4
Connects via USB	Yes	Yes	Yes	Yes	Yes
Connects via Bluetooth	Yes	Yes	Yes	Yes	No
Rechargeable battery for cordless operation	Yes	Yes	Yes	No (AC adapter only)	No (AC adapter only)
Works with PASCO Capstone Software	Yes	Yes	No	Yes	Yes
Works with SPARKvue Software	Yes	Yes	Yes	Yes	No
Accepts PASPORT Sensors	Yes	Yes	Yes	Yes	Yes
Accepts ScienceWorkshop Sensors	No*	No*	No*	Yes	Yes
Maximum Sampling Rate	Sensor-dependent <1000 Hz	Sensor-dependent <1000 Hz	Sensor-dependent <5000 Hz	Up to 2 MHz on one channel	10 MHz on two channels simultaneously
Signal Generator	N/A	N/A	N/A	±8 V, at 400 mA, DC to 100 kHz	#1 ±15 V at 1 A, DC to 100 kHz #2 & #3 ±10 V at 50 mA DC to 500 kHz, independent
Included Items	USB Cable	AC adapter, USB cable, fast response temperature probe, voltage probe	AC adapter, USB cable, fast response temperature probe, voltage probe	USB cable, power supply	USB cable, power supply
Expansion Port	No	No	No	No	44-pin port with voltage outputs, analog inputs, and digital I/O channels

* The AirLink, SPARKlink Air, and SPARK LXi can accept most ScienceWorkshop sensors with the proper adapter (see page 45), although they won't have the same high maximum sample rates. One exception is the Sound Sensor (UI-5101), which is not recommended for use with an adapter.

The PASCO 850 Universal Interface:

The Ultimate Sensor Interface for Physics and Engineering

Clear the clutter on your lab bench. The 850 Universal Interface combined with PASCO Capstone software can replace multiple expensive pieces of equipment.

An incredible value!



850 Universal Interface

+

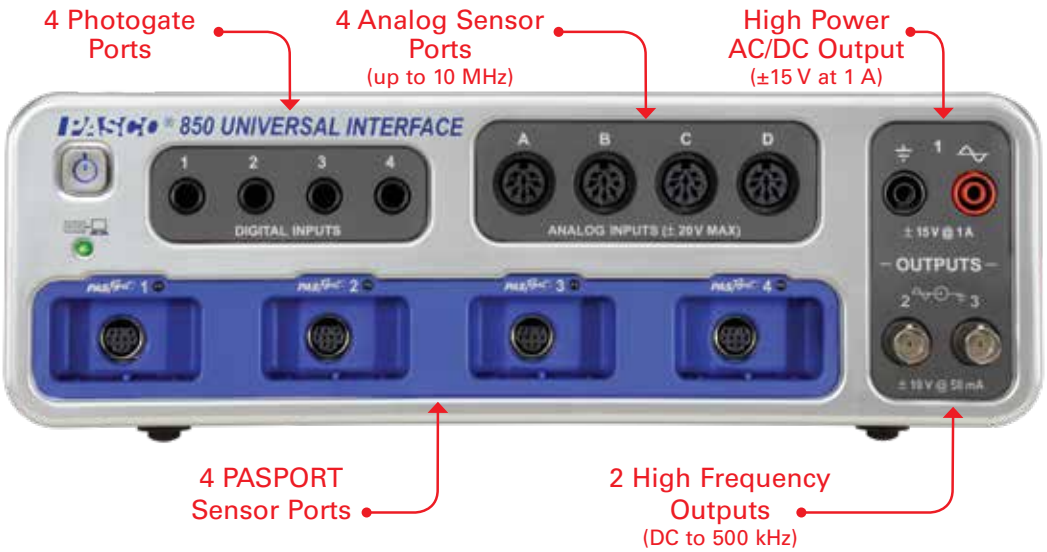


PASCO Capstone Software

=



DC Power Supply, Oscilloscope, Digital Multimeter, and Function Generator



- **Study AC Circuits:** 10 MHz sample rate on two analog channels simultaneously; two independent high frequency outputs (50 mA at 10 V; DC to 500 kHz)
- **Power Speakers and String Vibrators:** High power function generator (1 A at 15 V; DC to 100 kHz)
- **Use Any Sensors You Have:** Compatible with ScienceWorkshop and PASPORT sensors; use at the same time
- **Explore Modulation:** External trigger input/output for synchronizing multiple 850s
- **Do 87 Core Physics Experiments:** Check out the Comprehensive 850 Physics Lab Manual (UI-5813; see page 78). Download online at pasco.com/comprehensivephysics
- **See detailed specifications:** www.pasco.com/850

Order Information

850 Universal Interface UI-5000

Requires:

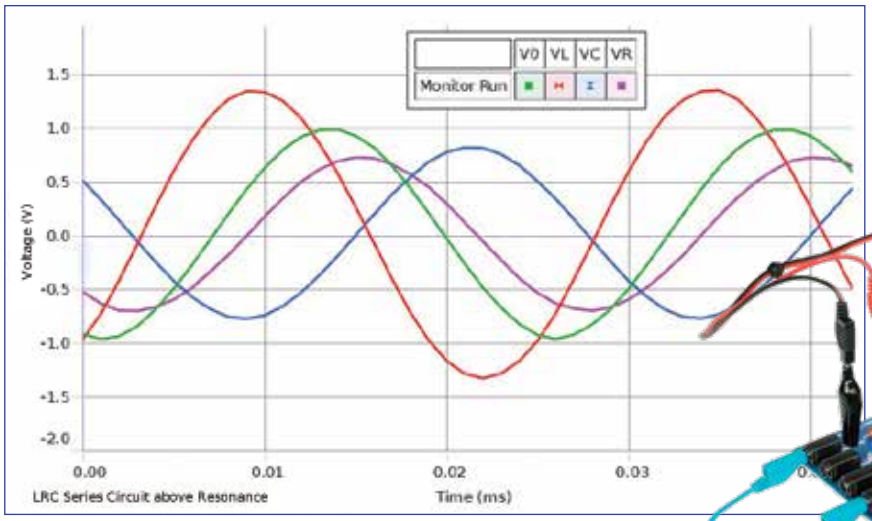
PASCO Capstone Software ..... p. 70-73

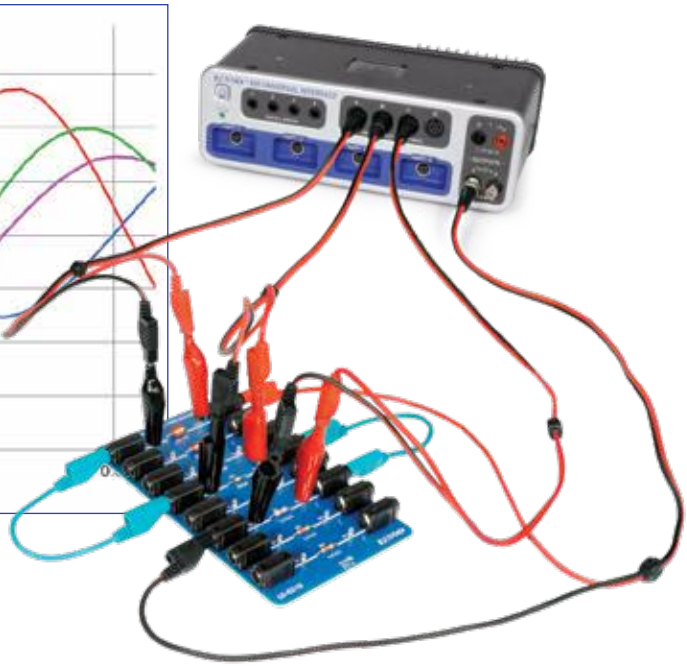
Recommended:

BNC Function Generator Output Cable ..... p. 27

Replacement Part:

850 Power Supply UI-5200





Four Channel Oscilloscope in PASCO Capstone

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.

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.



UI-5119



UI-5129



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

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

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

The PASCO 550 Universal Interface…

This powerful interface for Physics connects wirelessly or via USB.

This is the interface with the measurement capability for all types of physics experiments. It features:

- 2 MHz sampling rate
- 2 high-speed analog inputs
- 2 digital inputs for photogates and other timing sensors
- 2 PASCO PASPORT sensor inputs
- Signal generator with built-in Voltage and Current sensors.
- Use with other PASPORT interfaces
- Connect to computers via USB
- Bluetooth® classic connectivity

With the 550, your Physics lab is equipped with high-speed data collection, signal generation and power supply, oscilloscope and FFT displays, timers, and more.



550 Universal Interface Specifications:

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

2 Digital Inputs

Digital sensors such as Photogates and Time-of-Flight plug directly into the 550 Interface.

- Compatible with all ScienceWorkshop digital sensors
- Sensor Connect Detection
- 0-5 V TTL
- Bi-directional

2 PASPORT Inputs

Compatible with PASCO's complete line of more than 80 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: 1.33 mV, 12-bit DAC.
Max Output Current: 400 mA at 8 V, over-current detection
Selectable Voltage Limit
Selectable DC Offset
Frequency Sweep Function
Measure Output Current, Voltage, Frequency, Peak Amplitude

Order Information

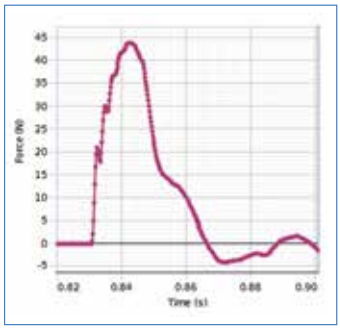
550 Universal Interface.....UI-5001

Requires:
PASCO Capstone Software..... pp. 70-73
or
SPARKvue Software..... p. 74

Advantages of Using ScienceWorkshop Sensors with the 550 and 850 Universal Interfaces

The 550 and 850 Universal Interfaces are called "Universal" because they are capable of using ScienceWorkshop sensors as well as PASPORT sensors. Although the PASPORT sensors are the newer digital line of sensors, there are advantages to using the older analog technology in the ScienceWorkshop sensors. Here are a few examples:

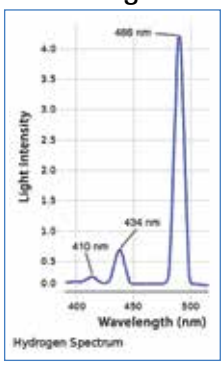
1. High Speed Collision with the Force Sensor (CI-6537); see page 36.



A cart colliding with a Force Sensor with a clay bumper was recorded at 5000 Hz sampling rate. Detail of the collapse of the clay can be seen in the data.



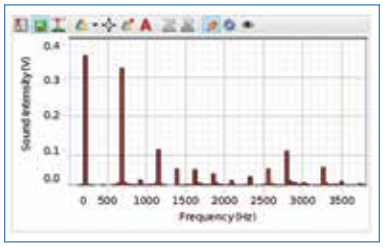
2. Detecting the Violet Hydrogen Lines with the High Sensitivity Light Sensor (CI-6604); see page 52.



This light sensor has a high gain that, when combined with the interface gain, allows even the dimmest of the Balmer series to be detected.



3. Sound FFT Spectrum of a Clarinet Note with the Sound Sensor (UI-5101); see page 60.

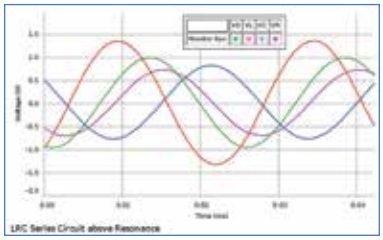


Now with Auto-ID

This FFT of a note being played on a clarinet was captured at a sample rate of 20 kHz. The waveform can also be seen on an oscilloscope in Capstone software.



4. LRC Circuit with the Voltage Sensor (UI-5100); see page 54.



Now with Auto-ID

This oscilloscope display in PASCO Capstone shows the voltages across several components of an LRC circuit. Sample rates required for this can be as high as 10 MHz.



AirLink® and SPARKlink® Air

Capture data remotely inside or outside of the lab.

The AirLink and the 2-port SPARKlink Air allow users to connect any of PASCO's 80+ PASPORT sensors via USB or Bluetooth. When used wirelessly they allow a freedom and range of movement not available with cabled interfaces. They also provide the ability to easily collect data in the field when needed.

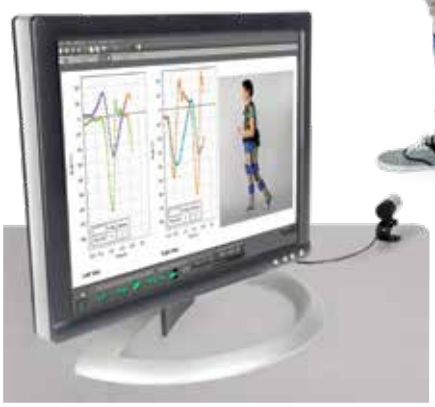
The SPARKlink Air is used here with two Angle Sensors, part of the PS-2137 Goniometer System. The data is sent via Bluetooth to the desktop computer and displayed live with the video recorded by the web cam.



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.



Webcam
Record live video synched to sensor data.



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

SPARKlink Air

PS-2011



Includes

- Two sensor ports
- Built-in temperature and voltage sensors with probes
- USB and Bluetooth Classic connection

Order Information

SPARKlink Air PS-2011
Shown in use with:
Goniometer..... PS-2137 ..... p. 61
Additional Goniometer Probe PS-2138
Required:
PASCO Capstone Software ..... pp. 70-73

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

AirLink

PS-3200



Includes

- One built-in PASPORT sensor port
- USB and Bluetooth 4.0 connection
- USB cable

Order Information

AirLink PS-3200

10-port USB Charging Station

PS-3501

Charge up to 10 wireless sensors via USB cable, included with the sensor.

(Go to pasco.com for more info.)



Order Information

10-port USB Charging Station PS-3501

PASPORT and ScienceWorkshop Sensor Index

PASPORT Sensors:

- Have digital outputs that allow multiple measurements per channel with reduced noise
- Compatible with all current PASCO interfaces, as well as discontinued PASPORT interfaces

ScienceWorkshop Sensors:

- PASCO's original line of sensors
- Analog Voltage output perfect for teaching about sensing elements
- Compatible with 550 and 850 Universal Interfaces, as well as discontinued ScienceWorkshop interfaces.

Sensor Description	Product #	Page #
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PASPORT	PS-2170	68
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PASPORT Sensor Extension Cable

PS-2500



Extends the distance a sensor can reach by 2 m. Two cables CANNOT be connected together or used on a sensor that already has a cable.

Order Information

PASPORT Sensor Extension Cable..... PS-2500

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

Motion Sensor

PS-2103A

PASPORT



PASCO's PASPORT Motion Sensor is 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.

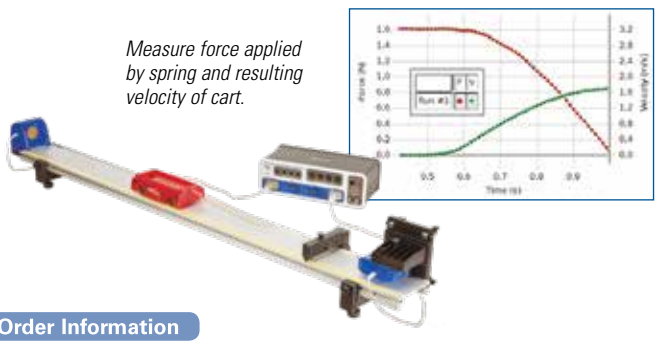
Specifications

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

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.



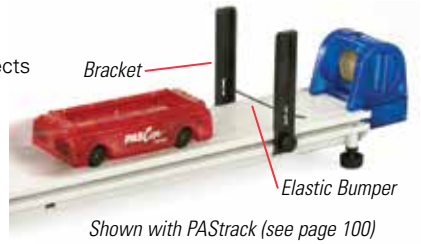
Order Information

Motion Sensor PS-2103A
Recommended:
Motion Sensor Guard SE-7256
Magnetic Motion Sensor Bracket PS-2546
Cart Adapter Accessory ME-6743

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 100)

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

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

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

Motion Sensor II

CI-6742A

ScienceWorkshop



PASCO's digital ScienceWorkshop Motion Sensor II is 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.

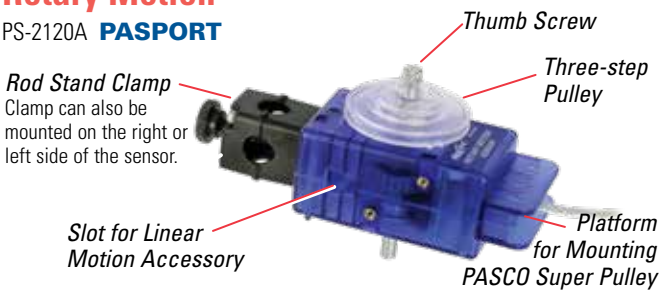
Connector: Dual stereo phone plug for 850, 550, and ScienceWorkshop interfaces.

Order Information

Motion Sensor II CI-6742A
Recommended:
Motion Sensor Guard SE-7256
Magnetic Motion Sensor Bracket PS-2546
Cart Adapter Accessory ME-6743
Accessory Cable CI-6748
Allows CI-6742A to be used with CBL/EA100.

Rotary Motion

PS-2120A **PASPORT**



PASCO's PASPORT Rotary Motion Sensor is the most versatile position and motion-measuring device available for the physics lab. Measure angle and angular velocity or measure distance and linear velocity using the rack or the pulley. This sensor is 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.

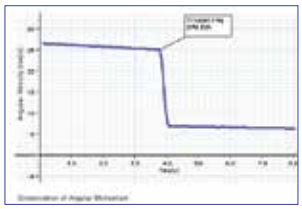
Specifications

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

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

Conservation of Angular Momentum

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





Order Information

Rotary Motion Sensor PS-2120A
Recommended:
Linear Accessory Kit CI-6688A
Three-step Pulley CI-6693

Linear Accessory Kit

CI-6688A



Includes rod clamp and solid aluminum rack.



Shown in use measuring magnetic field from a coil.

See page 58.

Order Information

Linear Accessory Kit CI-6688A

Rotational Inertia Accessory

ME-3420

NEW

Use the Rotational Inertia Accessory to study rotational inertia, pendulum oscillations, and conservation of angular momentum.
See page 176.



Coming soon!
Check pasco.com for availability.

Order Information

Rotational Inertia Accessory ME-3420

Rotary Motion

CI-6538

ScienceWorkshop



Measure angle and angular velocity or measure distance and linear velocity using the rack or the pulley. This sensor is also bi-directional, indicating the direction of motion.

Specifications

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 850, 550, and ScienceWorkshop interfaces

Order Information

Rotary Motion Sensor CI-6538
Recommended:
Linear Accessory Kit CI-6688A
Three-step Pulley CI-6693

How the Rotary Motion Sensor is used

Chaos/Driven Harmonic Accessory

CI-6689A

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

See page 177.



Order Information

Chaos/Driven Harmonic Accessory CI-6689A

Centripetal Force

ME-9821

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

See page 174.



Order Information

Centripetal Force ME-9821

Educational Spectrophotometer

OS-8539

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



See pages 286-287.

Order Information

Educational Spectrophotometer System OS-8539

Ballistic Pendulum Accessories

Ballistic Pendulum Accessory ME-9892

Mini Launcher Ballistic Pendulum Accessory ME-6829



See page 139.

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 112.

Order Information

Track String Adapter ME-6569

Dynamics Track Mount CI-6692

Linear Translator

OS-8535A

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

See page 279.



Order Information

Linear Translator OS-8535A

Gyroscope

ME-8960

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

See pages 178-179.



Order Information

Gyroscope ME-8960

Heat Engine

TD-8572A

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

See page 207.



Order Information

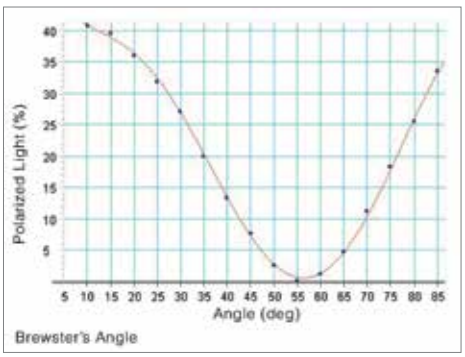
Heat Engine TD-8572A

Polarization Analyzer

OS-8533A

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

See page 272.





Graph shows the intensity of the reflected polarized light as a function of the incident angle.
See Brewster's Angle Experiment on page 375.

Order Information

Polarization Analyzer OS-8533A

How to Select the Right Force Sensor or Load Cell for You

Part #	Sensor	Interface	Purpose
CI-6537	Force	550/850 interfaces or legacy 500/750 interfaces	• Higher sample rates up to 10 MHz (depends on interface) • Extra strain gauges cancel side-loads
PS-2189	High Resolution Force	Any PASPORT interface, 550, or 850	• More sensitive: 0.002 N resolution • Maximum sample rate is 1000 Hz • Good for Hooke's Law and Newton's Third Law
PS-2104	Force	Any PASPORT interface, 550, or 850	• Sample up to 5000 Hz on 550/850 interface • For more resolution, use PS-2189 • For lower price, use PS-3202.
PS-2141	Force Platform	Any PASPORT interface, 550, or 850	• Measures normal force only • Good for measuring hang time when a person jumps.
PS-2142	2-Axis Force Platform	Any PASPORT interface, 550, or 850	• Measures normal force and tangent force • Excellent for measuring human walking
PS-2200	100 N Load Cell	Any PASPORT interface, 550, or 850	• Requires PS-2198 Six Load Cell Amplifier or PS-2206 Dual Load Cell Amplifier • For measuring loads in bridges or other structures made with PASCO Structures System
PS-2201	5 N Load Cell	Any PASPORT interface, 550, or 850	• Requires PS-2198 Six Load Cell Amplifier or PS-2206 Dual Load Cell Amplifier • Used with PASCO Structures System to measure smaller loads or to measure accelerations during bridge vibrations

Force Sensor

CI-6537 **ScienceWorkshop**

- ±50 N range
- High sample rate



PASCO's durable, reliable Force Sensor has been 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 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
Maximum Sample Rate: Depends on interface

Order Information

Force Sensor CI-6537

High Resolution Force

PS-2189 **PASPORT**

- 0.002 N resolution
- Dynamic over-sampling

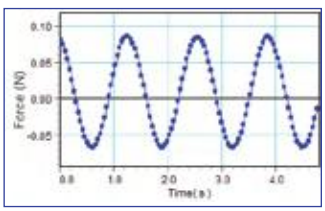


Also see the Wireless Force Acceleration Sensor on page 11.

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



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



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.

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!



Order Information

High Resolution Force Sensor PS-2189
Shown in use with:
Force Sensor Balance Stand CI-6460
Mass and Hanger Set ..... ME-8979 p. 197
Spring Set ..... ME-8999 p. 167

Force Sensor

PS-2104 **PASPORT**



- Binocular force beam minimizes side force measurements

The Force Sensor is ideal for the student lab. Finger holes are provided for handheld 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

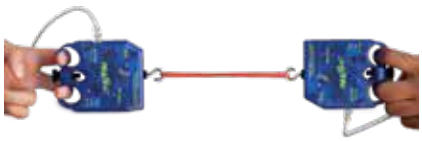
Range: ±50 N

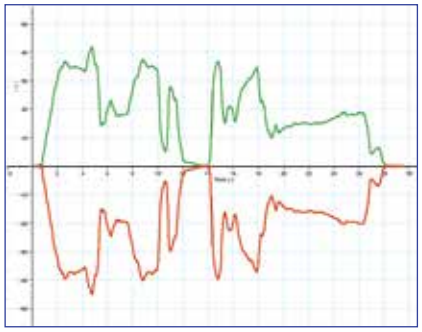
Resolution: 0.03 N or 3.1 grams

Zero (Tare) Function: Push-button

Max Sample Rate: 1000 Hz; 5000 Hz for the 550 and 850 interfaces

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 PS-2104
Recommended:
Force Bracket..... ME-6622
Rocket Engine Test Bracket ME-6617

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

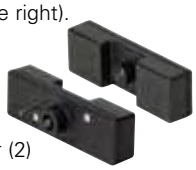
Bumper Accessory Set..... ME-9884

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 Bracket (above right).



Includes

- Magnetic Bumper (2)

Order Information

Magnetic Bumper Set ME-9885A

Force Bracket

ME-6622

The Force Bracket with bumpers mounts the PASCO Force Sensor directly to a dynamics track. It includes 5 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.



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

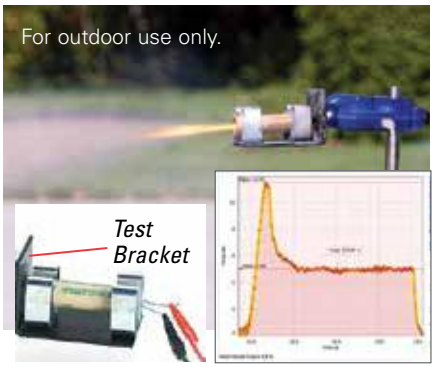
Force Bracket..... ME-6622

Rocket Engine Test Bracket

ME-6617

- A perfect supplement for rocketry studies

With the Rocket Engine Test Bracket attached to a Force Sensor (ScienceWorkshop 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.



Order Information

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

Choice of Load Cell Amplifiers:

Load Cell Amplifier (6 ports)

PS-2198

PASPORT

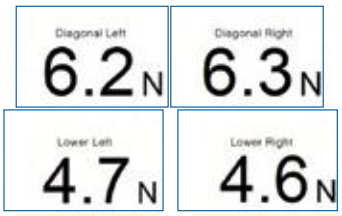


This Load Cell Amplifier can accommodate up to six load cells and only needs a single port on any PASCO interface to connect to the USB port on a computer. This is useful for doing an extensive analysis of a bridge by inserting six load cells at various points in the structure to see if theory matches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

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

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





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

Shown in use with Structures Systems Truss Set (ME-6990). See page 149.

Includes

- Load Cell Amplifier
- 100 N Load Cell (4)

Order Information

Load Cell Amplifier (6 ports) PS-2198

Required for Use:

Load Cell 100 N PS-2200

Load Cell 5 N PS-2201

Also Available

Load Cell and Amplifier Set PS-2199



Set Includes

- Load Cell Amplifier
- Load Cells 100 N (4)
- Instruction manual

Dual Load Cell Amplifier

PS-2205

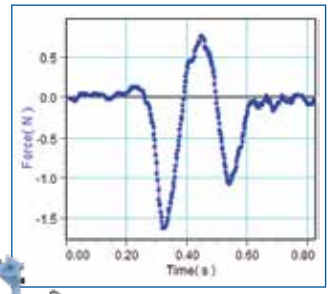
PASPORT

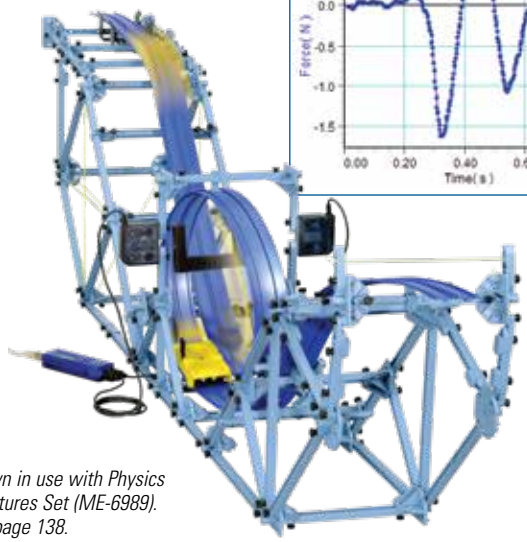


This Amplifier is for applications where only one or two load cells are needed, such as measuring the force on the track at the top of a roller coaster loop. If you only want to examine the forces in a bridge one at a time, you can move a single load cell around in the bridge.

The Amplifier accepts either the 100 N load cell or the 5 N 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 100 N PS-2200

Load Cell 5 N PS-2201

Also Available

Load Cell and Dual Amplifier Set PS-2206



Set Includes

- Dual Load Cell Amplifier
- Load Cell 100 N (1)

Two ranges of load cells

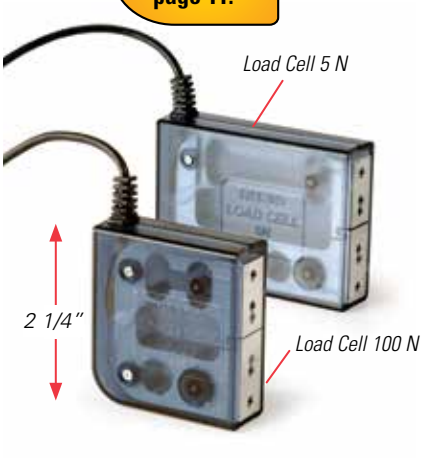
Load Cell 100 N

PS-2200

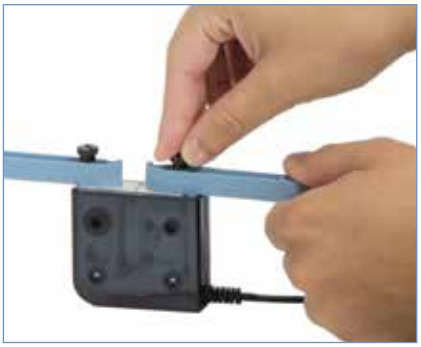
Load Cell 5 N

PS-2201

Also see the new Wireless Load Cell on page 11.



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
Accuracy: ±1% (±1 N)
Resolution: 0.02 N
Safe Overload: ±150 N

Specifications (PS-2201)

Range: ±5 N
Accuracy: ±1% (±0.05 N)
Resolution: 0.001 N
Safe Overload: ±7.5 N

Order Information

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

Measure support forces with a Force Platform

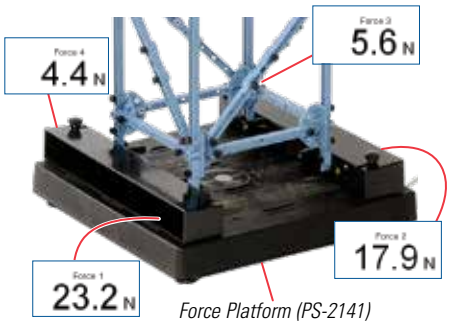
Force Platform Structures Bracket

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 152.



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. 40
Large Structures Set.....ME-7003 p. 152

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.



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. 197
Small "A" Base .....ME-8976 p. 186
Steel Rod 60 cm long (threaded).....ME-8977 p. 186

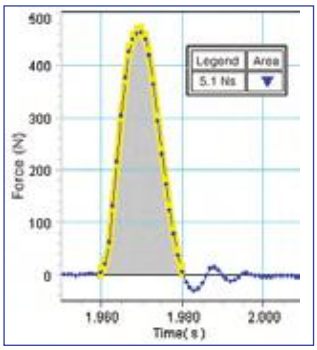
Force Platform

PS-2141

- 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 850 Interface)
Resolution: 0.1 N
Mass: 4 kg (without handles)

Order Information

Force Platform PS-2141
Recommended:
Handle Set PS-2548

2-Axis Force Platform

PS-2142

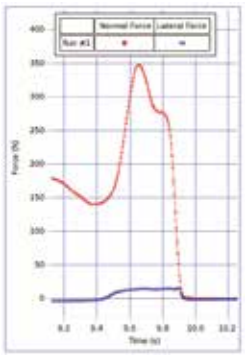
- Large jumping and landing surface



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 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 PS-2142
Recommended:
Handle Set PS-2548

Force Platform Handle Set

PS-2548

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.



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.





Order Information

Force Platform Handle Set PS-2548

Includes

- 2 sturdy metal handles

Force Platform Structures Bracket

ME-6988A

See page 33.



Includes

- Brackets (2)
- Screws (4)

Order Information

Force Platform Structures Bracket ME-6988A

Visual Accelerometer

PS-2128

PASPORT

- 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.



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

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.

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 (1)
- Three AA batteries

Order Information

Visual Accelerometer.....PS-2128

3-Axis Acceleration/Altimeter

PS-2136A **PASPORT***

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



Also see the new Wireless Accelerometer/ Altimeter on page 11.

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

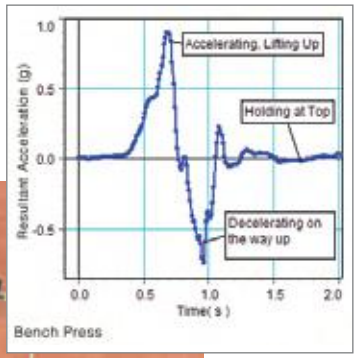
Max data rate for altitude: 20 samples/second

Five Simultaneous Measurements:

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

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.





Order Information

3-Axis Acceleration/Altimeter.....PS-2136A

Shown in use with:

550 Universal Interface.....UI-5001 p. 28

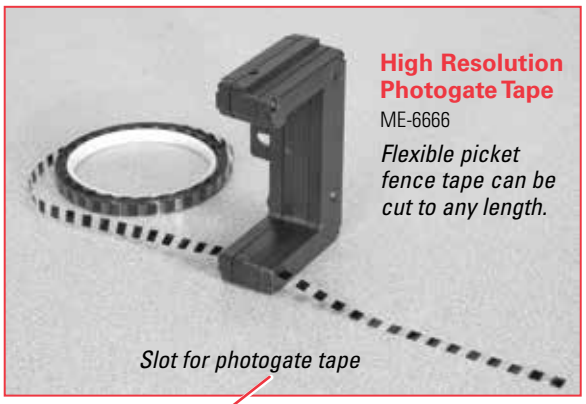
Smart Gate... *It's four photogates in one!*

PS-2180 **PASPORT**

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

Also see the new Wireless Smart Gate on page 11.

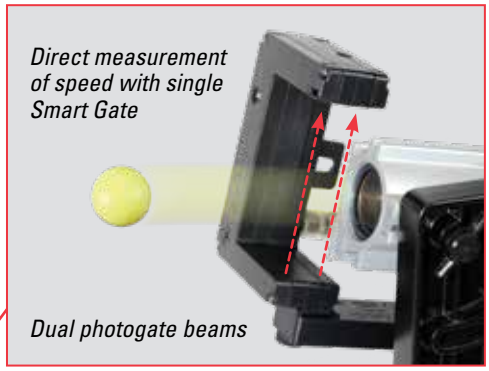
The Smart Gate has dual Photogate beams spaced at 1.5 cm to accurately measure speed. Built-in laser switch (when used with any laser) allows you to time objects too large to fit through the standard Photogate. Other features include a slot for Photogate Tape and an auxiliary port for an additional Photogate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



High Resolution Photogate Tape
ME-6666
Flexible picket fence tape can be cut to any length.











Includes
- Smart Gate
- Interface Cord



Order Information

Smart Gate	PS-2180	
Recommended:		
Time-of-Flight Accessory	ME-6810A	p. 45
High Resolution Photogate Tape	ME-6666	p. 44
Required:		
PASPORT Interface		

**See page 24 for the complete information about PASPORT and ScienceWorkshop sensors.*

Smart Gate System

PS-3701

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



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

Order Information

Smart Gate System PS-3701

Smart Gate Pulley System

PS-3702

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



Order Information

Smart Gate Pulley System PS-3702

The Photogates and Time-of-Flight Accessory on this page plug directly into the auxiliary port on the Smart Gate.

Photogate Head

ME-9498A



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 ME-9498A
Recommended:
Photogate Stand ME-9805

Photogate/Pulley System

ME-6838A



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 ME-6838A

Accessory Photogate

ME-9204B

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



Order Information

Accessory Photogate..... ME-9204B
Photogate Stand ME-9805

Photogate Pendulum Set

ME-8752

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





Photogate not included.

Order Information

Photogate Pendulum Set ME-8752

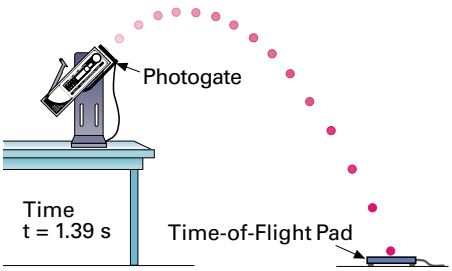
Time-of-Flight Accessory

ME-6810A



Typical Applications

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



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.

Order Information

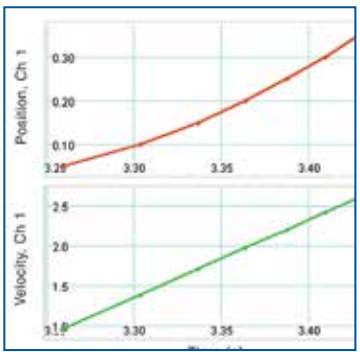
Time-of-Flight Accessory ME-6810A

The sensors on this page are digital sensors that plug directly into ScienceWorkshop, 550, and 850 Universal Interfaces. To use the sensors with a PASPORT interface, a Digital Adapter is required.

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

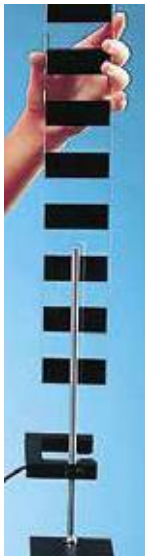
- Photogate Heads (2)
- Photogate Brackets (2)
- Picket Fences (2)
- Super Pulley with attachment screw (attaches Super Pulley to Photogate)
- Pulley Mounting Rod

Order Information

Photogates and Fences	ME-9471A	
Individual Components:		
Photogate Head	ME-9498A	p. 43
Photogate Brackets (2)	ME-9806	p. 112
Cart Picket Fences (2)	ME-9804	p. 112
Super Pulley	ME-9450A	p. 145
Pulley Mounting Rod	SA-9242	p. 145
Required for use with SPARKlink Air or AirLink:		
Digital Adapter	PS-2159	p. 45

Large Picket Fence

ME-9377A



Conduct freefall 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

Cart Picket Fences (set of 2)

ME-9804



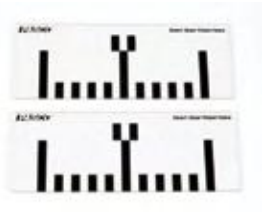
Order Information

Cart Picket Fences (set of 2) ME-9804

Smart Timer Picket Fences (set of 2)

ME-8933

See Smart Timer on pages 120-121.

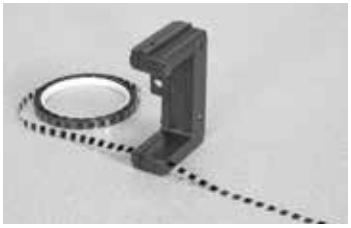


Order Information

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

Photogate Tape (Hi Res)

ME-6666



Attach this tape to moving objects to track their velocity. This photogate tape slides through the slot in the Smart Gate or Wireless Smart Gate.

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

Order Information

High Resolution Photogate Tape ME-6666
Shown in use with:
Smart Gate PS-2180

The sensors on this page are digital sensors that plug directly into ScienceWorkshop, 550, and 850 Universal Interfaces. To use the sensors with a PASPORT interface, a Digital Adapter is required.

Time-of-Flight Accessory

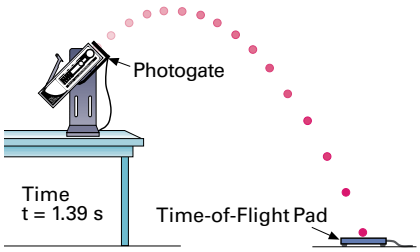
ME-6810A



The Time-of-Flight Accessory has a new rugged case. 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 ME-6810A
Required for use with SPARKlink Air or AirLink:
Digital Adapter PS-2159

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

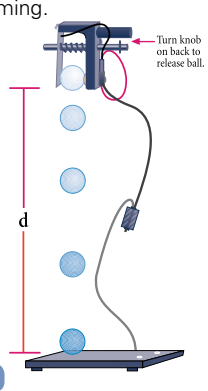
Phone Jack Extender Cord (20' cable).....PI-8117

Freefall Adapter

ME-9207B



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 ME-9207B
Required for use with SPARKlink Air or AirLink:
Digital Adapter PS-2159

G-M Tube/Power Supply

SN-7927A

- 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 . SN-7927A
Required for use with SPARKlink Air or AirLink:
Digital Adapter PS-2159

Digital Adapter

PS-2159



- 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 detects 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

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 ScienceWorkshop sensors with an 8-pin or 5-pin DIN connector such as:

- Colorimeter (CI-6747)
- Current (CI-6556)
- Force (CI-6537)
- Force, Economy (CI-6746)
- Infrared (CI-6628)
- Light (CI-6504A)
- Light, High-Sensitivity (CI-6604)
- Light, UVA (CI-9784)
- Magnetic Field (CI-6520A)
- Pressure Sensor-Absolute (CI-6532A)
- Sound (CI-6506B)
- Temperature (CI-6605A)
- Temperature, HIgh Accuracy (CI-6525)

Order Information

Analog Adapter PS-2158

How to Select the Right Pressure Sensor for You

Part #	Sensor	Interface	Purpose
CI-6532A	Absolute Pressure	550/850 interfaces or legacy 500/750 interfaces	• Higher sample rates up to 10 MHz (depends on interface) • Measures up to 700 kPa • Fast enough for Ratio of Specific Heats
PS-2107	Absolute Pressure	Any PASPORT interface, 550, or 850	• Measures up to 700 kPa • Good for Absolute Zero experiment
PS-2181	Dual Pressure	Any PASPORT interface, 550, or 850	• Measures up to 200 kPa • Maximum sample rate 1000 Hz • Best for heat engine experiment • Fast enough for Ratio of Specific Heats
PS-2164	Quad Pressure	Any PASPORT interface, 550, or 850	• Measures up to 200 kPa • Maximum sample rate 1000 Hz • For Venturi experiments
PS-2146	Absolute Pressure/Temp	Any PASPORT interface, 550, or 850	• Measures up to 200 kPa • Maximum sample rate 100 Hz • Excellent for Absolute Zero and Ideal Gas Law

Absolute Pressure

CI-6532A **ScienceWorkshop**



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

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

Pressure Range: 0 to 700 kPa
Reference Vacuum Pressure: 40 mTorr
Number of Pressure Ports: One
Pin Configuration: 8-pin DIN plug on case
Maximum Sample Rate: Depends on interface

Order Information

Absolute Pressure Sensor CI-6532A

Absolute Pressure

PS-2107 **PASPORT**

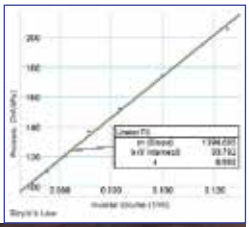


- Measure absolute pressure up to seven atmospheres
- Includes syringe for Gas Laws

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

Range: 0 to 700 kPa
Accuracy: ±2 kPa
Resolution: 0.1 kPa
Maximum Sample Rate: 200 Hz
Repeatability: 1 kPa



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

Order Information

Absolute Pressure Sensor PS-2107

Dual Pressure

PS-2181 **PASPORT**



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 page 352.
- Measure pressure drops in pipes



Instrument your pipe network with the Pressure Taps connected to the Dual Pressure Sensor (PS-2181). See page 182.

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 PS-2181

Pressure Taps

ME-2224



Order Information

Pressure Taps (set of 6) ME-2224

General Flow Sensor

PS-2222 General Flow Sensor only

PS-2225 General Flow Sensor with Venturi Tube

PS-2226 General Flow Sensor with Pitot Tube

PASPORT

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

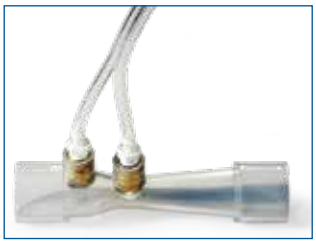
Venturi Range: 0 to 84 gpm (water); 0 to 773 gpm (air)

Venturi Accuracy: ±2 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 182-183 for more applications.

Order Information

General Flow Sensor with Venturi Tube PS-2225
General Flow Sensor with Pitot Tube PS-2226
Required:
PASPORT Interface ..... p. 30
PASCO Capstone Software ..... pp. 70-73
Also available separately:
General Flow Sensor without Probes PS-2222
Venturi Tube ME-2220
Pitot Tube ME-2221

Quad Pressure

PS-2164 **PASPORT**



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

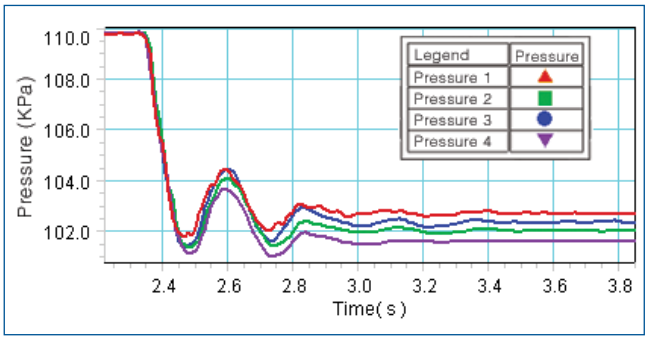
- Study pressure through a fluid circuit

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



The pressure at various points in a 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 PS-2164
Venturi Tube.....ME-2220 p. 47

Absolute Pressure/Temperature

PS-2146 **PASPORT**



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)

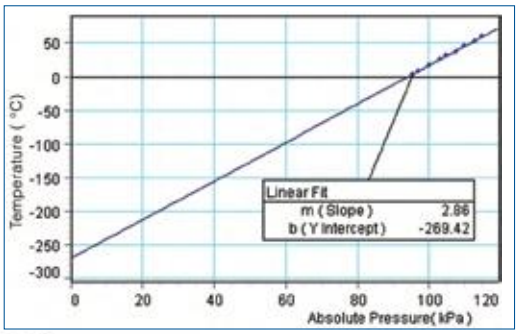
Specifications

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



Measure pressure and temperature of air in the sphere.

Order Information

Absolute Pressure/Temp Sensor PS-2146
Recommended:
Absolute Zero Sphere.....TD-8595 p. 206
Ideal Gas Law Apparatus.....TD-8596A p. 206

How to select the right Temperature Sensor/Probe

Part #	Sensor	Interface	Purpose
CI-6605A	Temperature	550/850 interfaces or legacy 500/750 interfaces	• Higher sample rates: maximum depends on the probe • General purpose for water/air from freezing to boiling
PS-2125	Temperature	Any PASPORT interface, 550, or 850	• Maximum sample rate 10 Hz • General purpose for water/air from freezing to boiling
PS-2143	Quad Temperature	Any PASPORT interface, 550, or 850	• Use for measuring up to four temperatures at once (different depths in water as it is cooled to freezing)
Temperature probes available for the above sensors CI-6605A, PS-2125, PS-2143:			
PS-2135	Fast Response Temperature Probe		• Small mass changes temperature quickly • For calorimetry
PS-2131	Surface Temperature Probe		• Attaches to skin or surfaces
PS-2153	Stainless Steel Probe		• Sturdy for mixing • -35°C to +135°C • More mass means it changes temperature more slowly
PS-2197	Non-Contact Temperature	Any PASPORT interface, 550, or 850	• -70°C to 380°C • Measure radiation from surfaces without touching
PS-2134	Type K Temperature	Any PASPORT interface, 550, or 850	• -200°C to +1,000°C • Measure temperature of liquid nitrogen and flames

Temperature

CI-6605A **ScienceWorkshop**

- Rugged sensor



PASCO's Stainless Steel Temperature Sensor offers a superior range, resolution and accuracy.

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..... CI-6605A

Temperature

PS-2125 **PASPORT**



Also see the new Wireless Temperature Link on page 12.

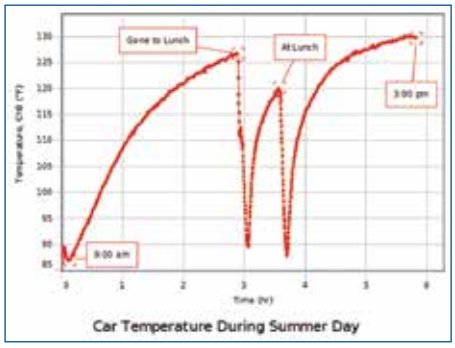
PASCO's Stainless Steel Temperature Sensor offers a superior range, resolution and accuracy. It reports temperature (in °C, °F, or K) whether it is immersed in liquids, held in the air, or touching a solid surface.

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



Capstone graph showing the temperature inside a parked car on a summer day. We turned on the air conditioning when we drove to lunch.

Order Information

Temperature Sensor..... PS-2125

Quad Temperature

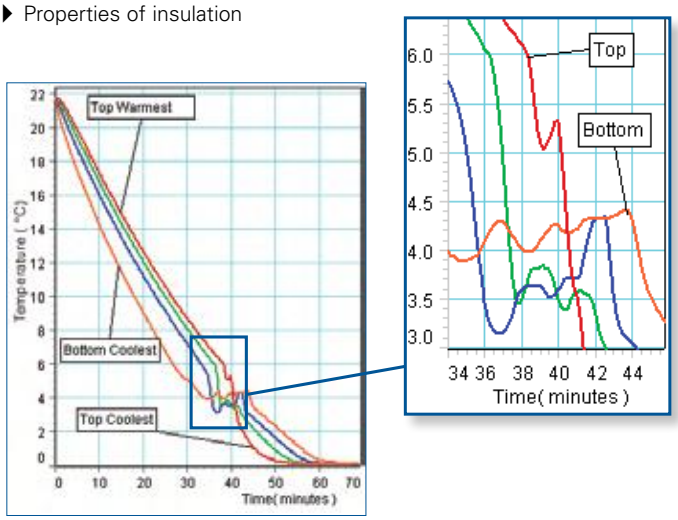
PS-2143 **PASPORT***



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.

Typical Applications

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



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.

Specifications

Accuracy: -35 to +135°C at ±0.5°C
Displays: °C, K and °F
Resolution: 0.0025°C
Maximum Sample Rate: 100 Hz

Includes

- Two Stainless Steel Temperature Probes (PS-2153)
- Three Fast Response Probes

Order Information

Quad Temperature Sensor PS-2143

Temperature Probes

Skin/Surface Temperature*

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* PS-2131

Fast Response Temperature Probe* (3 pack)

PS-2135



- Accurately measures temperature changes in real time
- Ideal for small or hard-to-reach spaces
- Includes 10 Adhesive Patches
- Adhesive patches hold the Temperature Probe in place.

Range: -30 to +105°C

Order Information

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

Stainless Steel Temperature Probe*

PS-2153



Range: -35 to +135°C

Order Information

Stainless Steel Temperature Probe*..... PS-2153

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

Temperature Sensor..... PS-2125 p. 49
Quad Temperature Sensor..... PS-2143 p. 50
Temperature..... CI-6605A p. 49

Non-Contact Temperature

PS-2197 **PASPORT**



- Non-contact
- -70°C to 380°C

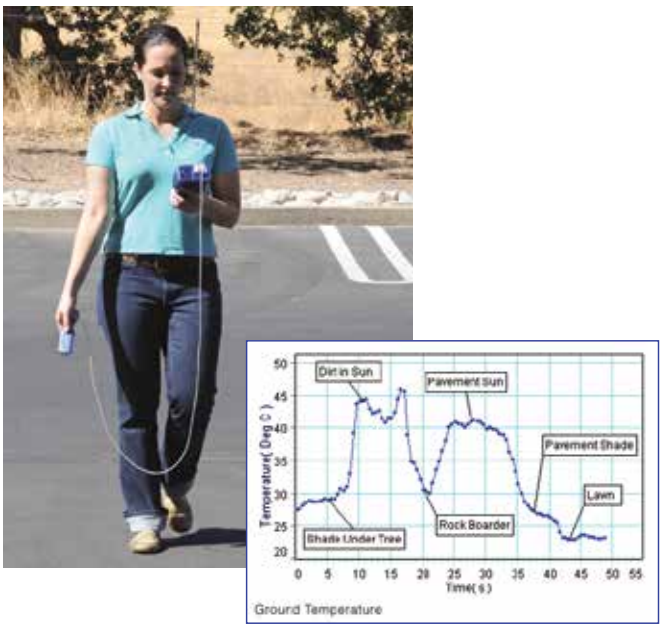
The Non-Contact Temperature Sensor measures surface temperature by detecting the emitted infrared light. Record the temperature of objects without touching them!

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 late-morning ground temperature 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..... PS-2197
Shown in use with:
PASCO Capstone Software..... pp. 70-73

Type K Temperature

PS-2134 **PASPORT**



- 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

How to Select the Right Light Sensor for You

Part #	Sensor	Interface	Purpose
CI-6504A	Light	550/850 interfaces or legacy 500/750 interfaces	• Higher sample rates up to 10 MHz (depends on interface) • Good for measuring the AC fluctuation of fluorescent and incandescent light bulbs
CI-6604	High Sensitivity	550/850 interfaces or legacy 500/750 interfaces	• Higher sample rates up to 10 MHz (depends on interface) • Good for diffraction and atomic spectra
PS-2176	High Sensitivity	Any PASPORT interface, 550, or 850	• Great dynamic range • Good for diffraction and atomic spectra • Less noise at slower sample rate
PS-2148	Infrared	Any PASPORT interface, 550, or 850	• For a lower price, use PS-3213 and get more functionality
PS-2150	Broad Spectrum	Any PASPORT interface, 550, or 850	• 300 to 10,000 nm range • Required for the blackbody experiment

Light

CI-6504A

ScienceWorkshop



Typical Applications

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

Specifications

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

Order Information

Light Sensor CI-6504A

High Sensitivity Light

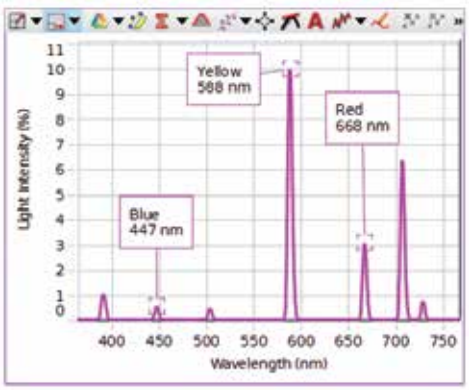
CI-6604

ScienceWorkshop



Typical Applications

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



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

Specifications

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

Order Information

High Sensitivity Light Sensor CI-6604

High Sensitivity Light

PS-2176 **PASPORT**

- Ideal for low light experiments



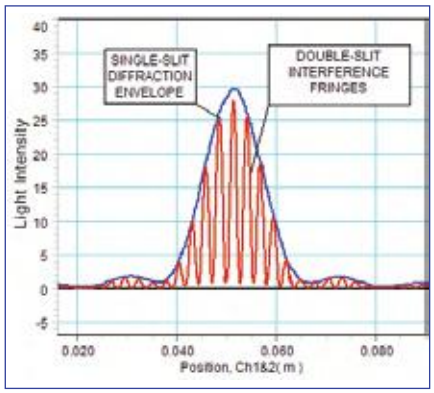
The High Sensitivity Light Sensor is designed to perform visible light studies from low intensity spectral studies to daylight. Built-in automatic variable oversampling reduces noise.

Typical Applications

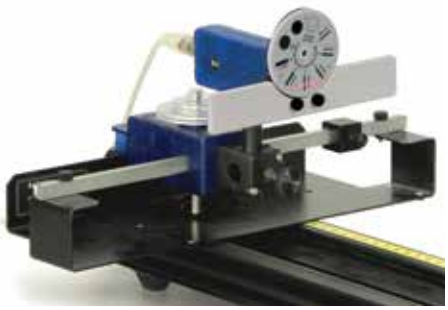
- Spectrophotometry
- Interference and diffraction patterns
- Measure light intensity vs. distance

Specifications

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



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



Order Information

High Sensitivity Light Sensor PS-2176

Infrared Light

PS-2148

PASPORT



- For heat studies

The Infrared Light 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

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

Order Information

Infrared Light Sensor PS-2148

Broad Spectrum Light

PS-2150 **PASPORT**

- For use with Spectrophotometer
- Ideal for Black Body Spectrum



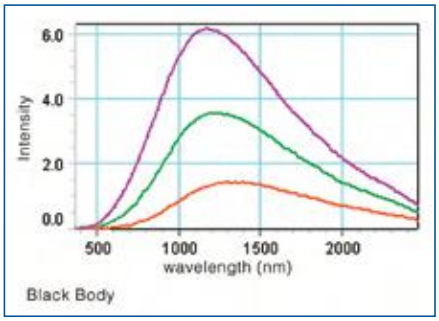
The Broad Spectrum Light Sensor is designed specifically for use with our Educational Spectrophotometer System OS-8539 and Prism Spectrophotometer Accessory OS-8543 for Black Body experiments. The Broad Spectrum Light Sensor uses a thermopile and window combination that respond to both the near infrared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

Typical Applications

- Black Body Experiment

Specifications

Sensing Element: BaF_2 window, xenon gas-filled thermopile
Spectral Response: 300 to 10,000 nm
Maximum Sample Rate: 100 Hz



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. *See page 290.*



Order Information

Broad Spectrum Light Sensor PS-2150

How to Select the Right Voltage and Current Sensor for You:

Part #	Sensor	Interface	Purpose
UI-5100/ UI-5110 CI-6556	Voltage Current	550/850 interfaces or legacy 500/750 interfaces	• Higher sample rates up to 10 MHz (depends on interface)
UI-5100/ UI-5110 PS-2184	Voltage Current Probe	550/850 interfaces or legacy 500/750 interfaces	• Higher sample rates up to 10 MHz (depends on interface) • Ideal for LRC circuits
PS-2115	Voltage/Current	Any PASPORT interface, 550, or 850	• Gives voltage and current in one sensor. However, sample rate is limited to 1000 Hz so is not the best for high frequency circuits.
PS-2193	High Current	Any PASPORT interface, 550, or 850	• Use when you need to measure high currents. • Limited to 1000 Hz.
PS-2160	Galvanometer	Any PASPORT interface, 550, or 850	• Use when you need to measure small currents or voltages. • Limited to 1000 Hz.

For ScienceWorkshop 500 or 750 Interfaces:

Voltage

UI-5100 **ScienceWorkshop**
UI-5110 (Shrouded) **ScienceWorkshop**

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


UI-5100

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: ±20 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.


UI-5110 (Shrouded)

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

Order Information

Voltage Sensor UI-5100
Voltage Sensor (Shrouded) UI-5110

Current

CI-6556 **ScienceWorkshop**

- 1 Ω sensing resistor
- High sample rates



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 CI-6556

For 550/850 Interfaces and for High Speed Sampling:

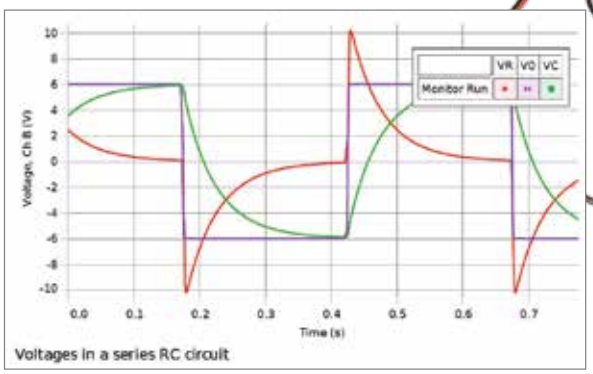
Voltage Sensor UI-5100/UI-5110

Current Probe PS-2184

When you're measuring voltage and current in AC circuits and need to sample fast, these sensors can sample as fast as 10 MHz on an 850 Universal Interface and up to 2 MHz on a 550 Universal Interface. The Voltage Sensors plug into the analog ports of these interfaces. The Current Probe is attached to the Voltage Sensor to measure the voltage drop across a precision 0.10 Ω resistor and outputs the resultant current calculation.

Since the 850 Interface analog gain can be set to x1000, very small currents (0.024 mA resolution) can be read with the Current Probe.

The 850 Universal Interface can measure at a rate of 10 MHz on two channels simultaneously; 1 MHz on three or four channels simultaneously. The 550 Universal Interface has a maximum sample rate of 2 MHz on one channel; 1 MHz on two channels simultaneously.





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.

Voltage

UI-5100 **ScienceWorkshop** UI-5110 (Shrouded) **ScienceWorkshop**

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



UI-5100

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.



UI-5110 (Shrouded)

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

Specifications

Voltage Range: ±20 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.

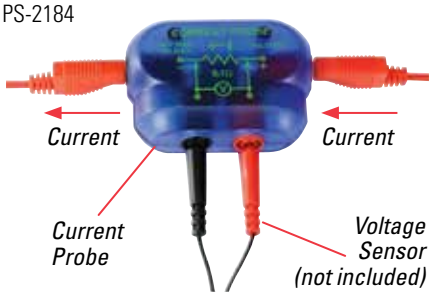
Order Information

Voltage Sensor UI-5100
Voltage Sensor (Shrouded) UI-5110

See page 22 for the complete information about PASPORT and ScienceWorkshop sensors.

Current Probe

PS-2184



The PS-2184 attaches to any 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
Maximum Sample Rate: Depends on interface

Order Information

Current Probe PS-2184

Voltage/Current

PS-2115 **PASPORT**

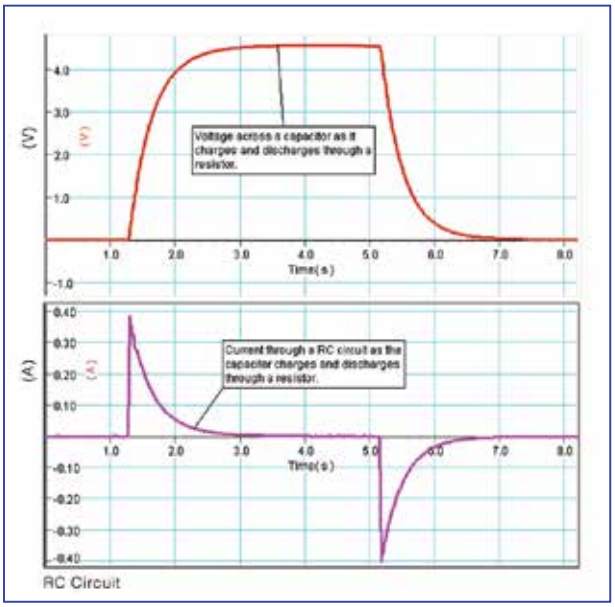
Also see the Wireless Current and Voltage Sensors on page 14.



The Voltage/Current Sensor combines both sensors in one case. This multi-measure probe uses only one connection so a single AirLink 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)



Capacitor voltage is shown as it is charged and discharged. The lower graph shows current through the series RC Circuit.

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

Order Information

Voltage/Current Sensor	PS-2115
Recommended:	
Alligator Clip Adapters (set of 10)	EM-8634

High Current

PS-2193 **PASPORT**

- 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

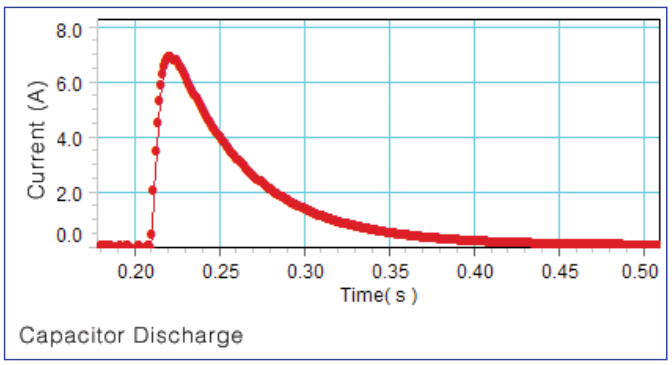
Sensing Element Series Resistance: 0.01 Ω

Maximum Common Mode Voltage: 10 V

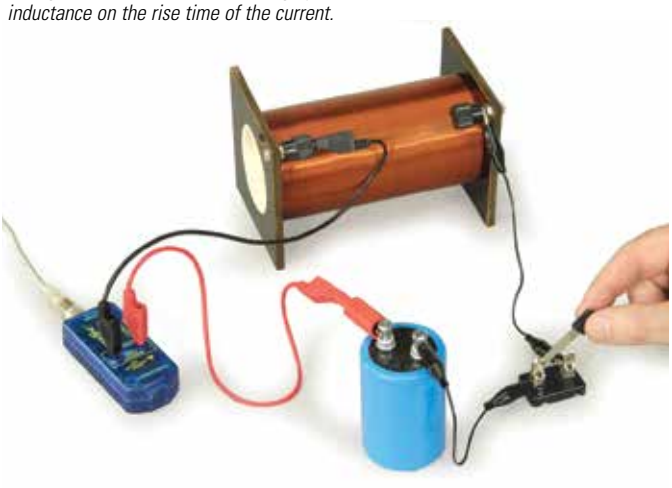
Maximum Continuous Current Without Damage: 12 A

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 coil's inductance on the rise time of the current.



Order Information

High Current Sensor	PS-2193	
Shown in use with:		
Capacitor (0.025 F) 2 pack	EM-8632	p. 227
Switch Set (SPST) 6 pack	EM-8815	p. 228
Air Core Solenoid	SE-7585	p. 236

Galvanometer

PS-2160 **PASPORT**



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.

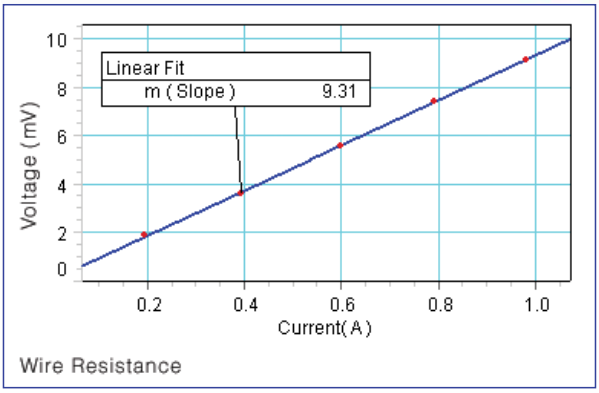
Specifications

Voltage Range: ±2000 mV, resolution of 0.1 mV

Maximum Sample Rate:
5000 Hz with the 850 and 550
1000 Hz with other interfaces

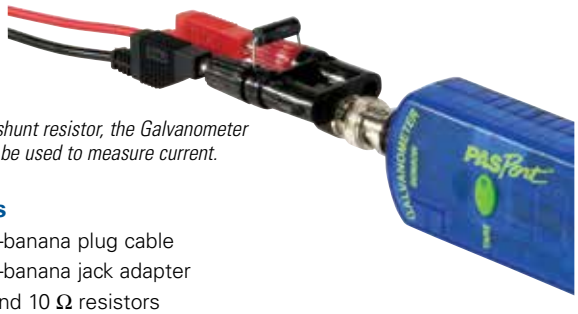
Input Impedance: 1 MΩ





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 PS-2160
Recommended:
Alligator Clip Leads (set of 10) EM-8634

Magnetic Field

PS-2112
PASPORT



Also see the new Wireless 3-Axis Magnetic Field Sensor on page 13.

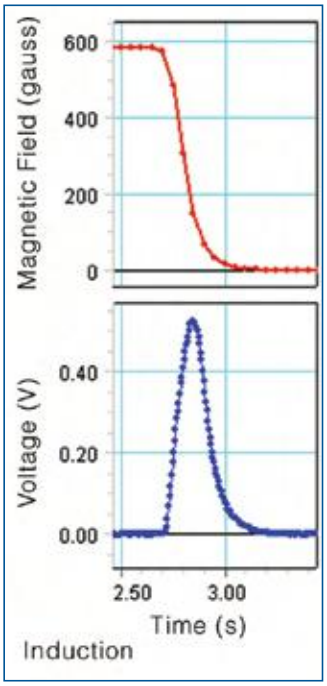
The Magnetic Field Sensor provides magnetic field measurement in a compact package. The sensor at the tip of the probe measures magnetic field strength along the axis of the probe.

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 at 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 Air (PS-2011), Coil (3200 turn; SF-8613), Bar Magnet (EM-8620), and Voltage/Current Sensor (PS-2115).

Order Information

Magnetic Field Sensor (Digital) PS-2112

Magnetic Field

CI-6520A **ScienceWorkshop**

Also see the new Wireless 3-Axis Magnetic Field Sensor on page 13.



- Measures radial or axial fields
- High sample rate

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
PASPORT



- 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).

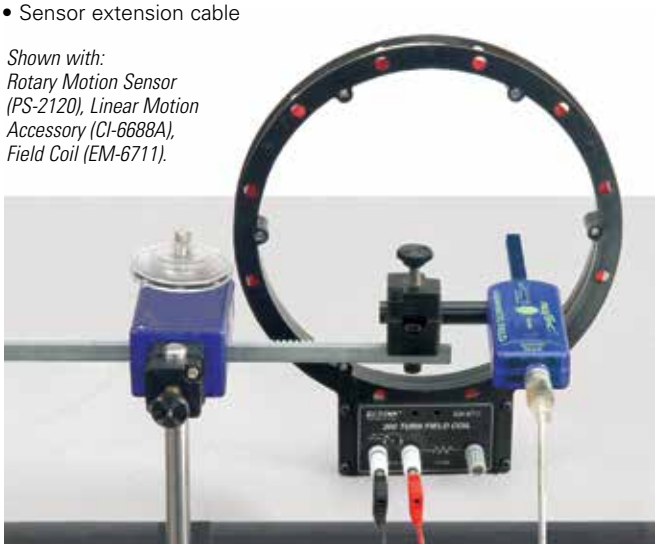
Specifications

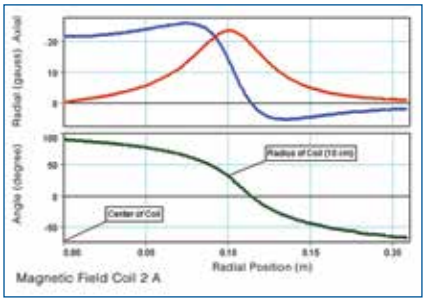
Range: ±1000 gauss
Accuracy: 5% of reading at 25°C (after four minute warm-up and Tare using Zero Gauss Chamber)
Resolution: 0.01 gauss at 10 Hz
Maximum Sample Rate: 1000 Hz
Repeatability: 0.05%

Includes

- Sensor handle
- Sensor extension cable

Shown with: Rotary Motion Sensor (PS-2120), Linear Motion Accessory (CI-6688A), 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 PS-2162
Recommended:
Zero Gauss Chamber..... EM-8652
Linear Accessory Kit..... CI-6688A p. 33

Charge

PS-2132 **PASPORT**



- 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.

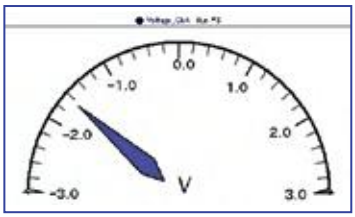
The Charge Sensor can also be used as a high impedance voltmeter (10^{12} Ω). It includes a 0.9 m shielded cable with alligator clips to eliminate stray fields.

Typical Applications

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

Specifications

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



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



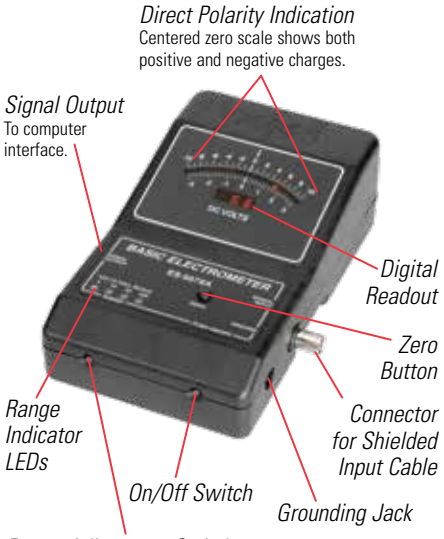
Order Information

Charge Sensor..... PS-2132
Recommended:
Faraday Ice Pail ..... ES-9042A p. 215

Basic Electrometer

ES-9078A

- For 550/850 and ScienceWorkshop Interfaces



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

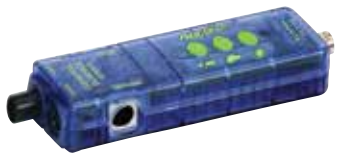
- Shielded input cable to connect the Electrometer to the Faraday Ice Pail or other source of charge
- Grounding cable with clip
- Interface cable
- Instruction and experiment manual

Order Information

Basic Electrometer.....ES-9078A

General Science Sensor

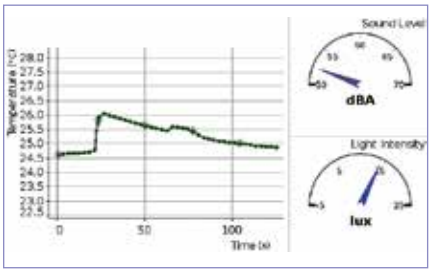
PS-2168 **PASPORT**



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 PS-2168
Recommended:
Charge/Discharge Circuit.....EM-8678A p. 221

Sound Level

PS-2109

PASPORT

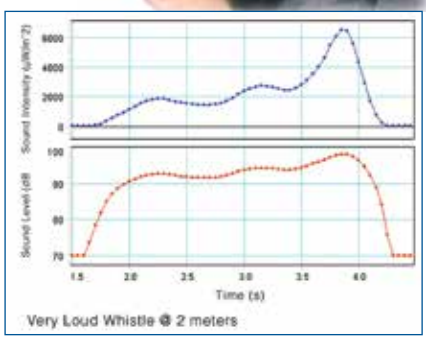


The Sound Level Sensor is designed to measure the intensity level of sound sources within proximity to the sensor. The sensor features three range switches to match the intensity range of the measured phenomena.

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

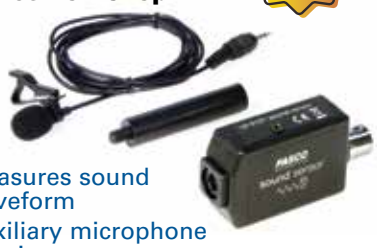
Sound Level Sensor..... PS-2109

Sound

UI-5101

ScienceWorkshop





- Measures sound waveform
- Auxiliary microphone on wire

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 9,000 Hz

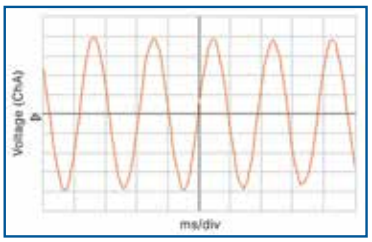
Decibel Range: 45 to >100 dB

Signal-to-Noise Ratio: < 60 dB

Amplification: Two stages condition low-level signals

Pin Configuration: 8-pin DIN plug on case

Sensor ID: Auto-identification on 550/850 Interfaces



The included auxiliary microphone can be used to probe a resonance tube.



Includes

- Sound Sensor
- Auxiliary microphone on wire (1.4 m long)

Order Information

Sound Sensor UI-5101
Replacement:
Auxiliary Microphone..... UI-5102

G-M Tube/Power Supply

SN-7927A

- 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

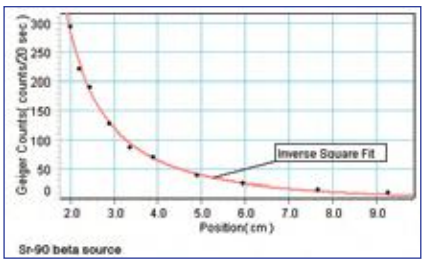
Count Detection: Audio signal

Window Thickness: 1.5 to 2 mg/cm², 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 SPARKlink Air or AirLink:

Digital Adapter ..... PS-2159 p. 45

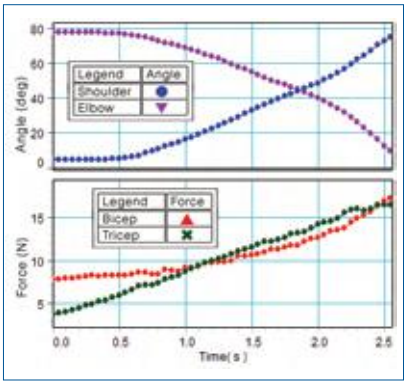
Human Arm Model

PS-2611
PASPORT

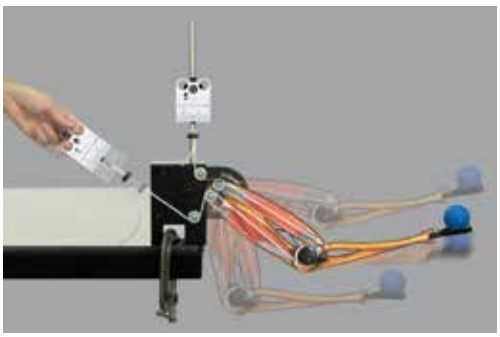


The Human Arm Model simulates the muscles and motion of an actual human arm. To activate the arm motion, students pull on the cord with a Force Sensor. Changes in position are measured at the shoulder and elbow using the two built-in potentiometers plugged into one Angle Sensor (PS-2139), included with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





Includes

- Human Arm Model
- Angle Sensor PS-2139

Order Information

Human Arm Model..... PS-2611

Required for force measurement:

Wireless Force Acceleration Sensor (2) ..... PS-3202 p. 11

Goniometer

PS-2137 **PASPORT**

- 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.

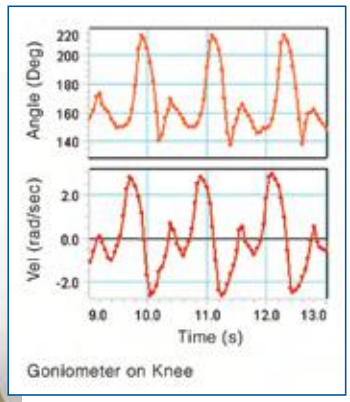
The PS-2137 includes one Angle Sensor (PS-2139) and one Goniometer Probe with Velcro® connection kit. To measure the motion of two joints simultaneously, simply purchase another Goniometer Probe.

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 PS-2137
Recommended:
Additional
Goniometer Probe..... PS-2138

Angle Sensor

PS-2139 **PASPORT**



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 (PS-2611).

Order Information

Angle Sensor PS-2139

EKG

PS-2111 **PASPORT**



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

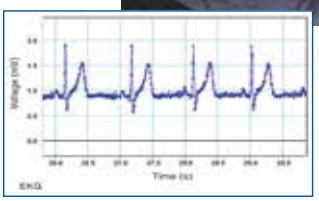
EKG Waveform:

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)





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 PS-2111
EKG Patches (100 each) CI-6620

Spirometer

PS-2152

PASPORT



With our Spirometer Sensor students can measure airflow, duration, and lung volume. Disposable mouth pieces are included 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

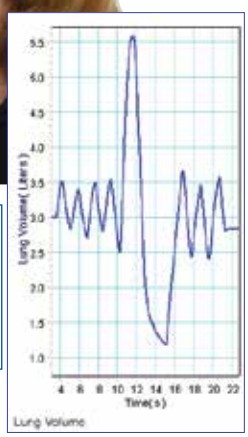
Sample Rate Range: 50 to 100 Hz



Measuring lung capacity



Replaceable mouthpiece clips



Order Information

Spirometer Sensor PS-2152
Spirometer Mouth Pieces (10-pack) PS-2522

Breath Rate

PS-2187

PASPORT

Also see the new Wireless Blood Pressure Sensor on page 17.

- 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 sides of the mask.

Two Modes

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



A graph showing a student's breath rate before, during, and after exercise

Includes

- Sensor with Tubing
- Pressure Clips (10)
- Masks (10)



Order Information

Breath Rate Sensor PS-2187
Replacement Clips (10) PS-2568
Replacement Masks (10) PS-2567

Ethanol Sensor

PS-2194

PASPORT



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.

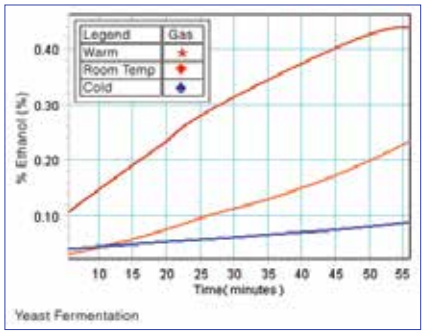
Specifications

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

Ethanol Sensor PS-2194

Shown in use with:

EcoChamber..... ME-6667

Magnetic Stirrer..... SE-7700

Optical Dissolved Oxygen

Also see the new Optical Dissolved Oxygen Sensor at pasco.com

PS-2196 **PASPORT**



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..... 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

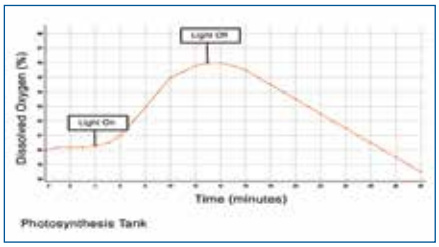
Photosynthesis Tank

PS-2521B

- Measure O_2 production directly
- Control the environment of an aquatic plant
- Study changes in photosynthesis and 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

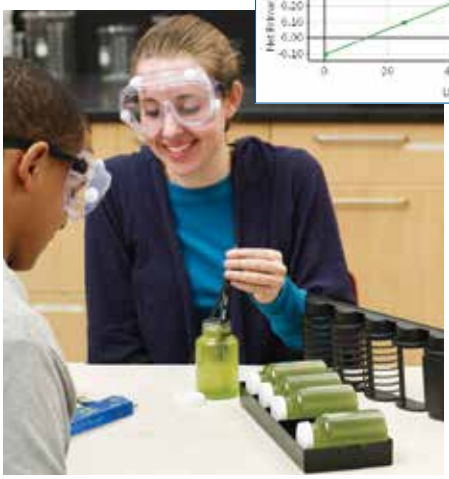
Aquatic Productivity Bottles

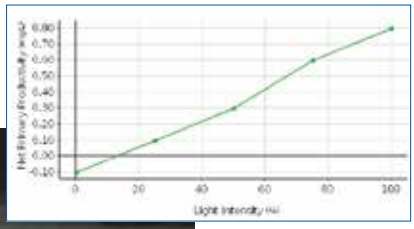
ME-6937

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 readings, 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

O_2 Gas

PS-2126A

PASPORT



Also see the Wireless CO_2 Sensor on page 17 and the new Wireless O_2 Sensor at pasco.com

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

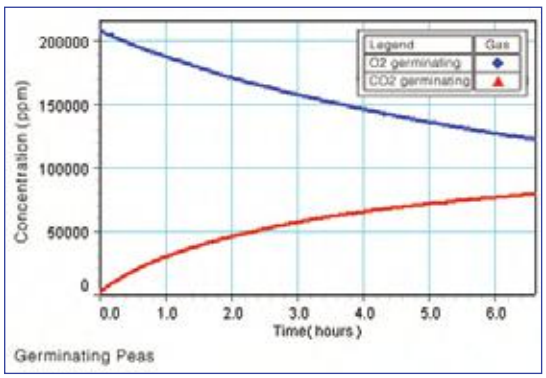
Flow Range: 0 to 100% oxygen concentration
Accuracy: ±1% (at constant temperature)
Resolution: 0.025%
Maximum Sample Rate: 100 Hz
Probe Shelf-life: Three years

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



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

WARNING! This product can expose you to Lead and Lead (II) Acetate Trihydrate, which are known to the State of California to cause cancer, birth defects, or other reproductive harm.
For more information go to www.P65Warnings.ca.gov.

Order Information

O_2 Sensor PS-2126A

EcoZone™ System ME-6668
EcoChamber ME-6667

- Three interconnected EcoChambers (ME-6668) or one stand-alone EcoChamber (ME-6667)
- 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.

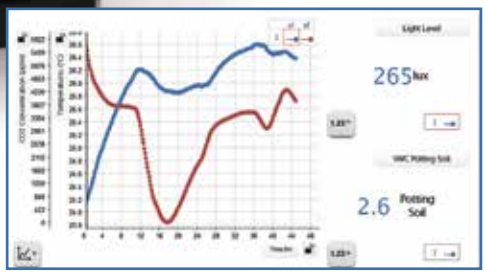


Opening connects the chambers and allows the interaction between the living and non-living components of each unique ecosystem.

The included cord efficiently wicks water between the chambers.

Cleanup 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



Observe the photosynthesis and respiration cycles of the simulated microclimate in the EcoZone and their effect on carbon dioxide.

Terrestrial Chamber *Aquatic Chamber*



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

ME-6668 includes

- Three individual EcoChambers with lids
- Custom tray for holding EcoChambers in a connected ecosystem
- Stoppers and connectors
- Cotton wick
- Syringe and plastic tubing





ME-6667 includes

- Acrylic chamber
- 7 stoppers of various sizes
- 5 probe stoppers
- 20 cc calibrated syringe
- Sample tube with connector

Order Information

EcoZone System ME-6668
EcoChamber..... ME-6667

Salinity

PS-2195 **PASPORT**

Also see the Wireless Weather Sensor on page 18.

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 PS-2195
Recommended:
PASPORT Extension Cable PS-2500

Water Quality Colorimeter

PS-2179 **PASPORT**

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!



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 PS-2179
Available Test Kits: (30 tests per kit)
ezSample Snap Vials (Colorimetric)
Iron EZ-2331
Nitrate EZ-2333B*
Ammonium EZ-2334A
Phosphate EZ-2337
Chlorine EZ-2339A
ezSample Field Titrators
Total Hardness EZ-2338
CO_2 ..... EZ-2341**
Alkalinity EZ-2340

* **WARNING!** This product can expose you to chemicals including ethylene glycol, which is known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

** **WARNING!** This product can expose you to chemicals including phenolphthalein, which is known to the State of California to cause cancer, and methanol, which is known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Soil Moisture

PS-2163 **PASPORT**



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 content for various species of plants
- Monitor soil moisture content to control irrigation in greenhouses

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 PS-2163

Thermocline

PS-2151

PASPORT



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-sensing (pressure) 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:

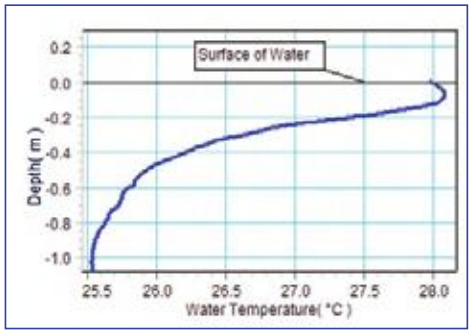
Range: 0°C to 100°C

Accuracy: ±1.5°C

Maximum Sample Rate: 10 Hz



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



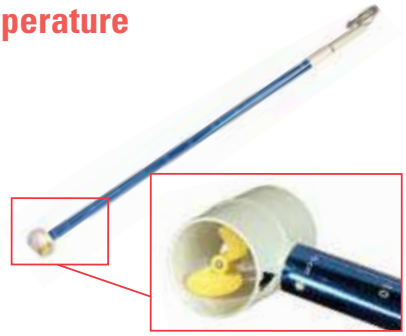
Order Information

Thermocline Sensor PS-2151

Flow Rate/Temperature

PS-2130

PASPORT



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

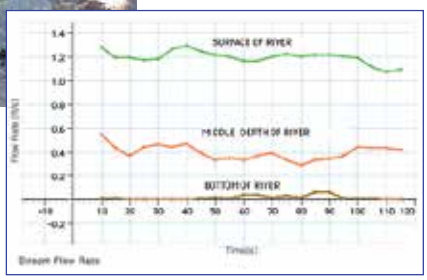
Maximum Sample Rate: 20 Hz

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 PS-2130

Advanced Chemistry Sensor

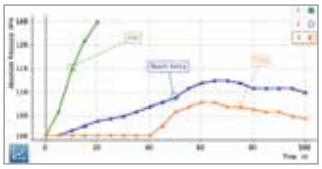
PS-2172 **PASPORT**



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
- 60 cc syringe, tubing and quick-release connectors (not shown)

Order Information

Advanced Chemistry Sensor PS-2172

Chemistry

PS-2170
PASPORT



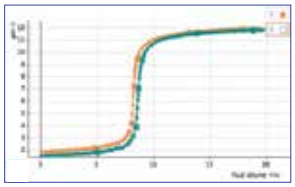
Gas laws, acid-base, thermochemistry and redox all with one sensor! Measure temperature, pH, gas pressure and voltage. Easy to store. Easy to use. All measurements can be made simultaneously.

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 PS-2170

Colorimeter

PS-2121
PASPORT



Also see new Wireless Colorimeter/Turbidity Sensor on page 18.

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.

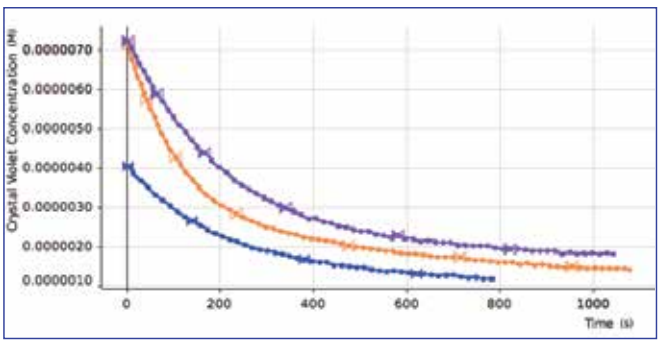
Typical Applications

- 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..... PS-2121
Replacement Cuvettes/Caps (6 each)..... PS-2509

pH

PS-2102
PASPORT



Also see the new Wireless pH Sensor on page 15.

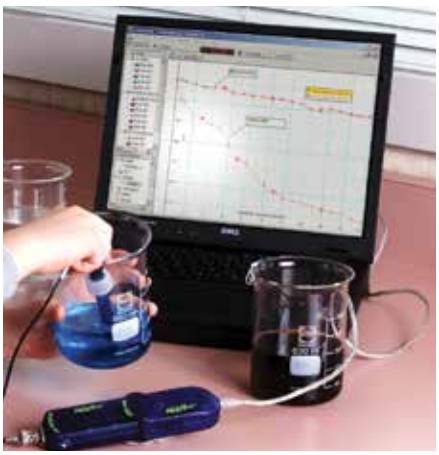
PASCO's pH Sensor measures the hydronium ion concentration in a solution and reports it as a pH value. This sensor is well-suited for a variety of activities where testing or monitoring acidity is important.

Typical Applications

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

Specifications

Range: 0 to 14 (probe-dependent)
Accuracy: ±0.1 (after calibration)
Resolution: 0.01
Electrode: gel-filled Ag-AgCl combination electrode
Maximum Sample Rate: 50 Hz



pH vs. volume graph



Order Information

pH Sensor PS-2102
Also available:
pH Replacement Electrode PS-2573

High Accuracy Drop Counter

PS-2117 **PASPORT**

Also see the new Wireless Drop Counter on page 15.

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.



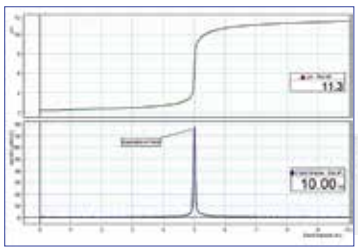
- Measures up to 40 drops per second with drops as small as 0.64 mm.
- Silicone rubber-sealed polypropylene is fluid-resistant and protects sensor from mild acids and bases.
- Automatically recalibrates for maximum sensitivity each time the unit is turned on.

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 PS-2117

Micro Stir Bar

PS-2565

Magnet is completely sealed to prevent damage from chemicals.

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.



Order Information

Micro Stir Bar (set of 5) PS-2565

PASCO capstone™ Software

Designed specifically to collect, display, and analyze data in physics and engineering labs

- Site license includes student home use
- For MAC® and Windows™

PASCO Capstone Basic Features

Sensors

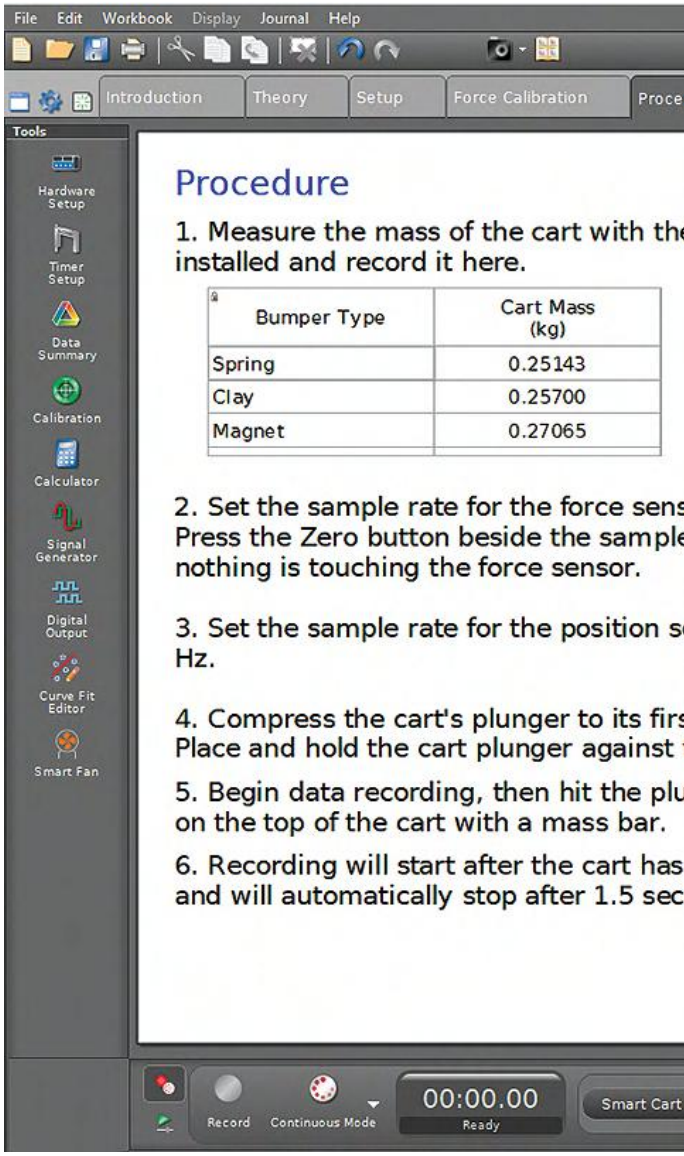
- Auto-ID sensors are recognized when they are plugged in (or identified through Bluetooth®)
- Works with PASPORT, ScienceWorkshop, and new wireless sensors
- In-app pairing of wireless sensors makes it easy to pick wireless sensors by proximity
- Pre-configured photogate timers

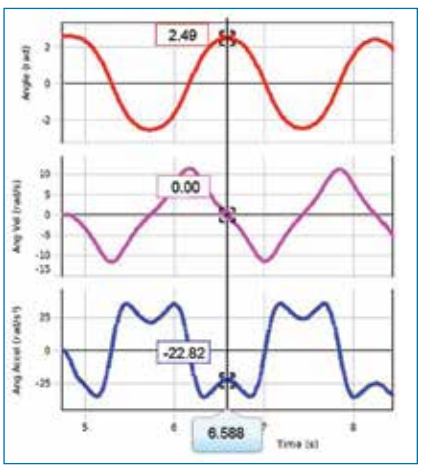
Workbook Format

- Basic displays include graph, table, digits, meter, oscilloscope, text box, picture.
- Make multiple pages with instructions and embedded live graphs.
- Collect data and display it in real time.
- Play back data in real time or slow or high speed.
- Enter data manually – easy setup in a table
- Lay out displays with smart guidelines.
- Create a Journal by taking snapshots of pages or displays.
- Copy and paste displays into documents.
- Made a mistake? Just hit the Undo button.

Graphs

- Draw predictions on graphs before taking data.
- Multiple y-axes and/or multiple plot areas
- Perform Quick-Calcs on the graph axis to linearize data.
- Curve-fits report the uncertainties in the parameters.
- Multi-coordinate tool gives y-values wherever it intersects data.





Multi-Coordinate Tool

This tool finds the values of all the measurements all at once. It's great for showing how the position, velocity, and acceleration are related in oscillations.

See Advanced Features on page 72.

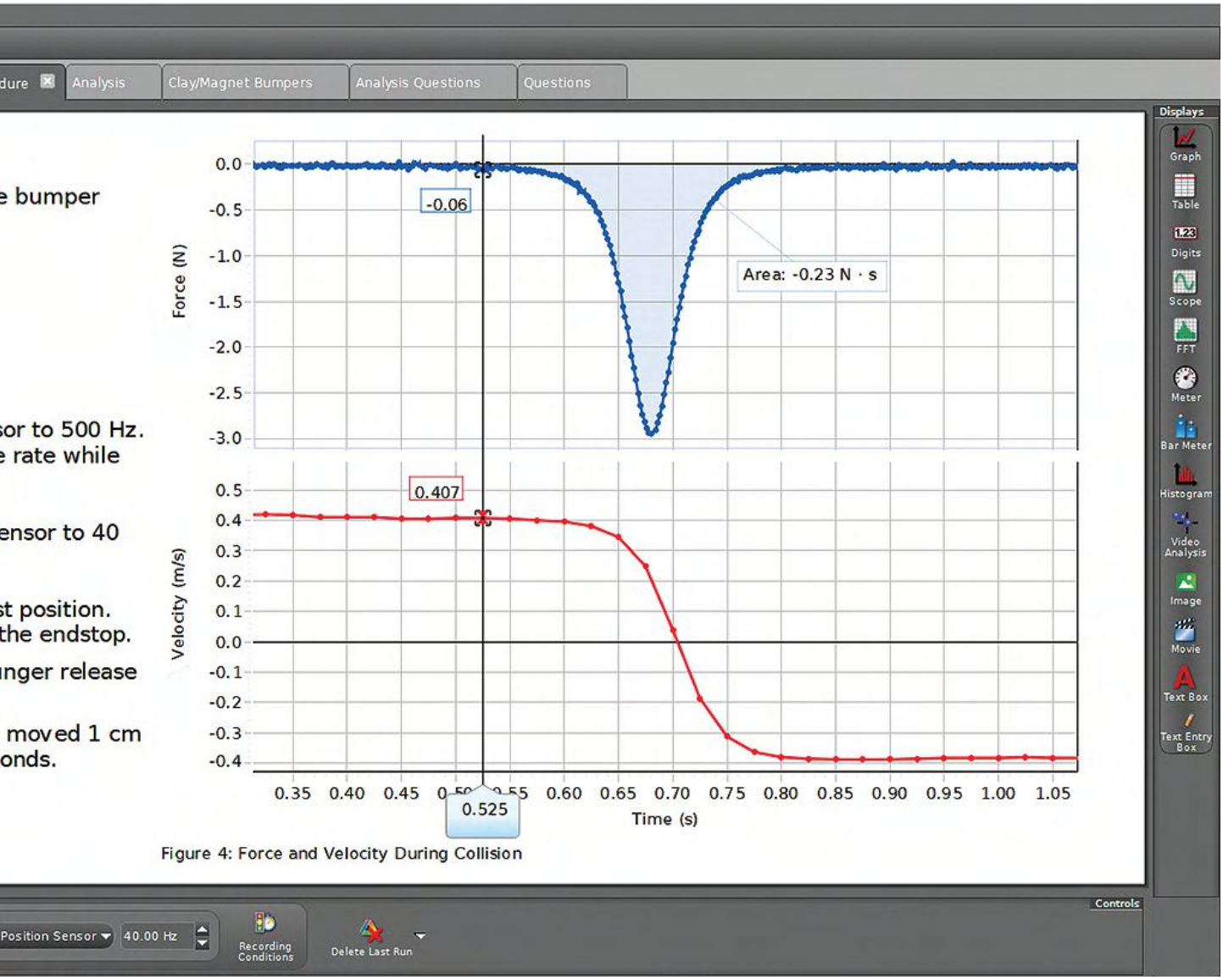
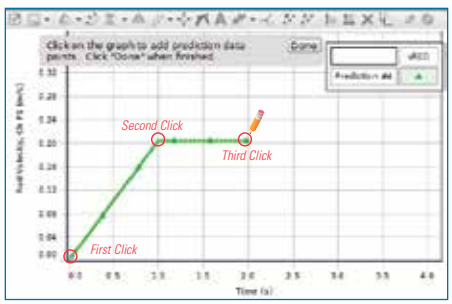
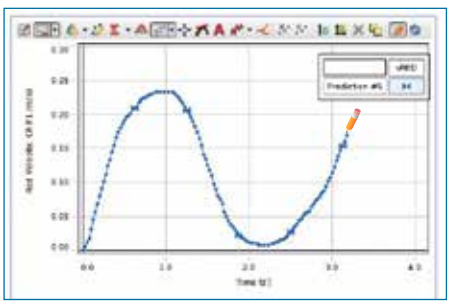


Figure 4: Force and Velocity During Collision





Prediction Tools

Predictions are a powerful tool for learning. Students draw what they think the data will look like and then collect the data run and compare it to their predictions. Predictions can be made either point-by-point with a straight line filled between them or free-form.

Download The Free Trial
www.pasco.com/Capstone

Order Information

PASCO Capstone Software
Single User License..... UI-5401
Site License UI-5400

PASCO capstone™ Software

Advanced Features

Sensors & Signal Generators

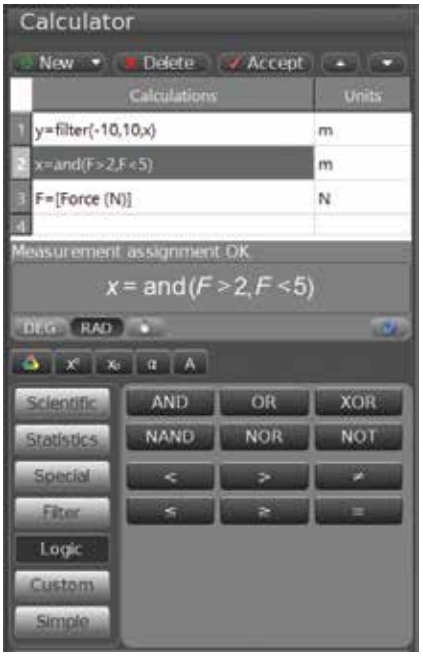
- Calibration wizard for sensors steps you through the calibration process.
- Create your own timers for photogates.
- Configure signal generators with DC offset.
- Scan through a range of frequencies.
- Control the output with a calculation.

Data Collection Modes

- Strip chart mode
- Start and stop conditions on time and sensor measurements
- FFT and oscilloscope
- Histogram
- Manual data collection: Keep sensor data points with click of button.
- Analyze video and display velocity and acceleration vectors on the video.
- Sync movies with sensor data.

Data Analysis

- Exclude or delete selected data points from analysis.
- Create models using the calculator.
- Calculated columns in tables
- Error bars
- Weighted linear fit that takes into account error bars
- More complex curve fits such as damped sine, Gaussian, sine series, and user-entered fits
- Smooth data directly on a graph with slider tool.
- Calculations involving logic statements and filters



Calculator

Sophisticated scientific calculator has statistics, calculus, filters, logic functions, and special operations such as amplitude and period.

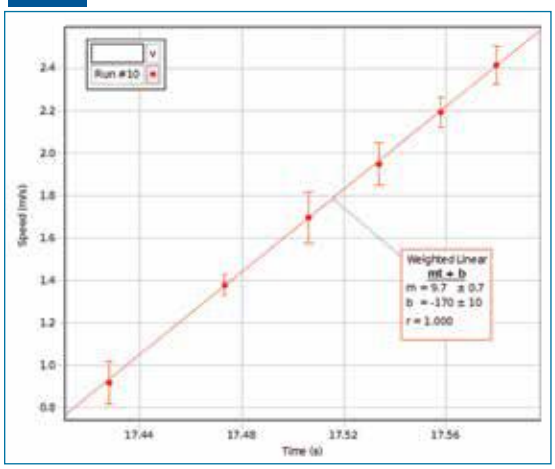
Table II: Energy

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

Versatile Tables

Calculated columns can be edited directly in the table. Insert or delete columns or change number of decimal places using toolbar buttons. Click and drag columns to rearrange them. Change run colors directly in the table.



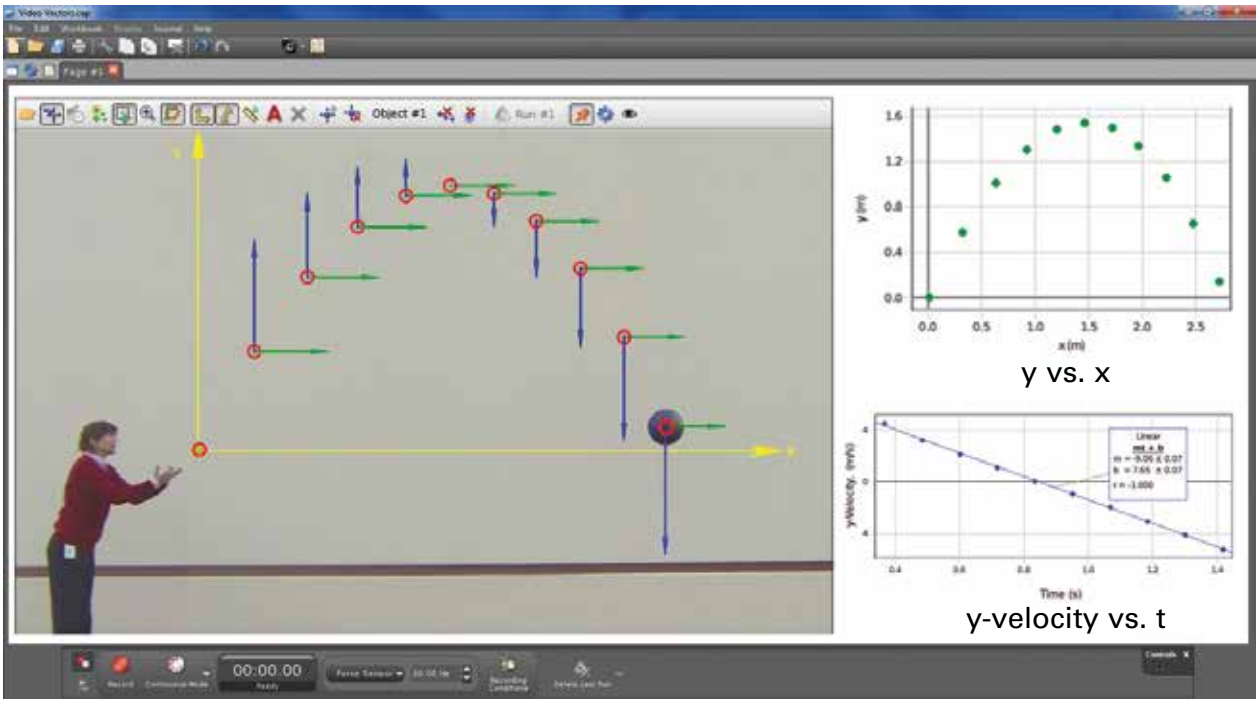
Error Bars and Weighted Linear Fits

Graph uncertainties using user-entered error bars, absolute error, or percent error. The weighted linear fit incorporates the error bars.

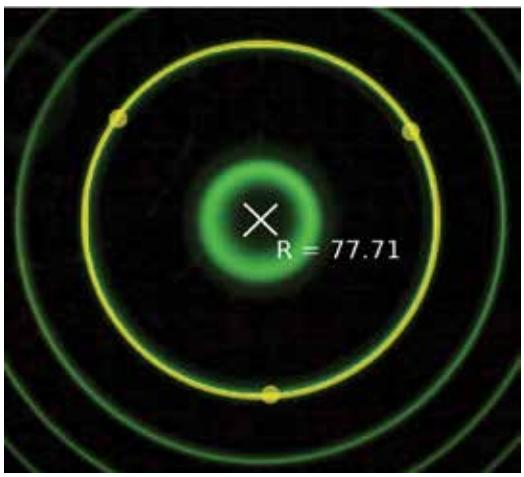
PASCO capstone™ Software

Video Analysis Included

- Study motion in two dimensions
- Start USB webcam and data collection simultaneously
- Display velocity and acceleration vectors
- Auto-track objects
- Free with PASCO Capstone







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

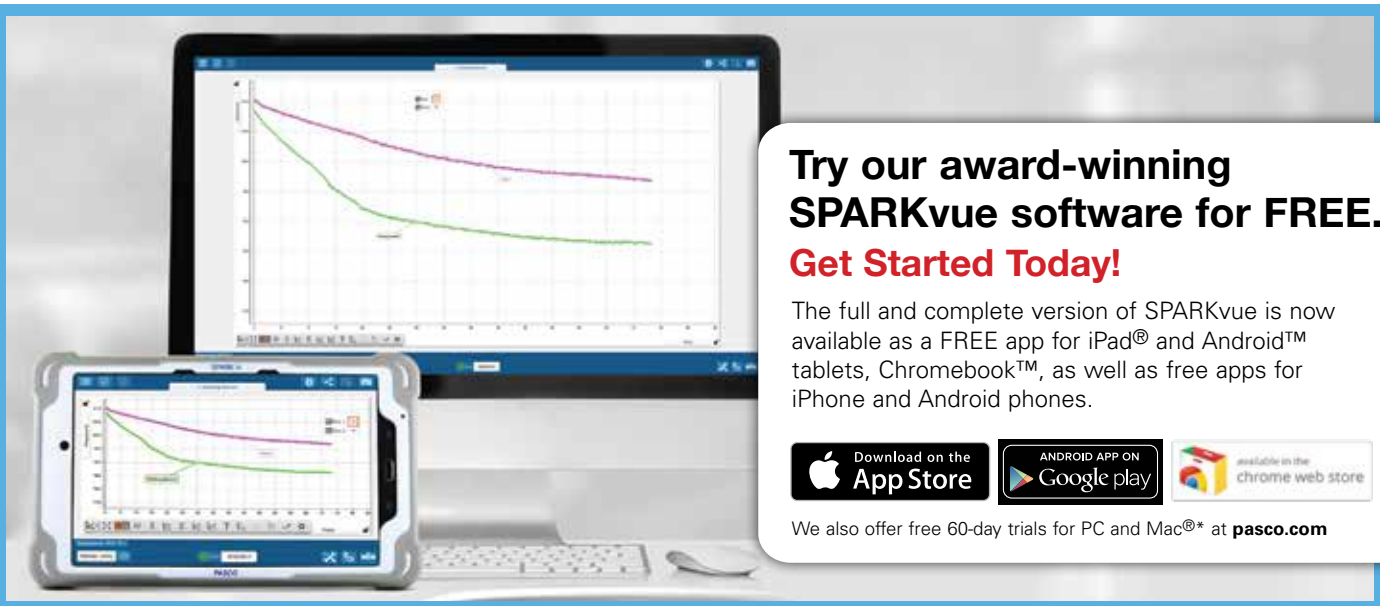
Single User License..... UI-5401

Site License UI-5400

SPARKvue® Software for Any Platform



- New Welcome screen allows you to start a new activity or open an experiment, with one click.
- Jump right into most common labs using Templates and Quick Start labs.
- Monitor sensor data without recording using the Live Data Bar.
- Configure, calibrate, and edit sensor properties with Hardware Setup button.
- Share experiment files directly to Cloud services such as Google Drive.



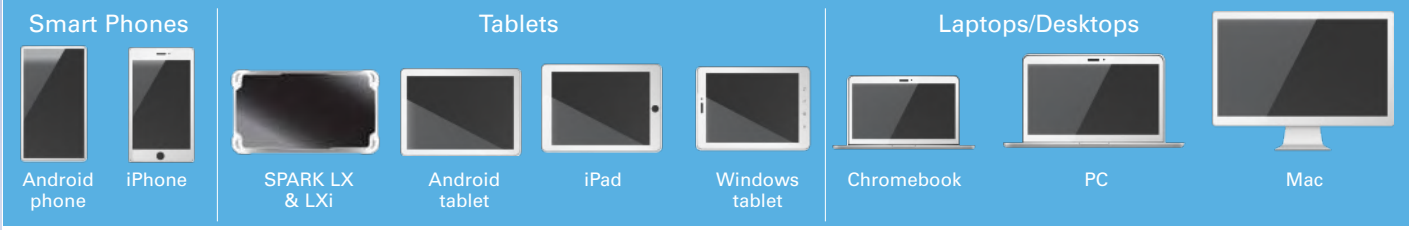
Try our award-winning SPARKvue software for FREE.

Get Started Today!

The full and complete version of SPARKvue is now available as a FREE app for iPad® and Android™ tablets, Chromebook™, as well as free apps for iPhone and Android phones.

Download on the App Store | ANDROID APP ON Google play | available in the chrome web store

We also offer free 60-day trials for PC and Mac®* at **pasco.com**



SPARKvue

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(site license) PS-2400

Windows® and Mac®

SPARKvue App

Free downloads for iPad, iPhone, Android tablets and phones, and Chromebook.

Visit www.pasco.com/downloads

Download on the App Store | available in the chrome web store

Order Information

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Upgrade to the new SPARKvue® 4.0 version

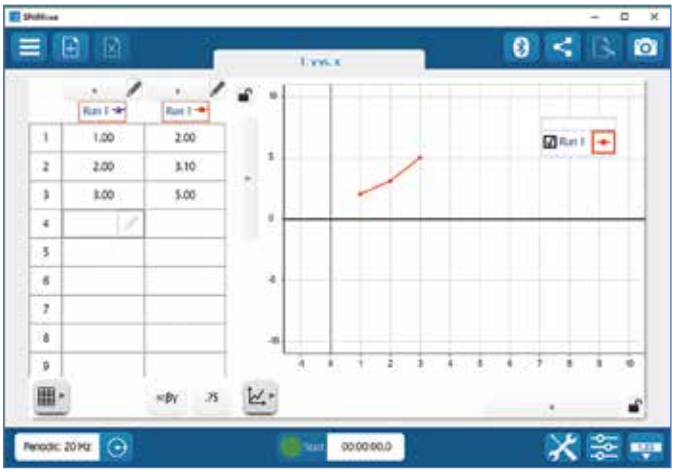
- SPARKvue 4.0 is even more intuitive.
- New entry screen makes getting started easier.



Choose from three entry paths:

1. Manual Entry

Select manual entry and simply start typing in your data in the table. The graph is already set up to start tracing your data.



2. Sensor Data

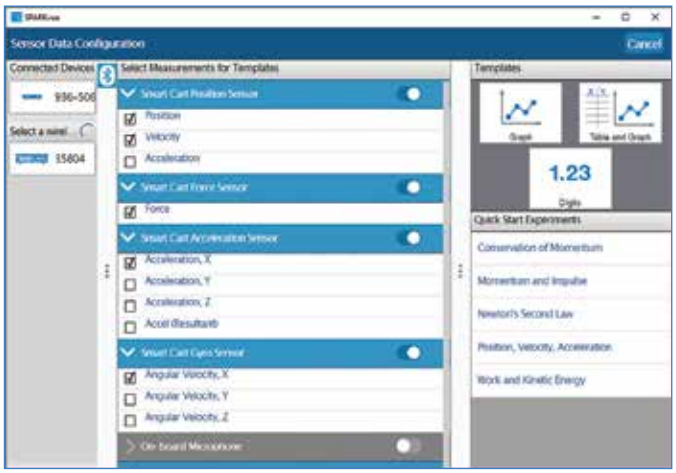
Select Sensor Data to connect to sensors and record data.



3. Remote Logging

Select Remote Logging to either set up a sensor to log data remotely or to download logged data from a sensor.





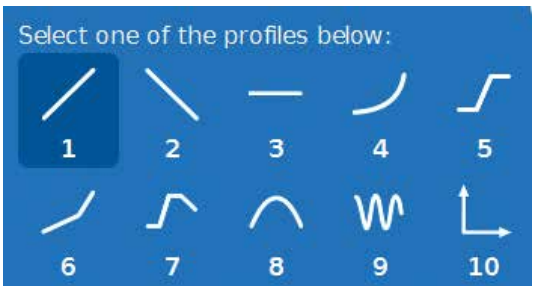
MatchGraph!™ Software

PASCO *MatchGraph!*

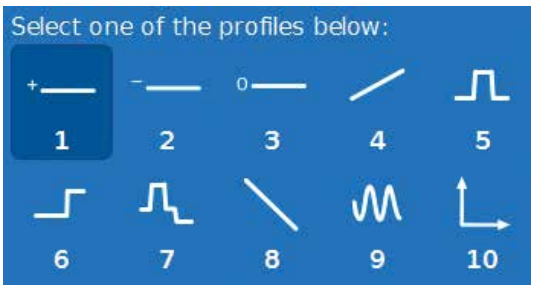
- Students feel the motion firsthand and learn to interpret motion graphs! Watch your students compete to get the best match score.
- The sample graphs to match include both Position vs. Time and Velocity vs. Time.
- The student moves back and forth in front of a motion sensor in an attempt to match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



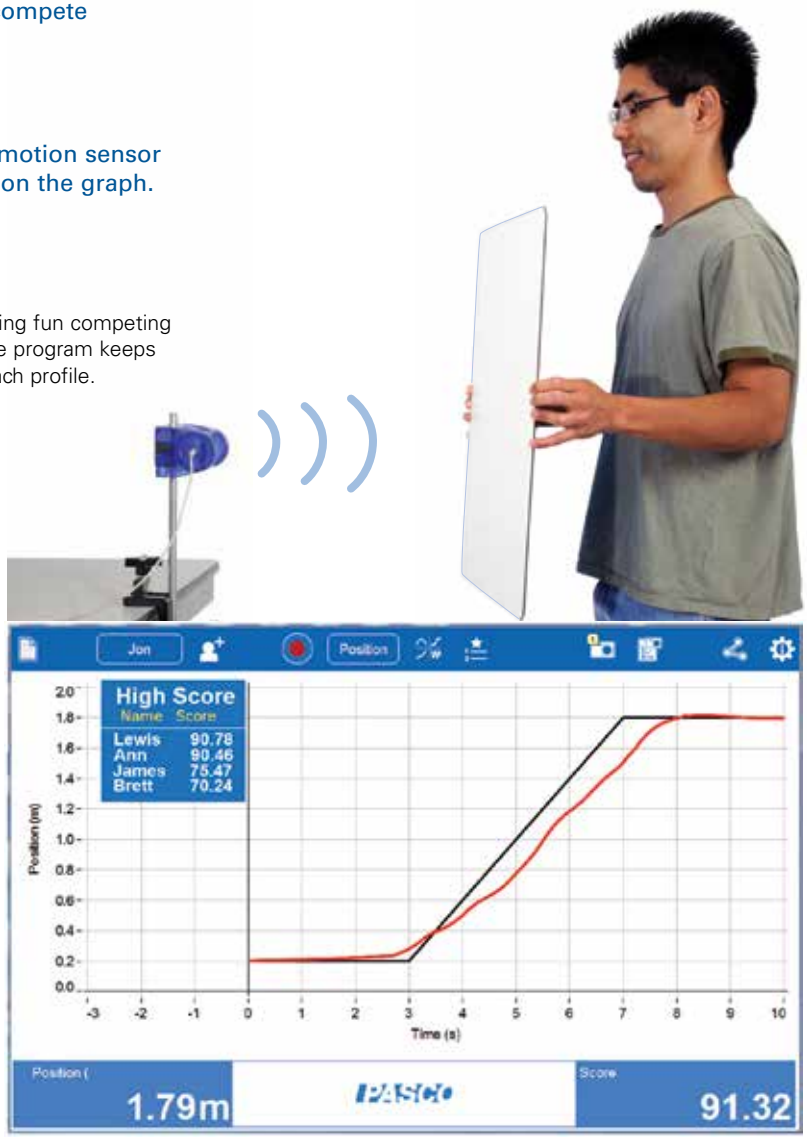
Students learn while having fun competing for the highest score. The program keeps track of the scores for each profile.



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.

MatchGraph!™ Software

Go to pasco.com/downloads and click on MatchGraph

Order Information

MatchGraph Kit..... UI-5822A
(Includes MatchGraph app, AirLink & Motion Sensor)

Order Information

Download FREE MatchGraph software for Mac® and Windows® computers at **pasco.com**. Download the free iPad® or Android™ app on the App Store or Google Play.

Required:

Wireless Motion Sensor .....PS-3219 p. 11
OR
PASPORT Motion Sensor* .....PS-2103A p. 32
OR
ScienceWorkshop Motion Sensor* .....CI-6742A p. 32
**Requires a USB or Bluetooth interface ; see pages 24-30.*
OR
Smart Cart..... ME-1240 (red) or ME-1241 (blue) p. 106

Download on the App Store
ANDROID APP ON Google play

Now works with all Motion Sensors and Smart Carts!

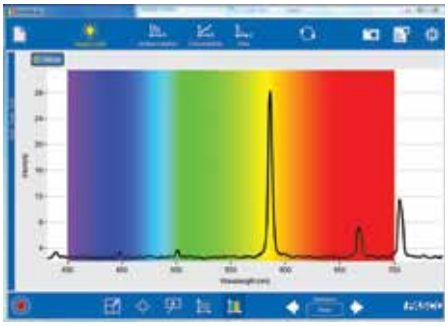
PASCO's Free Spectrometry Software Puts Learning First

PASCO's own software for the PASCO Spectrometer works on iOS®, Android™, Computers, and Chromebooks*

- 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

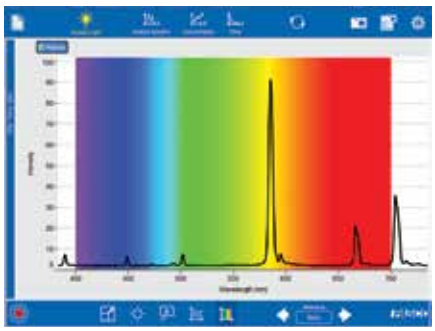
The four specially targeted activities are:

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.



Helium Spectrum

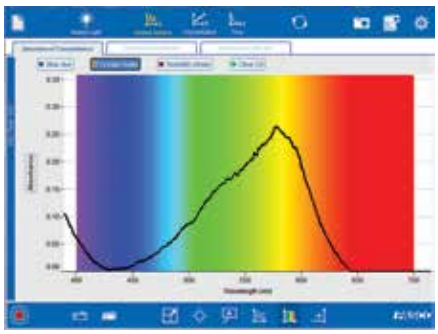
Shown using the optional Fiber Optic Cable.



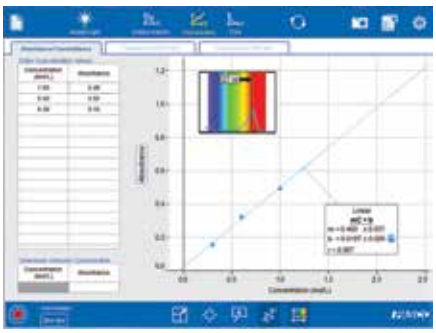
1. Analyze light sources with the optional fiber optic cable.

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

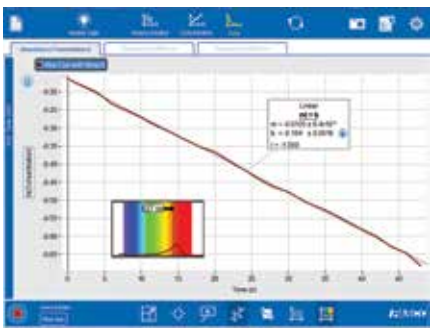
- Windows® and Mac® versions included with purchase.
- FREE for iOS®, Android™, and Chrome™.
- Designed specifically for introductory spectrometry experiments.



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.





Includes

- PASCO Spectrometer
- Cuvettes (10)
- Spectrometry Software

Our list of compatible Chromebooks is expanding rapidly. Check **pasco.com/compatibility for the latest updates.*

Order Information

PASCO Spectrometer.....PS-2600 pp. 284-285
Required for External Light Sources:
Fiber Optic Cable.....PS-2601 p. 284

850 Comprehensive Physics System

UI-5800C

NOTE: The 850 Universal Interface (UI-5000) must be purchased separately.

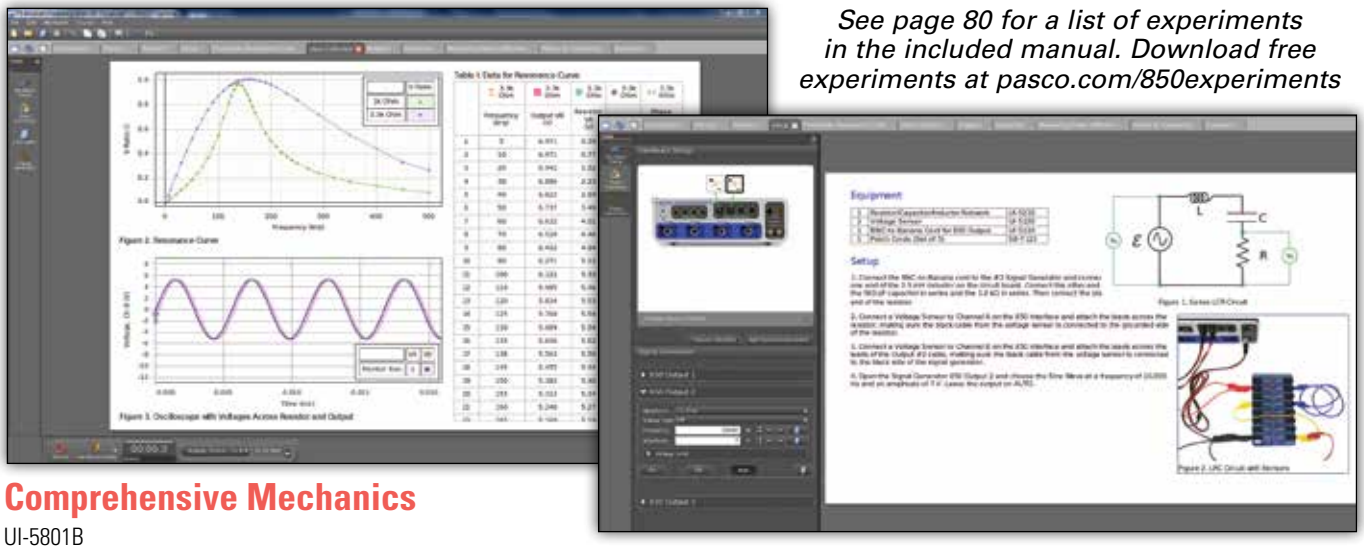
Designed for the 850 Universal Interface and PASCO Capstone™ Software

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 80 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 80 for a list of experiments in the included manual. Download free experiments at pasco.com/850experiments

Comprehensive Mechanics

UI-5801B

(Component of the 850 Comprehensive System UI-5800B)



UI-5801B Includes

Part No.	Description
ME-6622	Force Bracket
CI-6691	Mini Rotational Accessory
ME-6743	Cart Adapter
ME-6755	Compact Cart Mass (2)
ME-6806	Pi Set
ME-6810A	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)

Part No.	Description
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-5800C

Required:

850 Universal Interface ..... UI-5000 pp. 26-27

PASCO Capstone™ Software ..... pp. 70-73

Want Mechanics Only?

850 Comprehensive Mechanics UI-5801B

Comprehensive Waves, Optics, and Thermodynamics

UI-5802A *(Component of the 850 Comprehensive System UI-5800C)*



UI-5802A Includes

Part No.	Description
UI-5101	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	Adjustable 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-9606	Resonance Air Column
WA-9857	String Vibrator
WA-9605	Mini Speaker

The experiments for this section require some of the components of the 850 Comprehensive Mechanics UI-5801B.

See page 80 for manual. Download free experiments at pasco.com/850experiments

Comprehensive Electromagnetism

UI-5803 *(Component of the 850 Comprehensive System UI-5800C)*



UI-5803 Includes

Part No.	Description
EM-8620	Bar Magnets (2)
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	Magnetic Field Sensor, 2-axis
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.

See page 80 for a list of experiments in the included manual.

Comprehensive 850 Physics System (UI-5800C) Includes

- Comprehensive Mechanics UI-5801C
- Comprehensive Waves, Optics, and Thermodynamics UI-5802A
- Comprehensive Electromagnetism UI-5803

Order Information

850 Comprehensive Physics System UI-5800C

Required:

850 Universal Interface ..... UI-5000 pp. 26-27

PASCO Capstone Software ..... pp. 70-73

Also Available Separately:

850 Comprehensive Mechanics UI-5801B

850 Comprehensive Waves, Optics, and Thermodynamics UI-5802A

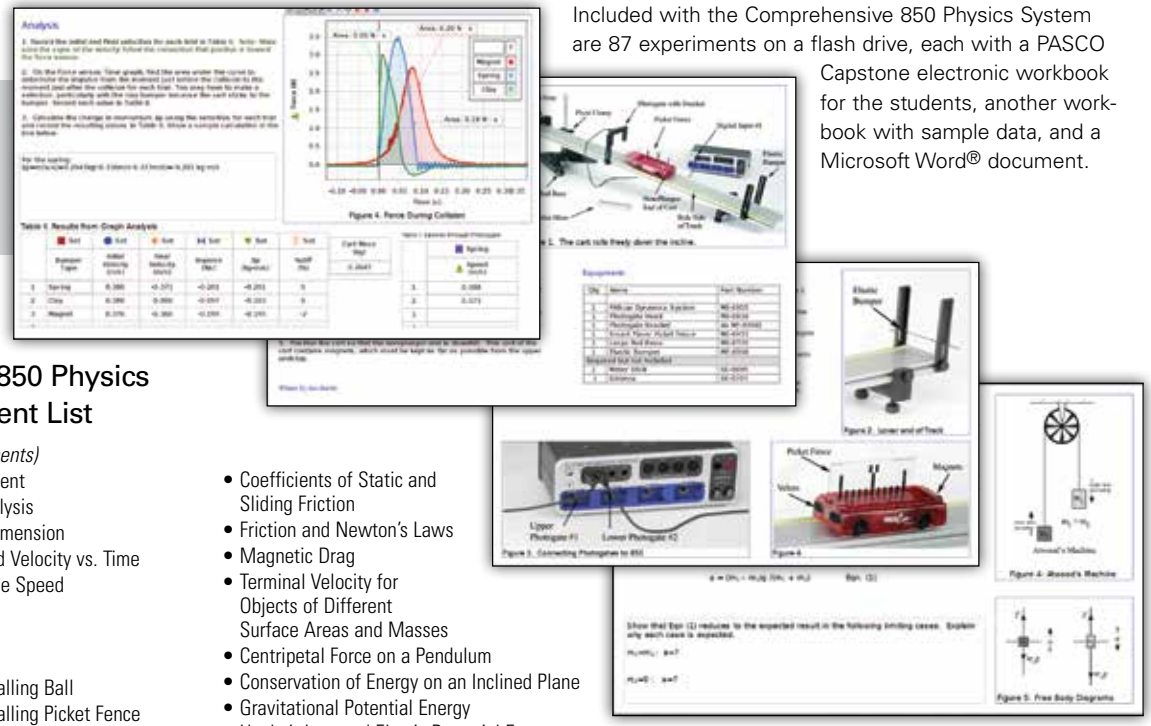
850 Comprehensive Electromagnetism UI-5803

850 Comprehensive Physics System Manual UI-5813

Comprehensive 850 Physics System Experiment Manual

UI-5813

See pages 78-79 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 vs. 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.

Download free experiments at pasco.com/850experiments

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 850 Mechanics 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	pp. 26-27
2.	PS-2189	High Resolution Force Sensor	p. 36
3.	PS-2103A	Motion Sensor	p. 32
4.	ME-9471A	Photogates and Fences	p. 112
5.	ME-8574	Discover Friction Accessory	p. 110
6.	ME-9429B	1.2 m Classic Dynamics System	p. 101
7.	ME-6622	Force Bracket	p. 37
8.	ME-8979	Mass and Hanger Set	p. 197
9.	ME-1242	Smart Fan Accessory	p. 117
10.	UI-5821	Lab Manual (not shown)	

Order Information

850 Mechanics System.....UI-5820

Required:

PASCO Capstone™ Software..... pp. 70-73

550 Universal Physics System

UI-5830

NEW

The 550 Universal Physics System provides a complete set of labs for mechanics, heat, light, sound, and electromagnetism. Each lab consists of student instructions in a Word® document that the instructor can modify as they like, a PASCO Capstone setup file ready for data collection, a Capstone file with sample data, and all the lab equipment required for the experiment.

This system was designed to use both wireless and wired sensors, combined with the 550 Universal Interface that serves as a DC power supply and function generator.



Part#	Equipment	Amt.
ME-3420	Rotational Inertia Accessory	1
ME-1240	Smart Cart Red	1
ME-1241	Smart Cart Blue	1
ME-8994	Dyn Track Feet, End Stops	1
ME-9493	1.2 m Starter Dyn Track	1
ME-9836	Track Rod Clamp	1
ME-9807	Friction Block – IDS	1
ME-1242	Smart Fan Accessory	1
PS-3223	Wireless Accel/Altimeter	1
ME-1244	Smart Cart Rod Stand Adapter	1
UI-5831	550 Experiment Manual	1

Not Pictured: UI-5831 550 Experiment Manual



Part#	Equipment	Amt.
UI-5101	Sound Sensor	1
	Calorimeter Cup	2
	Calorimeter Cup Lid	2
SE-7342	Tuning Fork Set	1
WA-9606	Resonance Air Column	1
WA-9605	Mini Speaker	1
OS-8515C	Basic Optics System	1



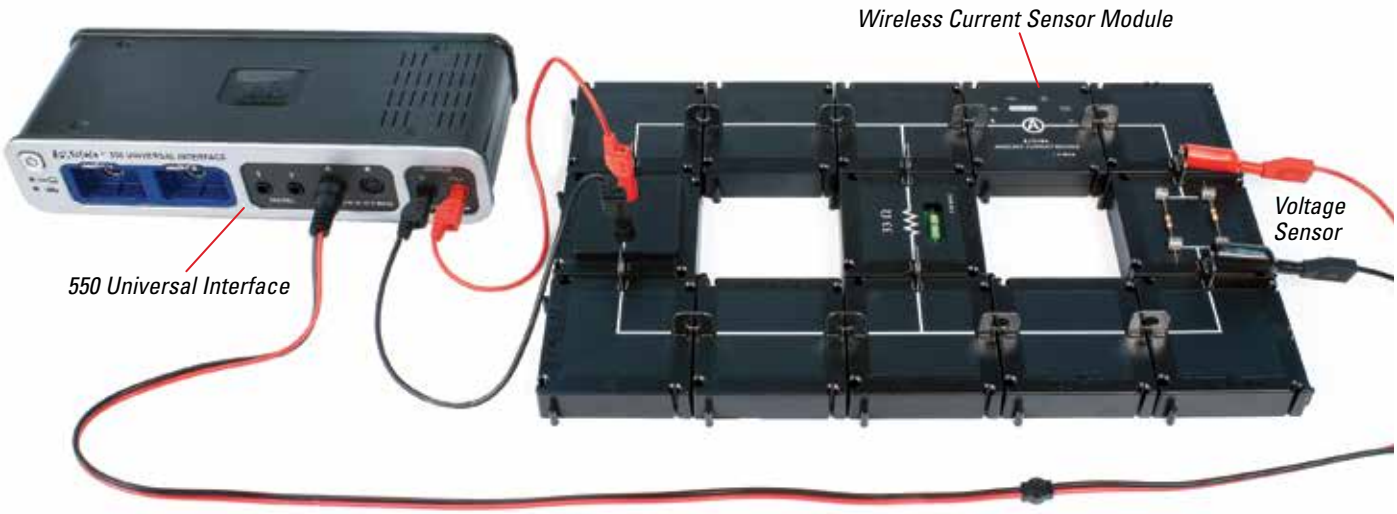
Part#	Equipment	Amt.
SF-7263	Bar Magnets, pair	1
	Modular Circuits	1
EM-3540	Modular Circuits Expansion Pack	1
PS-2132	Charge Sensor	1
EM-3534	Modular Circuits Current Sensor	1

550 Universal Physics System Experiment Manual

UI-5831

NEW

This complete manual is included with the 550 Universal Physics System (UI-5830). Each experiment consists of student instructions in a Word® document that the instructor can modify as they like, a PASCO Capstone setup file ready for data collection, a Capstone file with sample data, and all the lab equipment required for the experiment. All of this content is provided on a flash drive.



In this parallel resistor experiment, the 550 Universal Interface is used as the DC power supply and is used to measure the output voltage and the voltage across the resistors. The Wireless Current Sensor Module is used in-line in the circuit to measure the current in each loop.

Experiments

1. Introduction to Measurement
2. Uncertainty and Error Analysis
3. MatchGraph: Position and Velocity vs. Time
4. Instantaneous and Average Speed
5. Constant Acceleration: Graph P, V, A for a Fan Cart
6. Equations of Motion
7. Acceleration of a Freely Falling Ball
8. Acceleration of a Freely Falling Picket Fence
9. Constant Acceleration: Graph P, V, A for a Cart on Incline
10. Projectile Motion
11. Newton's First Law – No Net Force
12. Newton's Second Law – Acceleration
13. Newton's Second Law – Force and Acceleration
14. Newton's Second Law – Push-Pull a Cart
15. Newton's Third Law – Tug-of-War
16. Newton's Laws – Net Force
17. Newton's Second Law – Atwood's Machine
18. Friction and Newton's Second Law
19. Centripetal Acceleration
20. Conservation of Energy – Cart on an Inclined Plane
21. Conservation of Energy for a Simple Pendulum
22. Hooke's Law and Elastic Potential Energy
23. Work-Energy Theorem: Compare W to ΔE
24. Conservation of Momentum and KE in Collisions
25. Impulse and Change in Momentum
26. Ballistic Pendulum
27. Newton's Second Law for Rotation
28. Rotational Inertia
29. Rotational Kinetic Energy
30. Conservation of Angular Momentum
31. Simple Harmonic Motion – Mass on a Spring
32. Oscillations of Cart and Springs
33. Physical Pendulum
34. Period of a Large Amplitude Pendulum
35. Archimedes' Principle – Buoyant Force
36. Heat and Temperature
37. Transfer of Energy by Radiation
38. Specific Heat
39. Boyle's Law: P and V of a Gas at Constant T
40. Behavior and Characteristics of Sound Waves
41. Resonant Modes of Sound in a Tube
42. Speed of Sound in Air
43. Superposition of Sound Waves
44. Interference of Sound Waves
45. Object and Image Distances for a Thin Lens
46. Reflection and Refraction
47. Focal Length of a Concave Mirror
48. Optical Instruments: Telescope and Microscope
49. Variation of Light Intensity
50. Light Intensity vs. Distance
51. Polarization: Verify Malus' Law
52. Brewster's Angle
53. Diffraction of Light
54. Electrostatic Charges
55. Electric Field Mapping
56. Ohm's Law
57. Series and Parallel Circuits
58. Kirchhoff's Laws
59. RC Circuit
60. General Properties of Diodes
61. Magnetic Field Mapping
62. Induction – Magnet Through a Coil

Coming soon!
Check pasco.com for availability.

Order Information

550 Universal Physics System UI-5830
550 Universal Physics System Manual *(included in UI-5830)* UI-5831

Advanced Physics 1 Experiment Guide

PS-3812

This experiment guide covers the latest 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.
- Every lab employs the same strategies found in free response questions on the AP® exam.
- Includes editable student handouts.

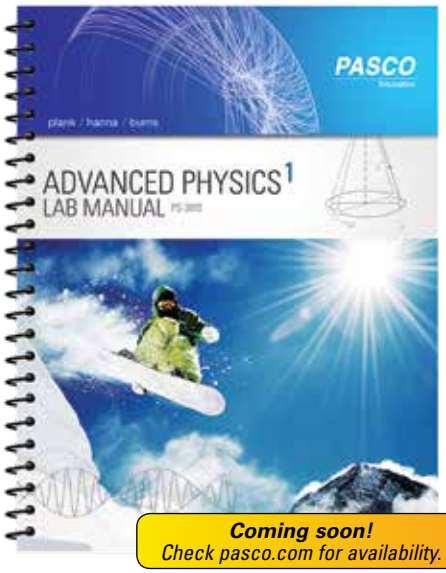
Prepare your students for inquiry investigations in the physics lab. Each lab is presented three ways:

- Structured
- Guided inquiry
- Student designed

You decide which level of inquiry is appropriate for each lab.

Each lab includes teacher resources:

- Pre-lab discussion and questions
- Procedural overview
- Teacher tips
- Sample data
- Assessment and synthesis questions
- Extended inquiry suggestions



Coming soon!
Check pasco.com for availability.

Order Information

Advanced Physics 1
Experiment Guide.....PS-3812

ADV PHYSICS 1 EXPERIMENTS	EQUIPMENT		ALIGNMENT	
LAB	Perform these labs with the PS-3813 Equipment Kit	Add the PS-3814 Expansion Kit to perform all these labs	IB® Standards*	AP® 1 Standards**
1. Graphical Analysis: Motion	✔	✔	2.1	3.A.1.1, 2, 3
2. Newton's Second Law	✔	✔	2.2	3.B.1.1, 2, 3, 3.B.2.1
3. Atwood's Machine	✔	✔	2.2	3.B.1.1, 2
4. Coefficients of Friction	✔	✔	2.2	3.C.4.1,2
5. Two Dimensional Motion: Projectiles		✔	1.3, 2.1	3.E.1.3, 4
6. Conservation of Mechanical Energy	✔	✔	2.3	5.B.4.1,2
7. Work and Kinetic Energy	✔	✔	2.3	4.C.2.1, 2
8. Conservation of Momentum		✔	2.4	5.D.1.3,5.D.2.2, 4
9. Momentum and Impulse	✔	✔	2.4	3.D.2.3, 4
10. Rotational Dynamics		✔	B.1	3.F.2.1, 2, 3.A.1.3
11. Rotational Statics		✔	B.1	3.F.1.1, 2, 3, 4, 5
12. Periodic Motion: Mass and Spring	✔	✔	4.1, 9.1	3.B.3.1, 2, 3, 4
13. Simple Pendulum	✔	✔	4.1, 9.1	3.B.3.1, 2, 3
14. Resonance and Standing Waves		✔	4.5, B.4	6.D.3.4, 6.D.4.1, 2
15. DC Circuits		✔	5.1, 5.2	1.B.1.2, 5.B.9.2, 3, 5.C.3.1

Each experiment guide includes video support!

How-to videos are included with the manual, on the PASCO web site and on YouTube, and can be installed on your own computers.



Try It!

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Advanced Physics 1 Equipment Kit

PS-3813



	Equipment	Part #	Qty
1.	Smart Cart (blue)	ME-1241	1
2.	PAStrack	ME-6960	1
3.	Dynamics Track End Stop (2 pack)	ME-8971	1
4.	Four Scale Meter Stick	SE-8695	1
5.	250-g Compact Cart Mass	ME-6755	2
6.	Mass & Hanger Set	ME-8979	1
7.	Super Pulley Kit	ME-9433	1
8.	Thread	ME-9875	1
9.	60-cm Stainless Steel Rod	ME-8977	1
10.	Aluminum Table Clamp	ME-8995	1
11.	Wireless Smart Gate	PS-3225	1
12.	Right Angle Clamp	SE-9444	1
13.	250-g Cart Mass	ME-6757A	3
14.	Discover Friction Accessory Tray	ME-8574	1
15.	45-cm Stainless Steel Rod	ME-8736	1
16.	Angle Indicator	ME-9495A	1
17.	Dynamics Track Rod Clamp	ME-9836	1
18.	Bumper Accessory Set	ME-9884	1
19.	Smart Cart Rod Stand Adapter	ME-1244	1
20.	90-cm Stainless Steel Rod	ME-8738	1
21.	Demonstration Spring Set	ME-9866	1
22.	Hooked Mass Set	SE-8759	1
23.	Photogate Pendulum Set	ME-8752	1
24.	Pendulum Clamp	ME-9506	1

Order Information

Advanced Physics 1 Equipment Kit PS-3813

Advanced Physics 1 Expansion Kit

PS-3814



	Equipment	Part #	Qty
1.	Smart Cart (red)	ME-1240	1
2.	Pendulum Accessory	ME-8969	1
3.	Aluminum Table Clamp	ME-8995	1
4.	Wireless Rotary Motion Sensor	PS-3220	1
5.	Stainless Steel Calipers	SF-8711	1
6.	Tension Protractor	ME-6855	2
7.	60-cm Stainless Steel Rod	ME-8977	1
8.	Aluminum Table Clamp	ME-8995	1
9.	Tuning Fork Set	SE-7342	1
10.	Resonance Air Column	WA-9606	1
11.	AC/DC Electronics Lab Kit	EM-8656	1
12	Wireless Voltage Sensor	PS-3211	1
13.	Wireless Current Sensor	PS-3212	1
14.	Photogate Mounting Bracket	ME-6821A	1
15.	Mini Launcher	ME-6825B	1
16.	Carbon Paper	SE-8693	1

Order Information

Advanced Physics 1 Expansion Kit..... PS-3814

Advanced Physics Sensor Bundle

Just need sensors?

PS-3818



	Equipment	Part #	Qty
1.	Smart Cart (red)	ME-1240	1
2.	Wireless Smart Gate	PS-3225	1
3.	Smart Cart (blue)	ME-1241	1
4.	Wireless Rotary Motion Sensor	PS-3220	1
5.	Wireless Voltage Sensor	PS-3211	1
6.	Wireless Current Sensor	PS-3212	1
7.	Wireless Pressure Sensor	PS-3203	1
8.	Wireless Magnetic Field Sensor	PS-3221	1

Order Information

Advanced Physics Sensor Bundle PS-3818

Advanced Physics 2 Experiment Guide

Coming soon!
Check pasco.com for availability.

PS-3815

This experiment guide covers the latest standards for College Board Advanced Placement Physics 2.

- Every lab is based on the College Board Learning Objectives.
- Data Analysis and Assessment Questions are designed to prepare students for the AP® Physics 2 exam.
- Every lab employs the same strategies found in free response questions on the AP® exam.
- Includes editable student handouts.

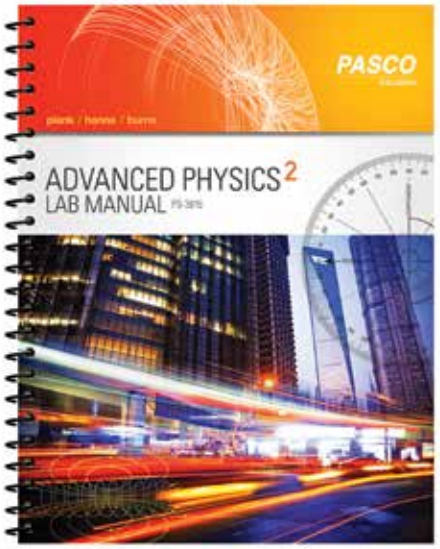
Prepare your students for inquiry investigations in the physics lab. Each lab is presented three ways:

- Structured
- Guided inquiry
- Student designed

You decide which level of inquiry is appropriate for each lab.

Each lab includes teacher resources:

- Pre-lab discussion and questions
- Procedural overview
- Teacher tips
- Sample data
- Assessment and synthesis questions
- Extended inquiry suggestions



Order Information

Advanced Physics 2
Experiment Guide.....PS-3815

ADV PHYSICS 2 EXPERIMENTS	EQUIPMENT		ALIGNMENT	
LAB	Perform these labs with the PS-3816 Equipment Kit	Add the PS-3817 Expansion Kit to perform all these labs	IB® Standards*	AP® 2 Standards**
1. Hydrostatic Pressure	✔	✔	B.3	3.C.4.1, 3.C.4.2
2. Buoyant Force		✔	B.3	1.E.1.2, 3.A.3.1, 3.C.4.2
3. Fluid Dynamics	✔	✔	B.3	5.B.10.1, 5.B.10.3, 5.B.10.4
4. Boyle's Law	✔	✔	3.2	5.B.7.2, 7.A.3.2, 7.A.3.3
5. Spherical Mirror Reflection	✔	✔	C.1	6.E.4.1, 6.E.4.2
6. Snell's Law	✔	✔	4.4	6.E.3.2, 6.E.3.3
7. Focal Length of a Converging Lens	✔	✔	C.1	6.E.5.1, 6.E.5.2
8. Interference and Diffraction	✔	✔	4.4, 9.2, 9.3	6.C.3.1
9. Electric Field Mapping		✔	5.1, 10.1	2.E.2.1
10. Magnetic Fields		✔	5.4	2.D.2.1, 2.D.3.1, 2.D.4.1
11. Magnetic Field Strength		✔	5.4	2.D.2.1
12. Electromagnetic Induction	✔	✔	11.1	4.E.2.1
13. Capacitor Fundamentals		✔	11.3	4.E.4.2, 4.E.4.3
14. Series and Parallel Capacitors		✔	11.3	4.E.5.3, 5.B.9.5
15. RC Circuits		✔	11.3	4.E.5.1, 4.E.5.2, 4.E.5.3
16. Planck's Constant		✔	12.1	6.F.3.1, 6.F.4.1

Each experiment guide includes video support!

How-to videos are included with the manual, on the PASCO web site and on YouTube, and can be installed on your own computers.



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Advanced Physics 2 Equipment Kit

Coming soon!
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PS-3816



	Equipment	Part #	Qty
1.	Water Reservoir	ME-8594	1
2.	Wireless Pressure Sensor	PS-3203	1
3.	Four-Scale Meter Stick	SE-8695	1
4.	Concave Mirror Accessory	OS-8457	1
5.	Basic Optics Light Source	OS-8470	1
6.	Optics Track, 1.2 m	OS-8508	1
7.	Basic Optics Ray Table	OS-8465	1
8.	Basic Optics Viewing Screen	OS-8460	1
9.	Converging Lens, 50-mm diam.	OS-8466A	1
10.	Adjustable Lens Holder	OS-8474	1
11.	Diffraction Plate	OS-8850	1
12.	Rod, 45-cm	ME-8736	2
13.	Aluminum Table Clamp	ME-8995	2
14.	Stainless Steel Calipers	SE-8710	1
15.	Three-finger Clamp	SE-9445	2
16.	Laser Pointer (with known wavelength)	SE-9716B/C	1
17.	Wireless Voltage Sensor	PS-3211	1
Not Pictured:	.539 ID Plastic Tube, 12"	640-014	1
	Magnet or Enameled Wire, 22-gauge	712-029	1

Order Information

Advanced Physics 2 Equipment Kit PS-3816

Advanced Physics 2 Expansion Kit

PS-3817



	Equipment	Part #	Qty
1.	Smart Cart (red)	ME-1240	1
2.	Aluminum Table Clamp	ME-8995	1
3.	Thread	ME-9875	1
4.	Overflow Can	SE-8568	1
5.	Right Angle Clamp	SE-9444	1
6.	Field Mapper Kit	PK-9023	1
7.	Student Power Supply, 18 VDC, 3 A	SE-8828	1
8.	Digital Multimeter	SE-9786A	1
9.	Neodymium Magnets (solid)	EM-8648B	16
10.	AC/DC Electronics Lab Kit	EM-8656	1
11.	Magnaprobe™ Wand	SE-7390	1
12.	4-mm Banana Plug Patch Cord	SE-9750	2
13.	Wireless 3-Axis Magnetic Field Sensor	PS-3221	1
14.	Wireless Current Sensor	PS-3212	1
Not Pictured:	Aluminum Cylinder	648-04768	1
	Brass Cylinder	648-04770	1
	Magnet or Enameled Wire, 22-gauge	712-029	1
	Capacitor, 100-µF	222-039	5
	Blue LED (450–500 nm)	527-047	1
	Green LED (501–565 nm)	527-048	1
	Yellow/Amber LED (566–620 nm)	527-049	1
	Red LED (621–750 nm)	527-050	1

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Advanced Physics 2 Expansion Kit..... PS-3817

Advanced Physics Sensor Bundle

Just need sensors?

PS-3818



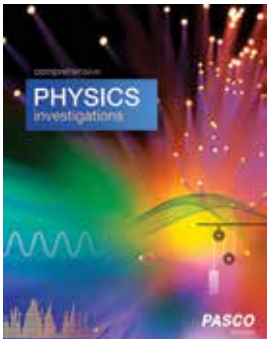
	Equipment	Part #	Qty
1.	Smart Cart (red)	ME-1240	1
2.	Wireless Smart Gate	PS-3225	1
3.	Smart Cart (blue)	ME-1241	1
4.	Wireless Rotary Motion Sensor	PS-3220	1
5.	Wireless Voltage Sensor	PS-3211	1
6.	Wireless Current Sensor	PS-3212	1
7.	Wireless Pressure Sensor	PS-3203	1
8.	Wireless Magnetic Field Sensor	PS-3221	1

Order Information

Advanced Physics Sensor Bundle PS-3818

Comprehensive Physics Investigations Lab Manual

EP-6326



Are you looking for more hands-on physics labs? The *Comprehensive Physics Investigations Lab Manual* includes over 40 labs and activities. Best of all, digital access to the **Online Teacher Resources** is included with purchase of the lab manual

- A single teacher guide is all you need to outfit your class or lab.
- Complete with guided inquiry lab activities, suggested answers, and much more

Investigations and activities in the lab manual cover topics such as:

- Graphs of Motion
- Motion Graphs
- Acceleration
- A Model for Accelerated Motion
- Newton's Second Law
- Hooke's Law
- Static and Kinetic Friction
- Projectile Motion
- Acceleration on an Inclined Plane
- Static Equilibrium
- Work and the Force vs. Distance Graph
- Inclined Plane and the Conservation of Energy
- Work and Energy
- Springs and the Conservation of Energy
- Work Done by Friction
- Design a Crash Barrier
- Conservation of Momentum
- Inelastic Collisions
- Elastic Collisions
- Levers
- Pulleys
- Ramps and Inclined Planes
- Gear Ratios
- Designing Gear Machines
- Torque
- Mechanical Advantage of Gears
- Oscillators
- Resonance
- Waves
- Interference
- Resonance and Sound
- Design a Musical Instrument
- Electricity and Circuits
- Voltage and Batteries
- Design a Lemon Battery
- Resistors and Ohm's Law
- Series and Parallel Resistances
- Electrical Power
- Compound Circuits
- Magnification of Mirrors and Lenses
- Reflection in a Plane Mirror
- Refraction of Light
- Creating Real and Virtual Images with Lenses
- Image Formation for a Convex Lens
- Build a Microscope and Telescope
- Phosphorescence

Order Information

Comprehensive Physics Investigations Lab Manual EP-6326

All the Physics Equipment You Need...

Comprehensive Physics Equipment Kit

EP-6490

This comprehensive kit includes:

- Forces and Motion Kit
- Oscillations, Waves, and Sound Kit
- Light, Color, and Optics Kit
- Simple Machines Engineering Kit
- Modular Circuits Kit



Order Information

Comprehensive Physics Equipment Kit EP-6490

These kits require either SPARKvue or PASCO Capstone software, available at **pasco.com/downloads**

Choose the Kits You Need...

Forces & Motion Kit

EP-3576

Forces + Motion Labs

- Graphs of Motion
- Motion Graphs
- Acceleration
- A Model for Accelerated Motion
- Newton's Second Law
- Hooke's Law
- Static and Kinetic Friction
- Projectile Motion
- Acceleration on an Inclined Plane
- Work and the Force vs. Distance Graph
- Inclined Plane and the Conservation of Energy
- Work and Energy
- Springs and the Conservation of Energy
- Work Done by Friction
- Design a Crash Barrier
- Conservation of Momentum
- Inelastic Collisions
- Elastic Collisions
- Ramps and Inclined Planes



Order Information

Forces & Motion Kit EP-3576

Go to **pasco.com** enter **EP-3576** for complete kit contents

Modular Circuits Kit

EM-3536

Modular Circuits Labs

- Electricity and Circuits
- Voltage and Batteries
- Design a Lemon Battery
- Resistors and Ohm's Law
- Series and Parallel Resistances
- Electrical Power
- Compound Circuits



Order Information

Modular Circuits Kit.....EM-3536

Go to **pasco.com** enter **EM-3536** for complete kit contents

Simple Machines Engineering Kit

EP-3577

Simple Machines Labs

- Static Equilibrium
- Levers
- Pulleys
- Gear Ratios
- Designing Gear Machines
- Torque
- Mechanical Advantage of Gears



Order Information

Simple Machines Engineering Kit.....EP-3577

Go to **pasco.com** enter **EP-3577** for complete kit contents

Light, Color & Optics Kit

EP-3558

Light, Color & Optics Labs

- Magnification of Mirrors and Lenses
- Reflection in a Plane Mirror
- Refraction of Light
- Creating Real and Virtual Images with Lenses
- Image Formation for a Convex Lens
- Build a Microscope and Telescope
- Phosphorescence



Order Information

Light, Color & Optics Kit.....EP-3558

Go to **pasco.com** enter **EP-3558** for complete kit contents

Oscillations, Waves & Sound Kit

EP-3578

Oscillations, Waves & Sound Labs

- Oscillators
- Resonance
- Waves
- Interference
- Resonance and Sound
- Design a Musical Instrument



Go to **pasco.com** enter **EP-3578** for complete kit contents

Order Information

Oscillations, Waves & Sound Kit EP-3578

Essential Physics Curriculum

This complete physics solution includes Textbook, e-Book, Digital Teacher Edition, and Equipment!

Essential Physics 3rd Edition is a comprehensive, full-color textbook paired with PASCO equipment, and it is the only e-Book for physics on the market. The program includes over 100 interactive tools that increase student engagement and understanding. *Essential Physics* is focused on practical applications that connect students to the physics of nature as well as technology.



***Essential Physics* is multiplatform: iOS, Android™, Chrome™, Windows®, and Mac®!**

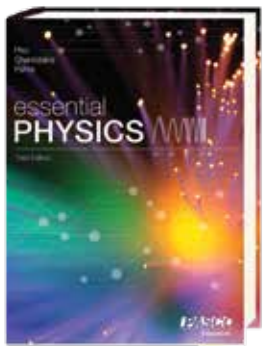
About the program:

- Rigorous yet accessible design
- Interactive simulations and equations
- Lessons follow the 5E design
- Strong mathematics scaffolding
- Formative and summative assessment tools
- Differentiation for advanced, below-level, and ELL students
- Works with your LMS and Google Classroom
- The e-Book includes 24/7 online/offline access. No Internet required!

Essential Physics Student Textbook

EP-6323

This rigorous yet accessible textbook includes core Physics topics that cover a complete year of instruction. The lessons follow the 5E model and include tools for differentiated instruction and ELL students. The *Essential Physics* curriculum aligns to state standards and was designed for the NGSS.



1. Science of Physics
2. Physical Quantities and Measurement
3. Position and Velocity
4. Acceleration
5. Forces and Newton's Laws
6. Motion in Two and Three Dimensions
7. Circular Motion
8. Static Equilibrium and Torque
9. Work and Energy
10. Conservation of Energy
11. Momentum and Collisions
12. Machines
13. Angular Momentum
14. Harmonic Motion
15. Waves
16. Sound
17. Electricity and Circuits
18. Electric and Magnetic Fields
19. Electromagnetism
20. Light and Reflection
21. Refraction and Lenses
22. Electromagnetic Radiation
23. Properties of Matter
24. Heat Transfer
25. Thermodynamics
26. Quantum Physics and the Atom
27. Nuclear Physics

Order Information

Essential Physics Student Textbook.....EP-6323

Essential Physics Student e-Book

See pages 92-93 for details.

The multiplatform *Essential Physics* Student e-Book includes an electronic version of the full textbook, as well as interactive simulations, embedded animations and videos, assessment, and 24/7 online/offline access.

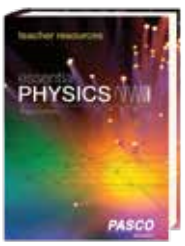


Order Information

Essential Physics Student e-Book

5-year access.....EP-6323-EB5

1-year access.....EP-6323-EB1



Essential Physics Teacher Resources EP-6324

This online all-digital Teacher Resource includes:

- Standards Alignment Guide for your state!
- Teacher Edition flash drive + Student Edition flash drive
- *Essential Physics* Teacher User Guide
- Teacher e-Book with five-year license
- Student e-Book with five-year license
- SPARKvue software

For more information on Teacher Resources, call 877-373-0300 (inside US) or 916-462-8383 (outside US).

A textbook and e-Book for all your students

What sets *Essential Physics* apart is the complete and interactive e-Book. When you purchase the e-Book, you get animations, videos, and interactive equations and simulations that bring concepts to life for students. Combined with digital resources for teachers, formative and summative assessment, and equipment for lab investigations, *Essential Physics* forms a seamless learning system for mastering physics.

The e-Book's interactive tools include:

31 videos

84 embedded interactive equations

71 interactive simulations

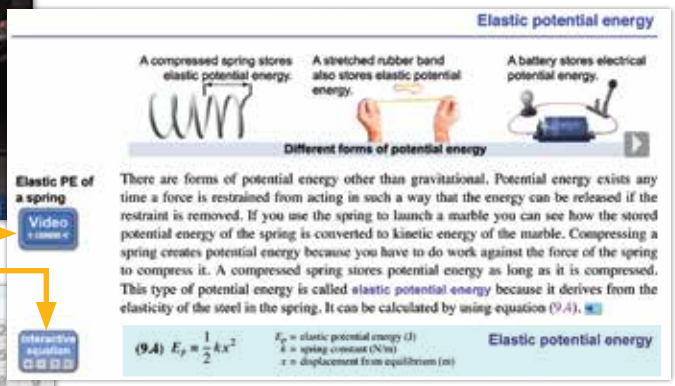
Full audio read

31 embedded animations

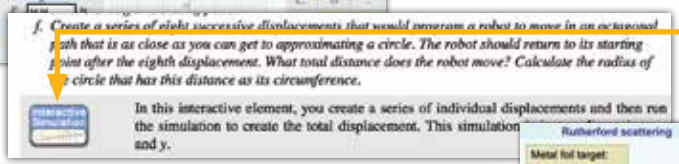
Summative assessment: The Infinite Test Bank

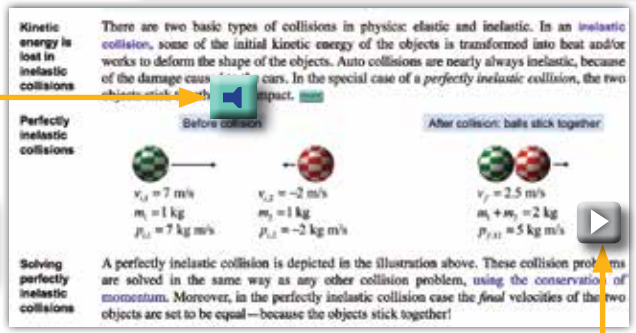
Formative assessment

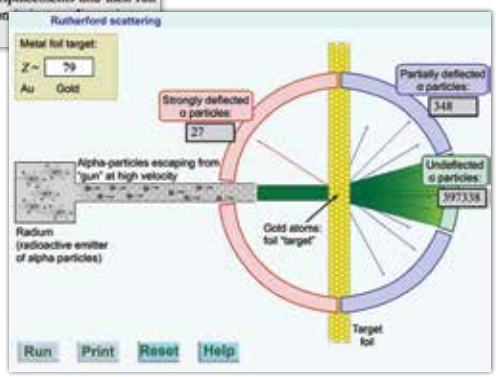


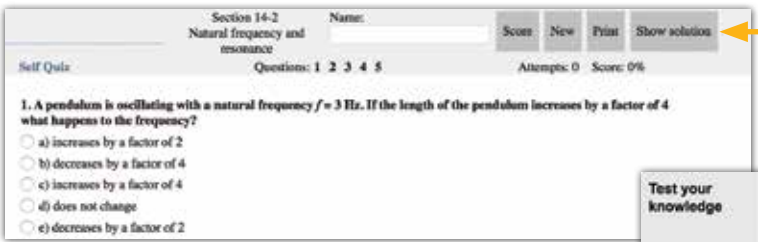


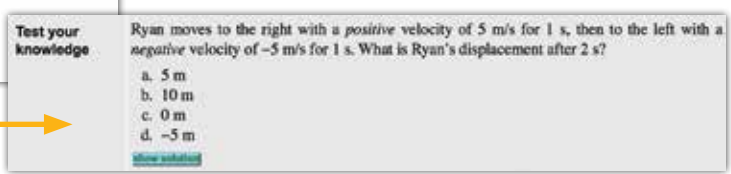






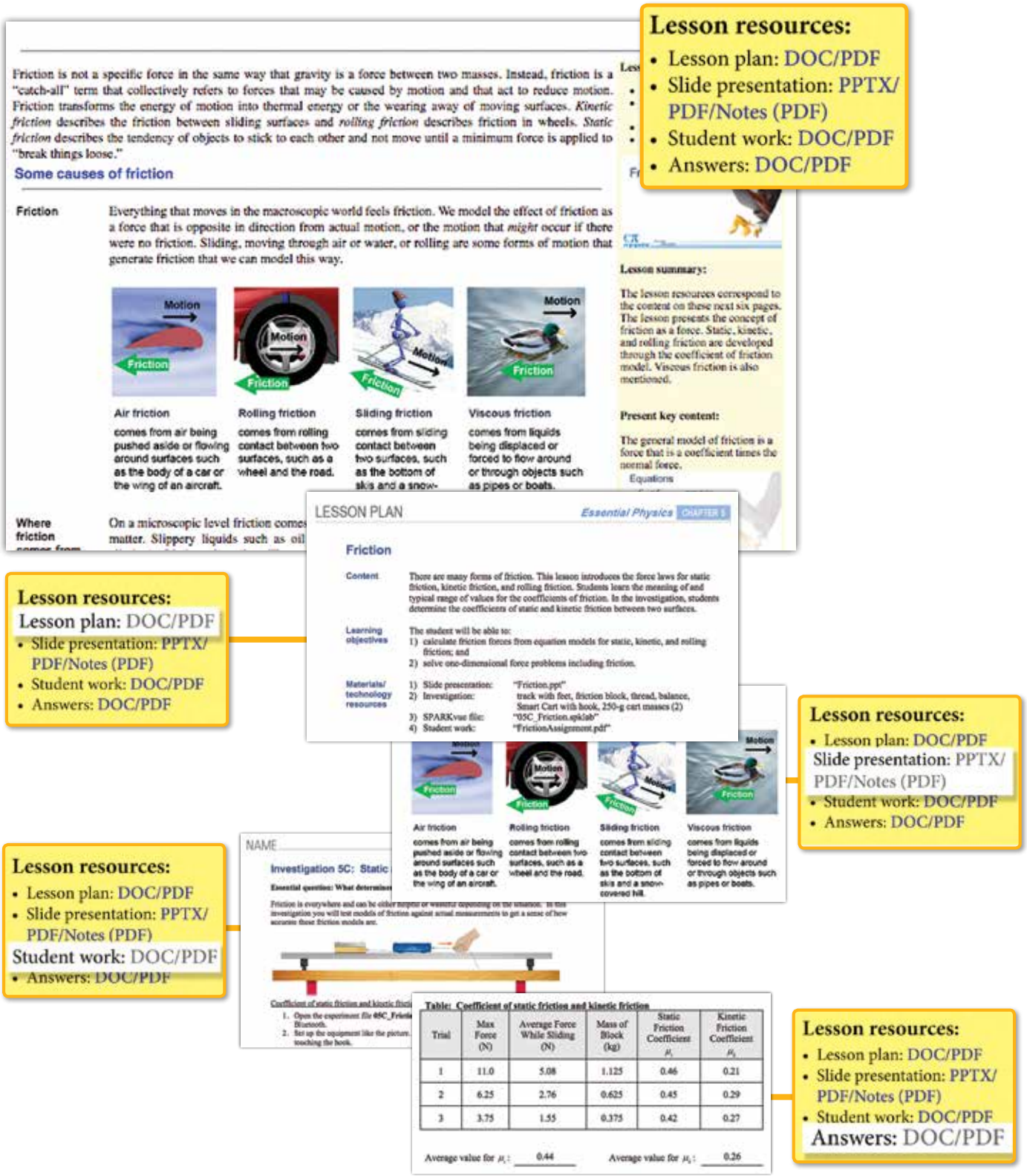




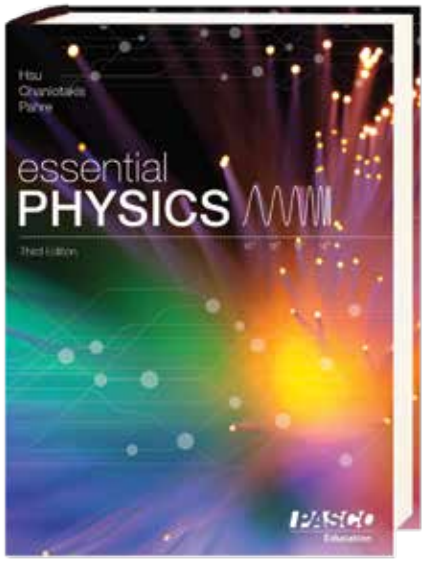


Essential Physics meets your state standards and supports STEM and NGSS!

The Digital Teacher Edition includes lesson plans, slide presentations, student work, and answer keys, all at point-of-use.



Choose the *Essential Physics* Textbook, e-Book, or Both!!



Essential Physics 3rd Edition Student Textbook

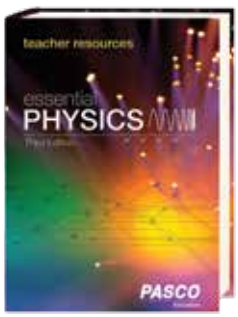
EP-6323



Essential Physics 3rd Edition Student e-Book

1-year license EP-6323-EB1

5-year license EP-6323-EB5



Essential Physics Teacher Resources EP-6324

This online all-digital Teacher Resource includes:

- *Standards Alignment Guide* for your state!
- Teacher Edition flash drive + Student Edition flash drive
- Essential Physics Teacher User Guide
- Teacher e-Book with five-year license
- Student e-Book with five-year license
- SPARKvue software

For more *Essential Physics* information,
contact your PASCO Education Specialist.

Email **sales@pasco.com** or phone **877-373-0300** (inside US)
or **916-462-8383** (outside US).

Visit our website at **pasco.com/essentialphysics**

Complete Your Physics Solution with *Essential Physics* Equipment.

Essential Physics Comprehensive Equipment Kit

EP-6490

This comprehensive kit includes:



Forces and Motion Kit





Oscillations, Waves, and Sound Kit



Simple Machines Engineering Kit



Light, Color, and Optics Kit

Projectile Launcher



Modular Circuits Kit

Also available:

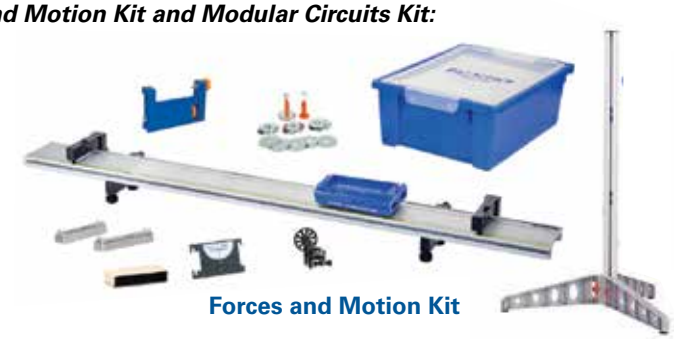
Standard Physics Equipment Kit

EP-3567A

This kit includes Forces and Motion Kit and Modular Circuits Kit:

Forces and Motion Kit:
- Wireless Smart Cart
- 1.2 m Track
- Dynamics Accessories

Modular Circuits Kit:
- Wireless Current Module
- Wireless Voltage Sensor
- Circuits Modules
- Circuits Accessories



Forces and Motion Kit



Modular Circuits Kit

For complete information, go to pasco.com/essentialphysics

Simple Machines Teacher Resources

EP-6483

- A single teacher guide is all you need to outfit your class or lab.
- Complete with guided inquiry lab activities, suggested answers, and much more
- Requires Simple Machines Engineering Kit



Questions are embedded throughout the activities. Other features include sequencing and key-term challenges. Opportunities to predict outcomes prior to data collection and post-lab multiple choice questions help to make the connection between lectures and labs as seamless as possible. And the lab activities are correlated to state and national standards. For more information, visit **pasco.com**

Simple Machines Engineering Kit

EP-3577

Our Simple Machines Engineering Kit engages students in a wide range of physics, physical science, and engineering concepts. Two triple-pulley blocks make it easy to build machines with mechanical advantage up to 6:1. Build all three classes of levers with our pair of 20-cm levers, or combine gears, levers, and pulleys together to show how rotating machines work.

Includes

- 10 N Metal Spring Scales (2)
- Tripod Stands (2) & Crossrail
- Universal Spring Hanger (2)
- Right-angle Connector with Pulley (2)
- Fixed Triple Pulley Block
- Hanging Triple Pulley Block
- Friction Block
- Quick-attach Gear Hubs (4)
- Gear Spacers (12)
- 20 cm Levers (2)
- 60 Tooth Spur Gears (2)
- 40 Tooth Spur Gears (2)
- 20 Tooth Spur Gears (3)
- 20 cm-diam. Large Pulleys (2)
- Weights
- String
- Gratnells® Storage Tray



Assembly shows included components.



Order Information

Simple Machines Teacher Resources EP-6483

Required:

Simple Machines Engineering Kit EP-3577

Curriculum

Programming and Robotics Teacher Resources

EP-6485



- 23 lessons and projects
- 7 interactive simulations
- Interactive IDE
- 23 slide presentations
- 23 student assignments
- Requires ErgoBot with ErgoBoard Robotics

Programming is one of the most valuable skills in the job market today and robotics is the cutting edge of technology. The ErgoBot Programming and Robotics system is a unique combination of hardware and software that makes it easier than ever before to get your students excited, engaged, and successful with both.

This unique module offers 23 lessons and projects covering introductory and intermediate programming, robotics, sensors, code development, variables, loops, logic structures, autonomous operation, design, engineering, optimization and performance testing.

Hardware and software work together to make the easiest, most engaging programming course ever created.

Hardware and software work together to make the easiest and most engaging programming course ever created.

- No assembly required
- 23 projects start from novice level
- Works with Windows® and Mac® OS X.
- Wireless Bluetooth® communication
- Practical for every classroom
- Go to **pasco.com** for more info!

Order Information

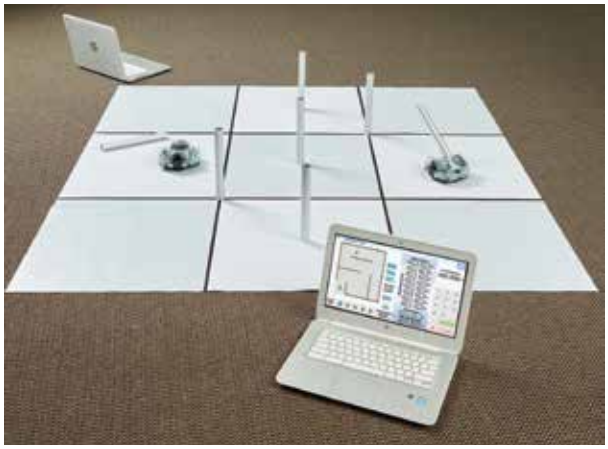
ErgoBot Programming and Robotics Teacher Resources	EP-6485
Required:	
ErgoBot with ErgoBoard Robotics	EP-6473
Also sold separately:	
ErgoBot	EP-6471
ErgoBoard Robotics	EP-6472

Equipment

ErgoBot with ErgoBoard Robotics

EP-6473

- Everything works right out of the box – nothing to solder or assemble.
- Designed for the classroom – use the same ErgoBot every period, all day.
- Projects 1-8 require no installed software. Students write easy code that gets the ErgoBot moving in less than 20 minutes.
- All three sensors are included and need only a few jumpers to connect.
- Build up to C-level programming language using logic and sensors.
- The teacher's guide includes 23 projects with lessons, slides, and a wealth of instructional material.
- The Arduino-compatible ErgoBoard is available separately to upgrade your existing ErgoBot.



The ErgoBot Robotics system includes the ErgoBot, the Arduino-compatible ErgoBoard, an IR distance sensor, a 5-position IR skirt sensor for line following, and more.

ErgoBot

EP-6471



Requires the Programming and Robotics Teacher Resources (above).

ErgoBoard with Sensors

EP-6472

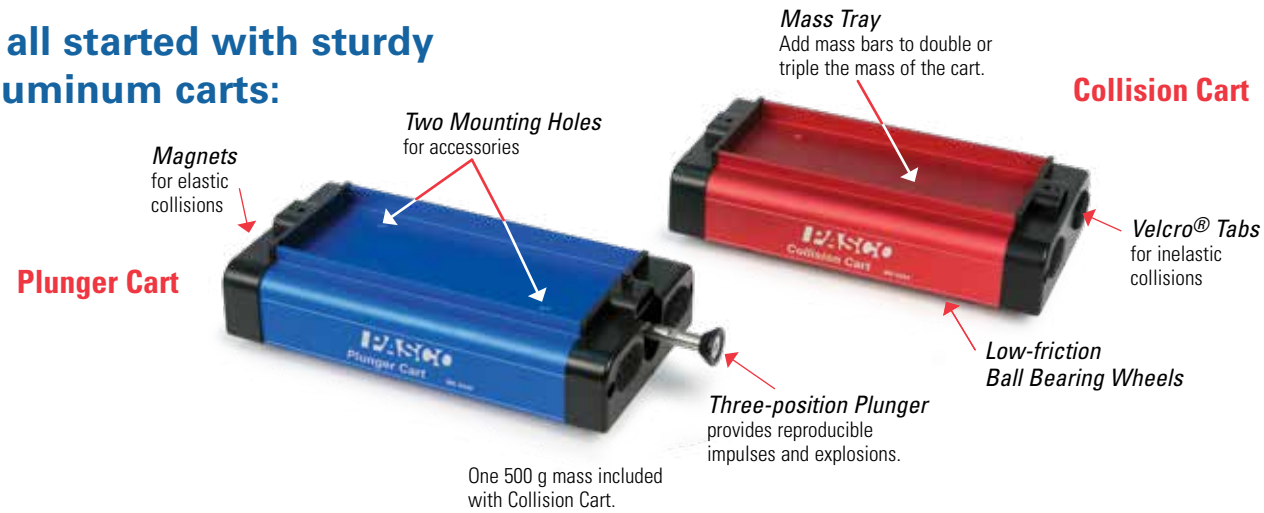
Add the Arduino-compatible ErgoBoard and sensors to your ErgoBot to study robotics and programming (requires an ErgoBot).



The Best Dynamics Systems in the World

PASCO introduced the first dynamics system in 1992... and we have been improving it ever since.

It all started with sturdy aluminum carts:



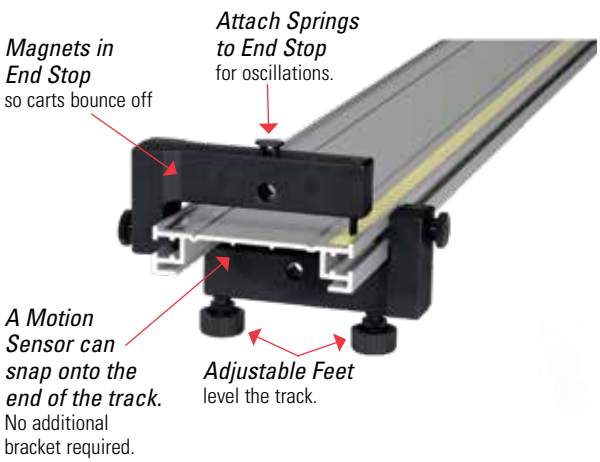
So little friction they will roll off the table if you set them down on their wheels! So sturdy they will survive the fall!





Spring-loaded retractable wheels prevent damage and keep your students from skating on them.

Soon, we added an aluminum dynamics track to align collisions:





New technologies lead to new innovations...

Plastic brought new possibilities:

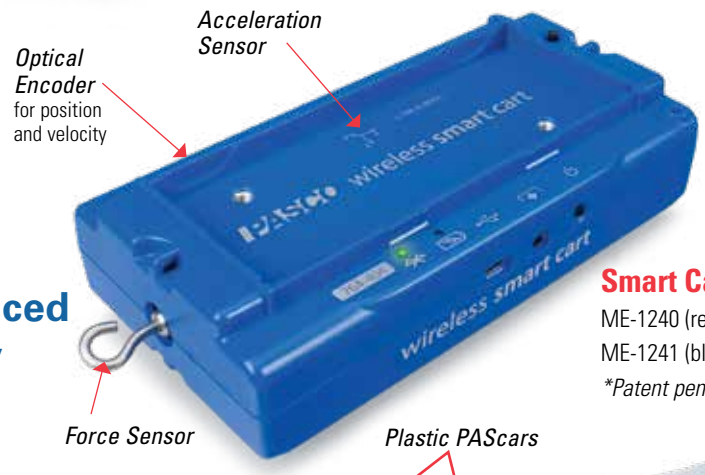
- Durable lightweight PAScars
- Curved track for Conservation of Energy



Plastic PAScars



Plastic PAStrack with Curved Sections



Smart Cart*
ME-1240 (red)
ME-1241 (blue)
*Patent pending

Then in 2016, PASCO introduced the Smart Cart, the first fully instrumented dynamics cart.



Snap together individual sections to make a track as long as you want with PAStrack.

Now, these three types of carts are compatible with both types of tracks, and there are many accessories to complete your lab.

See the next two pages to configure your dynamics system. →

How to choose the Dynamics System that's best for you:

1 Select the type of track you want.

Do you want metal or plastic tracks?



Metal Track Advantages

- Available in 1.2 m or 2.2 m lengths
- Straight and rigid
- Can do induced magnetic drag because it's conductive
- Feet can be placed at any position
- High-contrast scale



Plastic Track Advantages

- Can add tracks to make as long as you want
- Lightweight
- Can add curved track to do hills
- Built-in feet
- Storage: 1-meter track disassembles into two 50-cm parts
- Less expensive

2 Select the type of carts you want.

Do you want metal or plastic or Smart Carts?



Metal Cart Advantages

- Red and blue for distinguishing in collisions
- More inertia
- Sturdy body
- User-replaceable wheels



Plastic Cart Advantages

- Red and blue for distinguishing in collisions
- Least expensive
- Two string tie positions
- Plunger has a long throw.



Smart Cart Advantages

- Red and blue for distinguishing in collisions
- Completely instrumented with all the sensors you need for dynamics
- Two string tie positions
- Bluetooth 4.0 wireless: No interface required

3 Which system is best for you?

Basic System *Just Carts and Track*

Example shown:
ME-5705



OR

Standard System *Basic System + Accessory Pack*

Example shown:
ME-5715



Basic System includes

- Track
- 2 Carts
- 2 Feet
- 2 Endstops
- Rod Clamp
- 2 Mass Bars (4 with metal carts)

	Plastic Track 1 m	Metal Track 1.2 m	Metal Track 2.2 m
Plastic Carts	ME-5701	ME-5702	ME-5703
Metal Carts	ME-5704	ME-5705	ME-5706
Smart Carts	ME-5707	ME-5708	ME-5709

Standard System includes

- Track
- 2 Carts
- 2 Feet
- 2 Endstops
- Rod Clamp
- 2 Mass Bars (4 with metal carts)
- Spring Set
- Clamp-on Super Pulley
- Friction Block
- Angle Indicator

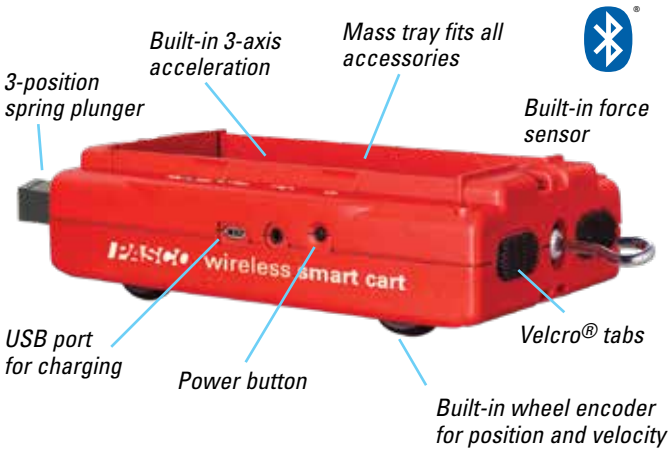
	Plastic Track 1 m	Metal Track 1.2 m	Metal Track 2.2 m
Plastic Carts	ME-5711	ME-5712	ME-5713
Metal Carts	ME-5714	ME-5715	ME-5716
Smart Carts	ME-5717	ME-5718	ME-5719

How to measure motion and forces on your dynamics system:

If you have a Smart Cart Dynamics System, you don't need any other sensors or interfaces.

1. Smart Cart

The Smart Cart has built-in sensors that measure its position, velocity, acceleration, force, and angular velocity. So there is no need to add any other external sensors. It's ready to measure, right out of the box. No interface is required because it connects wirelessly to any computing device.





Smart Cart (blue) ME-1241



Smart Cart (red) ME-1240 (*See page 102.*)

2. PASCO Capstone Software

The site license includes student home use.



(See pages 70-73.)

Order Information

Smart Cart (red)	ME-1240
Smart Cart (blue)	ME-1241
PASCO Capstone Software	
Single User License	UI-5401
Site License	UI-5400

OR If you have any other system, you need:

1. Wireless Force Acceleration Sensor (one or two)

We recommend the Wireless Force Sensors because they can ride in the carts without the added friction of a cord. Although a wired force sensor can be used mounted to the end of the track to show impulse, if you want to show the forces between two carts, the wireless force sensors are required.



Wireless Force Acceleration Sensor PS-3202 (*See page 11.*)

2. Motion Sensors (2) OR Photogates (2)

Two Motion Sensors can track the velocity (speed and direction) of both carts throughout a collision for Conservation of Momentum experiments. Photogates have to be placed at just the right position to capture the before and after speeds.



Motion Sensor PS-2103A *(See page 32.)*



Photogate Heads ME-9498A

Photogate Brackets ME-9806 *(See page 105.)*



Picket Fences ME-8933

3. An interface for the Motion Sensors or Photogates (550 or 850 Interface)

The 550 is sufficient for most labs, but the 850 will meet every need, particularly college labs.



4. PASCO Capstone Software

The site license includes student home use.



(See pages 70-73.)

Order Information

Wireless Force Acceleration Sensor (order 1 or 2)	PS-3202
Motion Sensor (order 2)	PS-2103A
Photogate Head (order 2)	ME-9498A
Photogate Brackets (2)	ME-9806
Smart Timer Picket Fences (2)	ME-8933
550 Universal Interface *(See p. 28)*	UI-5001
OR	
850 Universal Interface *(See p. 26)*	UI-5000
PASCO Capstone Software	
Single User License	UI-5401
Site License	UI-5400

OR Without an Interface, you need:

1. Wireless Force Acceleration Sensor (one or two)



Wireless Force Acceleration Sensor
PS-3202 (*See page 11.*)

2. Smart Timer with 2 Photogates

The Smart Timer is battery-powered and very easy to just set out on the lab bench and get going. However, on days when you want to measure force, you will still need a separate computing device for the wireless force sensors.



Smart Timer
ME-8930
(*See page 120.*)



Photogate Heads
ME-9498A

Photogate Brackets
ME-9806
(*See page 105.*)



Picket Fences
ME-8933



3. PASCO Capstone Software



The site license includes student home use.
(See pages 70-73.)

Order Information

Smart Timer ME-8930
Includes two fences, 9 VAC adapter and manual.
Wireless Force Acceleration Sensor (order 1 or 2)..... PS-3202
Photogate Head (order 2) ME-9498A
Photogate Brackets (2) ME-9806
PASCO Capstone Software
Single User License..... UI-5401
Site License UI-5400

OR With the traditional approach, you need:

1. Wireless Force Acceleration Sensor (one or two)



Wireless Force Acceleration Sensor
PS-3202 (*See page 11.*)

2. Tape Timer

The Tape Timer gets you back to basics. Students measure the dots to get speed and plot speed vs. time to get acceleration. On days when you want to measure force, you will still need a separate computing device for the wireless force sensors.

Tape Timer Sensor
ME-9283
(See page 123.)



3. PASCO Capstone Software



The site license includes student home use.
(See pages 70-73.)

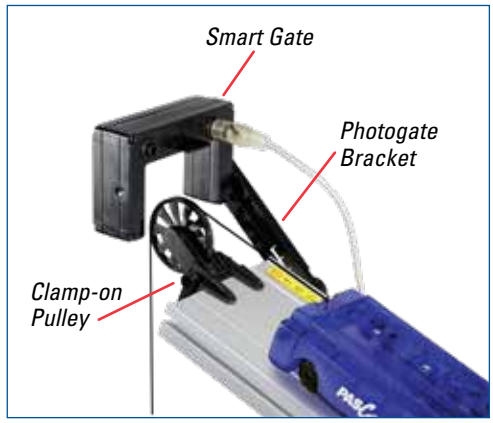
Order Information

Tape Timer..... ME-9283
Includes one roll of paper, 10 carbon paper discs, battery and manual.
Wireless Force Acceleration Sensor (order 1 or 2)..... PS-3202
PASCO Capstone Software
Single User License..... UI-5401
Site License UI-5400

Smart Gate

PS-2180

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.



NEW

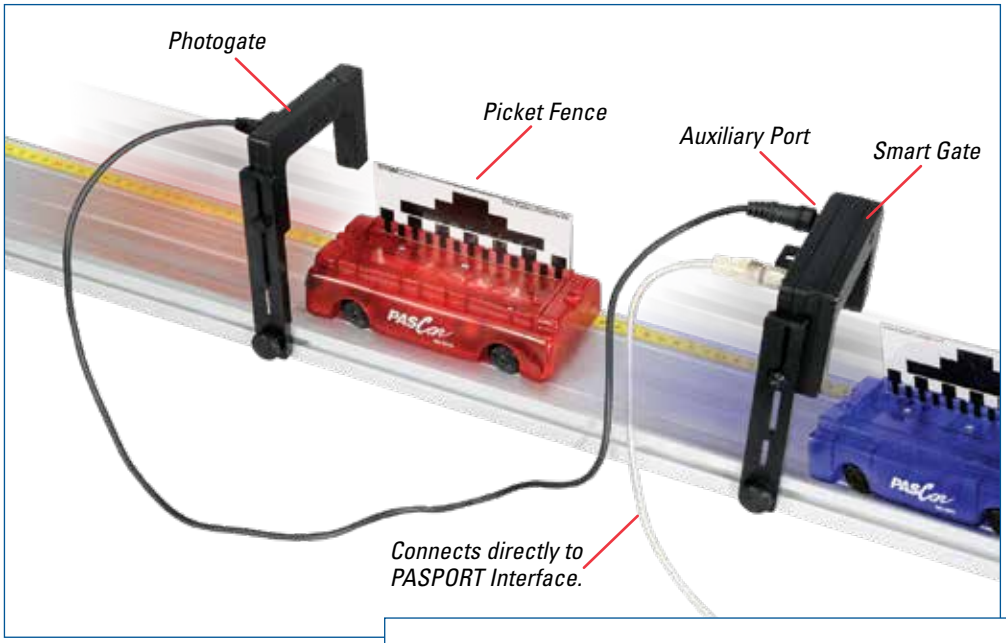
Wireless Smart Gate

Coming soon!
Check pasco.com for availability.

PS-3225

The Wireless Smart Gate has all the features of the Smart Gate (PS-2180), but it connects to your computing device via Bluetooth® or USB; it does not require an interface.





Smart Pulley

Use the Smart Gate and Photogate Bracket with the Clamp-on Super Pulley to create a "smart pulley."

Double Infrared Beams

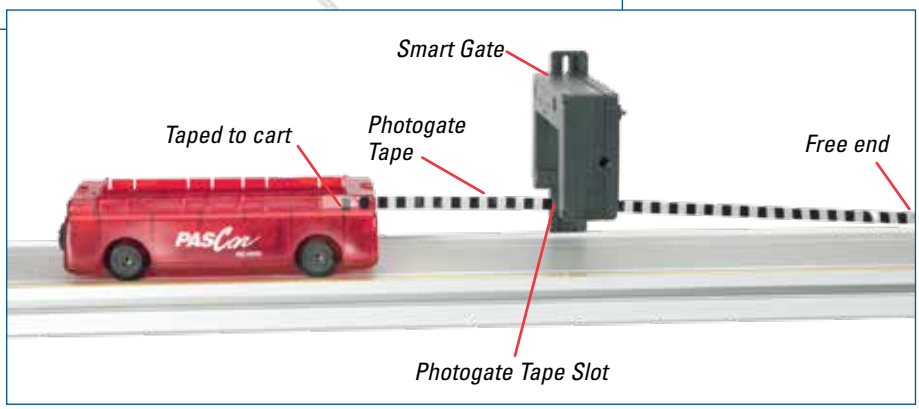
Using the double beam of the Smart Gate, the velocity of the cart can be determined accurately using the front edge of a single flag.

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



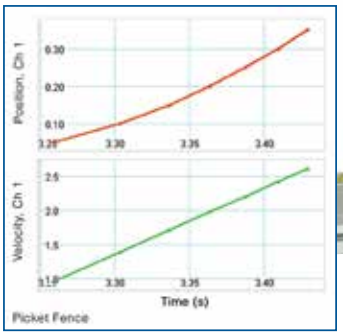
Order Information

Smart Gate	PS-2180	p. 42
Wireless Smart Gate	PS-3225	p. 10
Recommended:		
Photogate Head	ME-9498A	p. 43
High Resolution Photogate Tape	ME-6666	p. 44
Photogate Brackets (2)	ME-9806	p. 105
Cart Picket Fences (2)	ME-9804	p. 44
Super Pulley with Clamp	ME-9448B	p. 190

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. 43
Photogate Brackets (2)	ME-9806	
Cart Picket Fences (2)	ME-9804	
Super Pulley	ME-9450A	p. 190
Pulley Mounting Rod	SA-9242	p. 190
Required for use with PASPORT Interfaces:		
Digital Adapter	PS-2159	p. 45

Cart Picket Fences (set of 2)

ME-9804



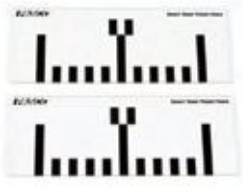
Order Information

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 (2)

- Attaches Photogates to PASCO Dynamics Tracks
- Easily Adjust Photogate Height

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.

(Photogates not included.)



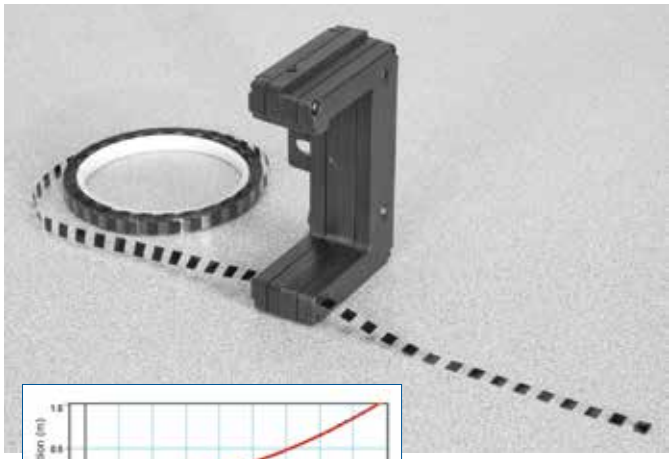
Order Information

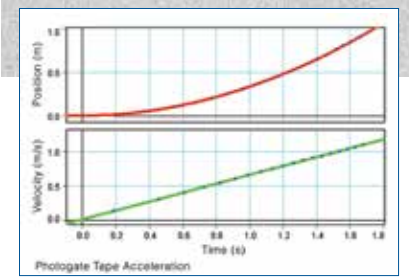
Photogate Brackets (2) ME-9806

Photogate Tape

ME-6666

Flexible Mylar® picket fence tape can be cut to any length. Tape slides into a Smart Gate 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 photogate tape through the slot to measure position, velocity, and acceleration. The band spacing on the tape is 1 cm from edge to edge.

Order Information

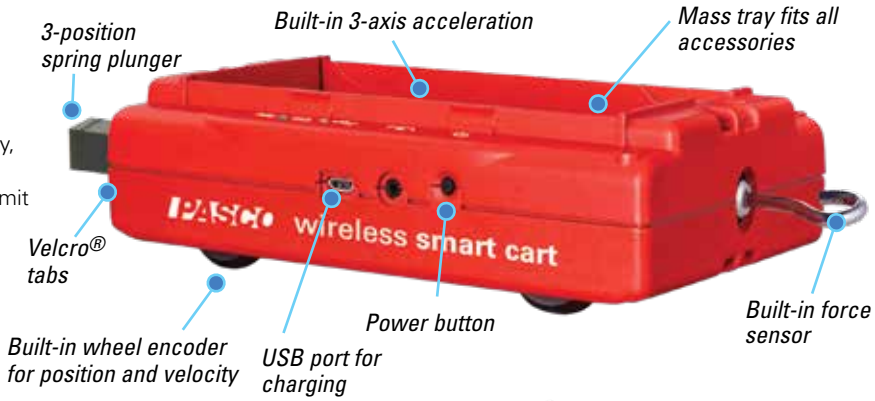
High Resolution Photogate Tape	ME-6666	
Required:		
Smart Gate	PS-2180	p. 42
Wireless Smart Gate	PS-3225	p. 10

Wireless Smart Cart

ME-1240 (red) ME-1241 (blue)

Here is the ultimate tool for your physics lab with built-in sensors that measure force, position, velocity, and acceleration. The Smart Cart can make these measurements on or off a dynamics track and transmit the data wirelessly over Bluetooth®.

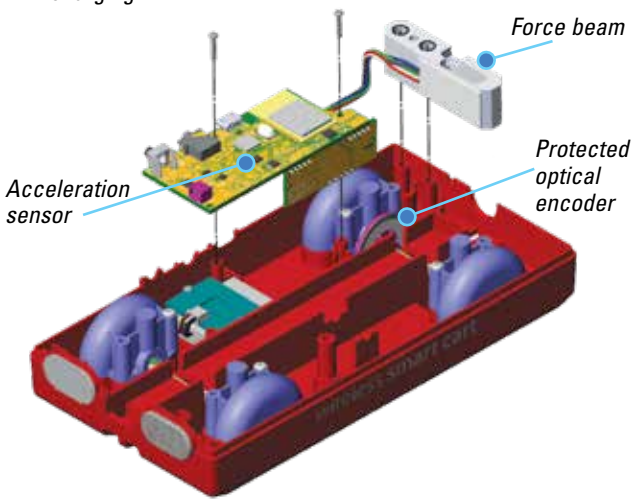
- Built-in force sensor (±100 N)
- Built-in 3-D acceleration sensor (±16 g)
- Optical encoder measures motion
- Data is transmitted wirelessly
- No interface required
- Rechargeable lithium-polymer battery



Imagine the possibilities…



1. Measure cart velocity on a curved track where Motion Sensors cannot work because there is no straight line of sight.



2. Directly measure the tension in the string connected to the Smart Cart.

Hang a mass over a pulley, hold the cart in place, and then let go. When the cart is stationary, the tension is equal to the hanging weight. When the cart accelerates, the tension is less than the hanging weight.



3. Measure oscillations of a cart and spring.

Measure position, velocity, and acceleration of the cart, and force of the spring.



4. Place the cart on the floor or table.

Measure velocity as cart travels across the floor or table without a track.

5. Use for collisions with two Smart Carts.

Each cart measures its own velocity and force. Will your students correctly predict the forces recorded by each cart for the following parameters?

- Use equal masses and unequal masses.
- Use the same spring bumpers on the Smart Cart force sensors and then change the spring on one Smart Cart to a weaker spring.



The magnetic bumper for the force sensor is included with the Smart Cart.

Read the review from *The Physics Teacher*



The PASCO Wireless Smart Cart: A Game Changer in the Undergraduate Physics Laboratory

Asif Shakur and Rainor Connor, Salisbury University, Salisbury, MD

With the introduction of the Wireless Smart Cart by PASCO scientific in April 2016, we expect a paradigm shift in undergraduate physics laboratory instruction. We have evaluated the feasibility of using the smart cart by carrying out experiments that are usually performed using traditional PASCO equipment. The simplicity, convenience, and cost-saving achieved by replacing a plethora of traditional laboratory sensors, wires, and equipment clutter with the smart cart are reported here.

Inelastic collision

We performed a simple inelastic collision experiment to ascertain the feasibility of using the wireless smart cart in an undergraduate laboratory setting. Two similar smart carts (red and blue) were placed on a 1-m PASCO aluminum track. The free PASCO app SPARKvue was installed on an iPhone. The app paired up with the blue cart via Bluetooth and recognized the unique identification sticker on the cart. We gave the blue cart a gentle push in the direction of the stationary red cart. The two carts collided and stuck together on the Velcro pads. The two carts moved together with a slower speed. Note that we only needed one iPhone to pair up with only one cart (blue) in order to draw meaningful conclusions. The velocity and time data (in addition to position, acceleration, and a raft of other data) were wirelessly transmitted by the smart cart to the iPhone as a CSV file (comma separated values). The data were tabulated in an Excel file, and a graph of velocity vs. time is depicted in Fig. 2.

Fig. 1. The PASCO Wireless Smart Cart.

Go to **pasco.com/smartcart**

Smart Cart Includes

- Hook
- Rubber bumper
- Magnetic bumper
- USB cable for charging

Order Information

Smart Cart (red).....ME-1240
Smart Cart (blue) ME-1241

Smart Fan Accessory

ME-1242

- Provides a Constant Force
- Hands-off Operation
- Sense and Control
- Manual Mode for Non-Smart Carts

If you use this fan on a regular cart, you can turn it on and select one of three speeds by pushing the button on the side. But plugging it into a Smart Cart gives this Smart Fan Accessory added capabilities:

- Remotely start and stop the fan.
- Adjust the thrust.
- Reverse the spin of the fan.
- Do sense and control.



Specifications

- Push-button for on/off: 3 speed settings
- Fits all PASCO dynamics carts
- Smart Cart required for extended Smart features
- Maximum thrust: 0.2 N
- Uses 4 AA batteries (alkaline or rechargeable)
- Lithium battery performance: On medium speed, fan slows after 5.2 hrs and stops after 5.6 hrs.
- Alkaline battery performance: On medium speed, fan slows after 1 hr and stops after 8.9 hrs.
- PASCO Capstone software required for full feature set.
- SPARKvue software provides ON/OFF button and thrust slider.



Includes

- Smart Fan Accessory
- Smart Cart Cable (19 cm)
- AA Alkaline Batteries (4)

Order Information

Smart Fan Accessory ME-1242
Requires:
Smart Cart or Dynamics Cart..... pp.98-99
PASCO Capstone Software..... pp.70-73
Suggested:
Battery Charger with 8 AA Rechargeable Batteries..... SE-3570

Smart Cart Rod Stand Adapter

ME-1244

NEW

This accessory allows the Smart Cart to be suspended from a rod stand. Use the Smart Cart's force sensor to measure the force of an oscillating spring and mass.

The Smart Cart can be mounted directly to a vertical rod or to a horizontal cross-rod.





Screw storage

Coming soon!
Check pasco.com for availability.

Order Information

Smart Cart Rod Stand Adapter.....ME-1244

Smart Cart Charging Garage

ME-1243



Charge up to five Smart Carts at once. Provides storage for the carts and accessory bumpers. Includes power adapter.

Order Information

Smart Cart Charging Garage ME-1243

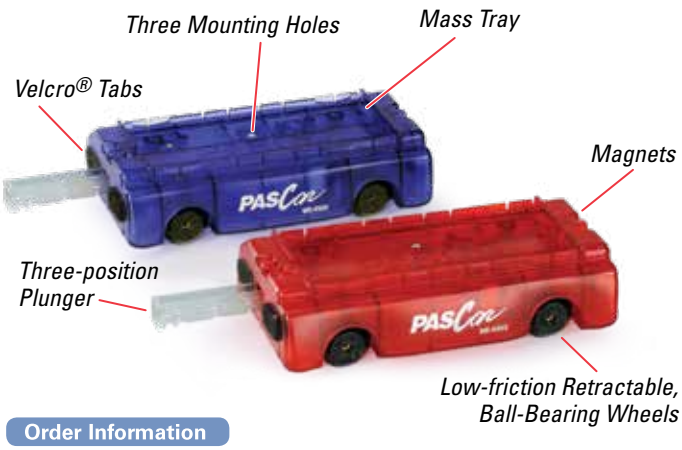
PASCO Dynamics Carts

PAScar

ME-6933 (red) ME-6934 (blue)

Each 250 gram polycarbonate plastic cart includes both a spring plunger, magnets and Velcro tabs for collision studies. The PAScars come in red and blue and are compatible with all PASCO Dynamics Tracks and accessories.

Polycarbonate Body
Total mass: 250 g



Order Information

PAScar (red)	ME-6933	
PAScar (blue)	ME-6934	
PAScar (set of 2)	ME-6950	
Replacement Supplies:		
Replacement Axles (4 pack)	ME-6957	p. 112
Cart Mass	ME-6757A	p. 109

PAStrack

ME-6960



Includes

- Two piece track
- Connector clips (2)
- Leveling feet (6)

Order Information

PAStrack	ME-6960

Curved PAStrack

ME-6841

For use with PAStrack ME-6960.



Includes

1. Concave-up Curved Piece
2. Concave-down Curved Piece
3. PAStrack Connector Clips (2)

Order Information

Curved PAStrack	ME-6841

Classic Aluminum Carts

Plunger Cart

ME-9430 (blue)

Collision Cart

ME-9454 (red)

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 (blue)	ME-9430	
Collision Cart (red)	ME-9454	
Replacement Supplies:		
Replacement Axles (4 pack)	ME-6957	p. 112
Cart Mass	ME-6757A	p. 109

Aluminum Starter 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

Track Rod Clamp

ME-9836



Track Rod Clamp fastens to the T-slot of a Dynamics Track and accepts 1/2" rod.

Order Information

Track Rod 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 (12 pack) ME-9868A

PAScar Cart Mass (set of 2)

ME-6757A



This 250 gram mass fits in any Dynamics Cart, the Motorized Cart (ME-9781), or the Discover Friction Accessory (ME-8574).

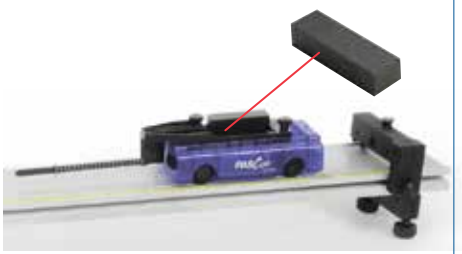
Order Information

PAScar Cart Mass (set of 2)..... ME-6757A

Compact Cart Mass

ME-6755

This 250 g mass allows students to change the mass of the Classic Cart or PAScar. It also fits on the Fan Cart (ME-9485).



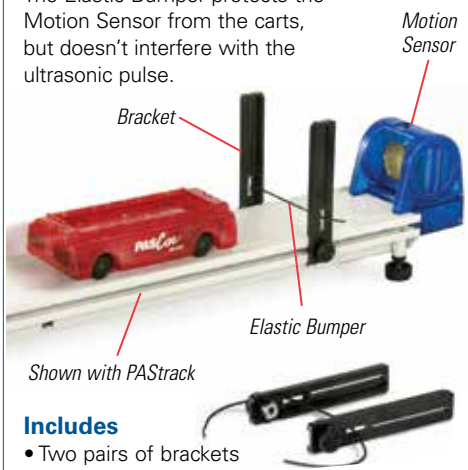
Order Information

Compact Cart Mass..... ME-6755

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

Super Pulley with Clamp

ME-9448B



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

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

Spring Set

ME-9803B



Includes eight identical springs: 8 cm long, 3.4 N/M spring constant.

Order Information

Spring Set (8)..... ME-9803B

Friction Block

ME-9807

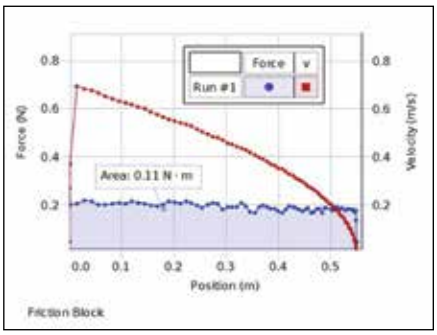


- Two types of material
- Vary surface area by using it flat or up on its side
- Hook for attaching a string to pull it
- Slot for a picket fence or flag for photogate timing

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



The sliding friction block does work on the moving Smart Cart and stops it quickly. The graph above shows the cart velocity and applied friction stopping force vs. the distance travelled by the cart and block. The area under the Force vs. Distance curve gives the work done, and the loss of kinetic energy can be calculated from the velocity.



Order Information

Friction Block..... ME-9807
Shown in use with:
Dynamics Track System .... See pages 98-101
End Stops (2)..... ME-8971 p. 109

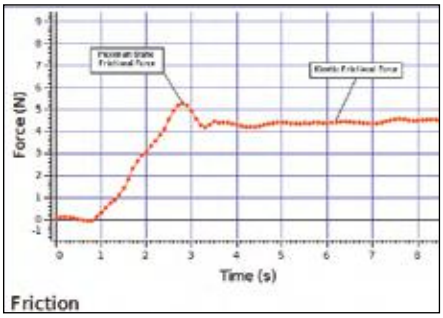
Discover Friction Accessory

ME-8574

See EX-5508 Sliding Friction Experiment on p. 326.



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 concepts such 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.



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.

Features

- **Easy Storage:** Friction trays are stackable
- **Versatile:** Students discover key friction concepts
- **Compatible:** Can be used with PASCO carts, masses, and Force Sensors



Includes

- Friction Tray - Felt
- Friction Tray - Cork
- Friction Tray - Plastic (2)

Order Information

Discover Friction Accessory ME-8574
Recommended:
Cart Mass..... ME-6757A p. 109
PASCar (red) ..... ME-6933 p. 102
PASCar (blue)..... ME-6934 p. 102
Force Sensor ..... See pages 36-37
Dynamics System .... See pages 98-101

Hooke's Law, Spring Potential Energy, and Work-Kinetic Energy Theorem, all in one cart launcher

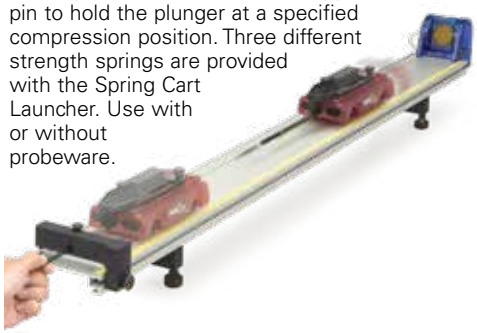
Spring Cart Launcher

ME-6843*



- Affordable cart launcher
- Hooke's Law
- Spring potential energy
- See EX-5504A Hooke's Law and Energy Stored in a Spring on p. 323

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. It fits into the bed of a Dynamics Cart or PAScar. 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.





Includes

- Spring Cart Launcher
- Trigger Pin
- Three Different Strength Springs

Order Information

Spring Cart Launcher..... ME-6843
Required:
Dynamics Track System ... See pages 92-93
**NOTE: Not compatible with the Smart Cart*
Recommended:
End Stops (2)..... ME-8971 p. 109
Replacement Springs..... ME-6847
(Three different strength springs, two each)
Compact Cart Mass..... ME-6755 p. 109

Force Bracket

ME-6622



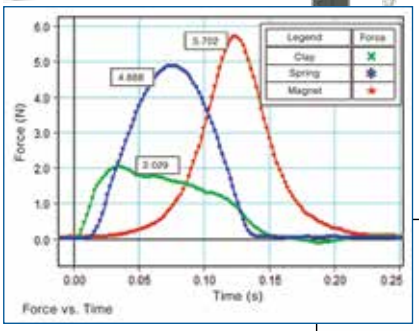
The Force Bracket with bumpers mounts the PASCO Force Sensor directly to a dynamics track. It includes 5 collision attachments for the Force Sensor and conveniently stores each attachment on the bracket itself.

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

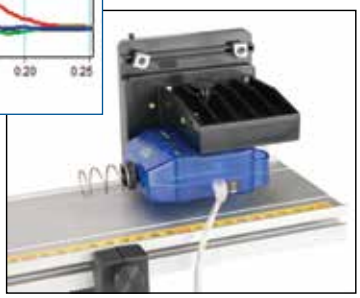


Wireless Force Acceleration Sensor (PS-3202) in cart collisions with fixed spring bumper on Force Bracket





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)

Order Information

Force Bracket..... ME-6622

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

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 Bracket.



Includes

- Magnetic Bumper (2)



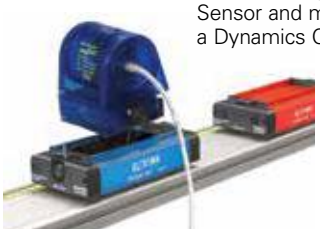
Order Information

Magnetic Bumper Set..... ME-9885A

Cart Adapter Accessory

ME-6743

The Cart Adapter Accessory allows the Motion Sensor 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



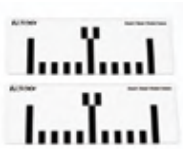
Order Information

Cart Adapter Accessory..... ME-6743

Photogate Bracket

ME-9806 (2)





ME-8933



ME-9804

Order Information

Photogate Brackets (2) ME-9806
Smart Timer Picket Fences (2)..... ME-8933
Dynamic Cart Picket Fences (2) ME-9804

Cart Replacement Axles* (4 pack)

ME-6957



**Not suitable for Smart Carts*

Although the ball bearings are designed for many years of use, the bearings may 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

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

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

Use your Rotary Motion Sensor to track cart motion.

Dynamics Track Mount

CI-6692

Track String Adapter (RMS/IDS Kit)

ME-6569



The Dynamics Track Mount (CI-6692) is used to mount the Rotary Motion Sensor to the Dynamics Track, allowing it to act as a high resolution, bi-directional Smart Pulley.



When used in conjunction with the Dynamics Track Mount (CI-6692), the Track String Adapter 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).

CI-6692 Includes

- Bracket



PS-2120A Includes

- Bracket with Pulley
- Cart String Clip
- Thread



Order Information

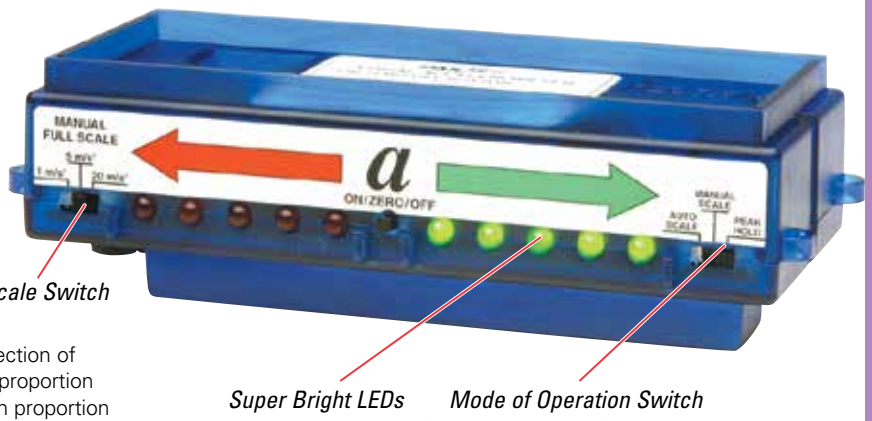
Dynamics Track Mount... CI-6692
Track String Adapter (RMS/IDS Kit)..... ME-6569

Teach the difference between velocity and acceleration.

Visual Accelerometer

PS-2128

- Clearly demonstrates the difference between velocity and acceleration
- Shows both direction and magnitude of acceleration
- Acts as a sensor when connected to a computer



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.



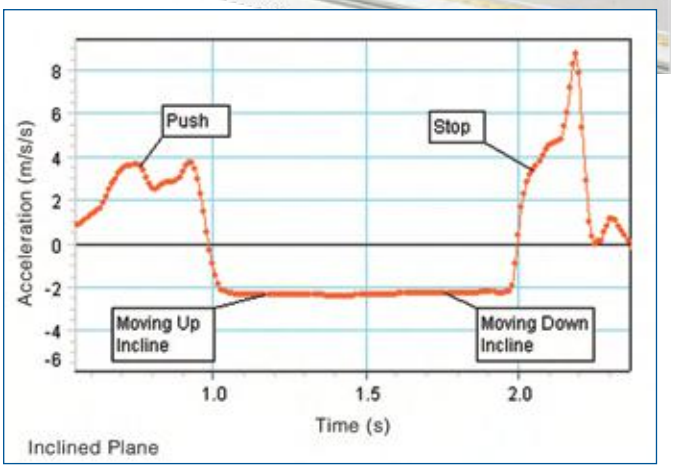
The Visual Accelerometer can be used with the Smart Fan Accessory (ME-1242).

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)
- Sensor Cable



Order Information

PASPORT Visual Accelerometer PS-2128
Smart Fan Accessory ME-1242

Show independence of x- and y-motion

Ballistic Cart Accessory

ME-9486

- Works every time
- Non-contact release
- Adjustable barrel

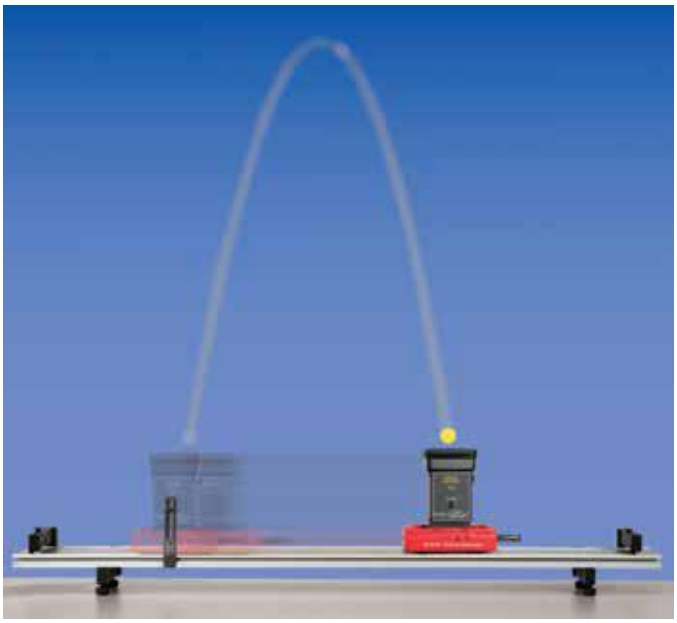
PASCO's Ballistic Cart Accessory helps beginning physics students grasp the independence of vertical and horizontal motion.

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.



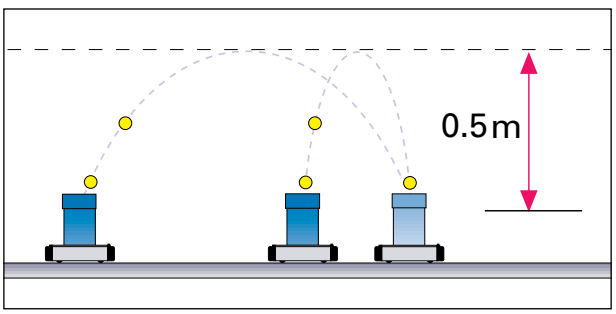
Compatible with PASCO Classic Carts, PAScars, GOcars, and Smart Carts.



Ballistic Cart Accessory attaches to a Smart Cart and projects a ball as it travels along a track.

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.



At slow or fast speeds, the results are the same.

Includes

- Ballistic Launcher
- Trigger Bracket
- Plastic Balls (2)
- 9 V Battery

Order Information

Ballistic Cart Accessory ME-9486

Required:

Dynamics System ..... pp. 98-101

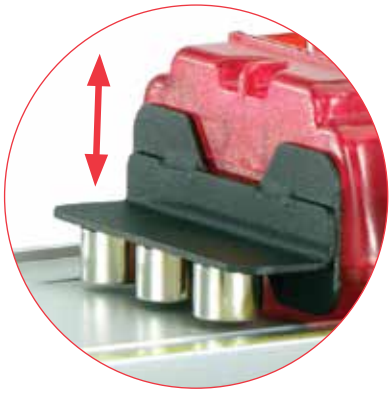
Recommended:

Smart Cart (red) ..... ME-1240 p. 102

Magnetic Damping Accessory

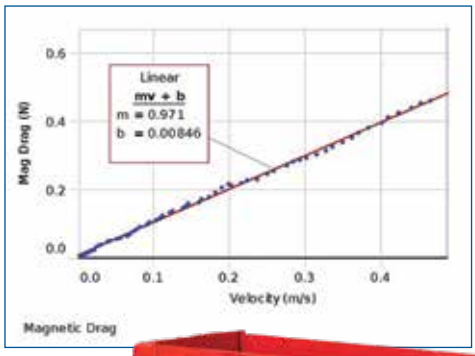
ME-6828

- Magnets cause eddy currents in aluminum tracks
- Magnetic drag is proportional to cart speed
- Damping Accessory connects to cart magnets
- Slide magnets up/down to adjust amount of drag



Magnetic Damping using the new wireless Smart Cart

Measure the magnetic drag force directly with on-board force sensor in the Smart Cart. The Smart Cart also has an encoder that keeps track of its velocity. This plot of Force vs. Velocity shows the induced magnetic drag is proportional to the velocity.







Includes

- Bracket
- Magnets
- Keeper

Order Information

Magnetic Damping Accessory	ME-6828	
Equipment shown:		
Basic Smart Cart Metal Track System	ME-5708	p. 101
Dynamics Track Spring Set	ME-8999	p. 109

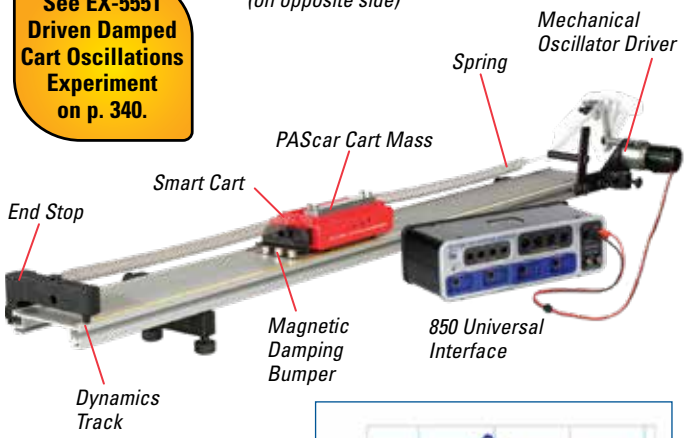
Mechanical Oscillator/Driver

ME-8750

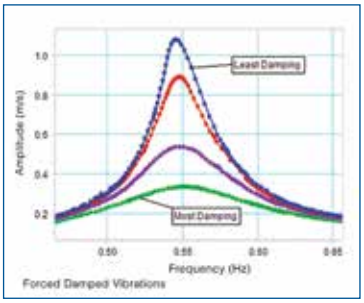
The Mechanical Oscillator/Driver delivers repeatable, low-frequency, high-force sinusoidal motion for harmonic motion experiments. Shown with the Smart Cart Standard Dynamics System (ME-5718), it also works with other Dynamics Systems having a metal track.



See EX-5551 Driven Damped Cart Oscillations Experiment on p. 340.



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.



Specifications

- **Sinusoidal Drive:** 12 VDC motor (frequency: 0.3-3 Hz, current: 0-0.3 A).
- **Adjustable Amplitude:** Up to 12 cm.
- **Mounts to Dynamics Track or Rod**
- **Photogate Mounting Holes**

Order Information

Mechanical Oscillator/Driver	ME-8750	
Shown in use with:		
Smart Cart Metal Track Standard System	ME-5718	p. 101
Magnetic Damping Bumper	ME-6828	
850 Universal Interface	UI-5000	p. 26

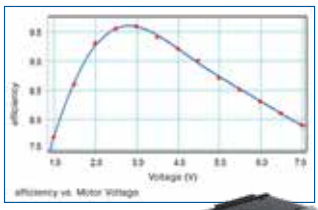
Motorized Cart

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 with a DC power supply or 850 Universal Interface signal generator.





This graph shows effect of increasing motor voltage on the efficiency.

The motor voltage is powered and controlled using the 850 Universal Interface.

Specifications

Adjustable Speed: ≈ 8-25 cm/s
Battery Power: Four "C" (not included)
External Power Input Jack
Battery Life (Alkaline): Six hours

Includes

- Motorized cart
- Cable for connecting to external power supply

Order Information

Motorized Cart	ME-9781	
PAStrack	ME-6960	p. 118
Curved PAStrack	ME-6841	p. 118
250 g Stackable Masses (2 pack)	ME-6757A	p. 109
Base and Support Rods	Various	p. 186

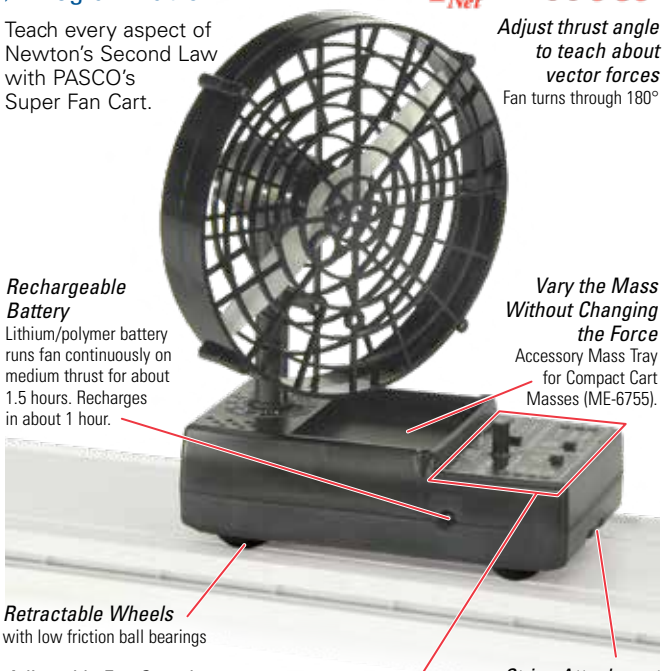
Super Fan Cart

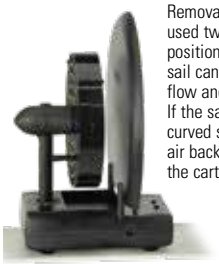
ME-6977

- Constant force
- Rechargeable
- Programmable

$$\vec{F}_{Net} = m\vec{a}$$

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.



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

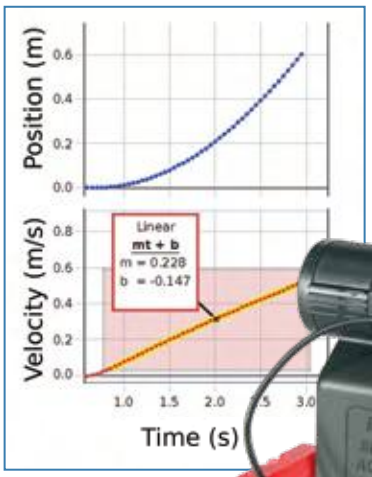
Order Information

Super Fan Cart	ME-6977	
Includes: Fan Cart, Sail and Charger		
Recommended:		
PAStrack	ME-6960	p. 118
Compact Cart Mass	ME-6755	p. 109

Smart Fan Accessory

ME-1242

- Provides a Constant Force
- Hands-off Operation
- Sense and Control
- Manual Mode for Non-Smart Carts



The Smart Fan Accessory becomes smart when plugged into a Smart Cart.



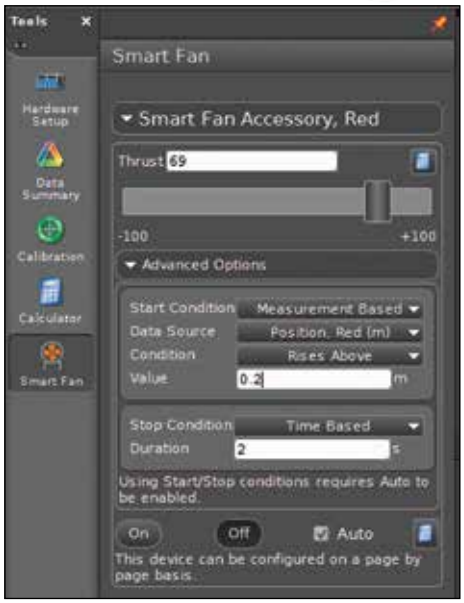
What makes this fan so smart?

If you use this fan on a regular cart, you can turn it on and select one of three speeds by pushing the button on the side. But plugging it into a Smart Cart gives this Smart Fan Accessory added capabilities:

- **Hands-off Operation:** You can turn the Smart Fan on and off wirelessly from your computing device.
- **Adjust the Thrust:** Move the slider in the software and watch the fan respond.
- **Reverse the Spin of the Fan:** Input a negative thrust to make the fan blow in the opposite direction.
- **Set Start and Stop Conditions:** Choose to start the fan when a measurement (such as Position) reaches a certain value. Make the fan stop after a certain time so the cart coasts during part of the experiment.
- **Sense and Control:** Program the Smart Fan thrust to respond to a calculation based on sensor measurements, for example:
  Thrust = -100*[Position]

  This will cause the fan to blow harder as the cart moves down the track, causing the cart to reverse, and eventually the fan will reverse when the Position becomes negative, accelerating the cart in the positive direction.





This is the control panel for the Smart Fan in PASCO Capstone software.

Specifications

- Push-button for on/off: 3 speed settings
- Fits all PASCO dynamics carts
- Smart Cart required for extended Smart features
- Maximum Thrust: 0.2 N
- Uses 4 AA batteries (alkaline or rechargeable)
- Lithium Battery Performance: On medium speed, fan slows after 5.2 hrs and stops after 5.6 hrs.
- Alkaline Battery Performance: On medium speed, fan slows after 1 hr and stops after 8.9 hrs.
- PASCO Capstone software required for full feature set.
- SPARKvue software provides ON/OFF button and thrust slider.



Make your fan rotatable:
3D print your own rotating base for the Smart Fan Accessory at pasco.com/diy



Includes

- Smart Fan Accessory
- Smart Cart Cable (19 cm)
- AA Alkaline Batteries (4)



Order Information

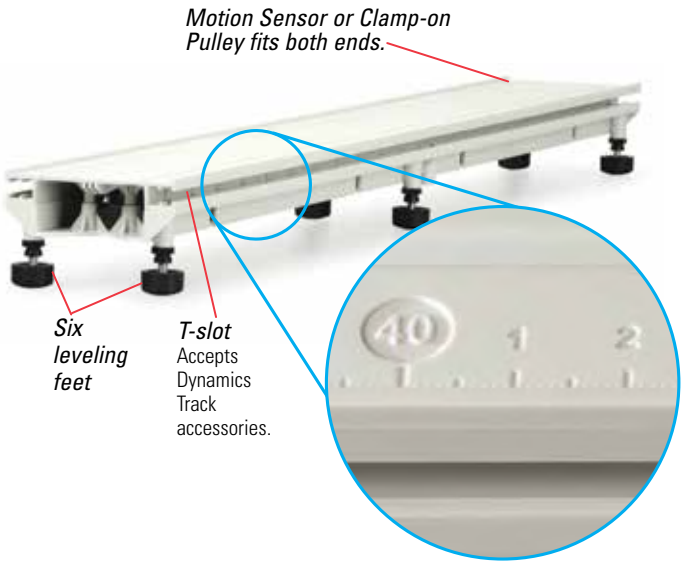
Smart Fan Accessory ME-1242
Requires:
Smart Cart or Dynamics Cart ..... p. 102
PASCO Capstone Software ..... pp. 70-73
Suggested:
Battery Charger with 8 AA Rechargeable Batteries SE-3570

Straight PAStrack

ME-6960

- 1 m length dynamics track
- Two-piece molded construction
- Accepts dynamics track accessories

This two-piece track construction makes storage easy. 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 clips (2)
- Leveling feet (6)



Order Information

Straight PAStrack ME-6960

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.





Includes

- Inclined Plane Accessory
- Rubber Cord, 1.5 mm square, 30 m

Order Information

Coming soon!
Check pasco.com for availability.

Inclined Plane Accessory ME-6965
Required:
PAStrack ME-6960

PAStrack Inclined Plane

ME-6967

The PAStrack Inclined Plane includes the Inclined Plane Accessory (ME-6965) and the PAStrack (ME-6960).



Order Information

Coming soon!
Check pasco.com for availability.

PAStrack Inclined Plane ME-6967

Curved PAStrack

ME-6841

- Attaches to Straight PAStrack with same connector clip
- Put two curved pieces together
- One concave up and one concave down

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.

Order Information

Curved PAStrack.....ME-6841



Includes

1. Concave-up Curved Piece
2. Concave-down Curved Piece
3. PAStrack Connector Clips (2)

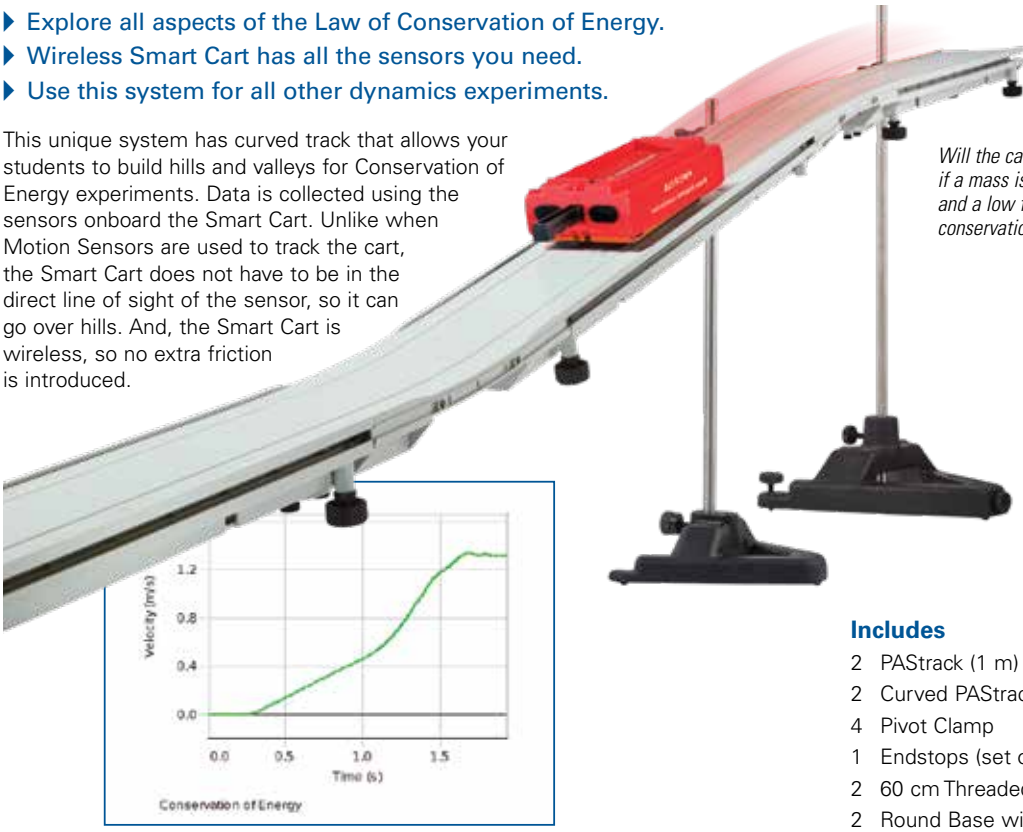
Conservation of Energy Experiments

Smart Cart Curved Track System

ME-5700A

- Explore all aspects of the Law of Conservation of Energy.
- Wireless Smart Cart has all the sensors you need.
- Use this system for all other dynamics experiments.

This unique system has curved track that allows your students to build hills and valleys for Conservation of Energy experiments. Data is collected using the sensors onboard the Smart Cart. Unlike when Motion Sensors are used to track the cart, the Smart Cart does not have to be in the direct line of sight of the sensor, so it can go over hills. And, the Smart Cart is wireless, so no extra friction is introduced.



Will the cart be going any faster at the bottom if a mass is added? With the Curved PAStrack and a low friction cart, students can investigate conservation of energy and answer that question.

The curved and straight track pieces can be combined to form a step, so the cart starts out on a nearly level upper step, travels down the step, and ends on a level straight section. This makes measuring the change in height very easy.

During the experiments, the mass of the cart is varied to see what effect, if any, it has on the results.

Another configuration forms a potential well so the cart oscillates back and forth.

This versatile system can also be used for regular dynamics experiments such as impulse and Newton's Second Law.

***Experiments can be downloaded at* www.pasco.com.**

Includes

2	PAStrack (1 m)	ME-6960
2	Curved PAStrack	ME-6841
4	Pivot Clamp	ME-9836
1	Endstops (set of 2)	ME-8971
2	60 cm Threaded Rod	ME-8977
2	Round Base with Rod	ME-8270
2	Small A-Base	ME-8976
1	2 Masses	ME-6757A
1	Smart Cart (red)	ME-1240

Order Information

Smart Cart Curved Track System.....ME-5700A
Required:
PASCO Capstone software (see pages 70-73)
Bluetooth 4.0 compatible computer

The Most Versatile Stand-Alone Timer Available

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

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

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.

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 43-45.

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Two Photogate Ports



Durable Positive-click Buttons



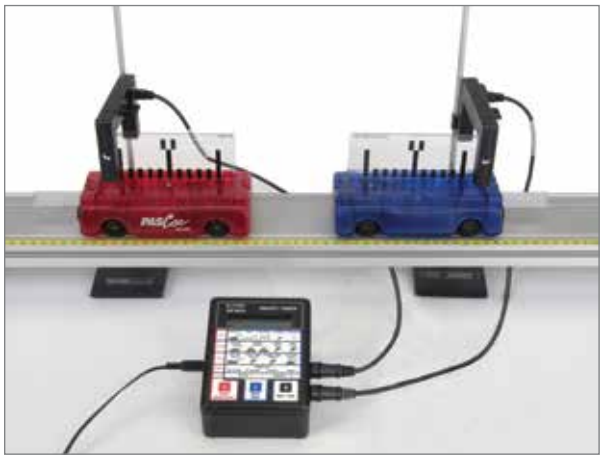
The microprocessor-based PASCO Smart Timer is the most versatile way to make time, speed, acceleration, and count measurements.



Speed of projectile—In Time: *Two Gates mode; determine the speed of a ball fired by a Projectile Launcher through two photogates.*



Speed 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.*



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. 43
Smart Timer Fences (2)	ME-8933	
Freefall Adapter	ME-9207B	p. 45
Photogate/Pulley System	ME-6838A	p. 43
Time-of-Flight Accessory	ME-6810A	p. 45
G-M Tube/Power Supply	SN-7927A	p. 45
Phone Jack Extender Cord	PI-8117	p. 45

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.



Four Timing Modes

0.1 ms Resolution

Memory
Record two times in rapid succession. The photogate will remember the first and the total of the two times.

Features

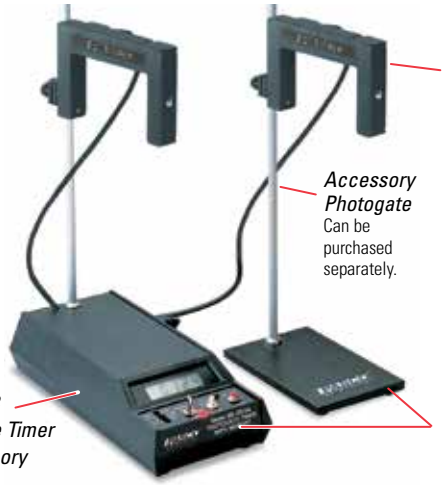
- **Built-in Photogate**: Timer serves as the base
- **0.1 ms Resolution** and 0.05% accuracy
- **Memory Function:** Allows two measurements in rapid succession, such as pre- and post-collision velocities
- **Easy Setup:** Turn it on and begin taking measurements
- **Portability or Plug-in:** Use four "C" cell batteries (not included) or 9 V AC adapter (included)

The Photogate Timers work with the following:

- Accessory Photogate
- Freefall Timer
- Time-of-Flight Accessory
- Laser Switch

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



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.



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

Freefall Apparatus

NEW

Student Timer

SF-7275

- Use with Freefall Apparatus (SF-7274)
- Also has manual start/stop
- Battery-powered

This student timer is designed to perform time measurements using photo cells, microphones, freefall equipment and other mechanical and electronic switches. The timer function can also be activated manually.

The student timer is supplied with batteries and a power adapter. The instrument turns itself off automatically after 5 minutes without any activity, both when battery powered and when powered with the power adapter.



DIN connectors
for microphones or photocells

Connector for mains adapter
(backside of the instrument)

On/off and reset button
awakens the instrument from sleep mode

Jack connectors
for connection of Freefall Apparatus, switch box or other accessories

Push-button
for manual start and manual stop

Specifications

Display: 5-digit floating point LED
Resolution: 0.01 ms
Max. time: 99999 s

Order Information

Student Timer	SF-7275

Tape Timer

ME-9283

- Crystal-controlled
- Two frequencies (10 Hz and 40 Hz)
- Easy-to-read dots



The Method

Provides students with a visual demonstration of speed and acceleration. A moving object pulls a paper tape through the timer. The timer prints dots on the tape at equal time intervals. The result is a series of dots on the paper tape, representing the position of the object as a function of time.

From the dots on the tape, the distance traveled can be measured, and the average speed for each time interval can be calculated. Plotting position versus time enables students to determine the average speed. Plotting the average speed for each time interval versus time enables acceleration to be determined.

The paper tape can be attached to air track carts, dynamics carts, falling masses or other objects.

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 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.



Calculate the acceleration due to gravity by dropping a mass attached to the tape.

Includes

- Roll of paper (1)
- Carbon paper discs
- Battery
- 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.

PASCO Stopwatch

ME-1234

- No alarm or clock
- Memory for stored event times
- Uses one AA battery
- Durable buttons

Are you tired of annoying stop-watch alarms going off all day? Are your students stuck in the clock mode and can't get their stop-watch 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.



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: One AA battery and instruction sheet

Order Information

PASCO Stopwatch	ME-1234
PASCO Stopwatch (10-pack)	ME-1235

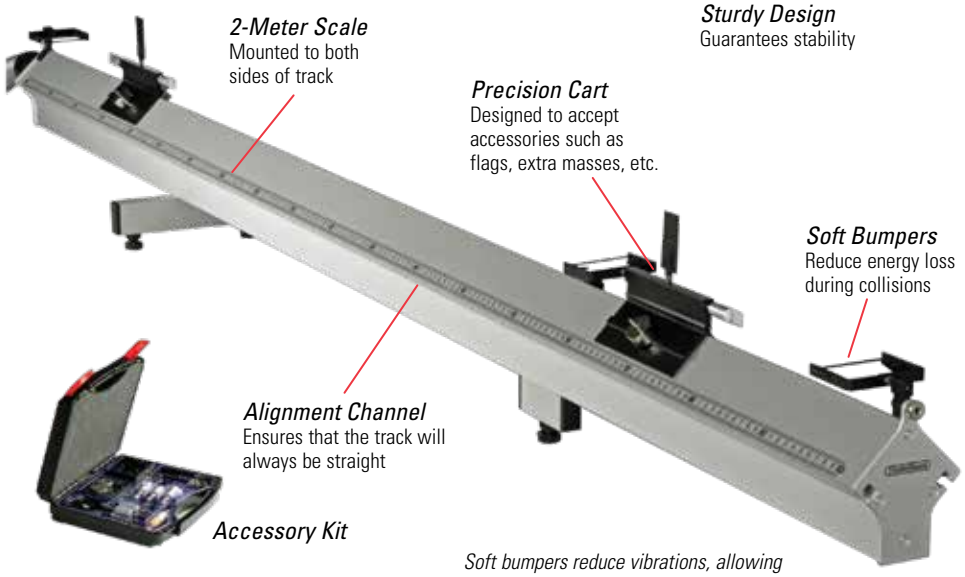
PASCO Air Track

SF-9214

Variable Output Air Supply

SF-9216

- Nearly frictionless linear motion
- Two meters long
- Complete accessories included



Soft bumpers reduce vibrations, allowing elastic collisions that really are elastic.

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:** Straight to within 0.04 mm over its entire 2-meter length.
- **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 125)
  - 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

Specifications

Length: 2 m (working distance 1.9 m)

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): 25 mm
- Glider Masses (4): 50 g
- Glider Bumper (3)
- 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 Case

Order Information

2.0 m Air Track SF-9214

Required:

Variable Output Air Supply SF-9216

Suggested:

Replacement Parts ..... see opposite page

Air Track Accessory Kit

SF-9295



A set of accessories comes with every PASCO Air Track. All that's needed is a timing system. The pieces of the set may be ordered separately.

Order Information

Air Track Accessory Kit.....SF-9295

Recommended:

Air Track Glider Kit.....SF-9224

Air Track Air Supply Hose (2 m).....SF-9298

Air Track T-Adapter and Hose.....SF-9217

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

Air Track 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.



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.)

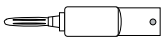
1. *Mass/Hanger Set-Air Track (1)*
   SF-6300



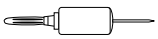
2. *Bumper with Holder-Air Track (3)*
   SF-6301



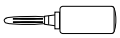
3. *Bumper Set-Air Track (3)*
   SF-6302



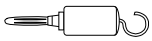
4. *Inelastic Collision Needle-Air Track (1)*
   SF-6303



5. *Wax Receptacle (1)*
   SF-6304



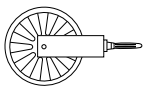
6. *Glider Hook (1)*
   SF-6305



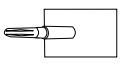
7. *Glider Mass (4)*
   SF-6307



8. *Ball-Bearing Pulley-Air Track (1)*
   SF-6308



9. *25 mm Flag (2)*
   SF-6311



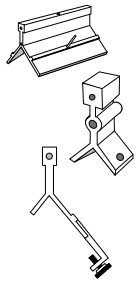
Not included in the SF-9295 Kit

(Must be ordered separately.)

10. *Glider-Air Track*
    SF-6306

11. *Fixed End Stop-Air Track*
    SF-6313

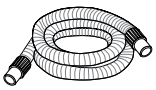
12. *Adjustable End Stop-Air Track*
    SF-6309



13. *Glider Kit-Air Track*
    (see photo below)
    SF-9224
    (Includes one glider, two 50 g masses, bumper with holder, and bumper blade.)

(The following two items are not pictured above and not included in the kit.)

14. *Air Supply Hose (2 m)-Air Track*
    SF-9298



15. *T-Adapter and Hose-Air Track*
    SF-9217
    (Allows two air tracks to be operated from one air supply.)



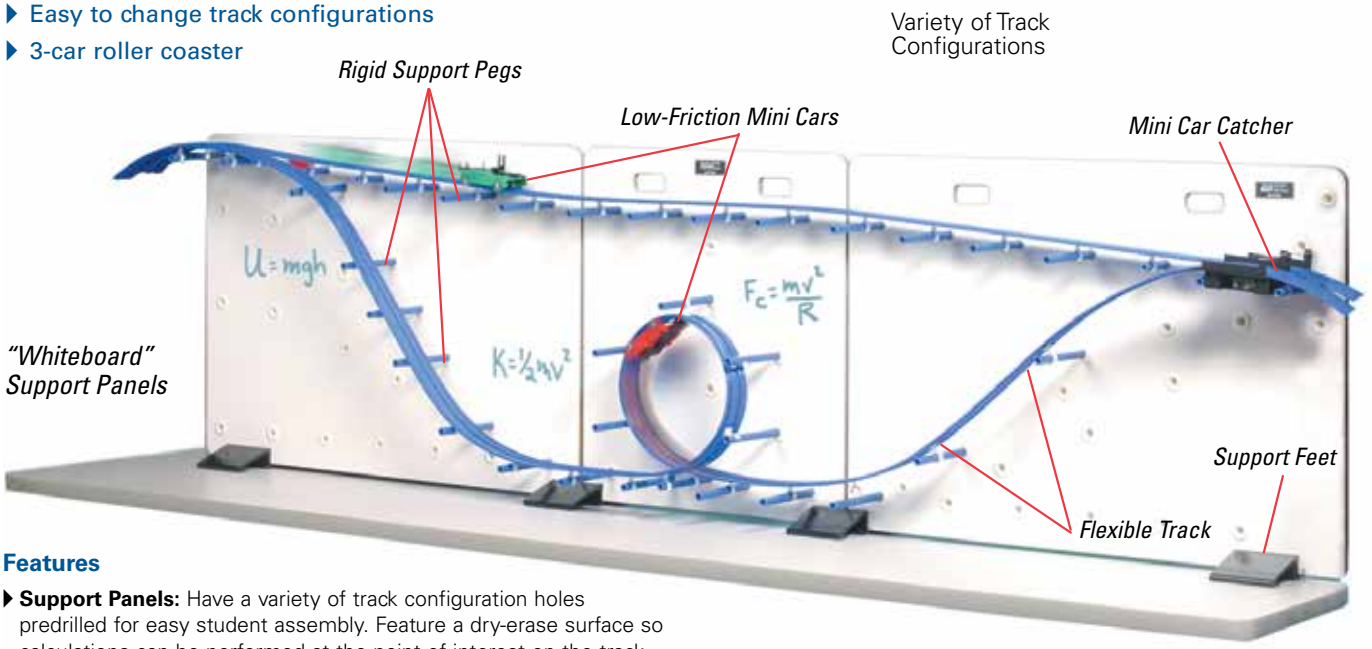


13. Additional Glider Kit.....SF-9224

Roller Coaster Complete System

ME-9812

- Quantitative studies of Energy Conservation
- Easy to change track configurations
- 3-car roller coaster



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.
  - 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.
- **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.

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.
- **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.



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. 43
Photogate Bracket (2)	ME-9806	p. 105
Roller Coaster Spares Kit	ME-9815	
Mini Car Set	ME-9813	
Roller Coaster Track (9.1 meters)	ME-9814	
Smart Timer	ME-8930	p. 120
or Computer Interface	pp. 24-25	

Loop-the-Loop

SE-7591

How high do you have to start the ball to make it go over the loop? Students use Conservation of Energy to determine how much potential energy is needed to have enough speed to make it around the loop.



Specifications

Base Dimensions: 15 cm x 38 cm
Height: 52 cm
Loop Diameter: 14 cm

Includes

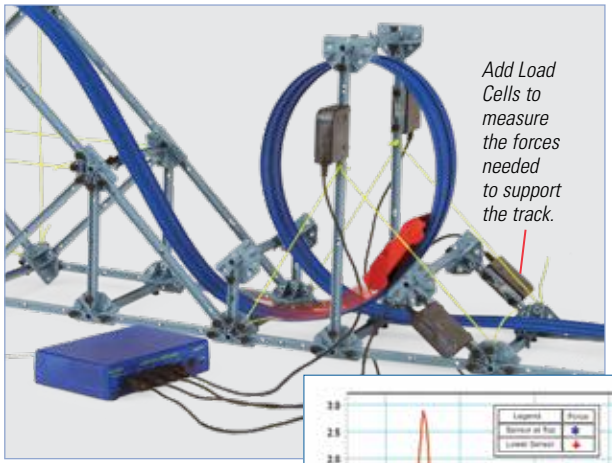
- Two steel balls (1.9 cm dia.)
- Wooden base
- V-shaped aluminum track

Order Information

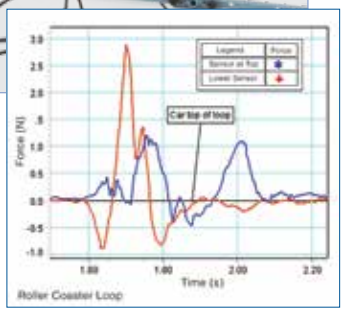
Loop-the-Loop SE-7591

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.



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.

Order Information

Large Structures Set	ME-7003	p. 152
Shown in use with:		
Load Cell & Amplifier Set	PS-2199	p. 38
Accessory Photogate	ME-9204B	p. 43

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. This is the only kit that is:

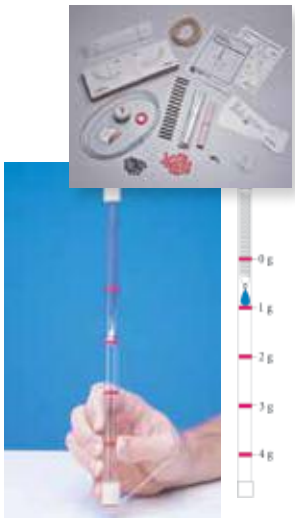
- Approved by the safety officers of major amusement parks across the USA.
- Student-tested in amusement parks by hundreds of schools.
- Teacher-tested in hundreds of Amusement Park Physics Workshops.
- Made with a metal coil spring for the Vertical Accelerometer (far more accurate than the commonly 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.

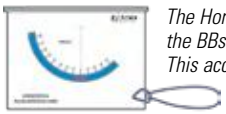


The Vertical Accelerometer: The stretch of the spring measures the vertical acceleration in "g's."

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

Hovercraft

ME-9838

- Students experience Newton's Laws
- Durable nylon skirt
- Rubber bumper
- Optional cordless air supply

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 firsthand the kinematics of frictionless motion.

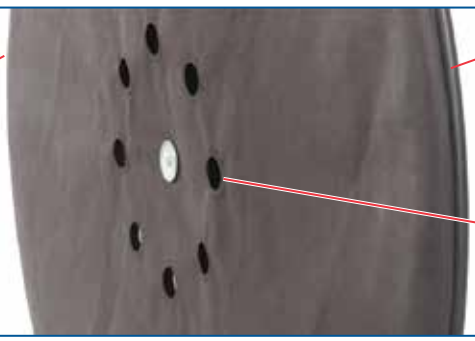


How It Works

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.

A Cordless Air Source (SE-8806) is orderable separately (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

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.



(Appearance may vary.)

Specifications

Diameter: 18.5 cm
Height: 6.0 cm

Includes

- Hover Puck
- Four "AA" Batteries

Order Information

Hover Puck SE-7335B
Recommended:
Motion Sensor ..... PS-2103A p. 32
Motion Sensor II ..... CI-6742A p. 32
Wireless
Motion Sensor ..... PS-3219 p. 9

Cordless Air Source

SE-8806



Includes

- Rechargeable Battery
- Charging Adapter

Note: 220 V version **not** available.

Order Information

Cordless
Air Source SE-8806

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.

Includes

- 3.8 cm diameter clear plastic tube with end caps
- Coin and "feather" (Styrofoam)
- Syringe vacuum pump

Order Information

Coin and Feather Tube SE-9788

Vacuum Pump

SE-7726

NEW

- 15 mTorr vacuum
- Pump the air out of a bell jar
- Use with Coin and Feather Tube (above)



This reasonably priced vacuum pump can obtain a vacuum down to 15 mTorr.

Features

- 1/2 HP, 1725/1425 RPM capacitor start motor with thermal overload protection
- 1/2" x 1/4" x 3/8" intake port
- 21-ounce (680 cc) oil capacity
- 2 stage direct drive to achieve deep 15-micron vacuum
- Lighter weight finned aluminum housing reduces heat during operation
- All metal construction including all brass fittings
- Completely field-repairable
- UL listed; made in the USA
- 24-month warranty

Coming soon!
Check pasco.com for availability.

Order Information

Vacuum Pump SE-7726

Constant Velocity Tubes (4)

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.

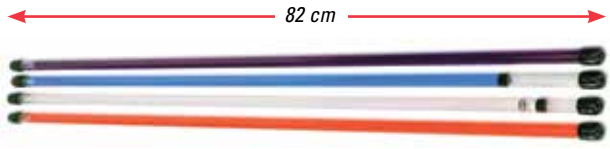


Constant Velocity Tubes effectively introduce the relationship between graphs and motion. Students can use a meter stick and a stopwatch to plot the position of the bubble as a function of time as it moves up the tube. Each tube has an obstruction that serves as the initial position for the bubble. The 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.

Includes both a bubble and a metal ball!



Order Information

Constant Velocity Tubes (4) SE-9072
Required:
Meter Stick (6 pack) SE-8827
PASCO Stopwatch ME-1234

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

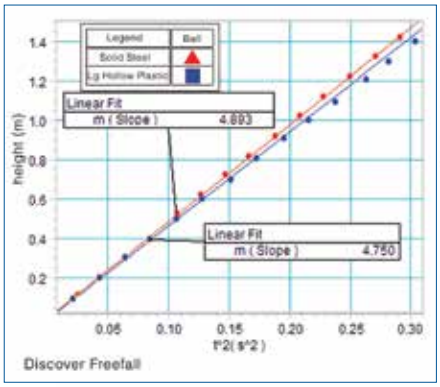
Discover Freefall System

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 186-189. The Drop Box also has built-in magnets to fasten directly to the ceiling.

Custom case with built-in rod clamp and magnets to fasten Drop Box to ceiling



Test button

Charging light

Set includes six different balls

Active feedback loop measures the magnetic field and adjusts current to null field and release ball in less than 1 ms.

This system can also accept the Target Accessory, ME-6854, to perform the shoot-the-target demonstration. See page 135.





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 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. 120
850/550 Interface		p. 26
Recommended:		
Freefall Balls Accessory	ME-9890	p. 193
Rods and Clamps		pp. 186-189

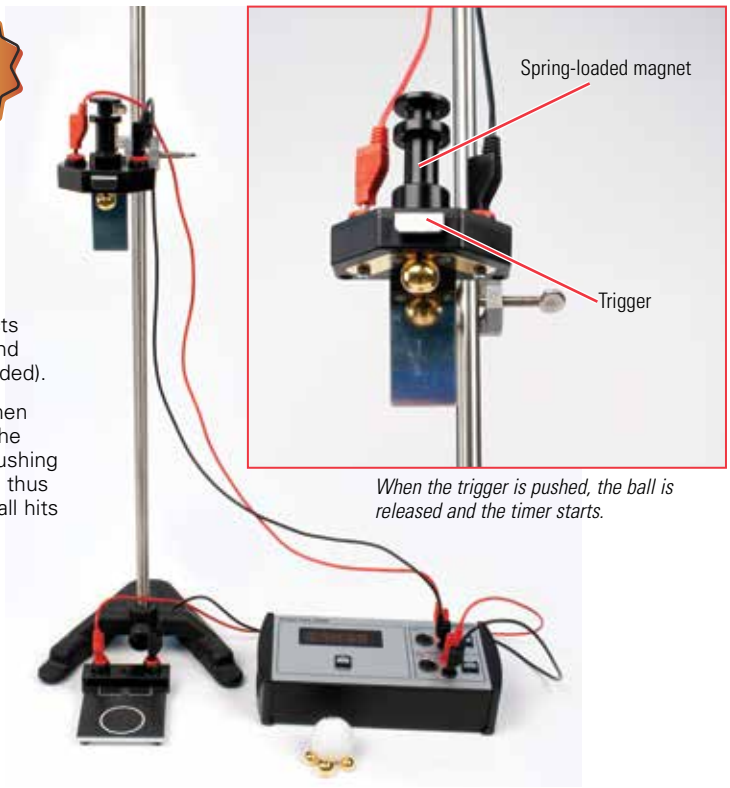
Freefall Apparatus

SF-7274

- Drop ball from rest and time the fall
- Explore effect of air drag on two different size balls with the same mass
- Precise and straight-forward device for measuring free fall

The acceleration of gravity g can be computed by measuring the drop distance and the fall time. The apparatus consists of a release mechanism that also acts as the start switch, a switch plate that acts as the stop switch, and conducting balls. The release mechanism and the switch plate are both connected to the Student Timer (not included).

The release mechanism has two contact plates that are shorted when the conducting ball being measured is in place and ready to drop. The steel ball is held in place by a spring-loaded neodymium magnet. Pushing the trigger will cause the ball to drop away from the contact plates, thus opening the counter start circuit just as the fall begins. When the ball hits the switch plate, the timer is stopped.



When the trigger is pushed, the ball is released and the timer starts.



When the ball hits the switch plate, the timer stops.

Order Information

Free Fall Apparatus	SF-7274	
Required:		
Student Timer	SF-7275	p. 122
Small A-base	ME-8976	p. 186
120 cm Stainless Steel Rod	ME-8741	p. 186
2 m Patch Cord Set	SE-9415A	p. 226
Replacement:		
Replacement Free Fall Ball Set	SF-7280	

Includes

- Magnetic release mechanism with mirror
- Switch plate
- 4 gold-plated steel balls (diameters 12 mm and 16 mm)
- Ping pong ball with same mass as 12 mm steel ball



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.



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.

Includes

- Ball release mechanism with stereo phone plug and receptor pad
- Four steel balls (1.9 cm,1.6 cm diameter)



Order Information

Freefall Timer Adapter	ME-9207B	
Required:		
Large Table Clamp	ME-9472	p. 189
Multi Clamp	ME-9507	p. 188
Rod (90 cm long)	ME-8738	p. 186
Photogate Timer	ME-9215B	p. 122
or Smart Timer	ME-8930	p. 120
or 850/550 Interface		p. 26

Projectile Launcher

ME-6800

- Accurate
- Durable



Add optional Smart Gate to measure launch velocity.



Three Repeatable Launch Ranges
Visible through viewing ports.

2.5 cm Nylon Balls

Plumb Bob
Indicates angle to 1/2°.

Loading Rod

Stable Launcher Base
Offers horizontal and variable angle launching positions.

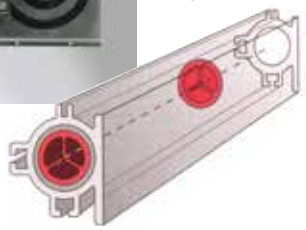
Unique Sights

Shoot-the-Target

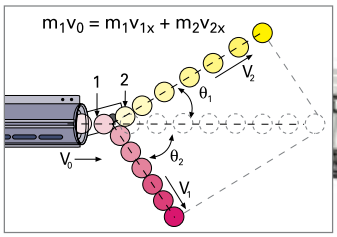
The "gun" is aimed directly at the target. Although the target "drops" the moment the projectile is fired, the ball still hits the target since the ball falls with the same acceleration.



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: 1.2, 3, 5 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
- Manual

Order Information

Projectile Launcher	ME-6800	
Shown in use with:		
Shoot-the-Target System	ME-6853	p. 135
Photogate Mounting Bracket	ME-6821A	p. 137
Smart Gate	PS-2180	p. 42
Recommended:		
Time-of-Flight Accessory	ME-6810A	p. 137
Large C-Clamp (6 pack)	SE-7285	p. 137
Plumb Bobs (10 pack)	SE-8728	p. 137

Launcher Spares Kit

ME-6802

Includes

- Loading Rod (10)
- 2-D Collision Accessory (2)
- Plastic Balls (10 pack)
- Sights (5 pack)
- Angle Indicator
- Plumb Bobs (12 pack)
- Thumbscrew to attach launcher to base (10)



Order Information

Launcher Spares Kit ME-6802

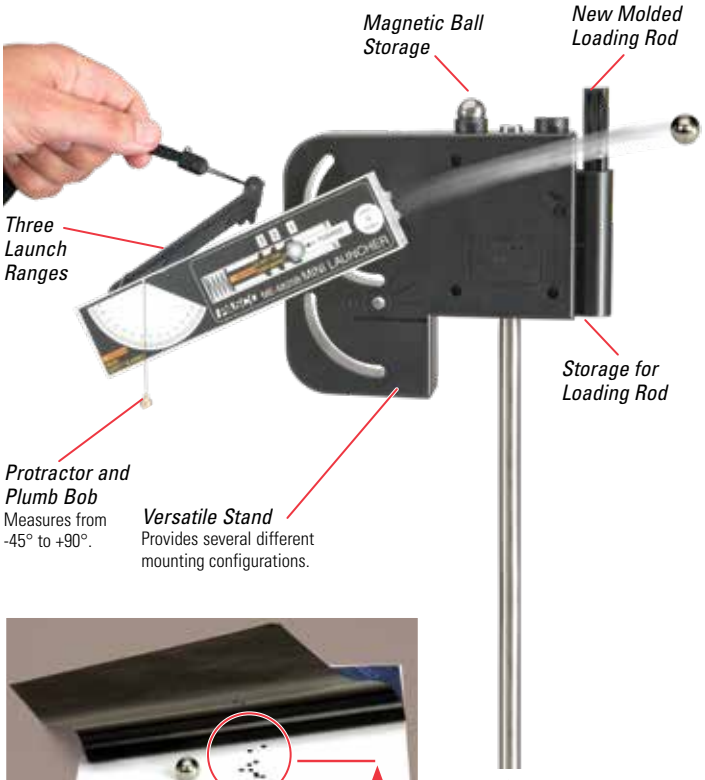
Mini Launcher

ME-6825B

- Ideal for tabletop projectile experiments
- Fires at downward angles
- Low cost

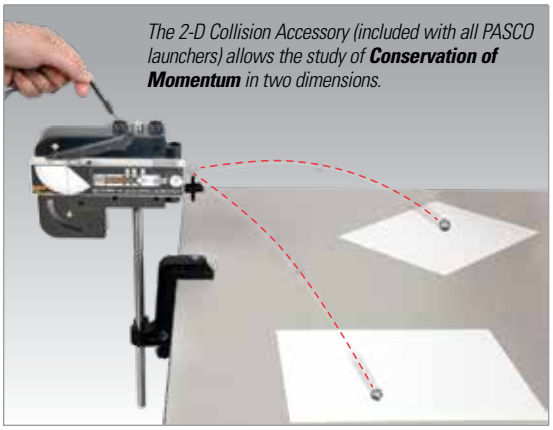
New bracket features include:

- Magnetic ball storage
- New plunger storage
- Shooting positions now labled



Typical pattern for Mini Launcher –
Ball was launched 10 times off 1 m 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
- Projectile Balls
- Loading Rod
- Safety Glasses
- 2-D Collision Accessory
- Manual

Order Information

Mini Launcher	ME-6825B	
Recommended:		
Photogate Mounting Bracket	ME-6821A	p. 137
Smart Gate	PS-2180	p. 42
Time-of-Flight Accessory	ME-6810A	p. 137
Large C-Clamp (6 pack)	SE-7285	p. 137
Steel Rod	ME-8736	p. 186
Plumb Bobs (10)	SE-8728	p. 137
Carbon Paper (100 Sheets)	SE-8693	p. 137
Metric Measuring Tape	SE-8712A	p. 192

Mini Launcher Spares Kit

ME-6824



Includes

- Loading Rod (10)
- 2-D Collision Accessory (2)
- Steel Balls (10 pack)
- Angle Indicator
- Plumb Bobs (12 pack)
- Thumbscrew to attach launcher to base (10)

Order Information

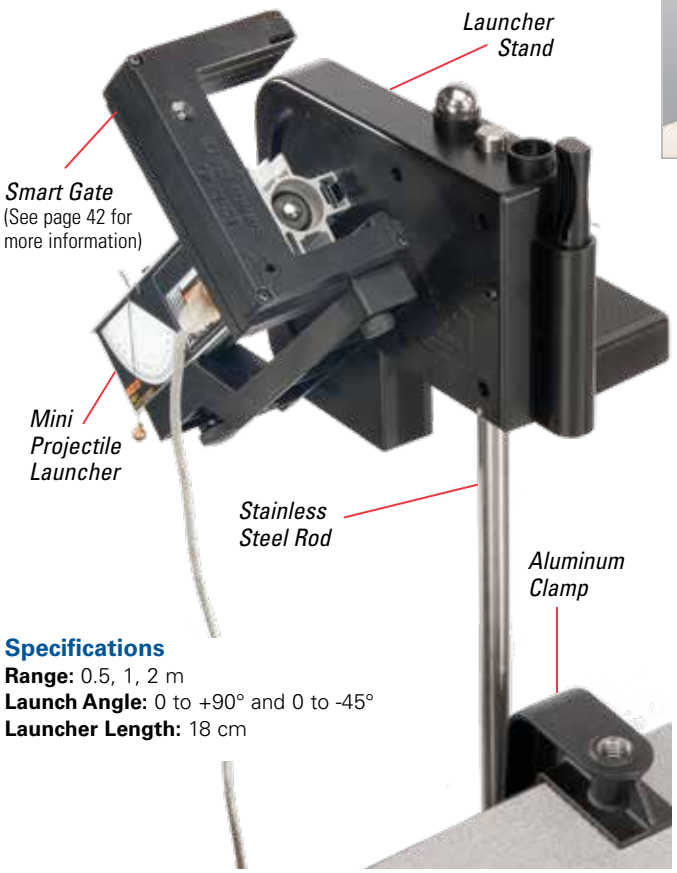
Mini Launcher Spares Kit..... ME-6824

Projectile Launcher Smart Gate System

ME-6798

- Vary height.
- Vary launch speed.
- Vary angle.
- 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 built-in photogate beams. 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.



Specifications

Range: 0.5, 1, 2 m
Launch Angle: 0 to +90° and 0 to -45°
Launcher Length: 18 cm

Includes

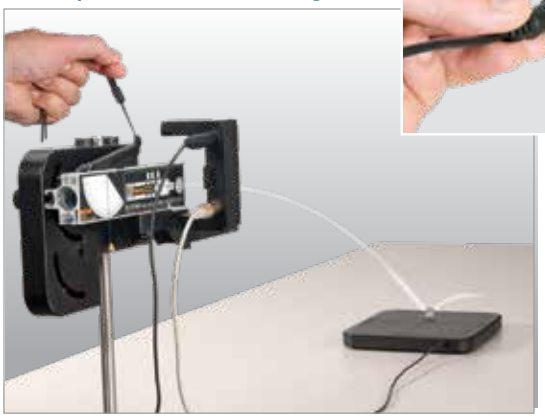
- Smart Gate with Mounting Bracket
- Launcher with Mounting Stand
- Steel Balls (2) with Loading Rod
- 2-D Collision Accessory
- Aluminum Table Clamp
- 45 cm Stainless Steel Rod



Order Information

Projectile Launcher Smart Gate System ME-6798
Shown in use with:
Time-of-Flight Accessory .....ME-6810A p. 135
Required:
PASPORT Interface

Add optional Time-of-Flight





Daisy-chain Time-of-Flight to Smart Gate.

Smart Gate connects directly to a PASPORT interface.

Projectile Launcher Wireless Smart Gate System

NEW

ME-6796

Choose this wireless option to eliminate cables between the computer and the projectile launcher. The Wireless Smart Gate has all the features of the Smart Gate (PS-2180), but it connects to your computing device via Bluetooth® or USB; it does not require an interface.



Includes

- Wireless 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

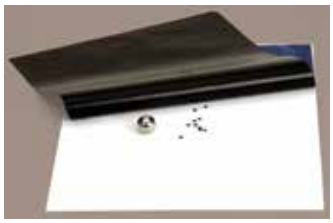
Order Information

Projectile Launcher
Wireless Smart Gate System.....ME-6796

Carbon Paper (100 sheets)

SE-8693

Use to mark the position of the ball.



Order Information

Carbon Paper (100 sheets) SE-8693

Time-of-Flight Accessory

ME-6810A

- For use with all PASCO launchers

Includes

- Time-of-Flight Accessory
- Instruction Manual
- Experiment Guide



Order Information

Time-of-Flight Accessory ME-6810A

Shoot-the-Target

ME-6853

- Demonstrate independence of *x*- and *y*-motion
- For use with all launchers

The PASCO Shoot-the-Target Accessory, in combination with a projectile launcher, demonstrates that acceleration is constant for all objects in freefall, regardless of initial velocity. A target is initially suspended near the ceiling, and a projectile launcher is aimed directly at it. As soon as the projectile is shot from the launcher, the target is released. The projectile hits the target as it falls, proving that both objects accelerate downward at the same rate.

Before it falls, the target is attached to the drop box by a permanent magnet so it can hang indefinitely, even when the drop box is not powered. A photogate detects the projectile as it leaves the launcher and triggers the drop box. The drop box releases the target by driving a current through a coil that cancels the field of the permanent magnet.



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:

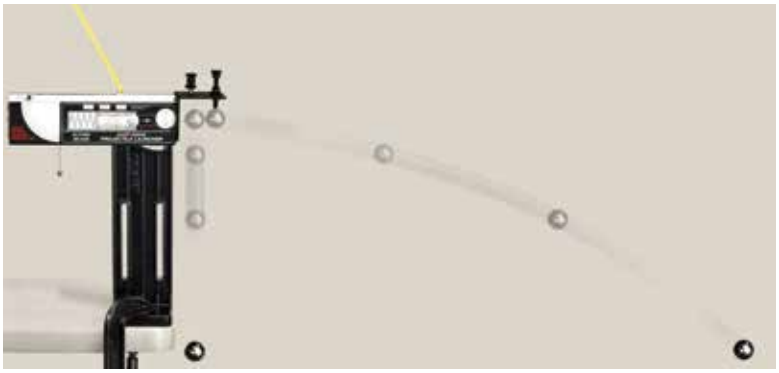
Projectile Launcher ..... ME-6800 p. 132

Mini Launcher ..... ME-6825A p. 133

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)



When the solid ball hits the hanging solid ball, the hanging ball shoots out horizontally, while the ball shot out of the launcher drops straight down.

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.



Either the solid steel ball or hollow steel ball is hung by a magnet.

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:
Projectile Launcher ..... ME-6800 p. 132

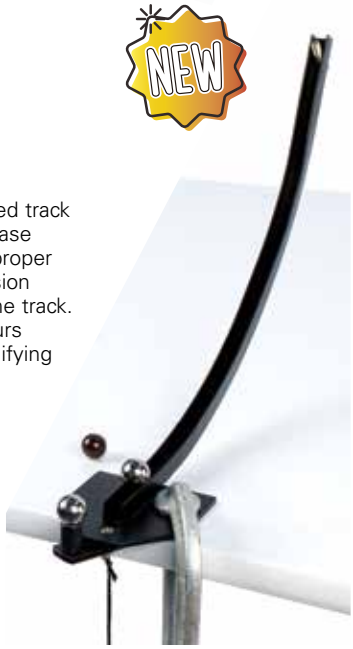
Ball Ramp

NEW

SE-7596

- Use for Projectile Motion
- Use for 2-D Collisions

This apparatus consists of a curved track with a base at one end. On the base is a support to hold a ball at the proper height for a center-to-center collision with a second ball rolling down the track. The track is level so collision occurs only in the horizontal plane, simplifying calculations.



Includes

- 25 cm one-piece track
- 3 balls (12 mm diameter): 2 steel, 1 glass
- Plumb bob

Order Information

Ball Ramp SE-7596

Drop-Shoot Demo

NEW

SE-7592

- Demonstrates the independence of horizontal and vertical components of projectile motion

Releasing the spring causes one ball to drop directly down while the other is projected horizontally. Listen and you'll hear that both hit the floor at the same time! The Drop-Shoot Demo is 25 cm long.

Includes

- Metal base with spring launcher
- Rod (10 cm long)
- Steel balls (2)



Order Information

Drop-Shoot Demo SE-7592

Time-of-Flight Accessory

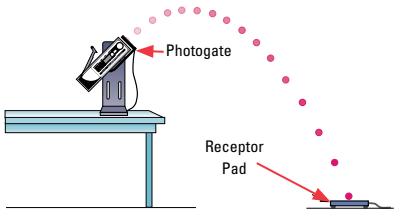
ME-6810A

▸ 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
- Experiment Guide

Order Information

Time-of-Flight Accessory ME-6810A

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. 43
Accessory Photogate ..... ME-9204B p. 43

Small Steel Balls (10 pack)

ME-9872



These 1.6 cm diameter steel balls are used with the Mini Launcher (ME-6825B).

⚠ 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.

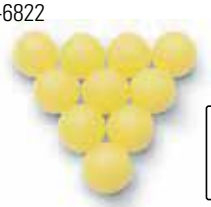
Purchase this 4 pack of 2.5 cm diameter balls for use with PASCO Short or Long-Range Projectile Launchers (ME-6800 or ME-6801).

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.

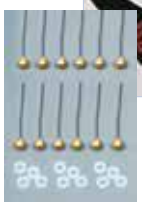
Order Information

Projectile Launcher Sights (5 pack) ME-9865

Projectile Launcher Plumb Bobs (12 pack) ME-9868A



This kit includes 12 brass plumb bobs and 12 washers to replace lost or broken parts from any of PASCO's projectile launchers.



Order Information

Projectile Launcher Plumb Bobs (12 pack) ME-9868A

"C" Clamps

SE-7285

These rugged clamps are perfect for attaching a variety of objects to a table. Size 10 cm (4 inch).



Order Information

"C" Clamp (6 pack) SE-7285

Plumb Bobs (10 pack)

SE-8728



Order Information

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

Ballistic Pendulum

ME-6830

- Extremely accurate: ±2.5% of predicted values
- Both elastic and inelastic experiments
- Projectile launcher experiments
- Now includes ME-6800 bracket!

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.

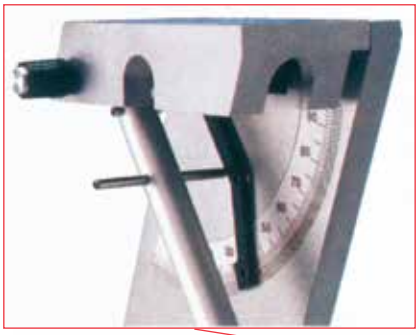
Using the projectile mass, the pendulum mass, and the rise in pendulum height, students can calculate the gravitational potential energy of the system.

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.

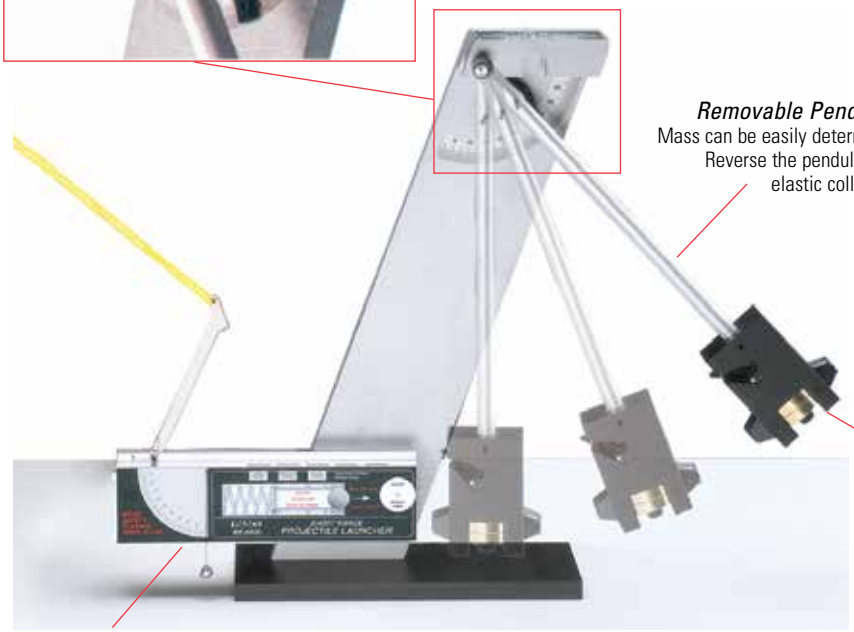
Applying the Law of Conservation of Momentum, the projectile's speed is easily calculated.

An additional mounting bracket is included to perform the full range of projectile launcher experiments.





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.

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 page 132).

Includes

- Ballistic Pendulum and Base
- Projectile Launcher
- Projectile Launcher Base
- 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. 137
Shoot-the-Target	ME-6853	p. 135
Time-of-Flight	ME-6810A	p. 45
Large C Clamp (6 pack)	SE-7285	p. 137

Already own a PASCO Projectile Launcher?

The base and pendulum assembly can be purchased separately.

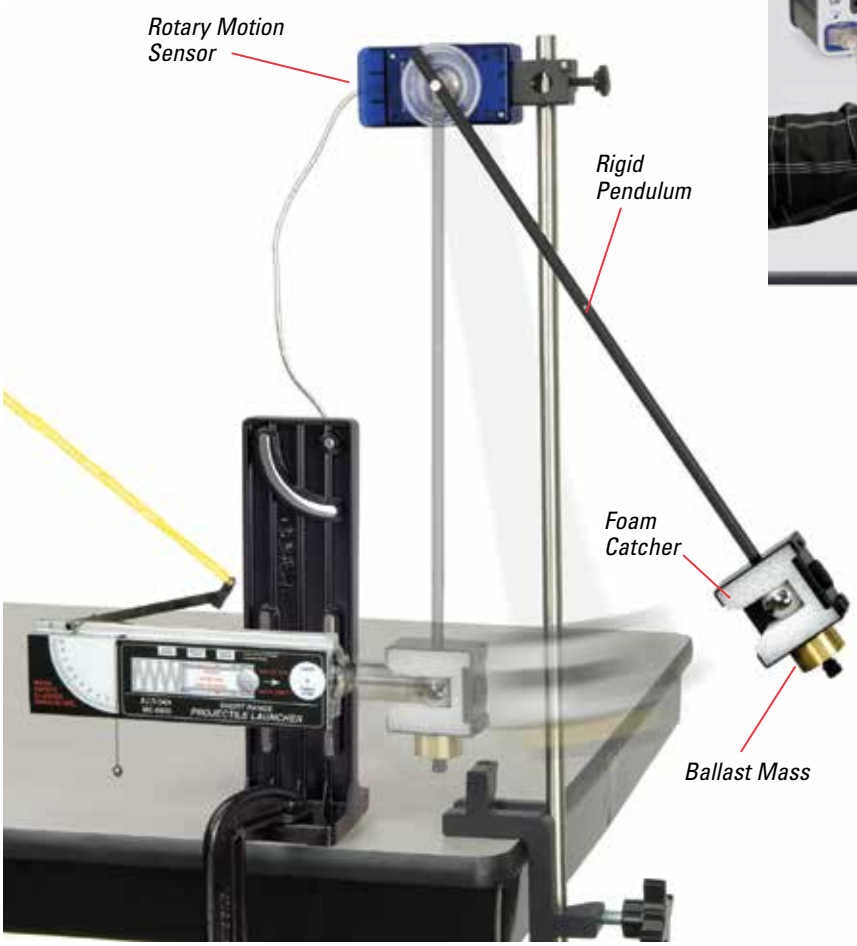
See Ballistic Pendulum (No Launcher) in the order block for more information.

Ballistic Pendulum Accessory

ME-9892 (for use with the ME-6800 Projectile Launcher on page 132)

- Both are accessories to the Rotary Motion Sensor
- For elastic and inelastic experiments
- Low cost

Both of these 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 a detailed study of the collision using conservation of angular momentum.



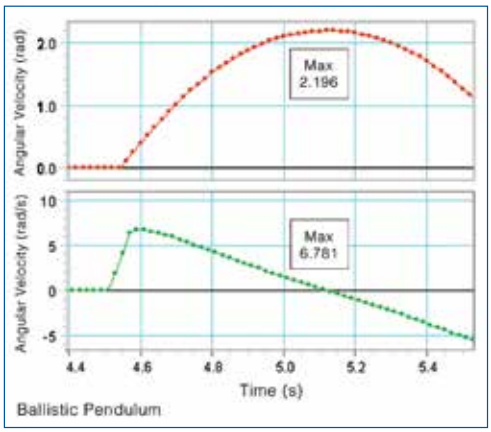
Order Information

Ballistic Pendulum Accessory	ME-9892	
Required:		
Projectile Launcher	ME-6800	p. 132
Rotary Motion Sensor	PS-2120A	p. 33

Mini Launcher Ballistic Pendulum Accessory

ME-6829 (for use with the ME-6825B Mini Launcher on page 133)





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.

Both accessories include:

- Pendulum Arm with Catcher
- Ballast Mass
- Steel Ball



Order Information

Mini Launcher Ballistic Pendulum Accessory	ME-6829	
Required:		
Mini Launcher	ME-6825B	p. 133
Rotary Motion Sensor	PS-2120A	p. 33

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. Simultaneously pull the string of each from the same vertical height down to the base. 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

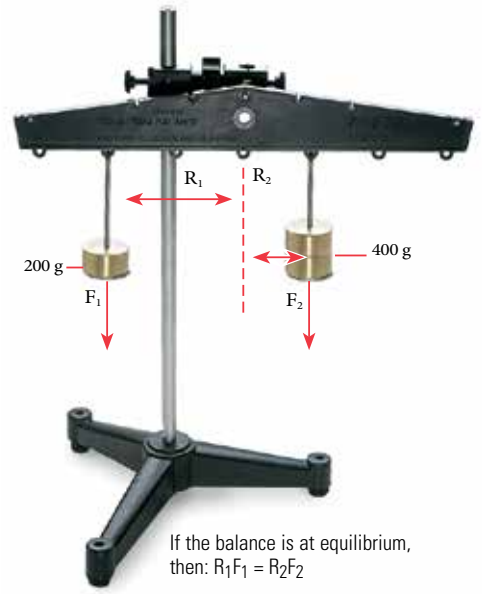
Pulley Demonstration System..... SE-8685

Equal Arm Balance

ME-8949

Developed for Workshop Physics® activities

The Equal Arm Balance was specially designed to simplify the study of torques. This balance has a ball-bearing pivot.



With 200 g and 400 g masses placed as shown above, the balance remains in equilibrium.

Specifications

Total length: 34 cm
Maximum weight exerted on balance arm: 1 kg or 10 N



Includes

- Balance Arm with Ball-Bearing Pivot

Order Information

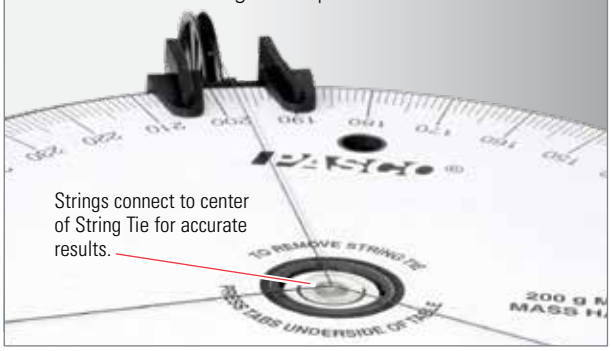
Equal Arm Balance..... ME-8949
Required:
Drilled Mass and Hanger Set..... ME-8979 p. 197

Force Table

ME-9447B

- High accuracy
- Easy, compact storage
- Inexpensive!

String tie
String Tie is captured to make setup 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
- Adjustable Super Pulleys with Clamps (3)
- Spool of thread (1)



Mass and Hanger Set is sold separately.

Order Information

Force Table.....ME-9447B
Required:
Mass and Hanger Set.....ME-8979 p. 197
Additional Pulleys:
Super Pulley with Clamp .....ME-9448B p. 190

Tension Protractor

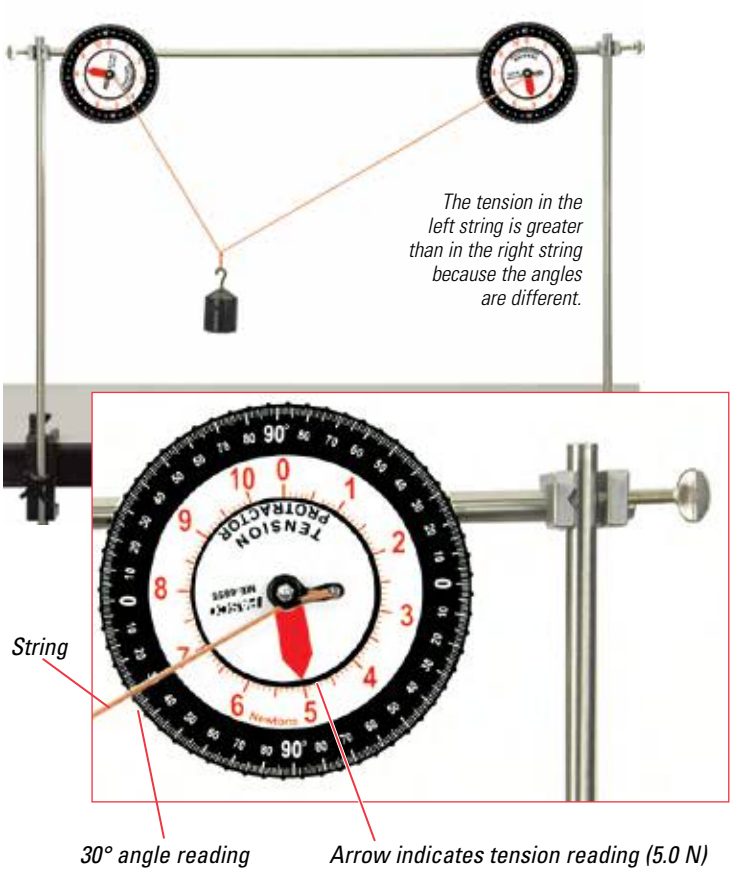
ME-6855

- Measure tension and angle with one device
- Large scale for viewing demonstrations
- Zero-adjust for torsion spring scale
- Built-in rod clamp

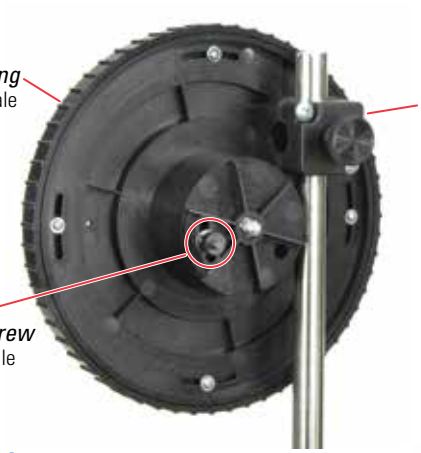
The Tension Protractor is a spring scale and a protractor integrated into one device. Perfect for static equilibrium experiments, the rotary dial indicates the tension in the string and the angle is read where the string passes over the degree scale on the outer ring. Since the Tension Protractor is supported on a rod, it has an advantage over other spring scales that tend to weigh down the string, changing the angle.

The string is wrapped once around a small pulley that is spring-loaded. The torsion spring scale is carefully calibrated at the factory and can be zeroed by the user using the thumb screw on the back. The red arrow that indicates tension is color-coded to match the Newton scale.

Even if the mounting rod is not plumb, the Tension Protractor's degree scale can be adjusted to read 90 degrees vertically by rotating the outer ring until the string with a hanging mass aligns with 90 degrees.



The tension in the left string is greater than in the right string because the angles are different.



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



A 50 gram mass hangs vertically from the Tension Protractor: The tension reads 0.5 N as expected and the outer degree scale is dialed to align the 90° mark with the string. This compensates for unlevel tables or bent rods.

Order Information

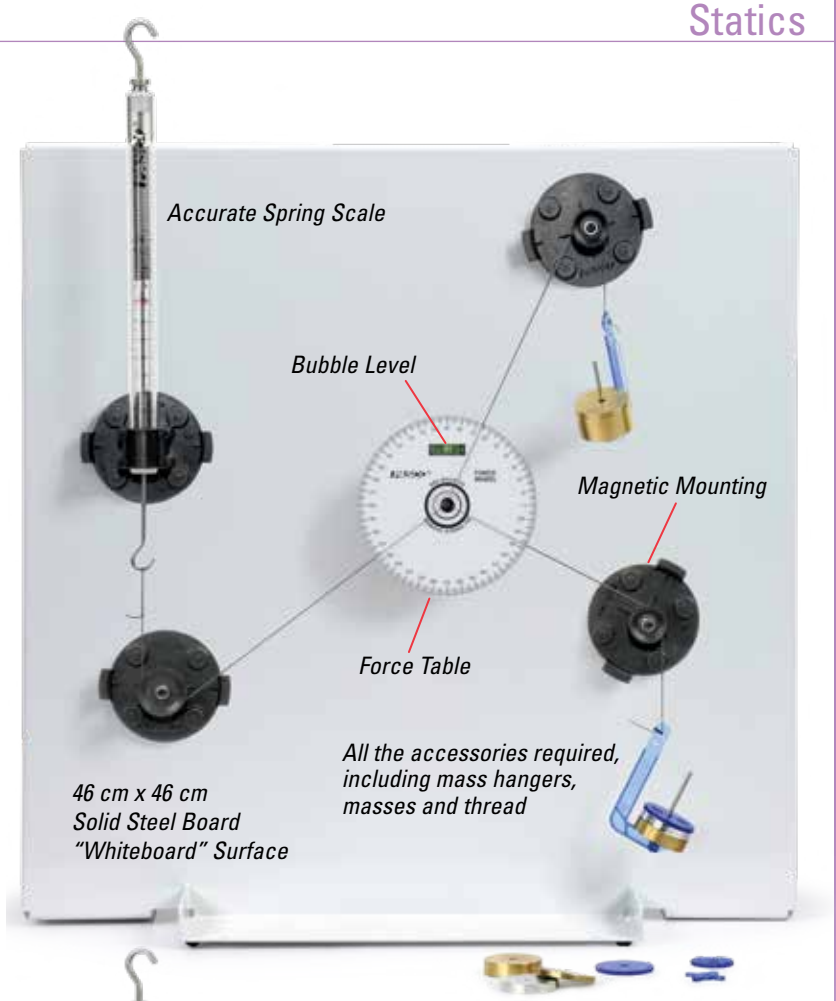
Tension Protractor	ME-6855	
Recommended:		
Large Table Clamp	ME-9472	pp. 188-189
90 cm Long Rod	ME-8738	p. 186
Multi-clamp	ME-9507	pp. 188-189
Hooked Mass Set	SE-8759	p. 197

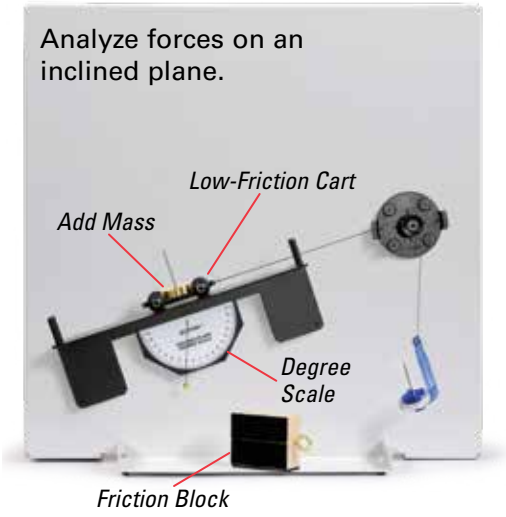
Statics System

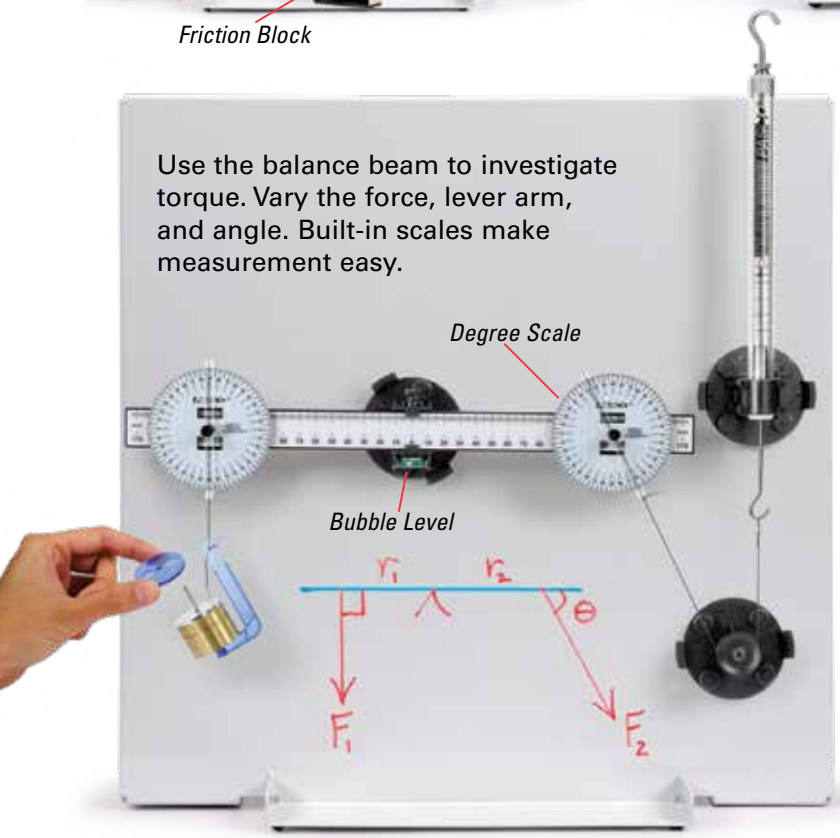
ME-9502

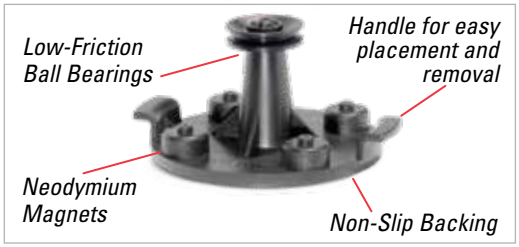
- Everything required for 15 experiments
- Comprehensive — from vector addition to simple machines
- Easy Setup — magnetic mounting

Here is 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
- Comprehensive Manual

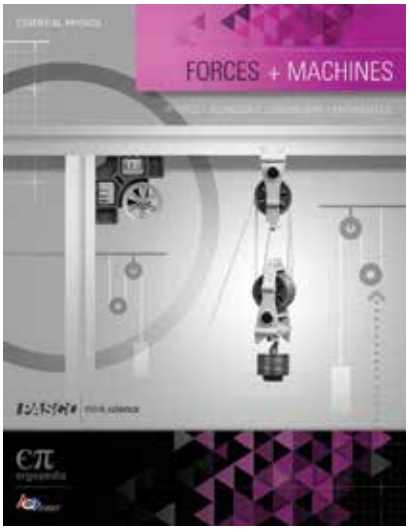
Order Information

Statics System	ME-9502
Additional Equipment:	
Statics Board	ME-9503
Spring Scale	ME-9824A
Statics Spares Package	ME-9504

Simple Machines Teacher Resources

EP-6483

- A single teacher guide is all you need to outfit your class or lab.
- Complete with guided inquiry lab activities, suggested answers, and much more
- Requires Simple Machines Engineering Kit



Questions are embedded throughout the activities. Other features include sequencing and key-term challenges. Opportunities to predict outcomes prior to data collection and post-lab multiple choice questions help to make the connection between lectures and labs as seamless as possible. And the lab activities are correlated to state and national standards.
For more information, visit **pasco.com**

Simple Machines Engineering Kit

EP-3577

Our Simple Machines Engineering Kit engages students in a wide range of physics, physical science, and engineering concepts. Two triple-pulley blocks make it easy to build machines with mechanical advantage up to 6:1. Build all three classes of levers with our pair of 20-cm levers, or combine gears, levers, and pulleys together to show how rotating machines work.

Includes

- 10 N Metal Spring Scales (2)
- Tripod Stands (2) & Crossrail
- Universal Spring Hanger (2)
- Right-angle Connector with Pulley (2)
- Fixed Triple Pulley Block
- Hanging Triple Pulley Block
- Friction Block
- Quick-attach Gear Hubs (4)
- Gear Spacers (12)
- 20 cm Levers (2)
- 60 Tooth Spur Gears (2)
- 40 Tooth Spur Gears (2)
- 20 Tooth Spur Gears (3)
- 20 cm-diam. Large Pulleys (2)
- Weights
- String
- Gratnells® Storage Tray



Assembly shows included components.





Order Information

Simple Machines Teacher Resources EP-6483
Required:
Simple Machines Engineering Kit EP-3577

Tripod Stand

EP-3572

Includes

- 68.6 cm extruded aluminum vertical rail
- Wide tripod base with aluminum legs and rubber feet
- Includes 5 sliding 14-20 inserts, already installed



Order Information

Tripod Stand EP-3572

Weights

EP-3563

Includes

- 2 mass hangers
- 25 fender washer masses



Order Information

Weights EP-3563

Super Pulley

ME-9450A

- 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
- Lightweight
- Precision dimensions

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

Smart Gate Pulley System

PS-3702



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)

Order Information

Smart Gate Pulley System.....PS-3702

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

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

Mounting Rods (10 pack)

ME-9483



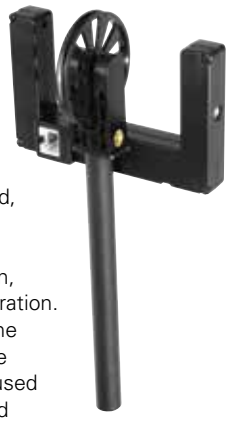
These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) screw into a Super Pulley.

Order Information

Mounting Rods (10 pack) ME-9483

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 44.

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

- Pulleys (2)
- Connecting Rod (1)

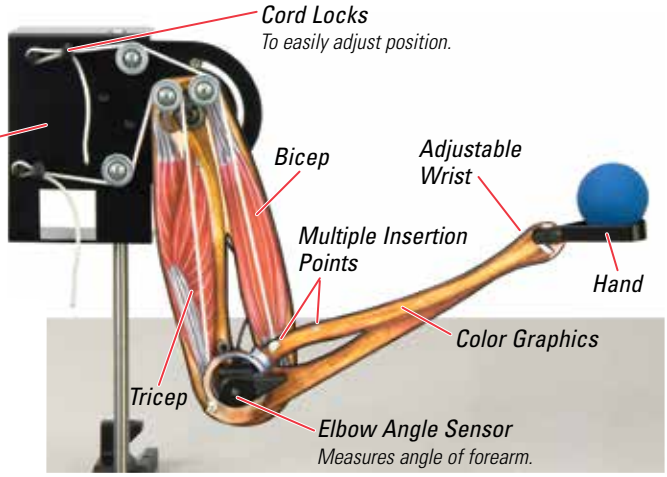
Order Information

Atwood's Machine.....SA-9241

Human Arm Model

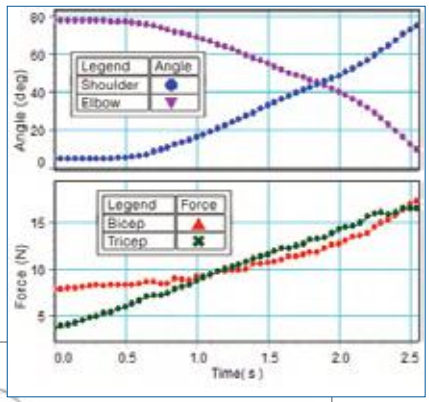
PS-2611

- Working model of the human arm
- Associate tricep/bicep muscle action with arm motion
- Measure torque resulting from lifting weights
- Actually throws a ball

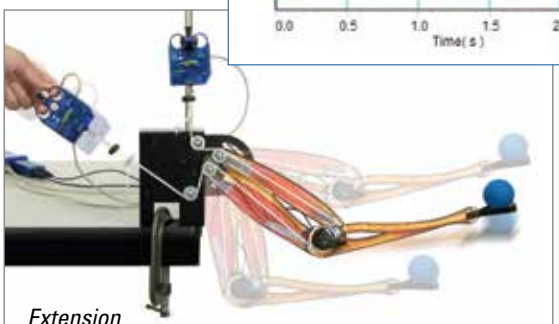


The Human Arm Model simulates the muscles and motion of an actual human arm. To activate the arm motion, students pull on the cord with a Force Sensor. Changes in position are measured at the shoulder and elbow using the two built-in potentiometers plugged into one Angle Sensor (PS-2139), included with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

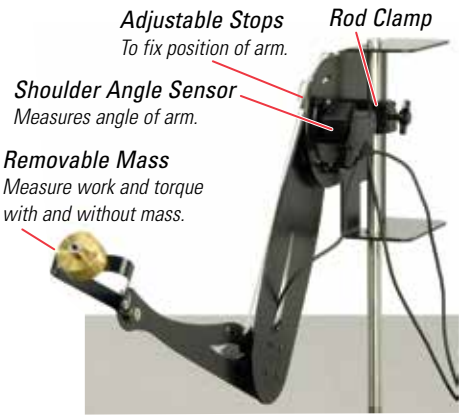
The Arm can perform many types of motion such as extending and lifting an object, curling, or throwing a ball overhand. Different arm muscles are activated depending on which pulleys are selected. Static force measurements can also be made to see how the muscle tension changes at various arm positions.

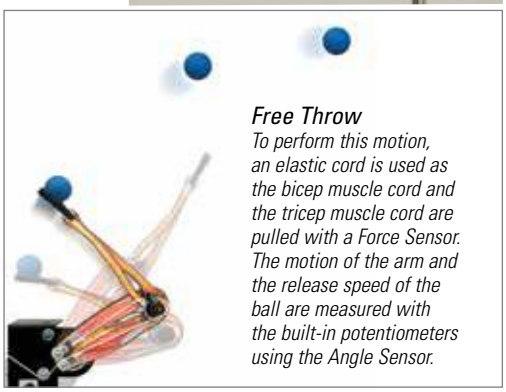


Angles and Forces During Extension:
The upper graph shows the angles of the elbow (violet trace) and the shoulder (blue) as the arm is extended as shown in the picture at right. Shown in the lower graph, the bicep tension (red) has little change at first and then rises sharply as the arm reaches out,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

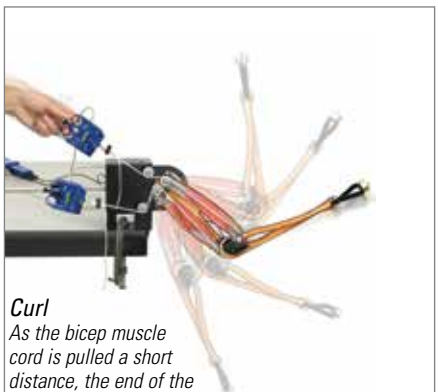


Extension
As the tricep muscle cord is pulled with a Force Sensor, another fixed Force Sensor records the tension in the bicep muscle cord.





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

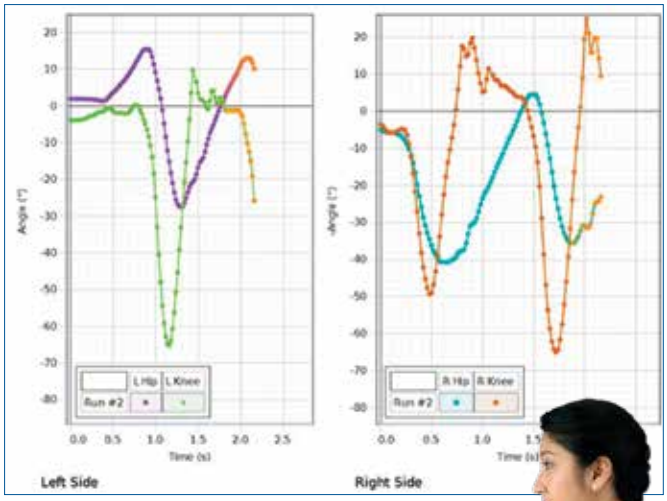
Human Arm Model	PS-2611	
Required:		
"C" Clamp or Large Table Clamp		pp. 188-189
Force Sensor (2)	PS-2104	p. 36
850 Universal Interface	UI-5000	p. 26

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
- Velcro Straps



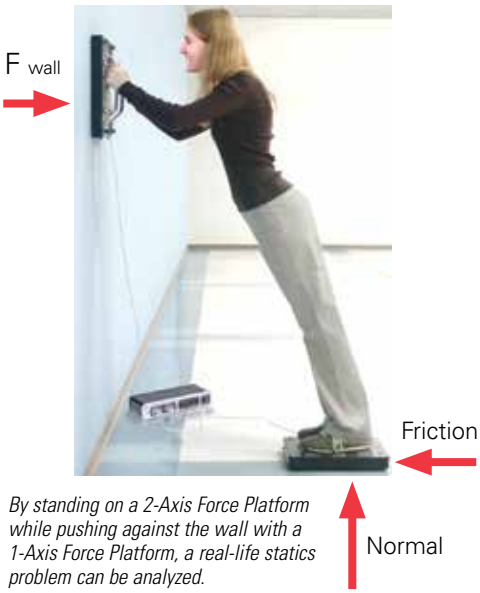
Order Information

Goniometer Sensor	PS-2137	
Recommended:		
SPARKlink Air	PS-2011	p. 30
Additional Velcro Straps	PS-2547	
Additional Goniometer Probe	PS-2138	

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) and can be mounted on one 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	PS-2142	p. 40
Force Platform	PS-2141	p. 40
Recommended:		
Handle Set	PS-2548	p. 40

Build any structure and instrument it.

Load Cell & Amplifier Set (6-port)

PS-2199

Dual Load Cell & Amplifier Set (2-port)

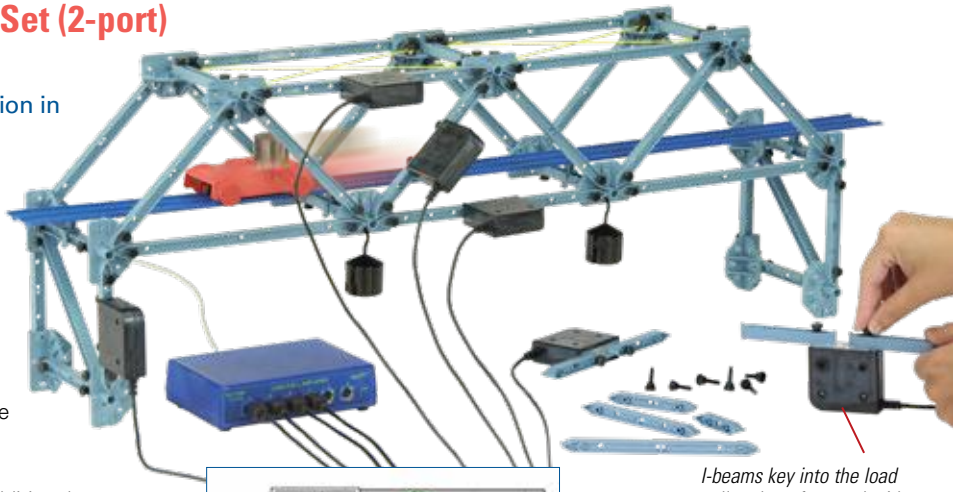
PS-2206

- Measure the compression and tension in the I-beam members
- Insert load cells into structures by substituting beams
- Use more than 6 load cells by connecting multiple amplifiers to one computer

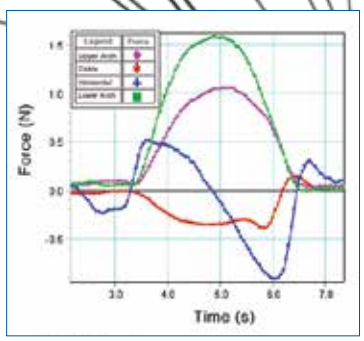
A load cell can be inserted into the design by replacing one beam with a load cell connected to two shorter beams. There is no need to completely disassemble the structure to add instrumentation.

PS-2199 includes four 100 N Load Cells; additional load cells can be purchased separately.
For more information, see page 38.

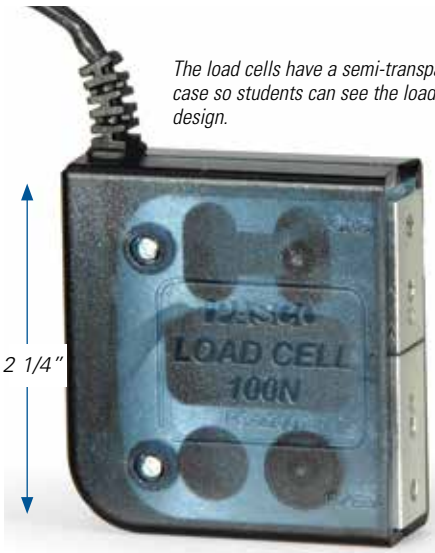
Shown in use with Bridge Set ME-6991.
Sold on page 150.



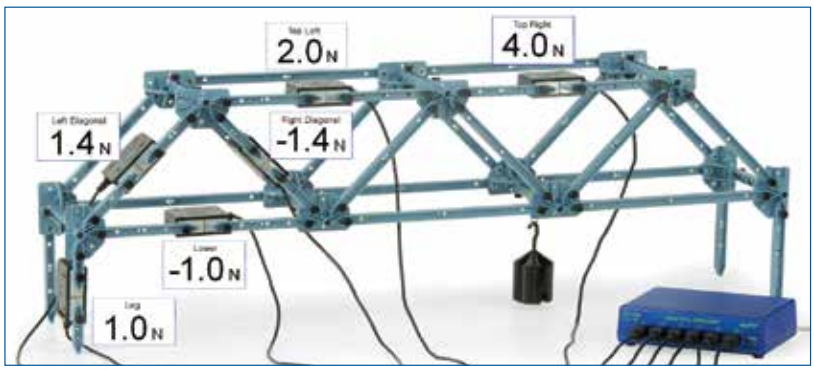
I-beams key into the load cell and are fastened with thumb screws.



As the car crosses the bridge, the forces measured by each load cell are graphed in real-time in PASCO Capstone™. Notice the diagonal member (green trace) switches from compression to tension as the car passes by.



The load cells have a semi-transparent case so students can see the load cell design.



Forces measured by Load Cells are displayed on a computer using PASCO Capstone software. A positive value represents compression.

Load Cell & Amplifier Set

PS-2199

Includes

- Load Cell Amplifier (6-port)
- 100 N Load Cell (4)



Dual Load Cell & Amplifier Set

PS-2206

Includes

- Load Cell Amplifier (2-port)
- 100 N Load Cell (1)



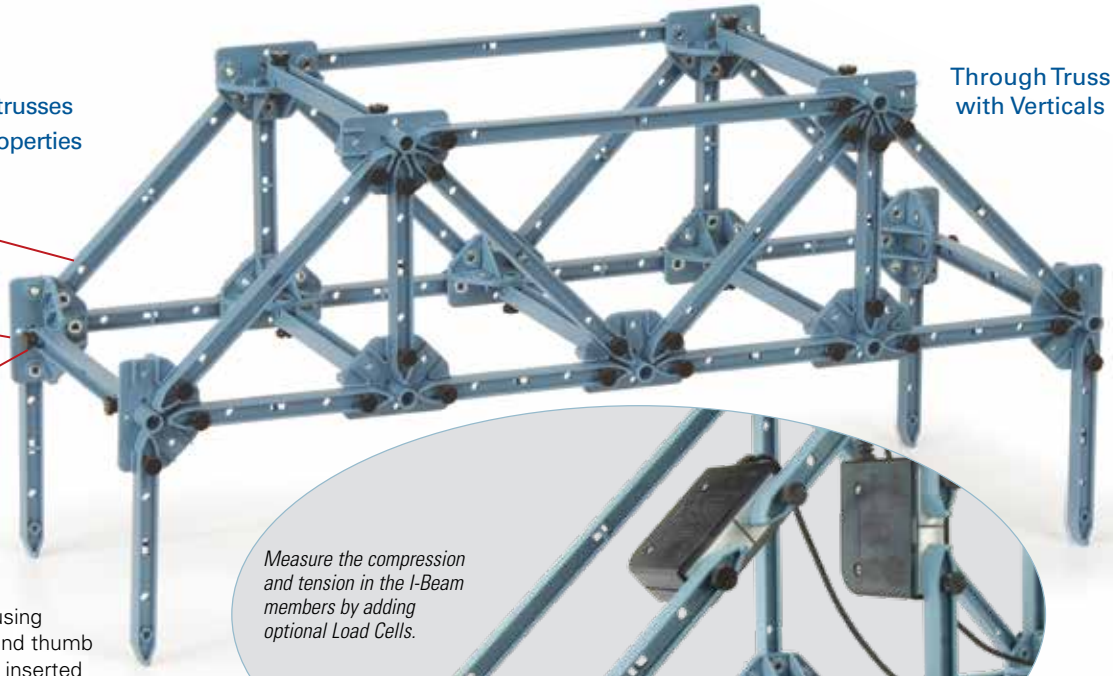
Order Information

Load Cell & Amplifier Set (6-port) (includes 4 load cells)	PS-2199	p. 38
Dual Load Cell & Amplifier Set (2-port) (includes 1 load cell)	PS-2206	p. 38
Required:		
PASPORT Interface to USB Computer		p. 24-25
Recommended:		
Additional 100 N Load Cell	PS-2200	p. 39
Load Cell 5 N	PS-2201	p. 39
Hooked Mass Set	SE-8759	p. 197

Truss Set

ME-6990

- Teach the basics of trusses
- Demonstrate the properties of I-Beams



Through Truss with Verticals

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.

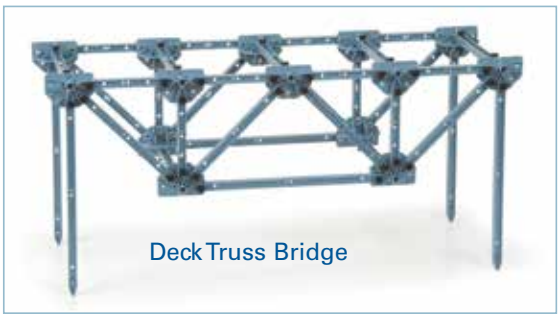






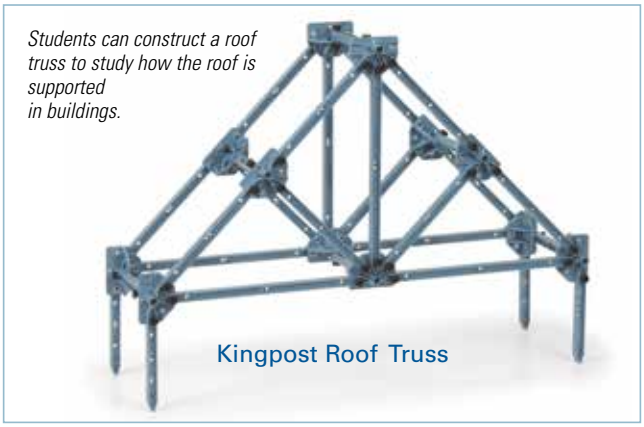
I-Beams key into the load cell and are fastened with thumb screws.





Deck Truss Bridge

Students can construct a roof truss to study how the roof is supported in buildings.



Kingpost Roof Truss

Truss Set 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), Screws (75), and Instruction Manual



Order Information

Truss Set* ME-6990

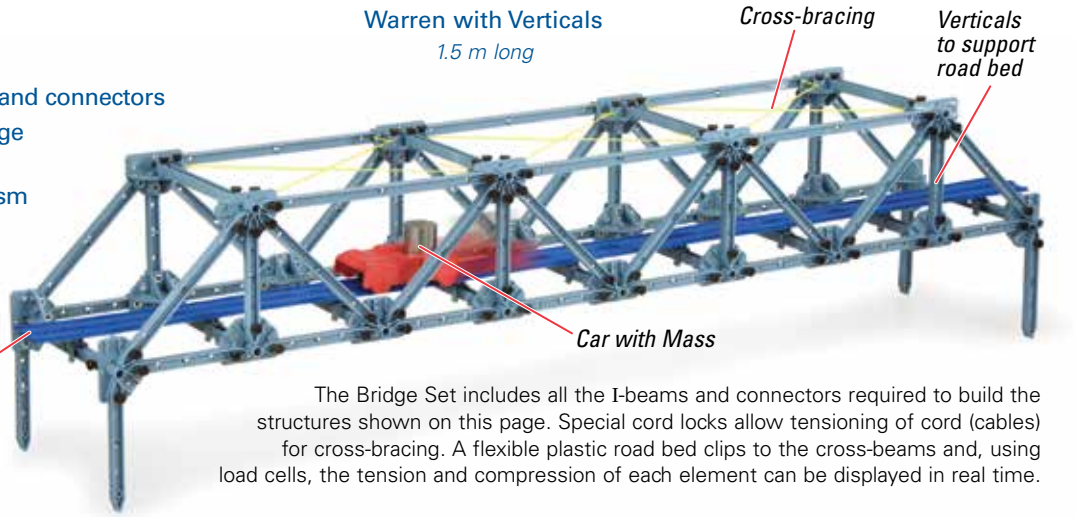
Recommended:

Load Cell & Amplifier Set (includes four load cells) ..... PS-2199 p. 38

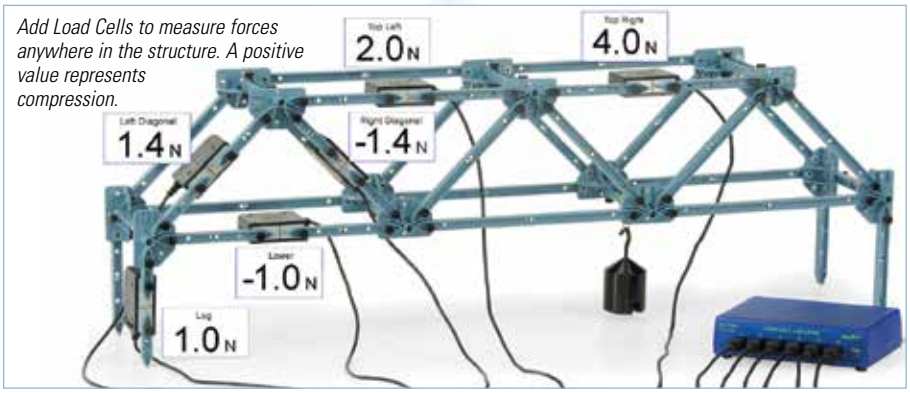
Bridge Set

ME-6991

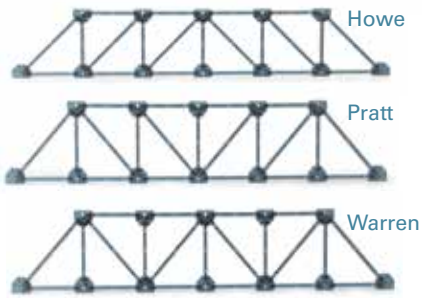
- Larger quantity of I-beams and connectors
- Study the principles of bridge construction
- Road bed and car add realism to bridges
- Add Load Cells to see dynamic loading as car traverses bridge



The Bridge Set includes all the I-beams and connectors required to build the structures shown on this page. 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.

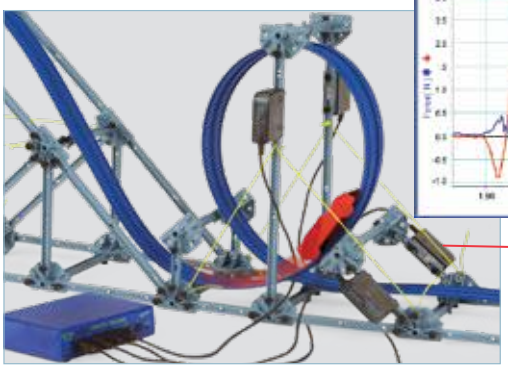


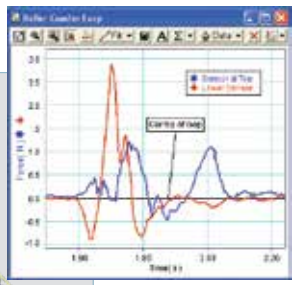
Add Load Cells to measure forces anywhere in the structure. A positive value represents compression.



Students can build several types of fundamental bridges including Howe, Pratt, and Warren bridges.

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 p. 126 for more roller coasters.

Deck Truss
80 cm long



Waddell "A" Truss
1 m long



The Waddell "A" Truss uses a cord (cable) for the center vertical member.

Bridge Set Includes

- I-beam #5 (16) 24 cm long
- I-beam #4 (36) 17 cm long
- I-beam #3 (36) 11.5 cm long
- I-beam #2 (16) 8 cm long
- I-beam #1 (16) 5.5 cm long
- Connectors (28)
- Screws (150)
- Flexible road bed (3 m)
- Track coupler
- Road bed clips (24)
- Car with flag and mass
- Starter bracket
- Cord tensioning clips (32)
- Yellow cord (1 roll)
- Instruction manual



Order Information

Bridge Set ME-6991

Recommended:

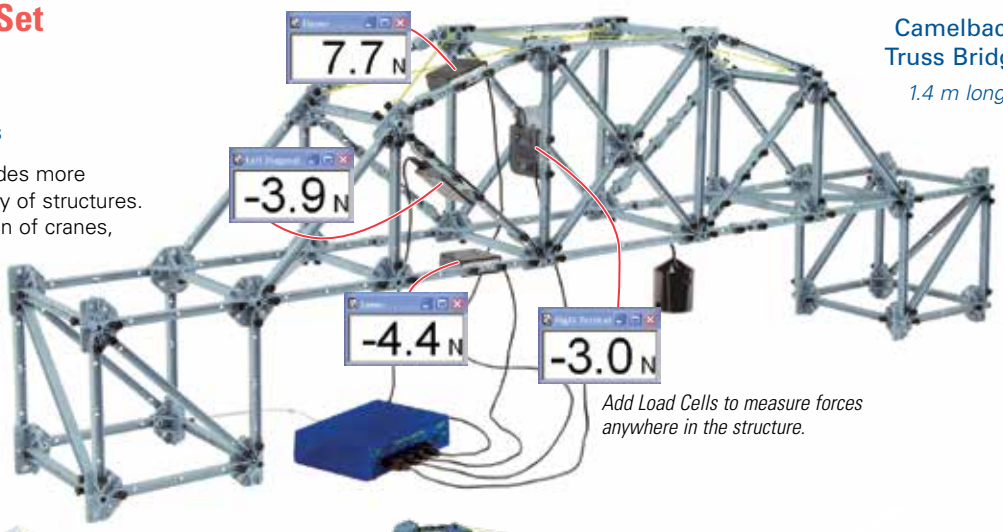
Load Cell & Amplifier Set
(includes four load cells) ..... PS-2199 p. 38

Advanced Structures Set

ME-6992B

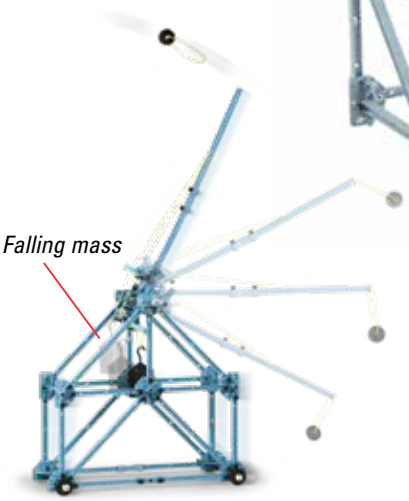
- Build larger bridges
- Build cranes, catapults, cars

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!



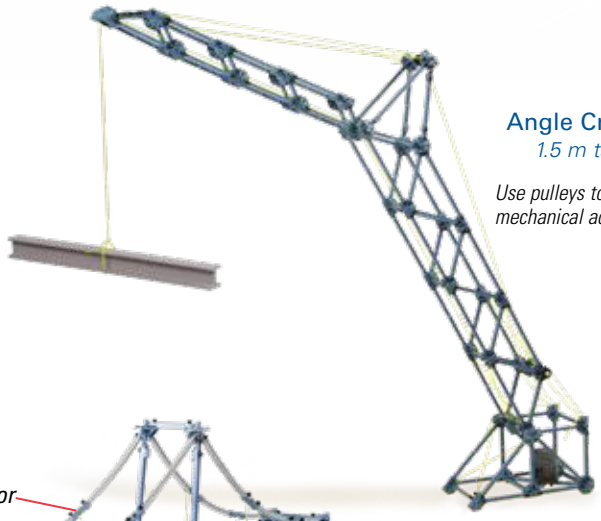
Camelback Truss Bridge
1.4 m long

Add Load Cells to measure forces anywhere in the structure.



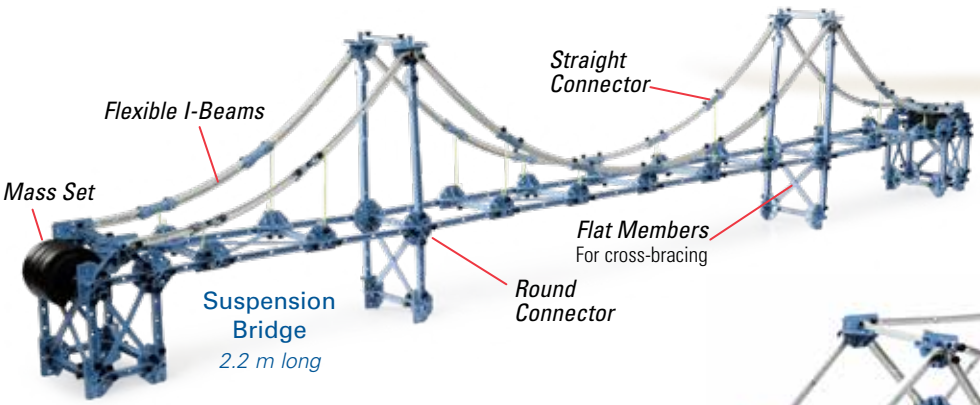
Catapult
60 cm tall

Throws a projectile over 10 meters! Wheels allow catapult to move.

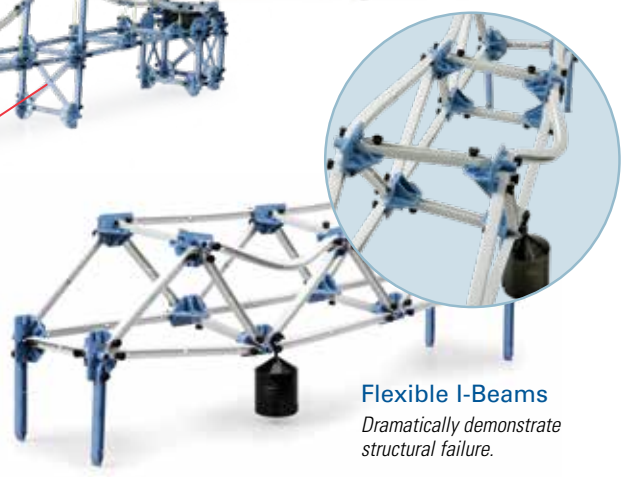


Angle Crane
1.5 m tall

Use pulleys to investigate mechanical advantage.



Suspension Bridge
2.2 m long



Flexible I-Beams
Dramatically demonstrate structural failure.

Advanced Structures Set Includes:

- Force Platform Bracket (2)
- I-Beam #5 (24) 24 cm long
- I-Beam #4 (54) 17 cm long
- I-Beam #3 (54) 11.5 cm long
- I-Beam #2 (24) 8 cm long
- I-Beam #1 (24) 5.5 cm long
- Flex I-Beam #5 (10) 24 cm long
- Flex I-Beam #4 (18) 17 cm long
- Flex I-Beam #3 (18) 11.5 cm long
- Flat Beams (16 ea. of 3 lengths)
- Axles (2 ea. of 3 lengths)
- Connectors (42)
- Cord Tensioning Clips (32)
- Round and Flat Connectors (6 ea.)
- PAStrack Fasteners (6)
- Angle and Straight Connectors (24 ea.)
- Sliding Connector (12)
- Pulleys, O-rings, Spacers (12 ea.)
- Collets (24)
- Drive Wheel with Rubber Tire (4)
- Structures Rod Clamps (2)
- Screws (300)
- Yellow Cord (1 roll)
- Instruction Manual





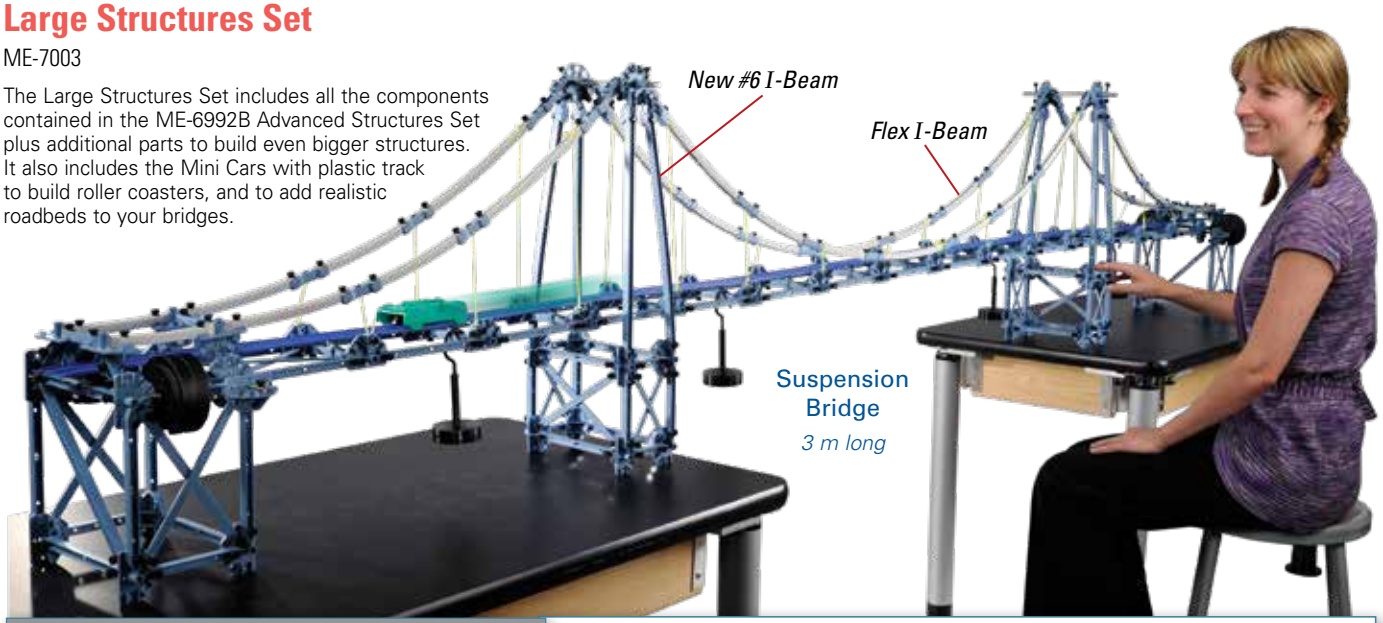
Order Information

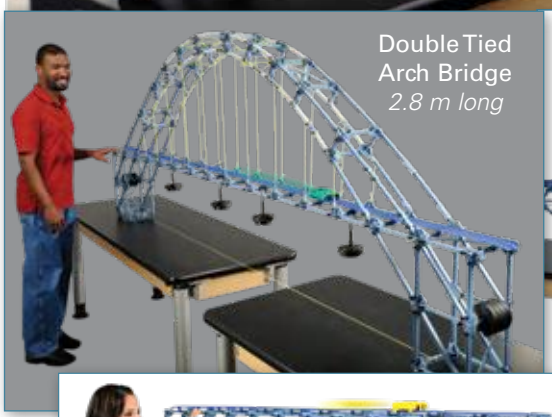
Advanced Structures Set.....ME-6992B
Shown in use with:
Load Cell & Amplifier Set
(includes four Load Cells).....PS-2199
Hooked Mass Set.....SE-8759
Large Slotted Mass Set.....ME-7566

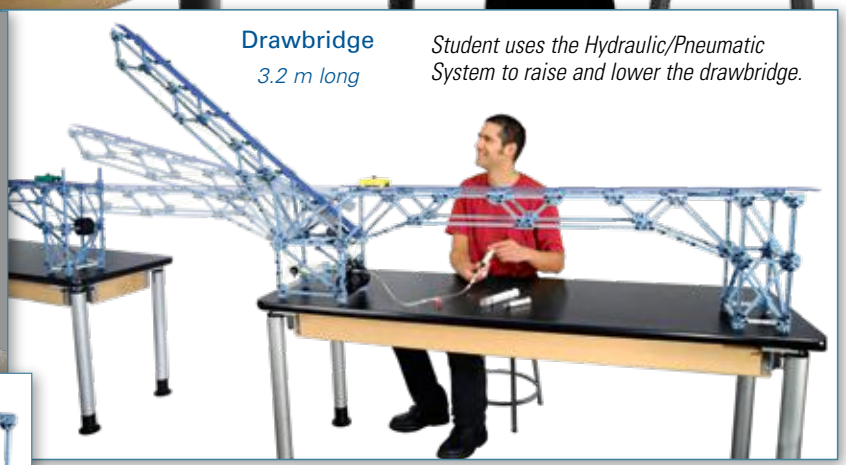
Large Structures Set

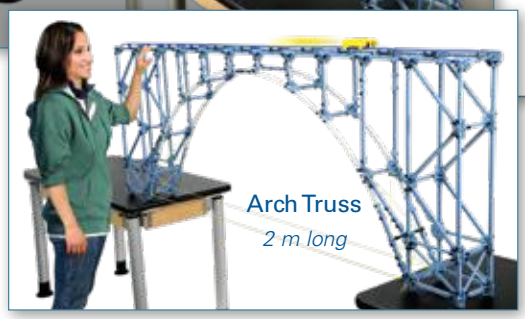
ME-7003

The Large Structures Set includes all the components contained in the ME-6992B Advanced Structures Set 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.









Add load cells to measure forces anywhere in the structure.



Large Structures Set Includes

- I-Beam #6 (24) 35 cm long
- I-Beam #5 (24) 24 cm long
- I-Beam #4 (54) 17 cm long
- I-Beam #3 (54) 11.5 cm long
- I-Beam #2 (24) 8 cm long
- I-Beam #1 (24) 5.5 cm long
- Flex I-Beam #5 (10) 24 cm long
- Flex I-Beam #4 (18) 17 cm long
- Flex I-Beam #3 (18) 11.5 cm long
- Flat Beams (16 ea. of 3 lengths)
- Axles (2 ea. of 3 lengths)
- Connectors (70)
- Cord Tensioning Clips (32)
- Yellow car and green car, each with ballast mass and flag
- Force Platform Bracket (2)
- Round and Flat Connectors (6 ea.)
- Angle and Straight Connectors (24 ea.)
- Drive Wheel with Rubber Tire (4)
- Pulleys, O-rings, Spacers (12 ea.)
- Structures Rod Clamps (2)
- Sliding Connector (12)
- PAStrack Fasteners (6)
- Collets (24)
- Screws (450)
- Yellow Cord (1 roll)
- Flexible road bed (9.1m)
- Road bed clips (24)
- Starter bracket (1)
- Track coupler (2)
- Instruction Manual



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. 38
Slotted Mass Set.....ME-7589 p. 197

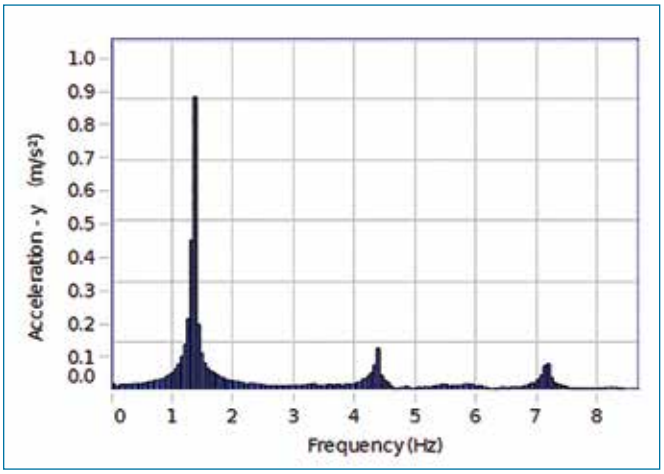
Shaking Tower Kit

ME-7018

NEW

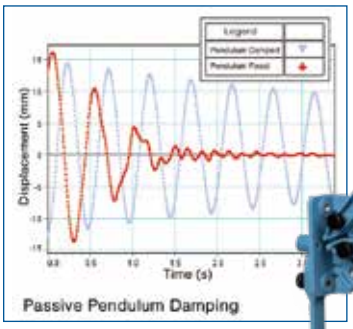
- Explore the resonance modes
- Measure accelerations with wireless sensors
- Demonstrate passive damping

Built from PASCO Structures beams, this tower is made to oscillate in its various resonance modes by a driver attached by a rubber band to the first floor of the tower. Wireless Load Cells with Accelerometers are attached to each floor to record how much shaking each floor experiences.

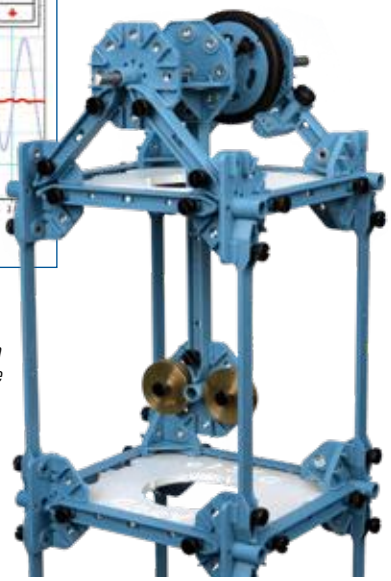


This FFT, generated in PASCO Capstone software, shows the frequency responses of the top Wireless Load Cell/Accelerometer.

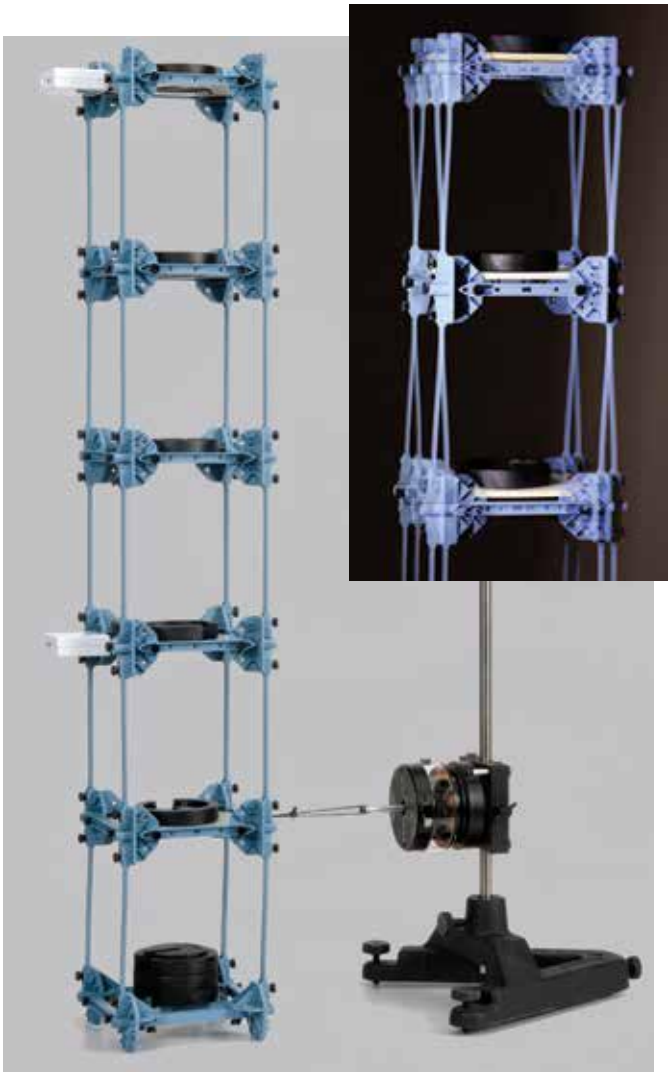
See the Shaking Tower Experiment (EX-5555) on page 343.



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.



In modern buildings, passive damping mechanisms are installed to damp out oscillations during earthquakes. The damping pendulum in this tower quickly stops oscillations.



The tower is shaken by the Mechanical Wave Driver, which is powered by an 850 Universal Interface or Function Generator.

ME-7018 Includes:

- #1 I-beams (10)
- #2 I-beams (8)
- #3 I-beams (24)
- #4 I-beam
- Nylon Spacers (2)
- Connectors (20)
- (F4) Flat Beams (20)
- Flat Round Connector (4)
- Full Round Connectors (5)
- Floors (5)
- Mass, 0.5 kg (10)
- Mass, 20 gram (2)
- Mass, 50 gram (2)
- Medium Shaft, Structures
- 2 Sets Screws (75 ea.)
- Sliding Connector
- Tire, Structures
- Wheel, Structures

Coming soon!
Check pasco.com for availability.

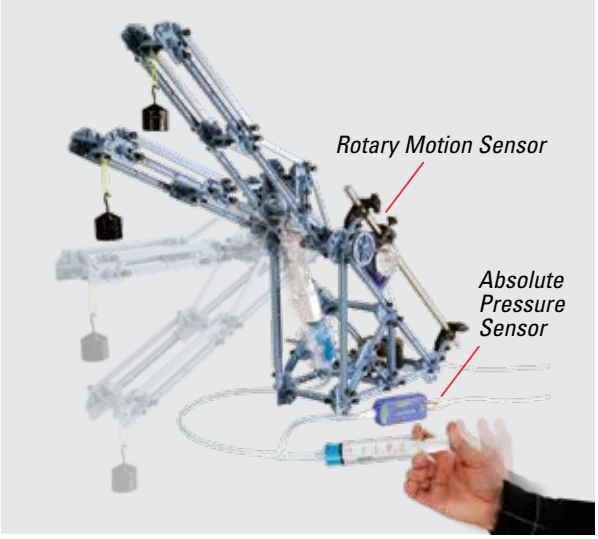
Order Information

Shaking Tower Kit	ME-7018
Required:	
Mechanical Wave Driver	SF-9324
2 m Patch Cord Set	SE-9415A
Large Rod Base	ME-8735
Threaded Rod 25 cm	ME-8988
Wireless Load Cells (4)	PS-3216
850 Universal Interface	UI-5000
PASCO Capstone Software	pp. 70-73

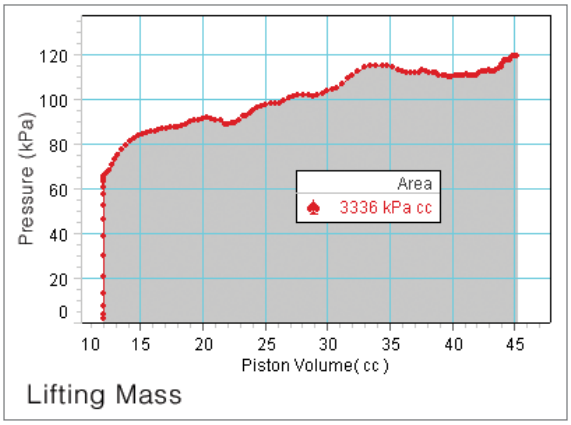
Hydraulic and Pneumatic Structures

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. 151
Steel Rod (45 cm)	ME-8736	p. 186
Absolute Pressure Sensor	PS-2107	p. 46
Rotary Motion Sensor	PS-2120A	p. 33

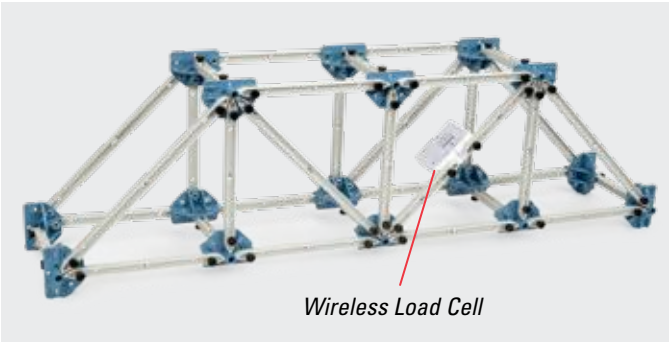
Building Better Bridges Kit

NEW

ME-3581

- A complete STEM kit to teach bridge-building
- Compatible with PASCO Structures System

Now is the perfect time for your students to learn about bridge-building and how bridges really work. This complete STEM kit allows students to learn and apply engineering design concepts. They can use the I-Beams to build bridges and structures that behave like the real thing! And with the included new Wireless Load Cell, students can measure forces under tension or compression anywhere in their structures.



The kit has flexible I-beams, and the Wireless Load Cell measures up to 50 N.



Includes

- Lab Activities
- Wireless Load Cell (with Bluetooth® 4.0 connectivity)
- Flexible I-Beams (various sizes)
- Connectors
- Truss Screws
- Weight Set
- Gratnells® Storage Tray

Lab Activities:

Forces in Equilibrium
Internal Forces
Moments in Equilibrium
Strength of Members
Truss Analysis

Order Information

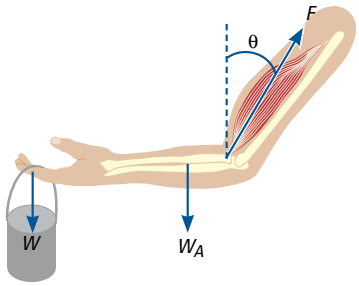
Building Better Bridges Kit	ME-3581	
Want an additional load cell?		
Wireless Load Cell	PS-3216	p. 11

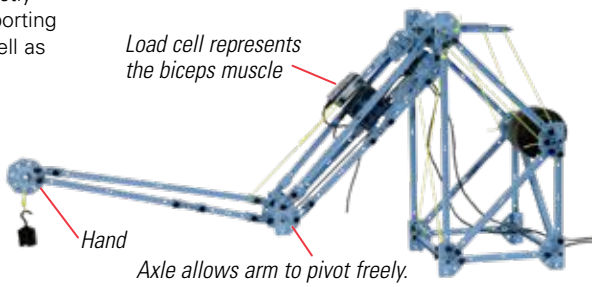
Human Structures Set

ME-7001

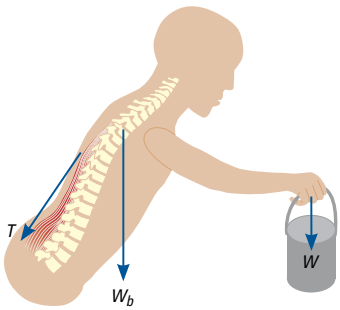
- Build models that represent real life examples.
- Construct all three models concurrently with this set.
- Bring homework problems to life!

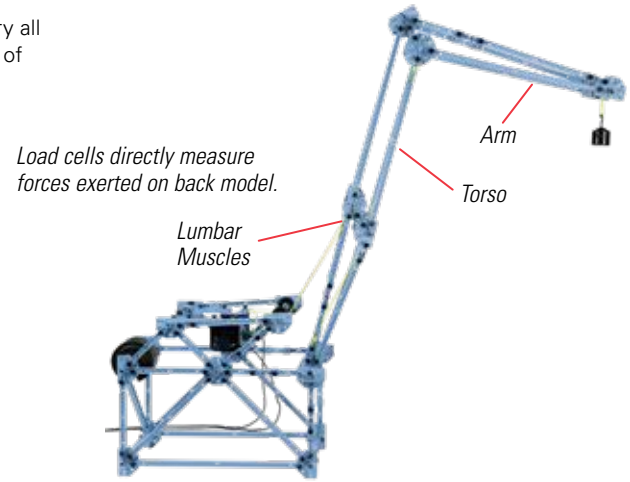
Human Arm Model: Students build a realistic arm model and directly measure the forces exerted by the biceps muscle (tension in supporting cord). Vary the length and angle of the upper and lower arm, as well as the point of attachment of the muscle.



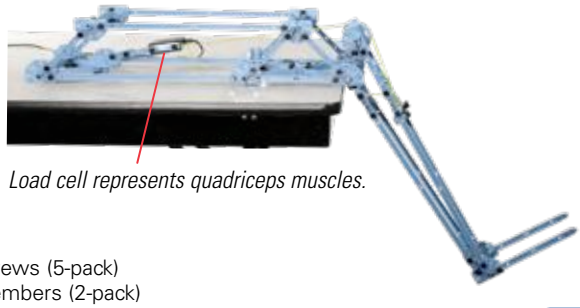


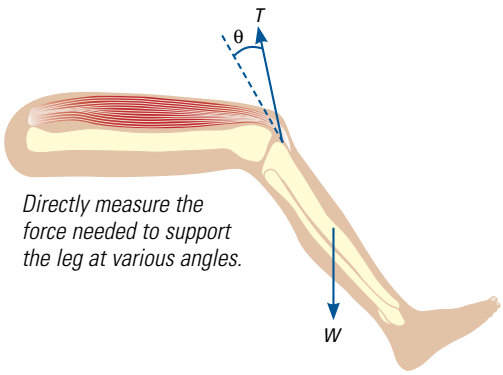
Human Back Model: Model the forces acting on a human back. Vary all parameters including position of back muscle attachment and angle of the torso. Directly measure the force exerted by the back muscles.





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

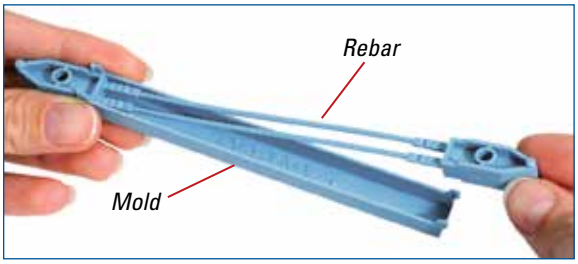
- Truss Set Screws (5-pack)
- Truss Set Members (2-pack)
- Connector Spares (2-pack)
- One package each:
  - #6 I-Beam Spares
  - Cord Lock Spares
  - Axle Spares
  - Round Connector Spares
  - Angle Connector Spares
- Roll of rubber cord

Order Information

Human Structures Set	ME-7001	
Shown in use with:		
Load Cell & Amplifier Set (includes four load cells)	PS-2199	p. 38
Hooked Mass Set	SE-8759	p. 197
Large Slotted Mass Set	ME-7566	p. 197

Cast Beam Structures Set

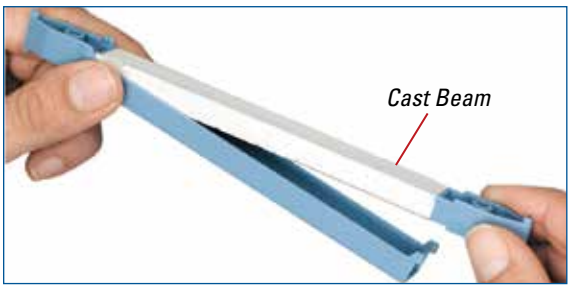
ME-7009



Step 1: The rebar with connecting ends snaps into the plastic mold.

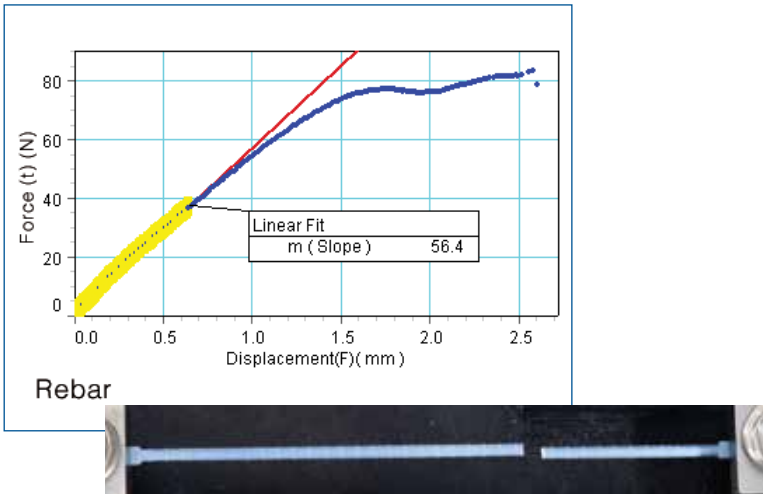


Step 2: Insert rebar into tensioning apparatus and pour a mixture of sand and plaster of Paris into the mold.



Step 3: After it dries, it is easy to remove the flexible plastic mold from the cast beam.

Make your own cast beams that look like pre-stressed concrete beams. Test them and you'll find they perform like them, too. 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, the mixture of sand and plaster of Paris, or using one or two rebar.



Measure Young's Modulus for the rebar.
The connecting ends can be cut off from the rebar allowing the rebar to fit into the Material Testing Machine (ME-8236) with Flat Coupon Adapter (ME-8238).

Cast Beam Structures Set ME-7009 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
- Axles (2 ea. of 3 lengths)
- Connectors (14)
- Cord Tensioning Clips (32)
- Round and Flat Connectors (6 ea.)
- PAStrack Fasteners (6)
- Angle and Straight Connectors (24 ea.)
- Collets (24)
- Screws (150)
- Pulleys, O-rings, Spacers (12 ea.)
- Sliding Connector (12)
- Reusable Plastic Molds (10)
- Rebar (30)
- Yellow Cord (1 roll)
- Instruction Manual

Required but not included:

- Sand and Plaster of Paris



Cast Beam Spares

ME-6983

Consumable replacement parts for Cast Beams. These can also be used with the Advanced Structures Set (page 151).

Includes

- 10 Reusable Plastic Molds
- 30 Rebar with Connectors



Order Information

Cast Beam Spares ME-6983

Order Information

Cast Beam Structures Set	ME-7009	
Also shown:		
Displacement Sensor	PS-2204	p. 39
Cast Beam Spares (Includes 30 rebar members,10 cast beam molds with connectors)	ME-6983	
Large Slotted Mass Set	ME-7566	p. 197
Round Base with Rod	ME-8270	p. 186
60 cm Threaded Rod	ME-8977	p. 186

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. 149

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

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

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

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

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.

Order Information

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. *#5 I-Beam Spares (ME-7017)*



6. *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 24 of the #5 I-beams, 24 cm long.*
6. *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
#5 I-Beam Spares ME-7017
Photoelastic I-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

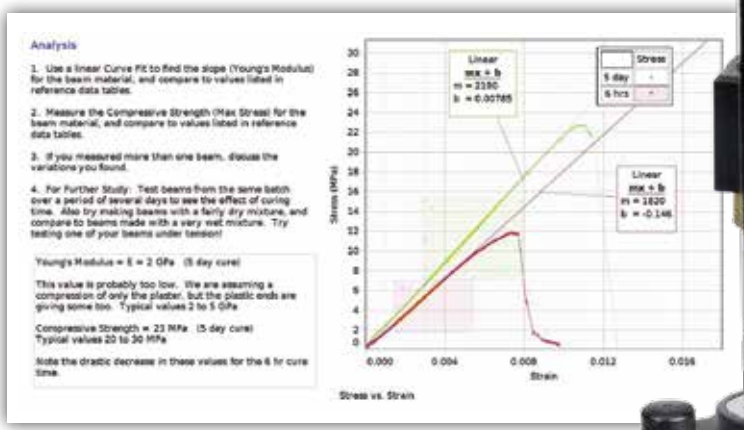
Comprehensive Materials Testing System

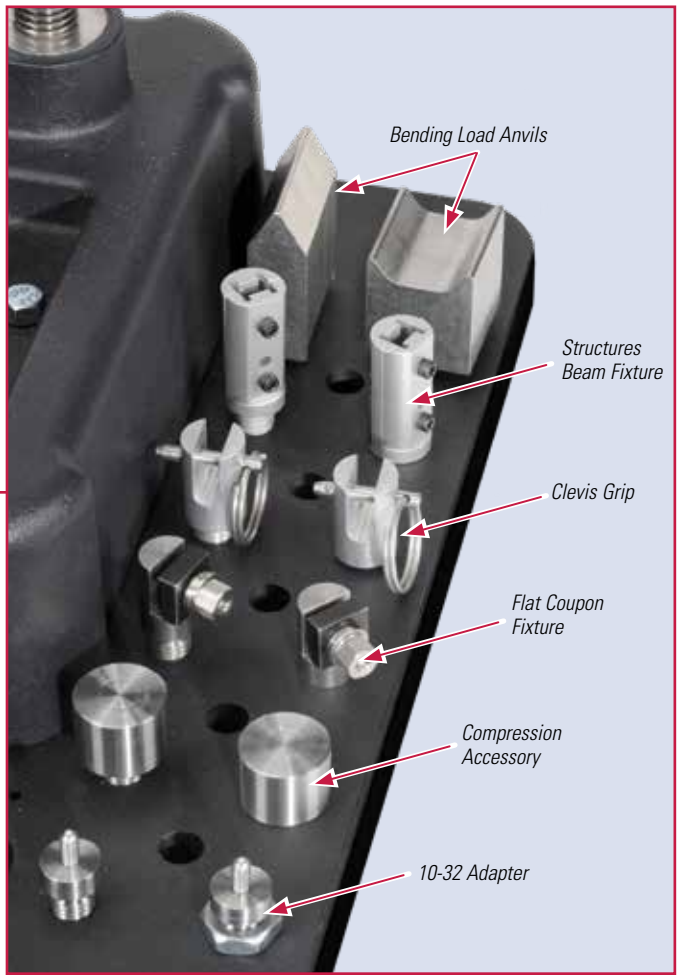
ME-8244

With this one system, your students can investigate:

- 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 setup instructions, theory, and detailed analysis questions.
Download experiments at **pasco.com/MTS**







Comprehensive Materials Testing System Includes:

- ME-8236 Testing Machine (with Safety Shields and Calibration Rod)
- Tensile Samples (10 of each): ME-8231 Aluminum, ME-8232 Brass, ME-8233 Annealed Steel, ME-8243 Steel, ME-8234 Acrylic, ME-8235 Polyethylene
- ME-8237 Bending Accessory
- ME-8249 Four-point Bending Load Anvil
- ME-8241 Photoelasticity Accessory (with Photoelastic Beams)
- ME-8239 Shear Accessory (with Shear Samples)
- ME-8229 Storage Base
- ME-8242 Structures Beam Fixture
- ME-7012 Thin Beams
- ME-6983 Cast Spares
- ME-8247 Compression Accessory (with Compression Samples)
- ME-8238 Flat Coupon Fixture
- AP-8222 Plastic Flat Coupons
- AP-8223 Metal Flat Coupons
- ME-8245 Clevis Grip
- ME-8246 10-32 Adapter
- PS-2100A USB Link
- UI-5401 PASCO Capstone Software Single User License



See complete experiments:
Tensile Testing of Metals ..... Page 345
Column Buckling ..... Page 346
Bending: 3-Point and 4-Point ..... Page 347

Order Information

Comprehensive Materials Testing System ME-8244
Materials Testing Machine ME-8236

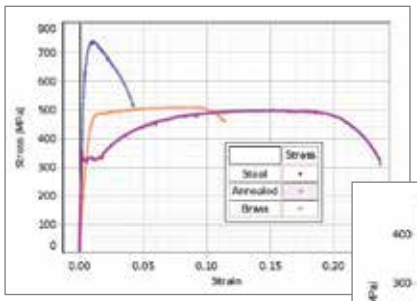
Materials Testing Machine

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 firsthand

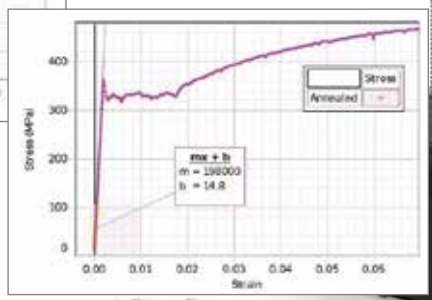
Measure force and displacement for various materials as they are stretched, compressed, sheared, or bent. Investigate material properties including Young's Modulus, Tensile Strength, Yield Strength, Ductility and Modulus of Resilience.

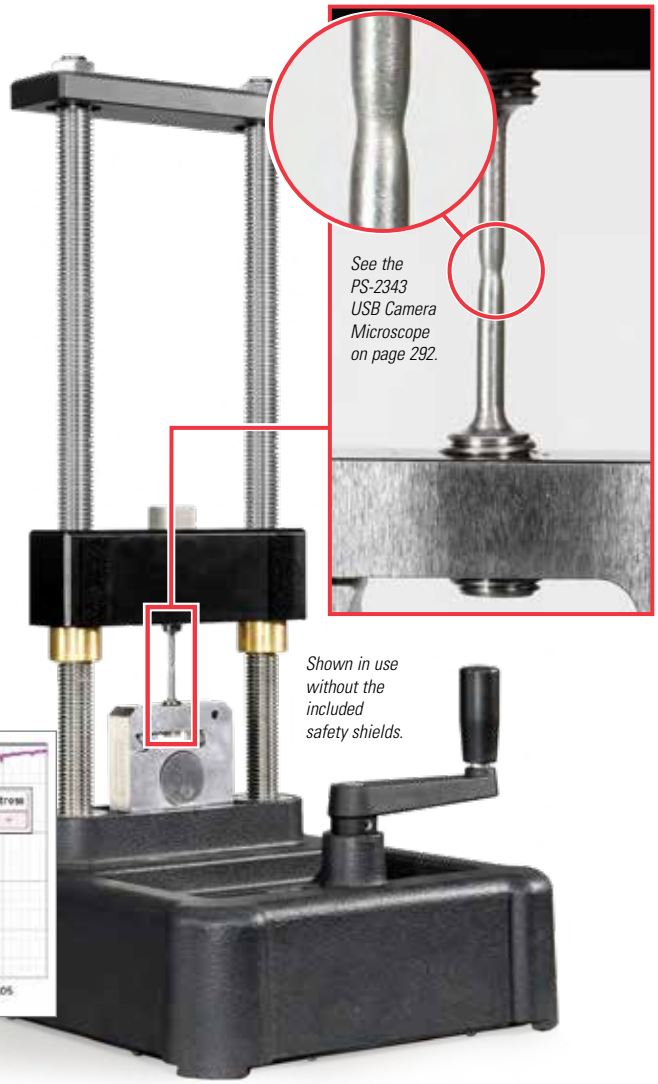
The Materials Testing Machine measures force with a 7100 N load cell and displacement with an optical encoder. It runs on PASCO Capstone software, which has a built-in compliance calibration wizard and has all the tools to record and display stress vs. strain, apply linear fits to find Young's Modulus, and to record and play back webcam movies of the breaking samples, synced to the data. See page 72.



Tensile Stress vs. 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 292.

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



ME-8236 Includes

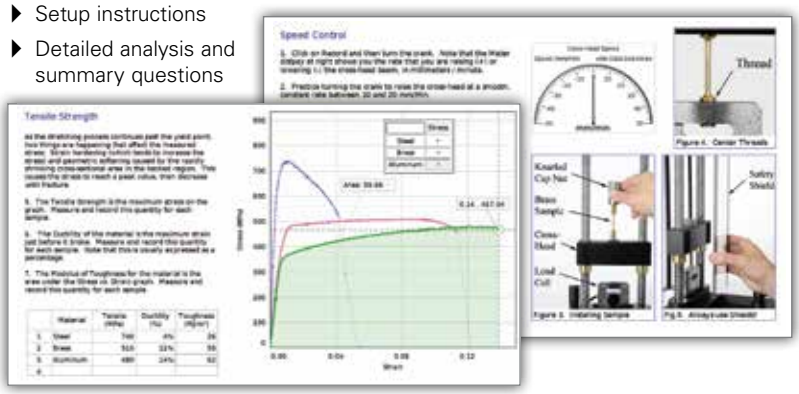
- Machine
- Compliance calibration rod
- Safety shields

(Requires Capstone software)

Workbooks include all instructions needed to perform the experiment:

- Introduction and theory
- Setup instructions
- Detailed analysis and summary questions

Download FREE www.pasco.com/MaterialsTester



Order Information

Materials Testing Machine	ME-8236
Required:	
PASCO Capstone Software	pp. 18-20
AirLink	PS-3200 p. 30
Tensile Samples (at left)	

Tensile Samples

Set of 10 each



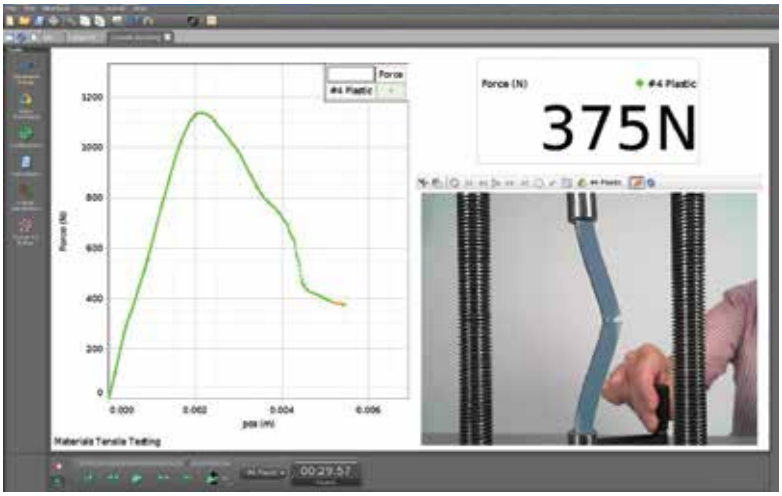
Order Information

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

Combining video with simultaneous data graphs is a very powerful tool.

- PASCO Capstone is data collection and analysis software that has a special built-in compliance calibration routine for the Materials Tester.
- It is shown here plotting a graph and recording a video that are synced together in real time. Data analysis tools such as curve fits and area under the curve are available.
- With any of PASCO's interfaces, you can take advantage of the power of PASCO Capstone by using some of the 80+ sensors from PASCO.



Enhance student understanding of the behavior of materials. PASCO Capstone software has the ability to embed live video from a webcam and sync the Materials Tester data to the recorded video. Then you can play back the video along with the data on the graph, stepping through one frame at a time to see the exact breaking point.

Order Information

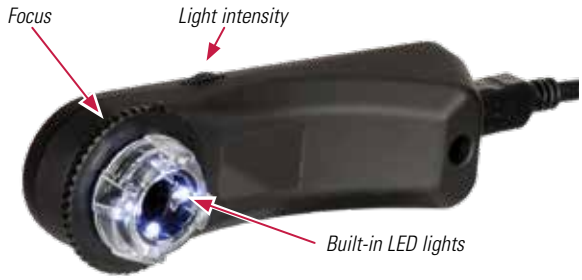
PASCO Capstone Software
Single User License..... UI-5401
Site License UI-5400

Download PASCO Capstone Trial Version at www.pasco.com/capstone

USB Camera Microscope

PS-2343

- Use as a web camera
- Optical zoom from 1x to 60x
- Built-in LED lighting



This versatile USB Camera Microscope can take pictures and video just like a digital camera, but it can also magnify like a microscope when it's up close to a specimen. And you can use it to take pictures showing lab setups, and document the appearance of materials before and after an experiment.

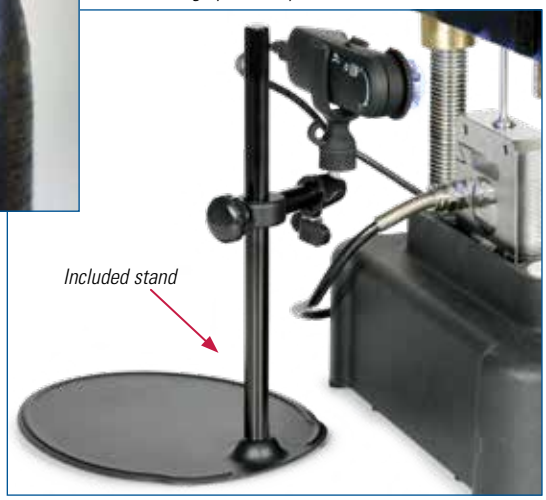
How It Works

Use with the video and image capture features in PASCO Capstone. Magnification of specimens can be changed by adjusting the dial located on the front of the camera.



Image of broken steel tensile sample taken with the microscope

As the tensile sample is being stretched, the force vs. time data is graphed in sync with the movie.



Includes

- Camera
- Microscope
- Stand

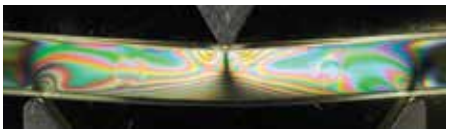
Order Information

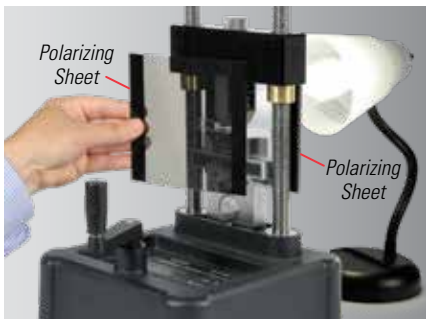
USB Camera Microscope..... PS-2343

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 that 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"
- One Photoelastic I-Beam Set (ME-7011)

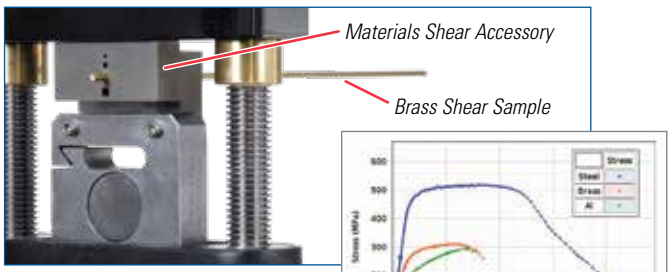
Order Information

Photoelasticity Accessory ME-8241
Photoelastic I-Beam Set.....ME-7011
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

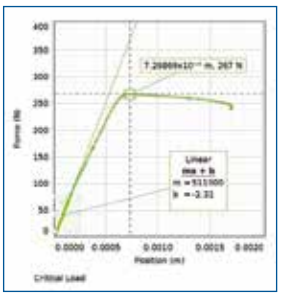
Materials Shear Accessory ME-8239
Replacement Supplies:
Shear Samples (set of 9) ME-8240

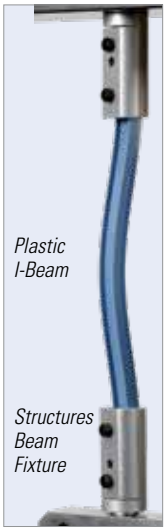
Structures Beam Fixture

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

- Clamps (2)





Order Information

Structures Beam Fixture.....ME-8242

Compression Accessory

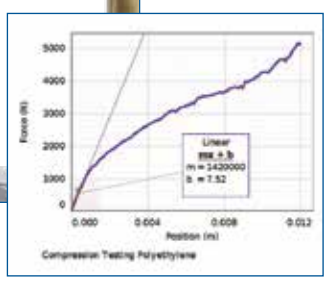
ME-8247

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

- Platform
- 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

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

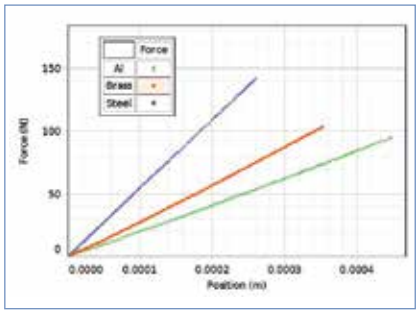
ME-8237

Perform three-point bending tests of various materials, including beams from the PASCO Structures System. Support anvils have adjustable separation up to 10 cm.



See EX-5559 Bending Experiment on p. 347.

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

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
- Adjustable support anvil
- Load anvil





ME-8249 Includes

- A two-point fixture that, 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

- Clamps (2)
- Wrench (1)



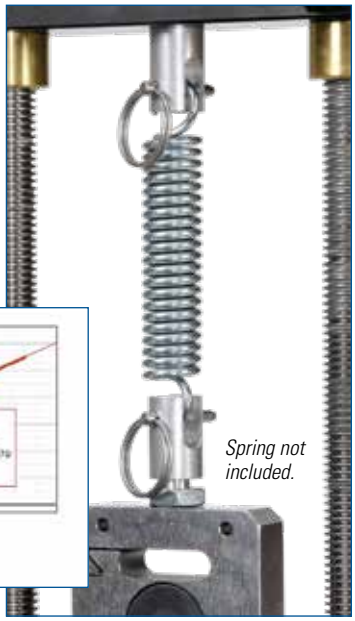
Order Information

Flat Coupon Fixture ME-8238
Plastic Test Coupons (40 coupons) AP-8222
Metal Test Coupons (50 coupons) AP-8223

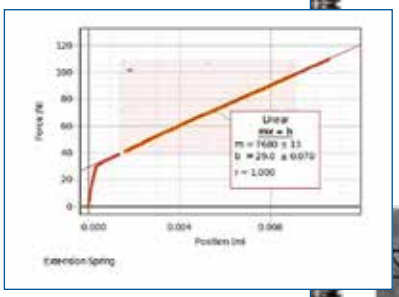
Clevis Grip

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

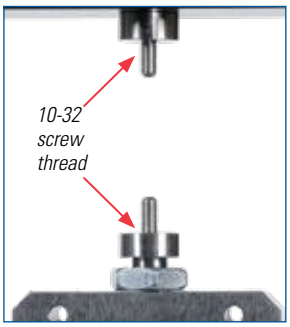
ME-8246

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

Looking for Tensile Samples for the legacy Stress/Strain Apparatus?

AP-8214A



Although the AP-8214A Stress/Strain Apparatus is obsolete, we will continue to supply the test coupons indefinitely to accommodate current users. These coupons are also useful in PASCO's new Materials Testing Machine (ME-8236). Please see pages 160-163 for this new Materials Testing Machine. There is a new adapter, the Flat Coupon Fixture (ME-8238), which allows these coupons to be tested in the new machine.

Plastic Test Coupons

AP-8222



Four types of color-coded samples, 10 pieces per sample:

- High impact polystyrene (HIPS)
- Nylon 6 (15% glass fiber reinforced)
- Acrylonitrile butadiene styrene (ABS)
- Polypropylene (PP)

Metal Test Coupons

AP-8223



Five types of samples, 10 pieces per sample (sample containers labeled with thickness in inches)

- Brass (thin) 0.003"
- Brass (thick) 0.005"
- Cold-rolled steel 0.003"
- Aluminum 0.003"
- Annealed steel 0.003"

Order Information

Replacement Plastic Test Coupons Full Set (40 coupons) AP-8222
Replacement Metal Test Coupons Full Set (50 coupons) AP-8223

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

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.



Column buckling





Demonstrate lack of torsional strength.

Includes

- Super-Flex I-Beam (24 inches long, 2 inches high)
- Instructions



Order Information

Super-Flex I-Beam..... ME-8987

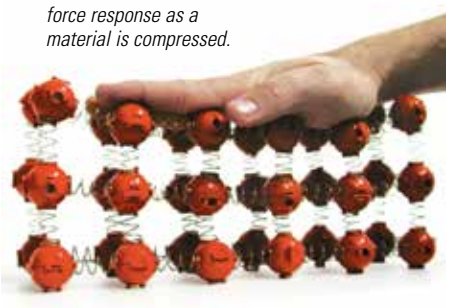
Matter Model

ME-9825A

The atoms of the Matter Model are brightly colored spheres with the bonds between the atoms modeled by springs, so that when forces are applied, the atoms can move in response.



Demonstrate the normal force response as a material is compressed.



Includes

- Atoms (4.5 g each) (40)
- Heavy, light and long springs (60 each)
- Nuts (to increase the atom mass) (30)
- 90 cm brass rod (for longitudinal waves)



The Matter Model is shipped in component pieces, ready for assembly.

Order Information

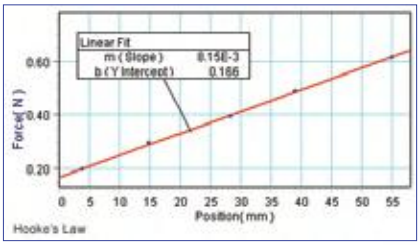
Matter Model..... ME-9825A

Hooke's Law Set

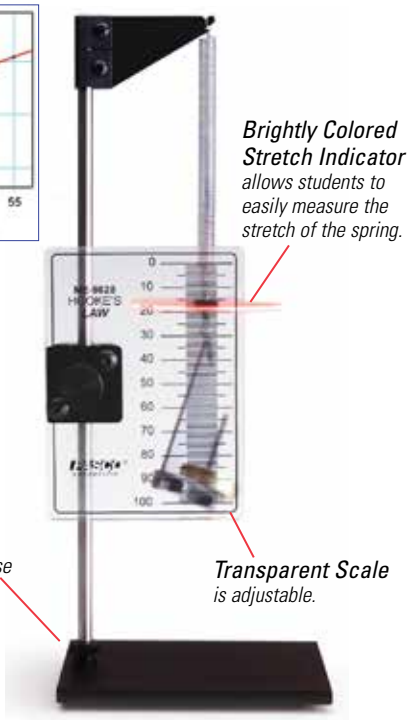
ME-9827

- 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, so you can stretch the 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 required to begin stretching the spring.



Brightly Colored Stretch Indicator *allows students to easily measure the stretch of the spring.*

Included *stand with heavy base*

Transparent Scale *is adjustable.*

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. 197

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

Dropper Popper

SE-7304

Invert this half rubber ball and drop it. It will bounce up higher than the release point. Discuss conservation of energy with your students.



There is a minimum height required to trigger the popper that can be related to barrier potentials.



Order Information

Dropper Popper.....SE-7304

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 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

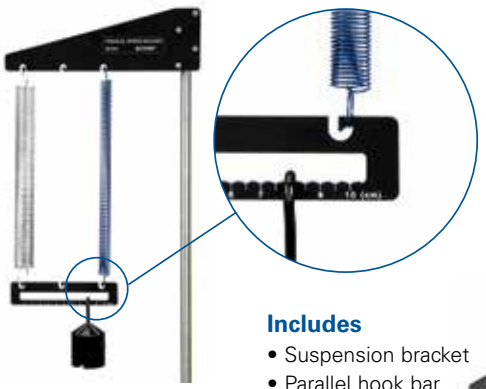
Recommended:

Hooked Mass Set.....SE-8759 p. 197

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.



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

Equal-Length Spring Set

ME-8970

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. 188

Hooked Mass Set.....SE-8759 p. 197

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 that hang from a pendulum clamp or stretch 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. 197

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

Snakey

SE-7331



This extra-long metal spring is ideal for studying 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

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

Photogate Pendulum Set

ME-8752

- Great for classic pendulum experiments



The Photogate Pendulum Set is a unique set of four pendulums that have the same shape and size, but different masses. Due to their cylindrical shape, these pendulums are ideal for use in timing experiments with the photogate. One pendulum each of brass, plastic, wood, and aluminum is included.

Typical Applications

- Determine relationship between period and mass
- Determine relationship between period and amplitude
- Determine relationship between period and length



Cylindrical shape allows easy calculation of the speed of the pendulum using the time it blocks the photogate. Photogate not included.

Order Information

Photogate Pendulum Set ME-8752

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

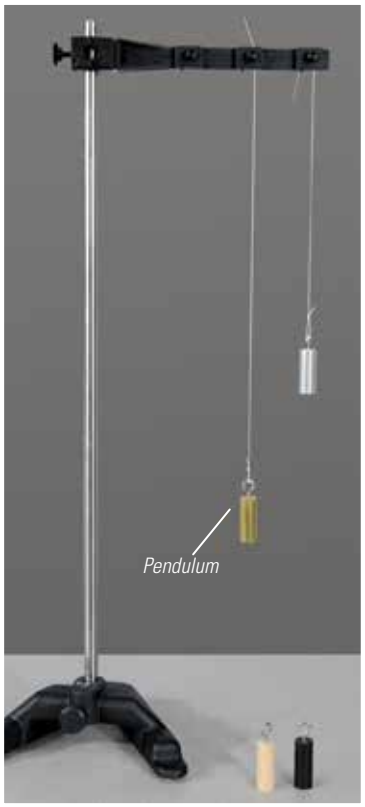
Dynamics Track Spring Set (12) ME-8999

Pendulum Clamp

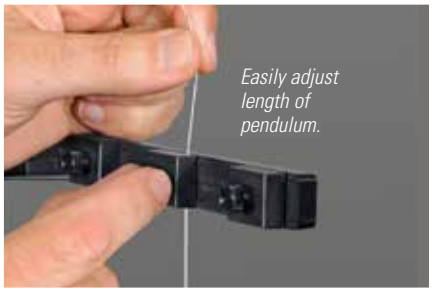
ME-9506



Hang up to three springs or pendulums. 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

Small "A" Base ..... ME-8976 p. 186

Stainless Steel Rod (45 cm.) ..... ME-8736 p. 186

PASCO's Complete Rotational System

ME-8950A

- 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.



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.

Components of this system

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.

Order Information

Complete Rotational System.....ME-8950A
Required:
Mass and Hanger Set..... ME-8979 p. 197

Interfacing Options

It is easy to use a computer to monitor rotational motion with the PASCO Rotational System. Here are two methods:

1. The ME-9498A Photogate Head mounts directly to the rotating platform base and measures angular speed. This works with the 850 and 550 Universal Interfaces. NOTE: PASPORT interfaces require a Digital Adapter (PS-2109).



Order Information

Recommended:
Photogate Head .....ME-9498A p. 43

2. The CI-6538 or PS-2120 Rotary Motion Sensor mounts to the base with an "A" Adapter and measures both angular speed and direction.



Order Information

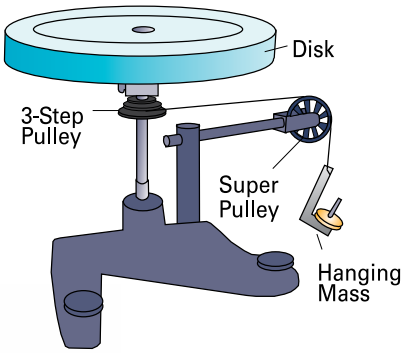
Required for use with ScienceWorkshop:
Rotary Motion Sensor..... CI-6538
Required for use with PASPORT:
Rotary Motion Sensor..... PS-2120A
"A"-base Rotational Adapter..... CI-6690 p. 179

Experiments you can do with this rotational system:

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.

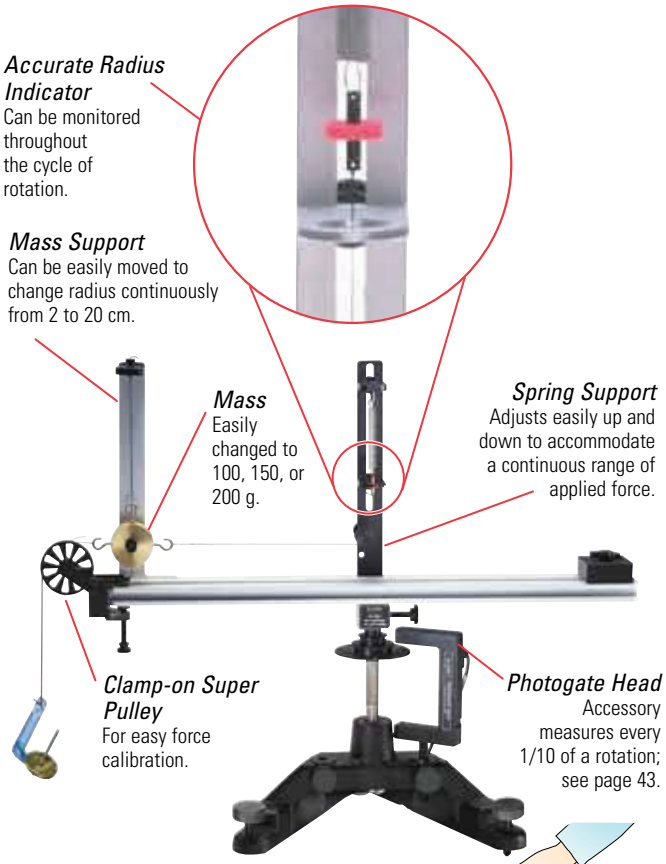
Rotational Inertia of Off-axis Disk

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.



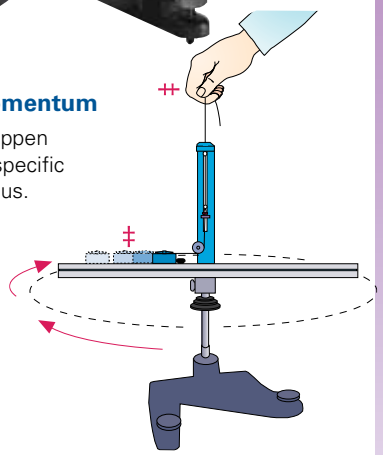
Centripetal Force

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.



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 170-171*

Rotating Platform and Rotational Inertia Accessory
p. 170



Centripetal Force Accessory
p. 170



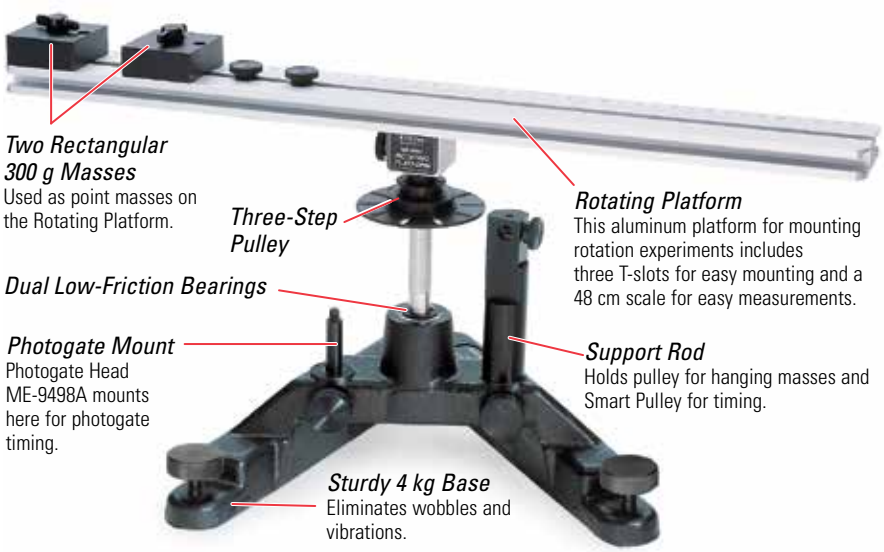
Rotational Motor Drive
p. 171



"A"-base Rotational Adapter
p. 171



Rotating Platform ME-8951



A Versatile Base

The stable base and precision bearings of the Rotating Platform are the foundation of PASCO's Rotational System. It serves as an excellent base for general rotation experiments.

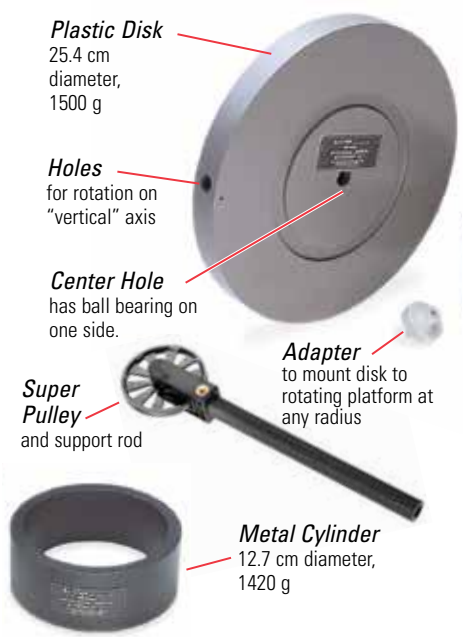
Order Information

Rotating Platform ME-8951
Recommended:
Rotational Inertia Accessory ME-8953
Centripetal Force Accessory ME-8952
Rotational Motor Drive ..... ME-8955 p. 171

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

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 to smoothly increase the angular speed of the Centripetal Force Accessory. The motor requires a 12 V DC power supply or a function generator.





Easily change the gear ratio of the motor drive by moving the drive belt to one of the three possible pulley steps.

Specifications

Motor: 12 V maximum, 0.2 A minimum
Base Spindle Speed Range: 10 to 600 rpm
Three-Step Pulley

Includes

- Motor
- Three-Step Pulley
- Drive Belt



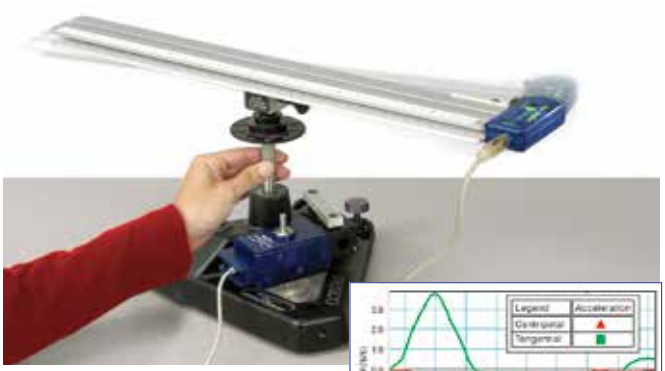
Order Information

Rotational Motor Drive	ME-8955	
Required:		
Rotating Platform	ME-8951	p. 170
850 Universal Interface	UI-5000	p. 26
or		
Function Generator	PI-8127	p. 249
or		
DC Power Supply	PI-9880	p. 244

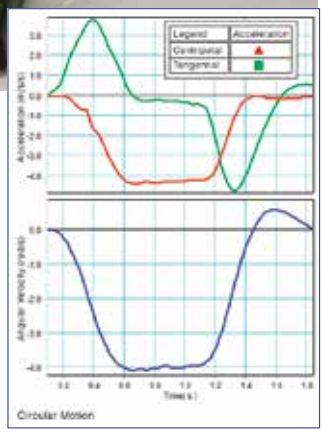
"A"-base Rotational Adapter

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. 170
Rotary Motion Sensor ScienceWorkshop	CI-6538	
or		
Rotary Motion Sensor PASPORT	PS-2120A	

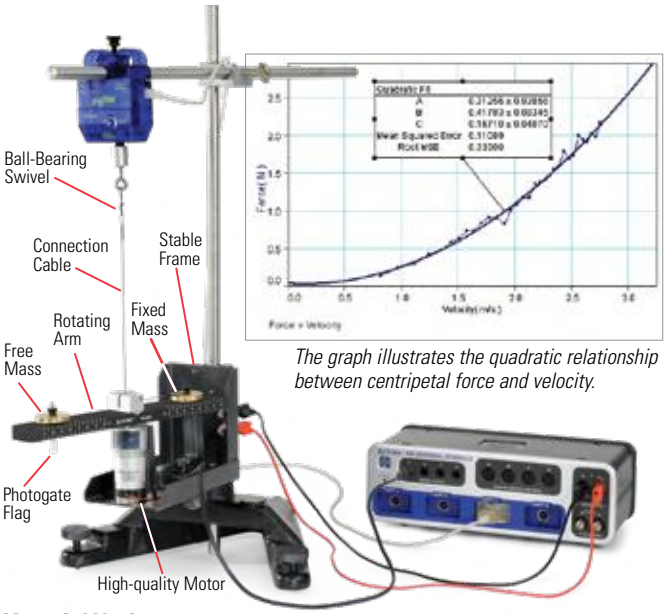
Centripetal Force Apparatus

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 ..... p. 36
Photogate Head ..... p. 43
Triple Output Power Supply ..... SE-8587 p. 244
Large Rod Base ..... ME-8735 p. 186
45 cm Steel Rod ..... ME-8736 p. 186
120 cm Steel Rod ..... ME-8741 p. 186
Multi Clamp ..... ME-9507 p. 188

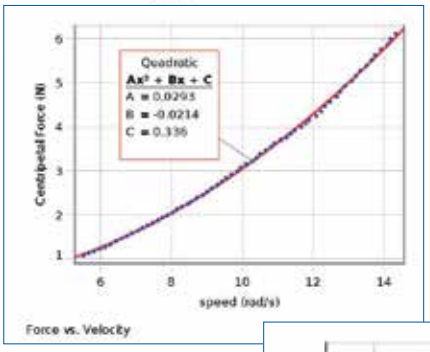
Wireless Centripetal Force Accessory

ME-8094

- Transmitting data wirelessly eliminates friction
- Uses Wireless Force Acceleration Sensor
- Vary speed, radius, and mass

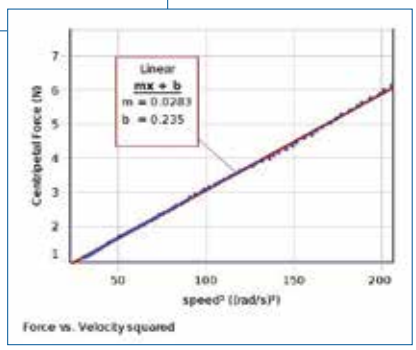
The Wireless Centripetal Force Accessory is a low friction sliding mass holder that connects to a Wireless Force Acceleration Sensor (PS-3202). When installed on a Rotating Platform (ME-8951), it provides a simple and direct measurement of centripetal force and acceleration. Vary the mass using the holed masses in the Mass and Hanger Set (ME-8979). The string length is easily adjusted to vary the radius.





This PASCO Capstone graph shows the Centripetal Force (measured directly by the Wireless Force Acceleration Sensor) versus Angular Speed as the platform slows down.

In this PASCO Capstone graph, a "QuickCalc" of speed squared has been chosen on the horizontal axis, resulting in a straight line.





Includes

- Low-friction sliding mass holder
- Mounting post for force sensor

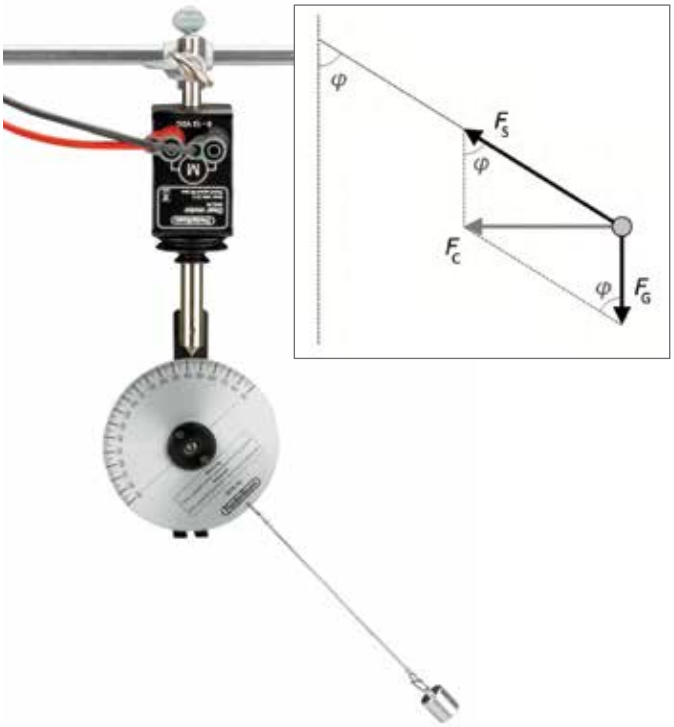
Order Information

Wireless Centripetal Force Accessory ME-8094
Required:
Wireless Force Acceleration Sensor PS-3202
Mass and Hanger Set ME-8979
Rotating Platform ME-8951
PASCO Capstone ..... pp. 70-73

Conical Pendulum

SF-7206

- Study effects of speed and radius on centripetal force.
- Determine g from the angle.



Powered with a 12 V DC power supply (not included), the apparatus rotates and the bob flies out, causing the angle indicator to rotate. The angle with the vertical is read on the graduated, balanced disk. The pendulum's length can be varied using four interchangeable wires with hooks. The Conical Pendulum is specially designed for Gear Motor SF-7204 (not included; see at right).



Includes

- Conical Pendulum
- 4 different length cables

Order Information

Conical Pendulum SF-7206
Required:
DC Gear Motor SF-7204
DC Power Supply SE-9720A
Large Table Clamp ME-9472
Multi Clamp ME-9507
Stainless Steel Rod 90 cm (2) ME-8738

DC Gear Motor

SF-7204



The gear motor operates on 0 to 12 V DC and yields gearing of 21:1 with a stable, slow motion. The motor is fitted with a removable winding shaft. With a thread, it can be used for slow, linear motion. The motor is suitable for use with the Conical Pendulum SF-7206.

Specifications

Voltage: 12 V DC
Current: 20 mA at 12 V (no load)
Gear Ratio: 21:1
Max Speed: 80 rpm

Order Information

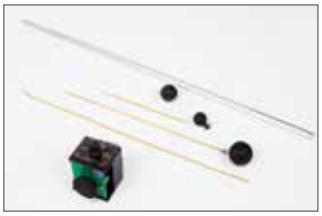
DC Gear Motor SF-7204
Required:
DC Power Supply SE-9720A

Circular Motion Apparatus

SF-7205

For demonstrating the laws of uniform circular motion, this small motor is fitted with a disk for attaching a rubber ball on a chain. The speed can be varied.





Includes

- Motor
- Special suspension rod (53 cm long)
- Three different rubber balls
- Suspension chains (different lengths)

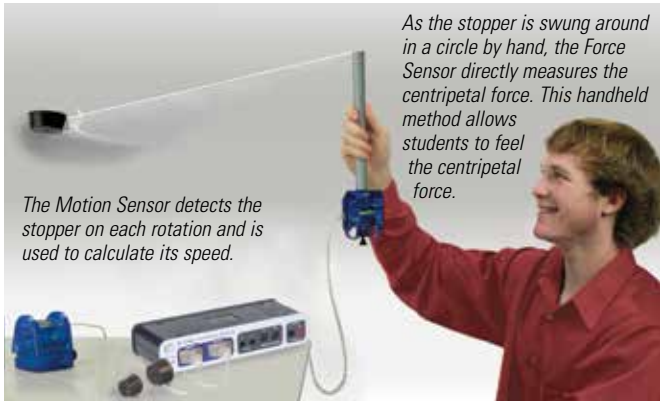
Order Information

Circular Motion Apparatus SF-7205
Required:
DC Power Supply SE-9720A
Large Table Clamp ME-9472
Multi Clamp ME-9507
Stainless Steel Rod 90 cm (2) ME-8738

Handheld Centripetal Force

Discover Centripetal Force Kit

ME-9837A



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.

Includes

- Rubber Stoppers (sizes 6, 8, 10)
- Plastic Ties (10)
- Yellow String (73 meters)
- Hollow Tube



Order Information

Discover Centripetal Force Kit	ME-9837A	
Shown in use with:		
High Resolution Force Sensor	PS-2189	p. 36
Motion Sensor	PS-2103A	p. 32
Required for Classic Approach:		
Hooked Mass Set	SE-8759	p. 197
Stopwatch	ME-1234	p. 123

Flying Pig

SE-6655

This classic centripetal force experiment is used in high school AP® Physics 1 curriculum. Hang from the ceiling, give it a push, and it flaps its wings as it "flies" in a circle.



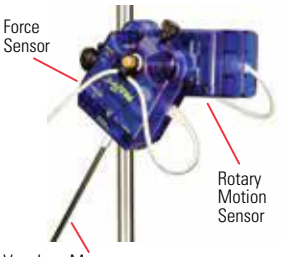
Order Information

Flying Pig (US only)	SE-6655	
Required:		
2 AA Batteries (not included)		

Centripetal Force Pendulum

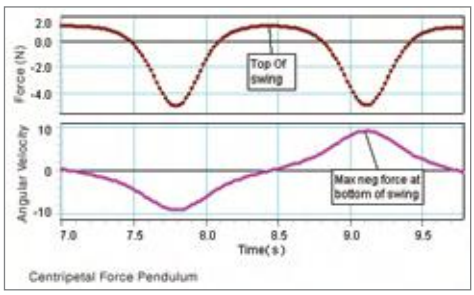
ME-9821

- 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 vs. 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. 186
45 cm Steel Rod	ME-8736	p. 186
90 cm Steel Rod	ME-8738	p. 186
Multi Clamp	ME-9507	p. 189
Rotary Motion Sensor	PS-2120A	
Force Sensor	PS-2104	

Rotational Inertia Set

ME-9774



Release two different sized objects simultaneously.

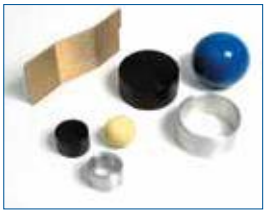


How It Works

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

Hollow Steel Ball



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 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

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. 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

- Red Wand (1)
- Blue Wand (1)



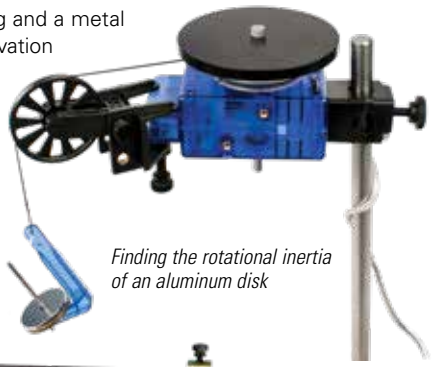
Order Information

Rotational Inertia Wands ME-9847

Rotational Inertia Accessory

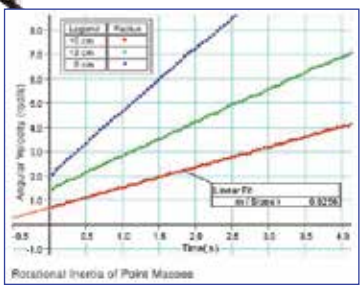
ME-3420

Add the Rotational Inertia Accessory to the Rotary Motion Sensor (PS-2120A) 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 an aluminum disk

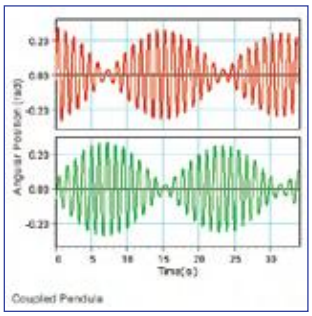




Finding the rotational inertia of point masses using the graph of Angular Velocity vs. Time

Coupled Pendulums

Couple two pendulums with a rubber band and plot the Position vs. Time for each pendulum. The result is a vivid example of energy transfer between the pendulums.





Pendulum Accessory

ME-8969

The pendulum rod and masses can be purchased separately.

Includes

- 38 cm Pendulum Rod (27 g)
- 75 g Mass (2)



Order Information

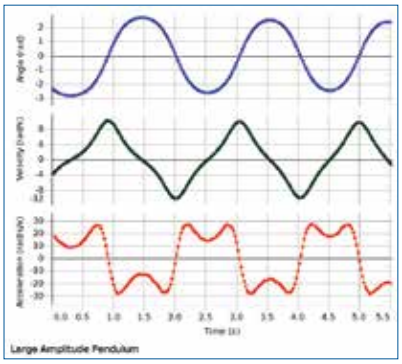
Pendulum Accessory ME-8969

Large Amplitude Pendulum

See page 338 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 vs. time. The period can be measured as a function of the amplitude of the pendulum and compared to theory.



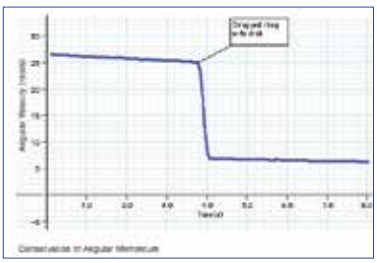


The displacement, velocity, and acceleration for large amplitude are plotted vs. time to show the difference in the sinusoidal motion of low amplitude oscillations.

Conservation of Angular Momentum

See page 337 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

- Disks (2): 8.9 cm diameter, 100 g
- Thin Ring: 8.9 cm o.d., 7.9 cm i.d., 100 g
- 38 cm Pendulum Rod (27 g)
- 75 g Mass (2)
- Clamp-on Super Pulley
- Alignment Guides (3): 3.9 cm radius, 1.7 g



Order Information

Coming soon!
Check pasco.com for availability.

Rotational Inertia Accessory ME-3420

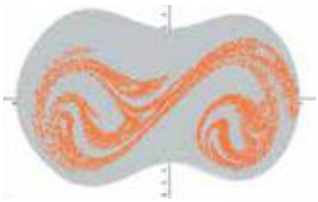
Also available:

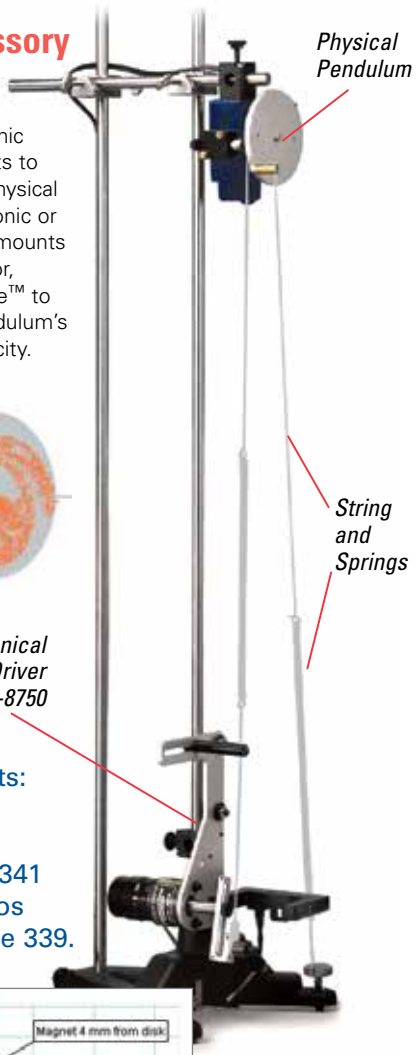
Ring and Disk Set ME-3419
(Includes ring, 2 disks, and 3 alignment guides)

Chaos/Driven Harmonic Accessory

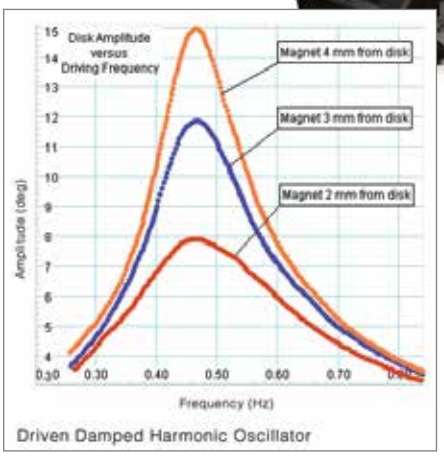
CI-6689A

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.





See full experiments: EX-5522A Driven Damped Harmonic Oscillator on page 341 and EX-5523A Chaos Experiment on page 339.



Angular Velocity vs. Frequency graph shows effects of magnetic damping on amplitude of resonance peak.

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

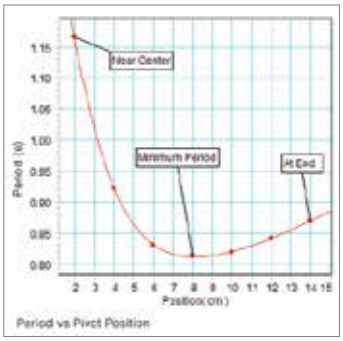
Physical Pendulum Set

ME-9833

This set of six objects is perfect for studying Physical Pendulums, Moments of Inertia, and the Parallel Axis Theorem. Each piece fastens directly to a Rotary Motion Sensor to measure the object's 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.







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
- Six Mounting Screws



Order Information

Physical Pendulum Set ME-9833

Gyroscopic Motion

Demonstration Gyroscope

ME-8960

- All components accessible
- Excellent demonstration tool
- Precision angle indicator

The unique low friction and open design of PASCO's Gyroscope allow studies of rotational motion never before possible with a commercial unit. The completely open design lets students stop precession by grabbing the vertical shaft and observing that the gyroscope dips. Rotational mathematics predicts the dipping action, but it could never be confirmed with traditional enclosed units.

How It Works

The disk is spun by wrapping a string around the pulley and pulling. Or the disks can be spun by hand. Add mass to either end of the gyroscope and it responds with a predictable precession. Many features make this an exceptional demonstration tool for rotational motion concepts.

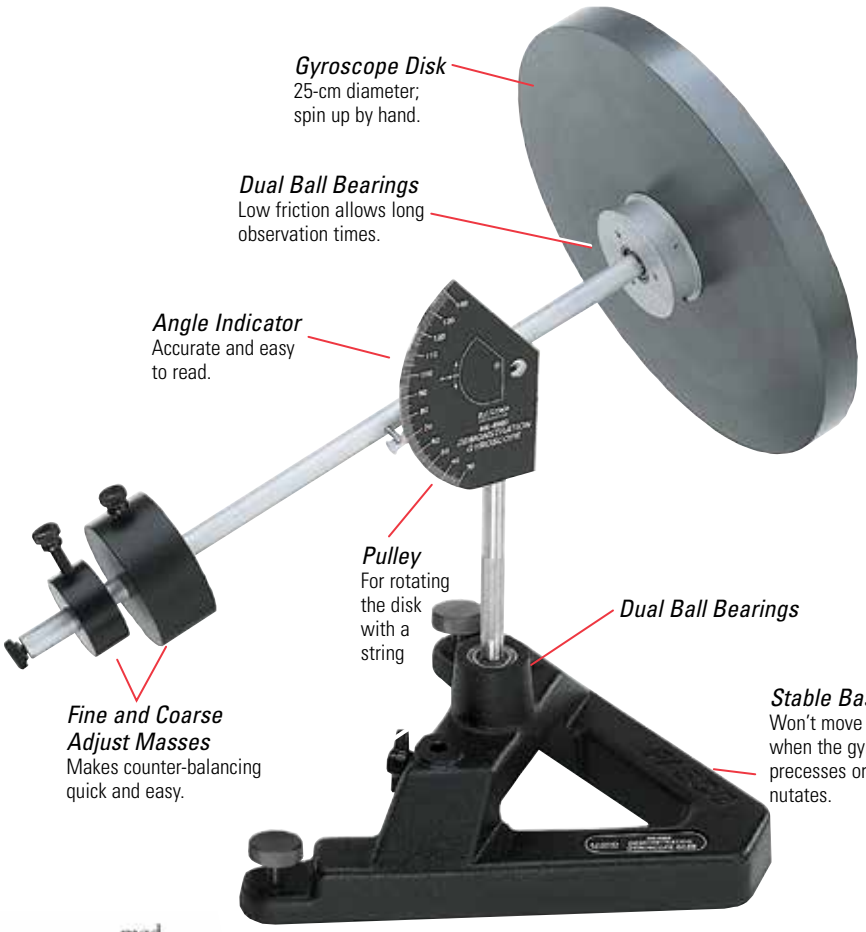
Features

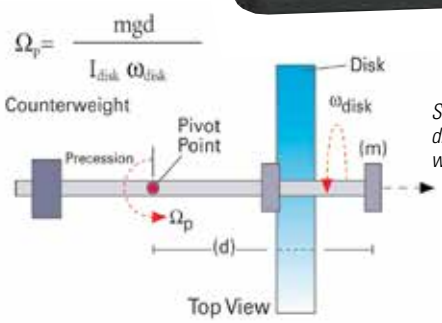
- **Low Friction:** The disk takes almost 6 minutes to slow to half of its original speed due to low-friction bearings in the gyroscope axle and vertical shaft.
- **Accurate Angle Indicator:** Measures from 30° to 140° and is easily read to the nearest degree. A retractable stop acts as a marker during experiments.
- **Easy Timing:** Low rotation speeds allow measurement of angular speed by counting revolutions and using a stopwatch.
- **Easy Balancing:** Two counterweights allow coarse and fine balance adjustment.
- **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.



Accessory Disk
Add a second disk spinning in same or opposite directions.

A Unique Experiment: Rotate two disks in opposite directions at the same speed. The angular momenta cancel and the total angular momentum of the gyroscope is zero. The result is no precession.





Students can determine the rotational inertia of the rotating disk. They can then check the measured precession rate when a mass (m) is added a distance (d) from the pivot point.

Order Information

Demonstration Gyroscope ME-8960
Recommended:
Accessory Disk and Mass ME-8961

Accessory Disk and Mass

ME-8961



Includes

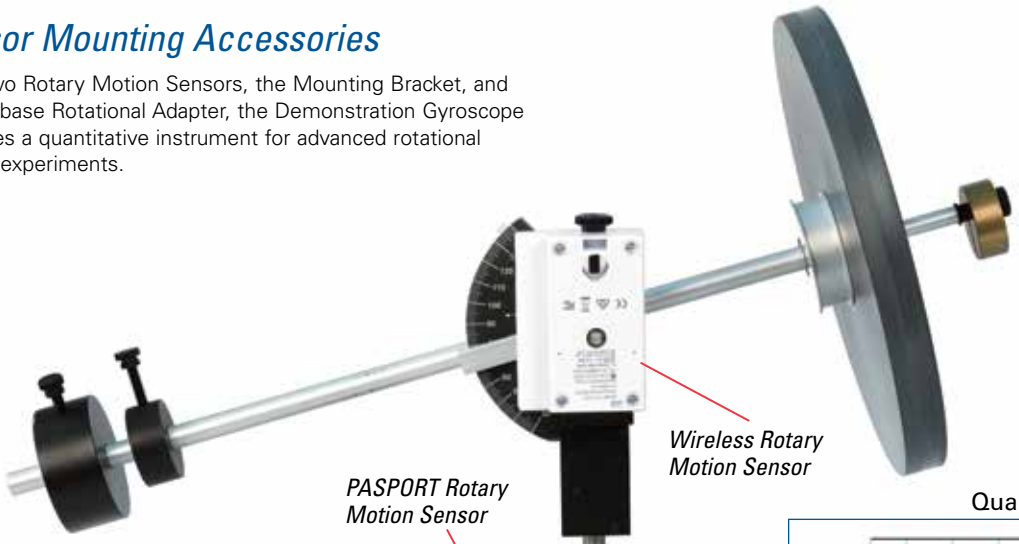
- Accessory Disk
- Extra Counter Mass

Order Information

Accessory Disk and Mass ME-8961

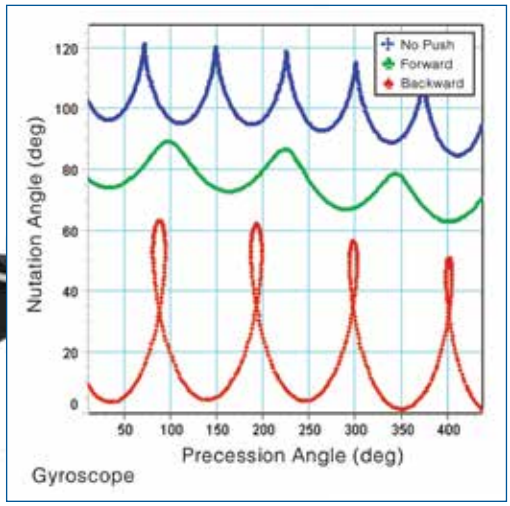
Sensor Mounting Accessories

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 the Gyroscope is released from rest, with no initial push forward or backward.

Rotary Motion Sensor/Gyroscope Mounting Bracket

ME-8963



With the Mounting Bracket and the "A"-base Rotational Adapter (CI-6690), the Demonstration Gyroscope becomes a quantitative instrument for advanced rotational motion experiments. With two Rotary Motion Sensors, students obtain a graphical picture of the Gyroscope's nutation and precession motions.

Order Information

For Recording Nutation Data:

Rotary Motion Sensor/Gyroscope Mounting Bracket ME-8963

Required:

Rotary Motion Sensor ..... PS-2120A p. 33

Interface ..... pp. 24-25

OR:

Wireless Rotary Motion Sensor ..... PS-3220 p. 9

"A"-base Rotational Adapter

CI-6690

Mounts a Rotary Motion Sensor to the base to monitor the Gyroscope's precession rate.

This accessory is not compatible with PS-3220 Wireless Rotary Motion Sensor.



Order Information

For Recording Precession Data:

"A"-base Rotational Adapter CI-6690

Required:

Rotary Motion Sensor ..... PS-2120A p. 33

Interface ..... pp. 24-25

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 (to demonstrate 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.

Sturdy 45 cm diameter rotating platform can be used with or without included chair.

Wrap rope around groove to apply torque.



Steel base



Includes

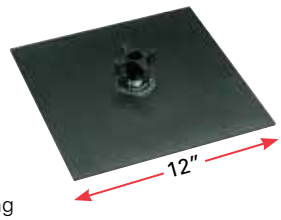
- Chair
- Rotating Platform with Leveling Feet

Order Information

Rotating Chair ME-6856
Shown in use with:
Photogate Head ME-9498A

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. Here is a great demonstration of the energy that can be stored in waves.





Order Information

Air Cannon SE-7370

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 boiling 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

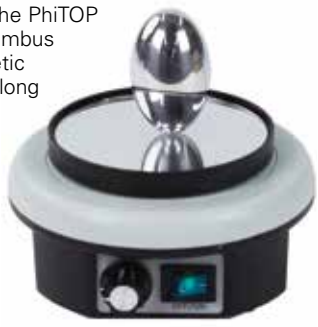
PhiTOP

SE-7594

NEW

The PhiTOP is an egg-shaped top (a prolate ellipsoid) that can be spun by hand to stand up on end. This is a fascinating demonstration used by Nikoli Tesla in 1893.

When spun with a magnetic stirrer, the PhiTOP replicates Tesla's famous Egg of Columbus demonstration. An alternating magnetic field will spin the PhiTOP from rest along its minor axis due to Lenz's law of electromagnetic induction. As the angular speed increases, the center of mass will rise, and the PhiTOP will spin along its major axis.





Includes

- PhiTOP
- Mirror Stand

Coming soon!
Check pasco.com for availability.

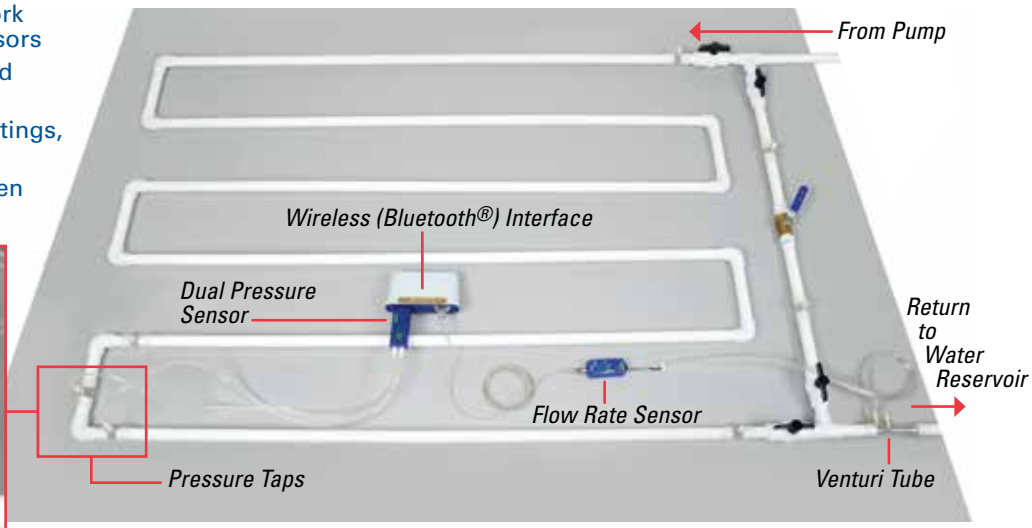
Order Information

PhiTOP SE-7594
Recommended:
Magnetic Stirrer SE-7700

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

When 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.

Create pump curves

Create a plot of pressure vs. 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.

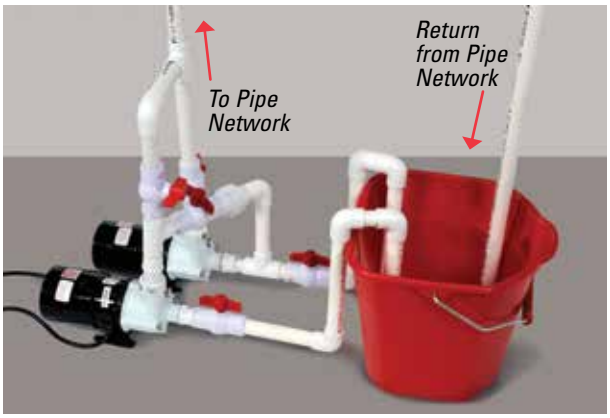
Portable interface

Use the SPARKlink Air (PS-2011) with a Dual Pressure Sensor (PS-2181) as a great portable pressure measurement system. The SPARKlink Air has two PASPORT sensor ports and can accommodate a General Flow Sensor to measure the volume flow rate and a Dual Pressure Sensor to measure the pressures along the pipe.

See Our New Experiments:

Piping Systems on p. 332
Pumping Systems on p. 333

Pressure Taps are installed before and after elbow joints to measure the pressure loss. The Venturi Tube measures the velocity.



Study one pump or two pumps in series and parallel.



General Flow Sensor

PS-2222



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.

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

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.

Pressure Taps

ME-2224



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.

ME-2224 includes six pressure taps and tubing.

Wireless Interface

The SPARKlink Air (PS-2011) is a Bluetooth® interface that allows the computer to be away from water spills. See page 30 for more information.



Order Information

General Flow Sensor	PS-2222	
Venturi Tube	ME-2220	
Pressure Taps (set of 6)	ME-2224	
Dual Pressure Sensor	PS-2181	p. 47
Required:		
PASPORT Interface		pp. 20-30
PASCO Capstone Software		pp. 70-73
PVC Pipe and Fittings (supplied by user)		
Pumps (2) (supplied by user)		
Shown in Use with:		
SPARKlink Air	PS-2011	p. 30
Optional Pitot Tube	ME-2221	p. 47

Water Pump

SE-7727

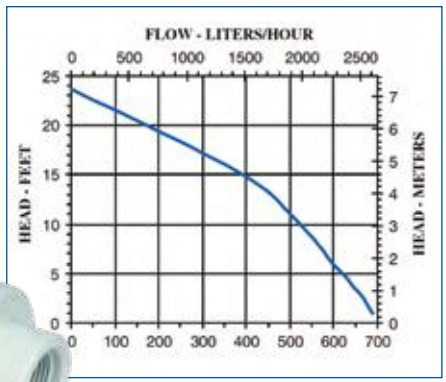
NEW

- Ideal for pipe network experiments

Features

- Little Giant Pump 4-MD Non-Submersible, In-line Use
- 1/12 hp open FC motor
- Glass-filled polypropylene magnet housing
- Glass-filled polypropylene volute
- Magnetic drive
- Nitrile O-ring
- Titanium thrust washers and shaft





Picture shows 12-inch (30 cm) ruler (not included) to indicate size.

Order Information

Water Pump SE-7727

Coming soon!
Check pasco.com for availability.

Explore the Equations for Fluid Flow Using Sensors

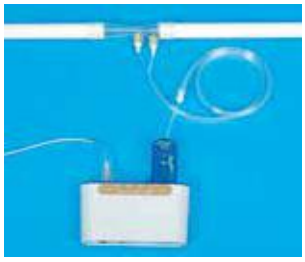
General Flow Sensor with Venturi Tube

PS-2225

- Measure fluid velocities and confirm the Continuity Equation
- Use Bernoulli's Equation to determine pressure difference
- Show faster moving fluids have lower pressures



The Venturi Tube has pressure taps at the narrow diameter and the larger diameter.



The General Flow Sensor connects to the Venturi Tube to measure the pressures.

Continuity Equation: $A_1 v_1 = A_2 v_2$

Bernoulli's Equation: $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$ *(at constant height)*

In this apparatus, the Venturi Tube has pressure taps at the narrow diameter and the larger diameter. The General Flow Sensor connects to the Venturi Tube to measure the different pressures due to different fluid velocities. You supply the ¾ inch PVC pipe and the water. It is suggested that you connect the pipe to a faucet with flexible tubing and, at the other end, let the water flow into a bucket resting on a Force Platform (PS-2141). As the water flows, the velocity can be determined by the changing weight of the bucket as measured by the Force Platform.

The recommended interface is the SPARKlink Air because two ports are required and it is convenient to have a wireless interface so your laptop can be away from the water. However, two AirLinks (PS-3200) or a 550 or 850 Universal Interface will do as well.

The experiments can be downloaded at www.pasco.com/fluids.

Order Information

General Flow Sensor with Venturi Tube PS-2225
Force Platform PS-2141
SPARKlink Air PS-2011
PASCO Capstone Software ..... See pages 70-73
Supplied by User:
PVC Pipe (3/4 inch), water, bucket
Recommended (for velocity verification):
Pitot Tube ME-2221

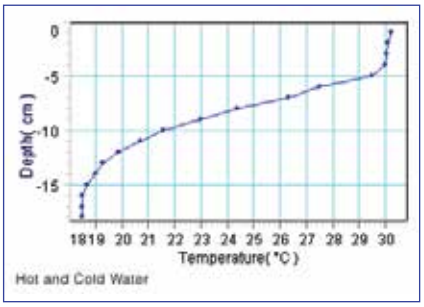
Density Circulation Model

ME-6816

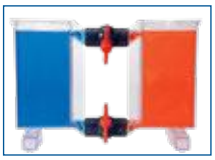


- Model density-driven circulation based on temperature, dissolved substances, or different liquids
- Demonstrate the driving forces of vertical ocean currents
- Measure temperature inversions based on density difference

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 66).



Here is data showing Temperature vs. Depth. Rapid temperature change occurs in the region where the two water bodies mix.



(fig. 1)

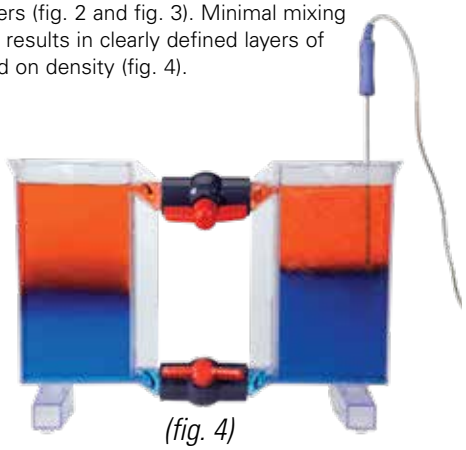


(fig. 2)



(fig. 3)

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 and fig. 3). Minimal mixing occurs and results in clearly defined layers of liquid based on density (fig. 4).



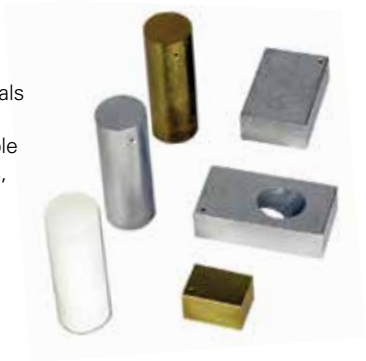
(fig. 4)

Order Information

Density Circulation Model ME-6816
Shown in use with:
Stainless Steel Temperature Probe ..... p. 49

Density Set

ME-8569A



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.
- One irregular shape: aluminum
- Instruction manual

Order Information

Density Set ME-8569A

Discover Density Set

SE-9719A

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

Mole Set

SE-7586A

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.



Includes

- Mole samples: Zinc, Aluminum, Iron, Copper
- Teaching Suggestions

Order Information

Mole Set SE-7586A

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

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:

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

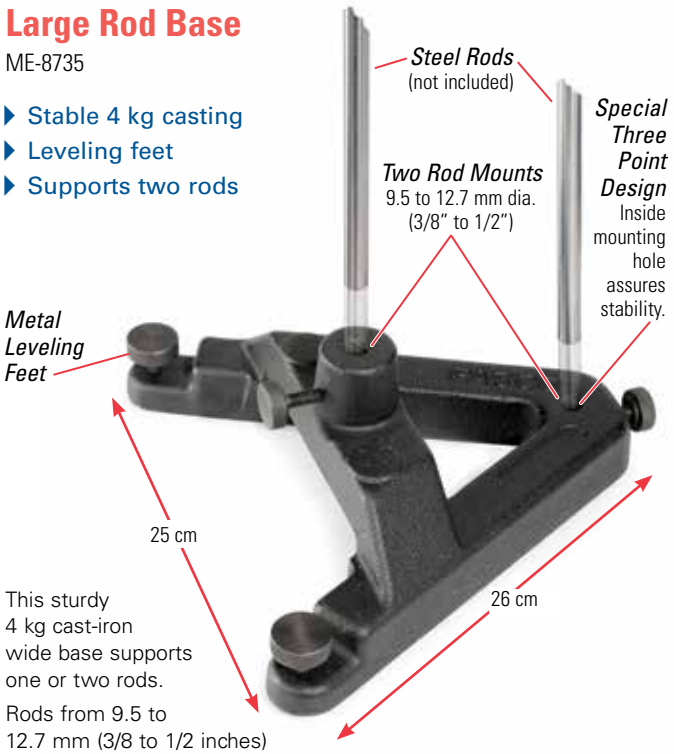
Order Information

100 ml Beaker (12 pack) SE-7287
1000 ml Beaker (6 pack) SE-7288
50 ml Graduated Cylinder (12 pack) SE-7289

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 from 9.5 to 12.7 mm (3/8 to 1/2 inches) diameter 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.



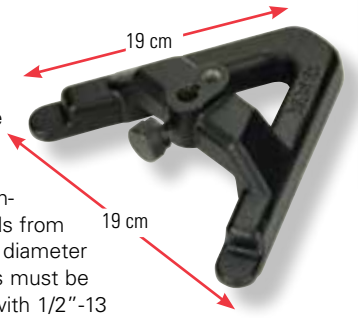
Order Information

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: 45 cm, 90 cm, and 120 cm.

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 are not included.)

120 cm Long
ME-8741

90 cm Long
ME-8738

60 cm Long
Threaded Rod
ME-8977

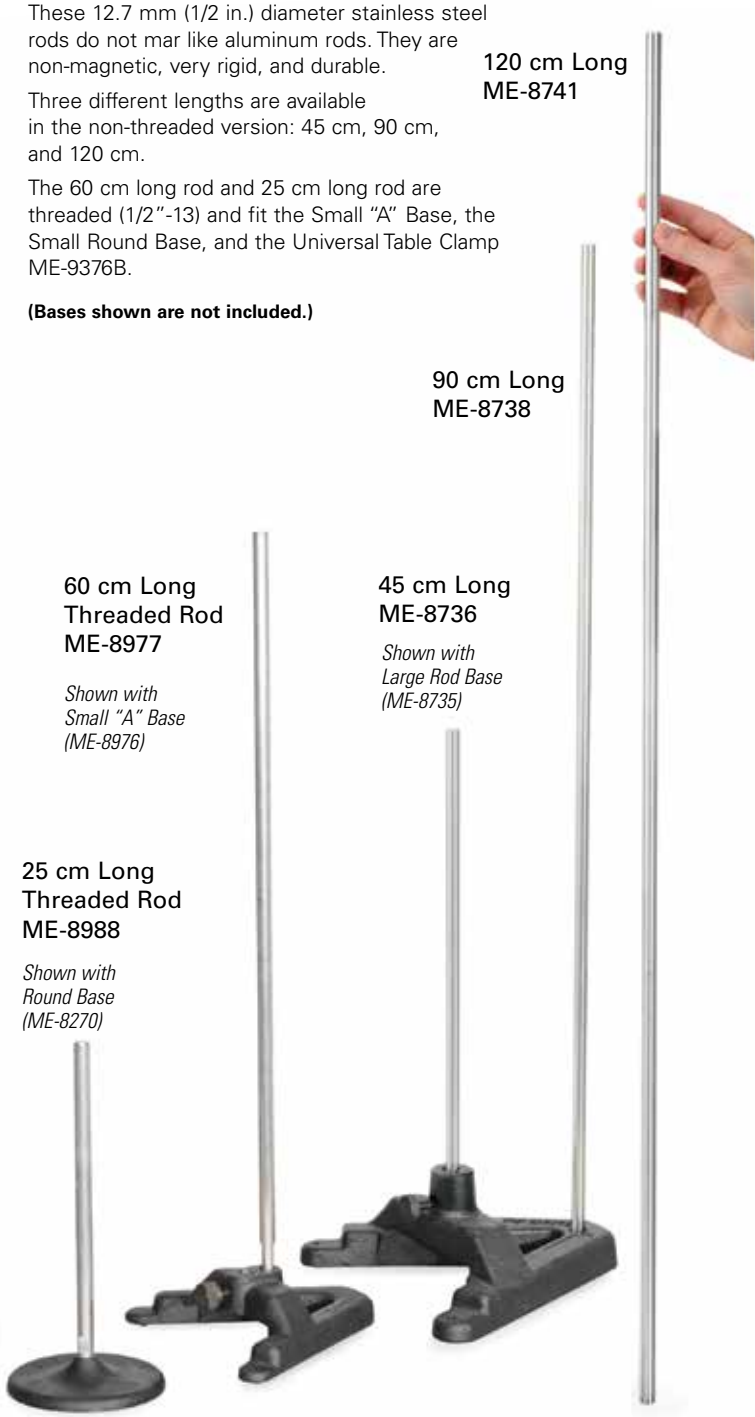
Shown with Small "A" Base (ME-8976)

45 cm Long
ME-8736

Shown with Large Rod Base (ME-8735)

25 cm Long
Threaded Rod
ME-8988

Shown with Round Base (ME-8270)



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

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. 186

Aluminum Clamp .....ME-8995 p. 189

Base and Support Rod

Large ME-9355

Round ME-8270



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. **Round Base with Rod:** The threaded steel rod is 12.7 mm (1/2 in.) in diameter and 25 cm long.

Order Information

Large Base and Support Rod ME-9355

Round Base with Rod.....ME-8270

How to choose the best mounting rod for you



Both of these rods are useful for mounting sensors, particularly photogates. Also, they work well as pulleys.

The SA-9242 stainless steel rod is the same length as the ME-9483 plastic rod. However, the steel rod has a smaller diameter that may not work with all clamps that require a standard 12.7 mm (1/2 in) diameter. The ME-9483 plastic rod is made of a hard plastic that clamp screws do not dent and it has a threaded brass stud. The lighter weight of the plastic rod will not damage pulleys when thrown into a bin.

Mounting Rods (10 pack)

ME-9483

These rigid plastic pulley handles (14 cm long, 12.7 mm diameter) have a 1/4"-20 metal stud that screws 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

Clamps

Right Angle Clamp
SE-9444

Buret/Utility Clamp
SE-9446

Three-finger Clamp
SE-9445



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

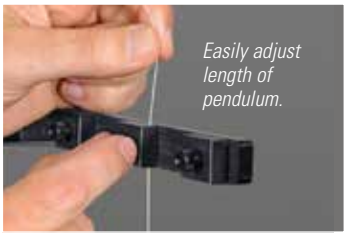
Right Angle Clamp	SE-9444
Buret/Utility Clamp	SE-9446
Three-finger Clamp	SE-9445

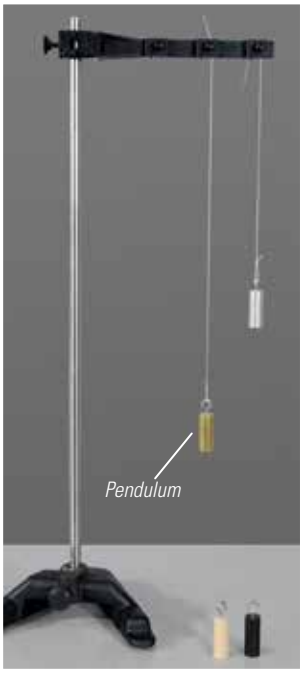
Pendulum Clamp
ME-9506



Hang up to three springs or pendulums. Suspension points are 54 mm apart. Fits rods up to 16 mm (5/8 inch) in diameter.

See page 167 for more information.





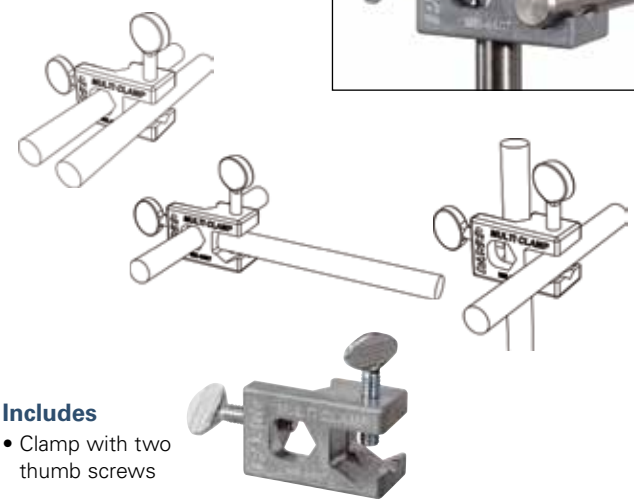
Order Information

Pendulum Clamp	ME-9506	
Shown in use with:		
Photogate Pendulum Set	ME-8752	p. 167
Small "A" Base	ME-8976	p. 186
Stainless Steel Rod (45 cm.)	ME-8736	p. 186

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

Table Rod Clamps

These 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

Universal Table Clamp ME-9376B
6.0 cm grip range

"C" Clamps

SE-7285 Large

This rugged clamp is perfect for attaching a variety of objects to a table. Available in 10 cm (4-inch) size.



Appearance may vary.

Order Information

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.

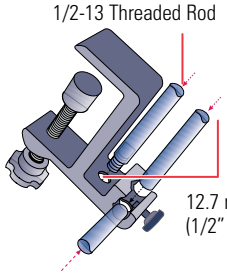


Order Information

Laboratory Jack	Model	Platform (cm)	Height (cm)	Load (kg)
Medium	SE-9373	15x15	7 - 25	25
Large	SE-9372	20x20	7 - 25	25

Universal Table Clamp

ME-9376B





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.



Order Information

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



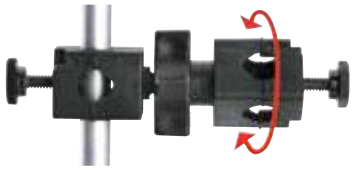
Order Information

Swivel Clamp (2 pack) ME-8743

Adjustable Angle Clamp

ME-8744

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

Pulleys

Super Pulley

ME-9450A

- 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
- Lightweight
- Precision dimensions

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

Smart Gate Pulley System

PS-3702



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

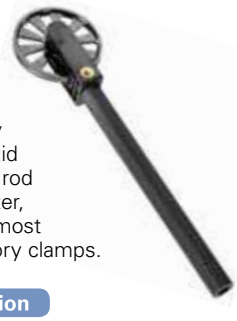
- Smart Gate (1) PS-2180
- Super Pulley (1) ME-9450A
- Super Pulley Rod (1)

Order Information

Smart Gate Pulley System.....PS-3702

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

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

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

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
- Connecting Rod

Order Information

Atwood's Machine..... SA-9241

Metric Spring Scales

(Five different ranges)

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.

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.



Graduations are easy to read, and the resolution is 2% of full scale.



PASCO Spring Scales: Five metric spring scales provide accurate measurements over a wide range of forces.

Order Information

Metric Spring Scales

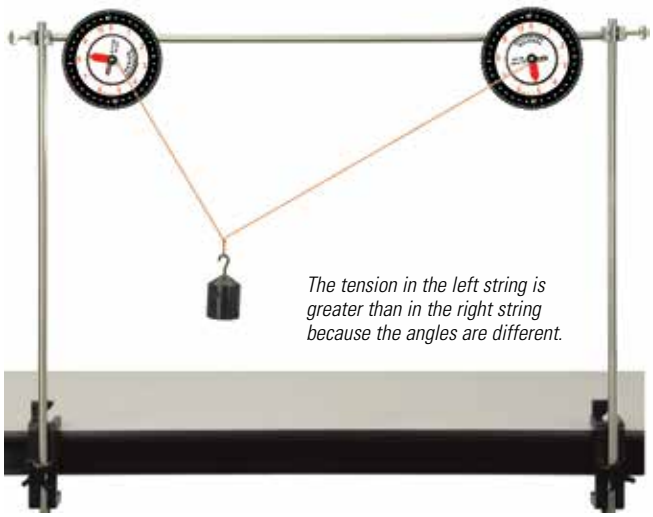
Model	Range	Resolution	Color
ME-9509	1.0 N	0.02 N	Red
ME-9510	2.0 N	0.04 N	Lt. Green
ME-9511	5.0 N	0.1 N	Brown
ME-9512	10 N	0.2 N	Dk. Green
ME-9513	20 N	0.4 N	Orange

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

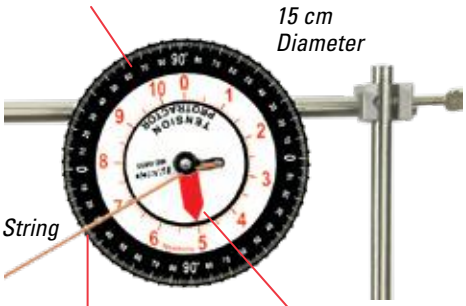
See page 139 for more information.



The tension in the left string is greater than in the right string because the angles are different.

Outside degree scale can be rotated to set the zero.

15 cm Diameter



String

30° Angle Reading

The red arrow indicates tension reading (5.0 N) of the torsion spring scale.

Includes

- One Tension Protractor



Order Information

Tension Protractor	ME-6855	
Recommended:		
Large Table Clamp	ME-9472	p. 189
90 cm Long Rod	ME-8738	p. 186
Multi Clamp	ME-9507	p. 188
Hooked Mass Set	SE-8759	p. 197

Metric Measuring Tape

SE-8712A



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

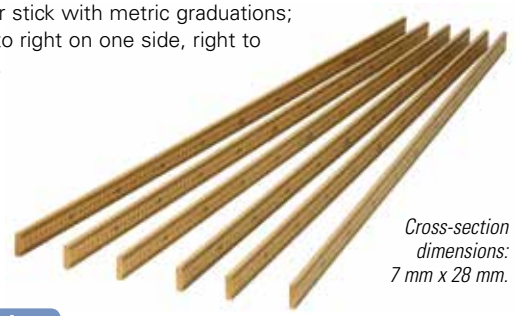
Stainless Steel Calipers..... SF-8711

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.



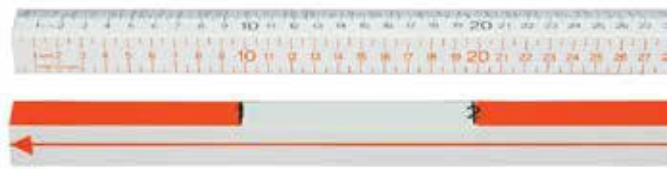
Cross-section dimensions: 7 mm x 28 mm.

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 130. The special stickers are used to attach the metal washers to the plastic balls, allowing them to be suspended from a magnet.

WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.





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)

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 the PASCO Projectile Launcher (ME-6800)

Order Information

Steel Balls (4 pack) ME-9864

Spherical Mass Set

ME-8968

This set includes four balls with a diameter of 2.5 cm each, but features 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 Projectile Launcher.

Order Information

Spherical Mass Set ME-8968

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).

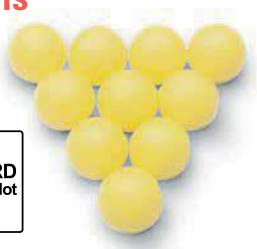
Order Information

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

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 Elastic 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-8986



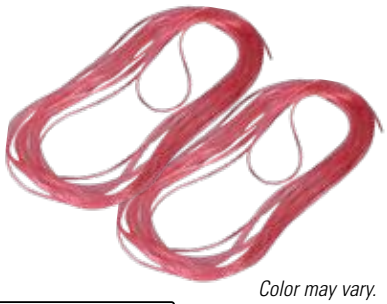
For Elastic Bumper (ME-8998)
Also fits Air Track Bumpers (page 121)

Order Information

Rubber Cord
(Spool of 30 m)..... ME-8986

Glow String (2 pack)

SE-8690



Color may vary.

⚠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



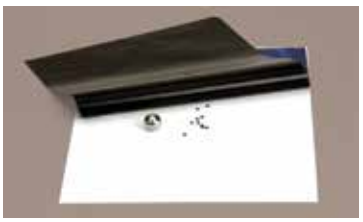
Stop falling objects from bouncing with PASCO's No-Bounce Pad. The 30 cm x 30 cm x 2.5 cm dimensions of the pad provide an ample target for gravity demonstrations. Prevents heavy objects from damaging the floor and prevents falling objects from being damaged on impact.

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 gradations 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

Gratnells® Rolling Carts

NEW

EP-3574 (2-column) EP-3575 (3-column)

These movable storage rack carts have been designed for Gratnells trays (sold separately). With this rack system, you can transport materials to and from the classroom. They include large castors with brakes for added stability.

Here is an ideal way to store PASCO sensors and equipment. These rolling carts can be configured for whatever size trays you need.

These carts can be used to store the equipment kits from the *Essential Physics* or *Essential Chemistry* curriculum, the storage trays we offer for wireless sensors, or any of the four sizes of empty trays that we offer for whatever you would like to store.



EP-3574



EP-3575

EP-3574:
Stores up to 8 Gratnells F2 trays
24 pairs of runners
Dimensions: 107 cm high, 70 cm wide, 43.5 cm deep

EP-3575:
Stores up to 12 Gratnells F2 trays
16 pairs of runners
Dimensions: 107 cm high, 102 cm wide, 43.5 cm deep

Assembly is required.
Trays not included.

Order Information

Gratnells Rolling Carts (2 col.) EP-3574
Gratnells Rolling Carts (3 col.) EP-3575

Gratnells® Storage Trays with Lids

NEW

These empty Gratnells storage trays with lids have a length of 427 mm and width of 312 mm. The depth of each follows:

F1: 75 mm

F2: 150 mm

F25: 225 mm

F3: 300 mm



F1 F2 F25 F3

Order Information

Gratnells Storage Tray (F1) Shallow PS-3326
Gratnells Storage Tray (F2) Deep PS-3327
Gratnells Storage Tray (F25) Extra Deep PS-3328
Gratnells Storage Tray (F3) Jumbo PS-3329

Storage Bins

SE-7560

These stackable plastic bins with lids are useful for storing sensors.
14" L x 9.5" W x 6.9" D



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 352 for an example.

14 cm x 14 cm x 19.5 cm tall

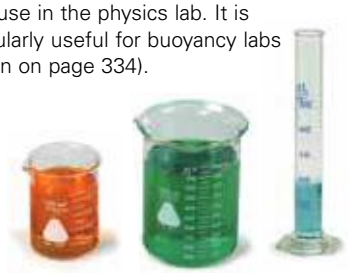


Order Information

3.8 Liter Plastic Container Set (set of 2) ME-7559

Glassware

This rugged borosilicate glassware is for use in the physics lab. It is particularly useful for buoyancy labs (shown on page 334).



Order Information

100 ml Beaker (12 pack) SE-7287
1000 ml Beaker (6 pack) SE-7288
50 ml Graduated Cylinder (12 pack) SE-7289

Discover Pi Set (10 pack)

ME-6819A

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.



Includes

- Each pack includes 4 Pi Circles: 5.2, 6.4, 8.9, 10.0 cm diameter
- Transparent Measuring Tape

Order Information

Discover Pi Set (10 pack) ME-6819A

Water Reservoir

ME-8594

This calibrated 1000 ml cylinder is useful for experiments (as shown on page 231), 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

Ohaus Electronic Balances

SE-8823A (220 g)
SE-8756B (420 g)
SE-8757B (2200 g)
SE-8758B (8200 g)



The Ohaus Scout SKX digital electronic balances 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 these balances easy to keep clean.

Specifications

Catalog #	SE-8823A	SE-8757B	SE-8758B	SE-8756B
Capacity:	0-220 g	0-2200 g	0-8200 g	0-420 g
Resolution:	0.01 g	0.1 g	1.0 g	0.01 g
Pan Size:	12 cm dia	16.5 x 4.2 cm	16.5 x 14.2 cm	12 cm dia.

Make these balances work with PASCO Capstone and SPARKvue on your computer via Bluetooth® or USB with:

Ohaus Bluetooth
Device Adapter SE-8822

Ohaus USB
Device Adapter SE-8821

Order Information

Ohaus Scout SKX Balances
220 g SE-8823A
420 g SE-8756B
2200 g SE-8757B
8200 g SE-8758B

Ohaus Triple-Beam Balance

SE-8723 (without tare)
SE-8707 (with tare)



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 Balances (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

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 g or 10 g 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 g 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)



Includes

- One 0.5 kg mass hanger
- 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)



Includes

- One 0.5 kg mass hanger
- 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

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

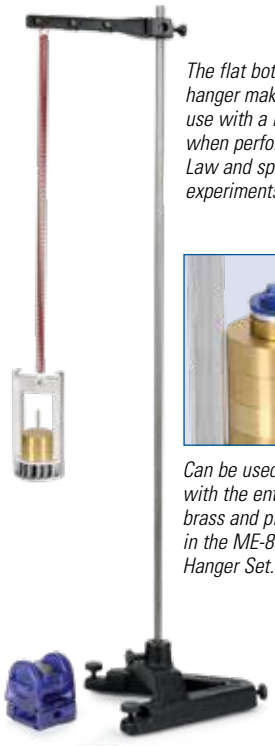
Hooked Mass Set..... SE-8759

1 kg Mass and Hanger Set

ME-9337 (1 kg set)

Set features a 200 g cast aluminum mass hanger with a steel post, and four "holed" 200 g 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.

Includes

- Mass hanger (ME-9350)
  Height of hanger: 16 cm
- Set of four masses (ME-9351)
  Diameter of masses: 5 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. 186
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



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 EVENT/RECALL button allows you to view the last event 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.



Two Display Modes:
MM:SS.SS (00:25.18) or
Decimal Seconds (25.18s)



It also sits on the table at a convenient viewing angle.



The PASCO Stopwatch fits comfortably in your hand.

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: One 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

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

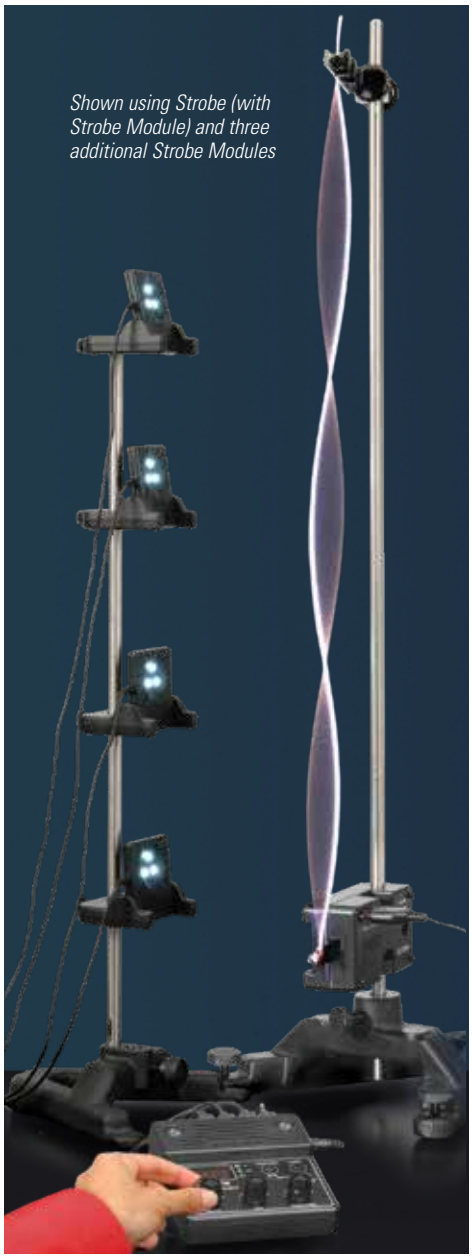
Strobe

ME-6978

- 1 Hz to 500 Hz
- Variable intensity
- Low cost

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

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

Order Information

Strobe..... ME-6978
(Includes Control Box and one Strobe Module)
Additional Strobe Modules ME-6982
Shown in use with:
String Vibrator ..... WA-9857A p. 254
Sine Wave Generator ..... WA-9867 p. 255

Stroboscope

SF-7202

NEW

- Bright xenon lamp has short flash duration
- Digital frequency display on back

The flash rate of this xenon strobe can be adjusted from 1 to 300 flashes per second (60 to 18,000 flashes per minute). The display can be switched between impulses per second, impulses per minute, and external triggering. There is an option to connect an external triggering device to the safety sockets to control the flash rate or connect an external digital counter to measure the impulse output. There is a threaded hole in the base to attach a tripod.



Specifications

Flash Rate Range: 1 to 300 Hz
Trigger Input Max: 300 Hz.
Dimensions: 18 x 24 x 12 cm

Order Information

Stroboscope.....SF-7202

Thermal Expansion Apparatus

TD-8856

- Use with Multimeter or Temperature Sensor
- Brass, copper, and aluminum tubes included

With PASCO's Thermal Expansion Apparatus, students can accurately and easily investigate the expansion of metals with increasing temperature.



Base
Provides storage for all three tubes.

Steam Generator
(sold separately)



Built-in Digital Gauge
Simple and very accurate measurements with 0.01 mm resolution



Built-in 10 kΩ Thermistor
Together with a digital ohmmeter, or Temperature Sensor directly measures the temperature of the tube.

Digital Multimeter
Measures thermistor resistance (sold separately).

Features

- **Built-in Digital Gauge:** Measures the rod expansion with (0.01 mm resolution).
- **Built-in Thermistor:** A 10 kΩ thermistor is connected directly to each tube, and the temperature can be determined using a digital ohmmeter or Temperature Sensor.
- **Heat with Steam or Water:** The fluid used may be steam or water at any temperature.
- **Three Drop-in Metal Tubes:** Each tube connects securely onto the rigid base. The other two can be simultaneously mounted on the base for convenient storage.



Thermistor cable connects directly to the Temperature Sensor.

Includes

- Base with built-in dial gauge and thermistor
- Expansion tubes: brass, copper and aluminum; 16 mm dia. (80 cm length)



Order Information

Thermal Expansion Apparatus	TD-8856	
Required:		
Steam Generator	TD-8556A	p. 201
Recommended:		
Digital Multimeter (ohmmeter)	SE-9786A	p. 250
Or		
Quad Temperature Sensor	PS-2143	p. 50

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 202-203 for additional Steam Generator applications.

Order Information

Steam Generator..... TD-8556A

Heater-Stirrer

PS-3401

- The Heater-Stirrer is the new lab essential!



This compact heater-stirrer has a white ceramic top that is ideal for heating and for seeing color changes when mixing solutions. It has been designed to withstand spills. Its safety features include warning labels and indicator LEDs. And the included rod makes it easy to support sensors.

When used as a heater:

This compact new Heater-Stirrer can boil water in minutes. The ceramic top provides an even heating surface and the indicator LEDs let you know when the top is hot.

When used as a stirrer:

This new apparatus is great for mixing solutions. The white top makes color changes during titrations easy to see.

Specifications

Speed range: 50-1500 rpm

Plate diameter: 135 mm

Max temperature: 310˚C

Includes

• Support rod.

Order Information

Heater-Stirrer..... PS-3401

Ball and Ring

SE-7597

- Demonstrates thermal expansion

When the Ball and Ring are at room temperature, the ball easily fits through the ring. Heat the ball in a Bunsen burner flame and it expands and no longer fits through the ring. If the ring is also heated, the ball will fit through it once again.



Specifications

Length: 23 cm

Ball Diameter at Room Temperature: 2.36 cm

Ring Inner Diameter at Room Temperature: 2.39 cm

Order Information

Ball and Ring.....SE-7597

Bi-metallic Strip

SE-7598

- Demonstrates differential thermal expansion
- Demonstrates how thermostats work

When heated in a Bunsen burner flame, this bi-metallic strip bends. The strip is steel on one side and brass on the other side. Since brass expands more than steel, the strip becomes longer on the brass side. As it cools, it becomes straight again.



Specifications

Blade Length: 12.5 cm

Order Information

Bi-metallic Strip SE-7598

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, and sheetrock
- Plastic tubing to connect steam generator
- Instruction manual and experiment guide

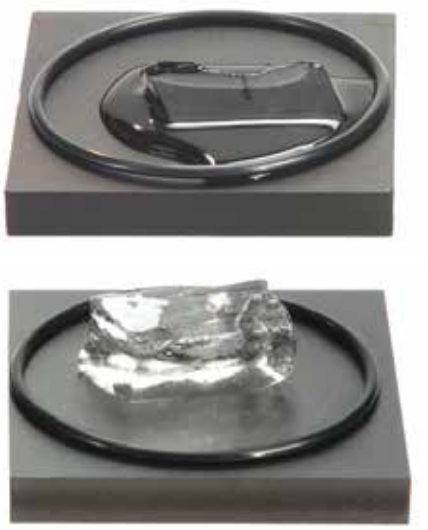
Order Information

Thermal Conductivity Apparatus..... TD-8561
Required:
Steam Generator..... TD-8556A p. 201
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

Basic Calorimetry Set

TD-8557B

An affordable introduction to thermodynamics

Styrofoam™ calorimeter cup (7.5 cm inside diameter, 10 cm deep) has 1.3 cm thick walls for excellent thermal properties. Set includes five different metal samples, a thermometer, plastic tubing, and a water trap that prevents unwanted condensation of steam.



Includes

- One calorimeter cup with lid
- Alcohol thermometer: 20°C to 110°C in 1° increments
- Samples of aluminum, copper, brass, zinc, and stainless steel: 80 g each
- Water trap and plastic tubing
- Instruction manual and experiment guide

Order Information

Basic Calorimetry Set	TD-8557B	
Required:		
Steam Generator	TD-8556A	p. 201
Ohaus Triple-Beam Balance	SE-8723	p. 196
Replacement Supplies:		
Calorimetry Cups (set of 6)	TD-8825A	

Specific Heat Set

SE-6849

This specific heat set has five different materials, all with 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	

Density Set

ME-8569A

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

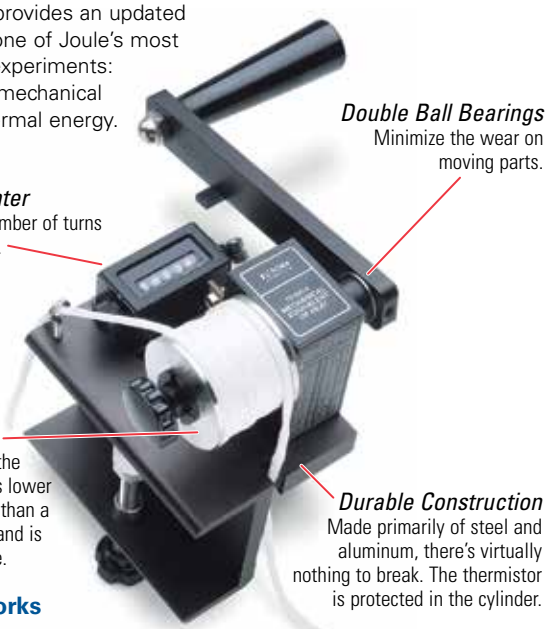
Density Set	ME-8569A

Mechanical Equivalent of Heat Apparatus

TD-8551A

- 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.



Double Ball Bearings
Minimize the wear on moving parts.

Crank Counter
Counts the number of turns on the handle.

Thermistor
Embedded in the cylinder, it has lower thermal mass than a thermometer and is less breakable.

Durable Construction
Made primarily of steel and aluminum, there's virtually nothing to break. The thermistor is protected in the cylinder.

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. 250
Triple-Beam Balance	SE-8707	p. 196

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 – Calorimeter

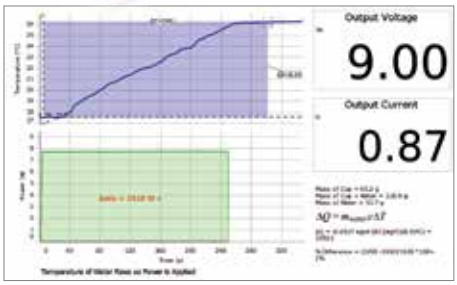
ET-8499

- 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.





The bottom graph displays the power output from the generator and the top 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 vs. Time curve.

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



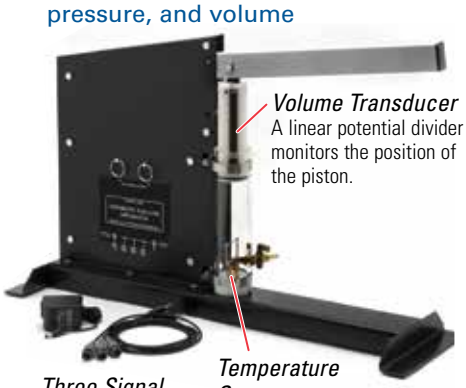
Order Information

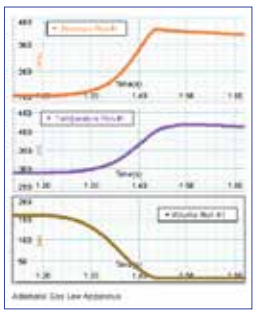
Energy Transfer – Calorimeter	ET-8499
Recommended for use with ScienceWorkshop:	
Temperature Sensor	CI-6605A
Voltage Sensor	UI-5100
Current Sensor	CI-6556
Recommended for use with PASPORT:	
Temperature Sensor	PS-2125
Voltage/Current Sensor	PS-2115

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 vs. 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:

PASCO Capstone Software..... pp. 70-73

A computer with an interface that will accept three analog signals simultaneously via 5 or 8-pin DIN connectors such as PASCO's 550 and 850 Interfaces.

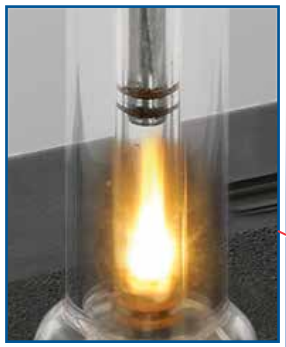
Compression Igniter

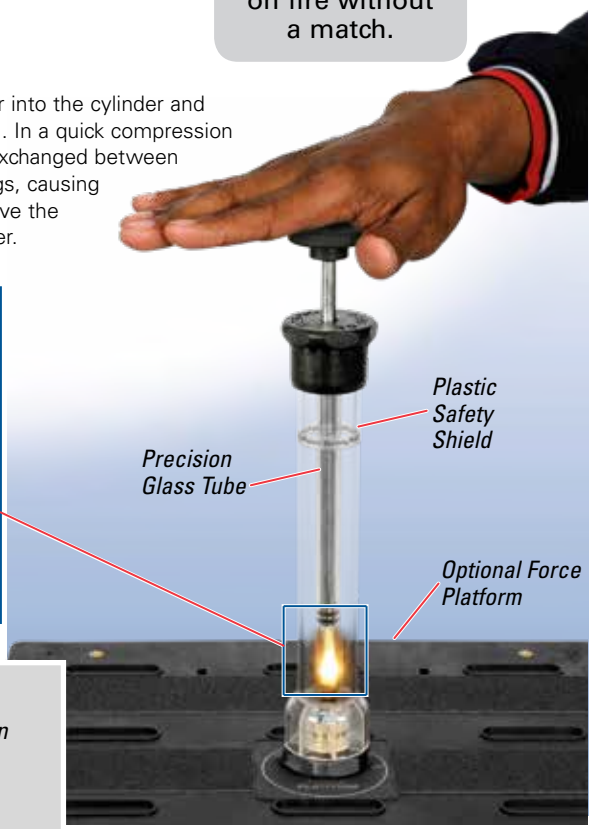
TD-8577

- 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.

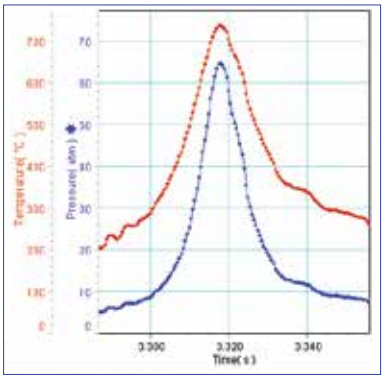






This Compression Igniter has been specially designed to be cleanable. The bottom screws off to clean out the soot and to load the paper. The large piston handle decreases the pressure on your hand and makes it easier to hit the piston quickly.

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. 40

Ideal Gas Law Apparatus

TD-8596A

- 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.

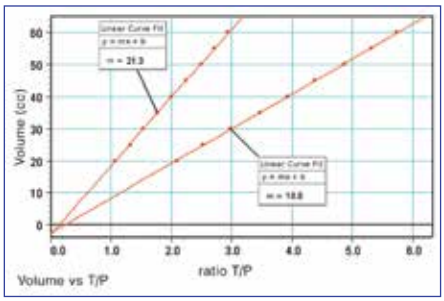


How It Works

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 allow 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 damaging of the thermistor within the syringe and to allow quick (adiabatic) volume changes.



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	
Shown in use with:		
Absolute Pressure/ Temperature Sensor	PS-2146	p. 48
AirLink	PS-3200	p. 30
PASCO Capstone Software		pp. 70-73

Absolute Zero Apparatus

TD-8595

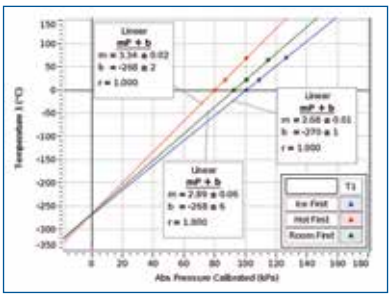
- Constant volume sphere
- Measure pressure and temperature directly using PASCO sensors
- Empirically determine the absolute zero temperature

The Absolute Zero Sphere is an effective tool for determining absolute zero temperature. Connect a Pressure Sensor and Temperature Sensor 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.



Absolute Zero Apparatus being used with PASPORT Absolute Pressure Sensor

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.



Includes

- Absolute Zero Sphere
- Built-in Fast Response
- Thermistor Probe
- Quick Connect Pressure Port



Order Information

Absolute Zero Sphere	TD-8595	
Shown in use with:		
Absolute Pressure/ Temperature Sensor	PS-2146	p. 48
AirLink	PS-3200	p. 30
PASCO Capstone Software		pp. 70-73

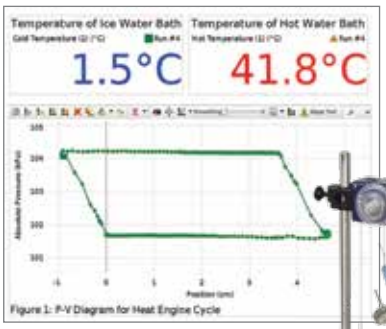
Heat Engine/Gas Law Apparatus

TD-8572A

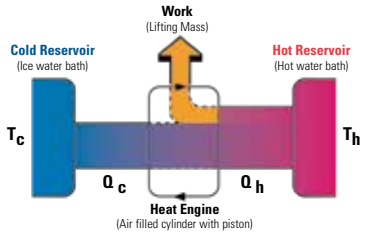
- Measure the actual efficiency of a real heat engine.
- Bring P-V diagrams to life.
- Low-friction graphite piston in glass cylinder
- See the complete experiment (EX-5530B) on page 352.

How It Works

1. 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, closing the isobaric/isothermal cycle.
2. The heat engine cycle is plotted in real time on a Pressure vs. Volume graph.
3. Pressure in the cylinder is measured by a pressure sensor, volume is measured by tracking the piston position with a rotary motion (or motion) sensor, and the temperature of the hot and cold baths are recorded with temperature sensors.
4. 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.



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.



Includes

- Heat Engine
- Air Chamber
- Rubber Stopper with hole
- Tubing with Quick
- Connect Fittings
- Shut-off Valve

Order Information

Heat Engine/Gas Law Apparatus	TD-8572A	
Shown in use with:		
850 Universal Interface	UI-5000	p. 26
Dual Pressure Sensor	PS-2181	p. 47
Rotary Motion Sensor	PS-2120A	p. 25
3 Liter Plastic Container Set (2)	ME-7559	p. 185
Small "A" Base	ME-8976	p. 176
60 cm Rod	ME-8977	p. 176

Specifications

Piston diameter: 32.5 mm

Maximum piston displacement: ≈10 cm

Heat Engine Accessory

Included in TD-8572A

TD-8581A

This replacement kit includes the set of parts for the Heat Engine (suitable for both versions TD-8572 and TD-8572A) that are most likely to need replacement after extensive use. These parts connect the air chamber and the pressure sensor to the Heat Engine.

Includes

- 1 Air Chamber
- 1 Rubber Stopper #10 with hole
- 2 Male Luer Lock Barbs
- 2 Female Luer Lock Barbs
- 1 Tube Connector 3/16 x 1/8"
- 1 Plastic Tee for 1/8" Tubing
- 1 One-way Stopcock
- 2 Female In-line 1/8" CPLG
- Polyurethane Tubing 1/8" ID 80 cm

Order Information

Heat Engine Accessory TD-8581A

Glass Stirling Engine

SE-8636A



See the pistons at work and look inside the glass cylinders at the Stirling Cycle principle in action. This engine is extremely interesting to watch and it is connected to a generator that lights LEDs. To illustrate the versatility of a Stirling Engine, we provide a burner for denatured alcohol and a platform for solid fuel.



Features

- Clear cylinders for viewing pistons
- Generator with LEDs
- Replaceable, adjustable Pyrex® heat cap
- Replaceable Pyrex power cylinder
- Solid hardwood platform
- Completely assembled and ready to run

Specifications

18 cm length x 9 cm width x 8 cm height

Order Information

Glass Stirling Engine SE-8636A

Colliding Spheres

SE-7303

NEW

- Demonstrates transformation of kinetic energy into heat
- Colliding spheres leave burn mark on paper

Hit these two steel balls together with a piece of paper in between. The kinetic energy is converted to heat and leaves a burn mark on the paper.



Diameter: 2 in (5 cm)

Coming soon!
Check pasco.com for availability.

Order Information

Colliding Spheres SE-7303

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.

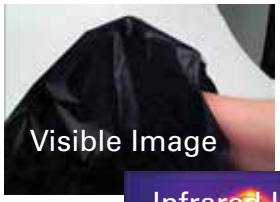
Order Information

Thermoelectric Converter TD-8550A

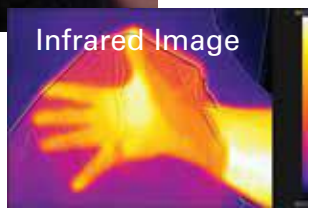
Required:
Containers for holding hot water, cold water, etc.
Triple Output Power Supply ..... SE-8587 p. 244
Partial Immersion Thermometer SE-9084B

FLIR C3 Thermal Imaging Camera

SE-7128A



Hand inside black garbage bag



- "See" into the infrared
- Simultaneously record visible and infrared snapshots
- Stream video using FLIR tools
- Record infrared movies in PASCO Capstone
- Determine temperatures from color coding
- WiFi-enabled

Extend your students' world into the infrared with this full-featured, pocket-sized thermal camera. This infrared camera takes two pictures at once: one in the visible spectrum and one in the infrared. An outline of the visible image is superimposed on the colorized infrared picture for reference. In addition to the color temperature scale there is a digital readout of the temperature. All of this is offered at a special educator's price.

Consider These Activities:

- Check light transmission through different media: Visible light easily passes through acrylic; IR doesn't. Visible light is not readily transmitted through black balloons, but they are transparent in the IR, as are silicon wafers and black plastic garbage bags.
- Slide a block on the table. We always tell our students that the energy is dissipated as heat. Show them!
- Look at your infrared reflection on a white board.
- Record infrared video in PASCO Capstone and sync to data from thermal experiments.
- Take off your shoes and follow your footsteps by looking at your infrared footprints.
- Evaluate different types of insulation.
- Measure the temperature of ice water.
- Beakers of water with different temperatures (as measured with the camera) come to an easily predictable temperature when mixed together.

Key Features

1. Light, slim profile
2. Bright 3" touchscreen
3. Built-in LED work light and flash
4. Big snapshot button stores thermal, visible, and visible overlay in each JPEG
5. Easy-access on-off button powers up fast
6. USB Micro-B file transfer and data streaming
7. Visible camera
8. Thermal camera
9. Intuitive user interface



Specifications

3" touchscreen
IR sensor: 80 x 60 pixels
Digital camera: 640 x 480 pixels
Temperature reading at each of the 4,800 pixels
Temperature range: -10°C to 150°C
Accuracy: ±2°C or 2%, whichever is greater
Onboard memory stores 500 sets of jpeg images
USB Micro-B connector
WiFi
Rechargeable Li-ion polymer battery with 2 h operating time
Weight: 0.13 kg (0.29 lb)
Size (L x W x H): 12.5 x 8.0 x 2.4 cm
2-year warranty on parts and labor
10-year warranty on detector

Includes

- FLIR C3 thermal imaging camera
- Tripod mount
- Power supply/charger
- USB cable
- ResearchIR software
- Access to FLIR education content with lectures, experiments, and teacher's guides

Order Information

FLIR C3 Thermal Imaging Camera.....SE-7128A

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

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

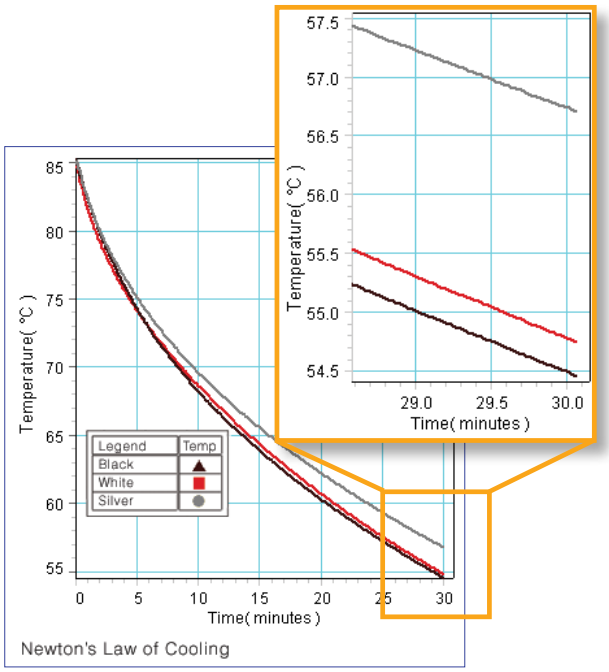
Non-Contact Temperature Sensor.....PS-2197
Requires an Interface (see page 30)

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. *(Wireless temperature probes not included.)*



The black, white, and silver Radiation Cans are filled with hot water and allowed to cool. Graphs made in PASCO Capstone.

Order Information

Radiation Cans (set of three) TD-8570A
Required to measure temperature:
Wireless Temperature Sensor..... PS-3201
OR
Partial Immersion Thermometer ..... SE-9084B p. 201

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. 250

Radiation Sensor

TD-8553

- Radiation detector
- Thermopile



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..... TD-8553
Required:
Basic Digital Multimeter..... SE-9786A p. 250

Stefan-Boltzmann 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 vs. Resistivity is provided).

Order Information

Stefan-Boltzmann Lamp TD-8555
Required:
12 V DC Power Supply – see p. 244

Thermal Radiation Laboratory

TD-8855





With the Radiation Sensor, a versatile Radiation Cube, and the Stefan-Boltzmann 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-Boltzmann Lamp uses a special bulb to provide a near-perfect point source, providing accurate results.

Finally, students can verify the Stefan-Boltzmann Law for both low and high temperatures by using the Radiation Cube for the low temperatures and the Stefan-Boltzmann Lamp for the high temperatures.







Typical Experiments

With Teacher's Guide and Sample Data.

1. Introduction to Thermal Radiation
2. Stefan-Boltzmann Law at Low Temperatures (Rrad = σT^4)
3. Inverse Square Law
4. Stefan-Boltzmann 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-Boltzmann Lamp
- Radiation Sensor

See opposite page for component details.

Order Information

Thermal Radiation Laboratory	TD-8855	
Required:		
Basic Digital Multimeter	SE-9786A	p. 250
Low Voltage Power Supply	SF-9584B	p. 244
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 226

Crooke's Radiometer

NEW

SE-7283

Demonstrates that black surfaces are better radiators



This product consists of a set of vanes, each with one shiny side and one black side, mounted on a spindle in a partially evacuated glass bulb. When exposed to the sun or other intense light, the vanes begin to rotate with the black side trailing. The black side heats the air next to it more than the shiny side, so the air pushes harder on the black side.

Dimensions: Diameter 8 cm; Height 13 cm

Order Information

Crooke's Radiometer	SE-7283

Van de Graaff Generator

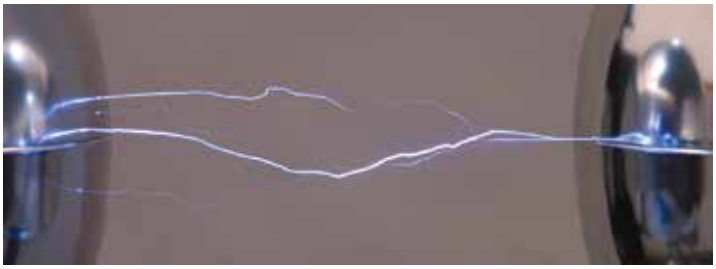
Van de Graaff Generator, High Voltage

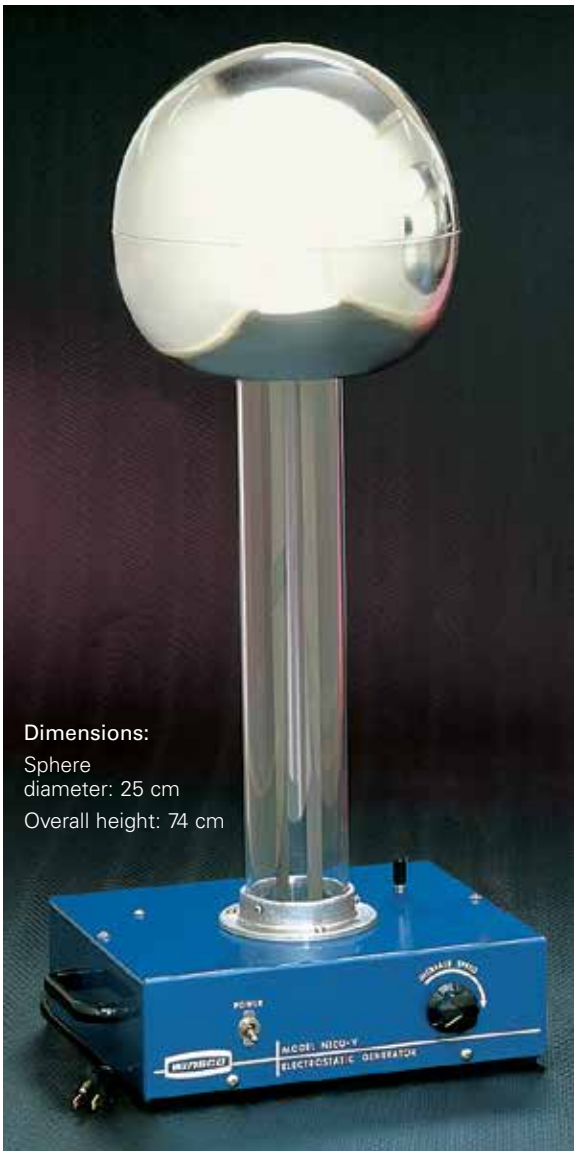
SE-8691

- 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.

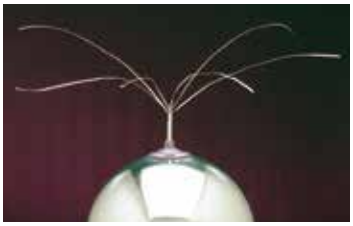




Electric Plume

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

SE-7355



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

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
- Three rubbing cloths (wool, silk, fur)

Order Information

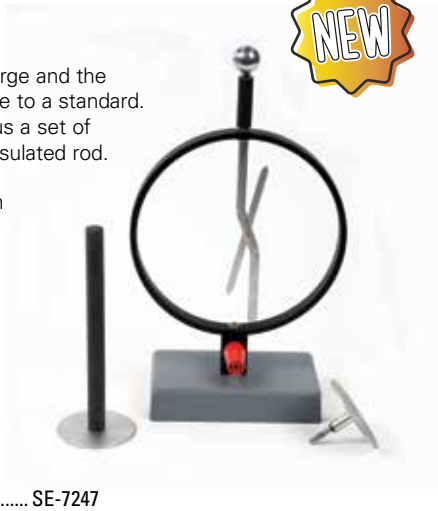
Classic Electrostatics Materials Kit SF-9068

Electroscope

SE-7247

Show the amount of charge and the sign of the charge relative to a standard. Includes charging ball plus a set of condenser plates with insulated rod.

Ring diameter: 150 mm



Order Information

Electroscope..... SE-7247

Pith Balls (Pack of 10)

SE-7719

These threaded pith balls are coated with a conductive material. Suspend two pith balls from a rod and charge with the Electrostatic Materials SE-6658.



Coming soon!
Check pasco.com for availability.

Order Information

Pith Balls (Pack of 10).....SE-7719

Electrostatics Materials

SE-6658

This electrostatics kit provides the necessary tools to separate positive and negative charges. Students can experiment with different combinations of cloth and rod materials to explore how each becomes charged.



Includes

- 3 fabric cloths (wool, cotton, silk)
- 3 rods (glass, ebonite, acrylic)

Order Information

Electrostatics Materials SE-6658

Dissectible Leyden Jar

SE-7718

▸ Acts as a capacitor



This Leyden Jar is designed for classroom demonstrations and comes with a durable inner and outer plate, a plastic dielectric, and instructions. The inner plate has a hook and ball attached, which makes it easy to charge with a Van de Graaff Generator or a charged rod.

Leyden Jar is 3" in diameter and 8" tall.



Order Information

Dissectible Leyden Jar SE-7718

Coulomb's Law Apparatus

ES-9070

See page 305.



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

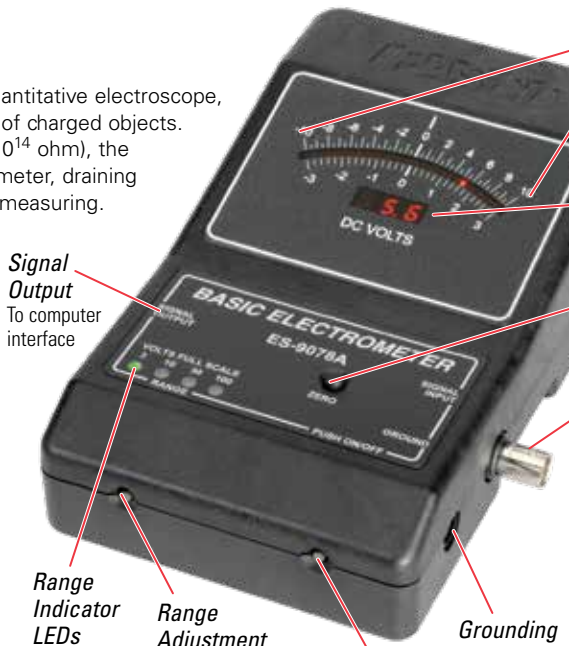
Includes

- 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 Sensor

PS-2132



- 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).

Order Information

Charge Sensor.....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.



Order Information

Charge Producers and Proof Plane ES-9057C

Replacement Pad Set

ES-9056 *(for ES-9057C)*



Includes

- Artificial leather pads (5)
- Blue vinyl pads (5)

Order Information

Replacement Pad Set..... ES-9056

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 vs. 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

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:

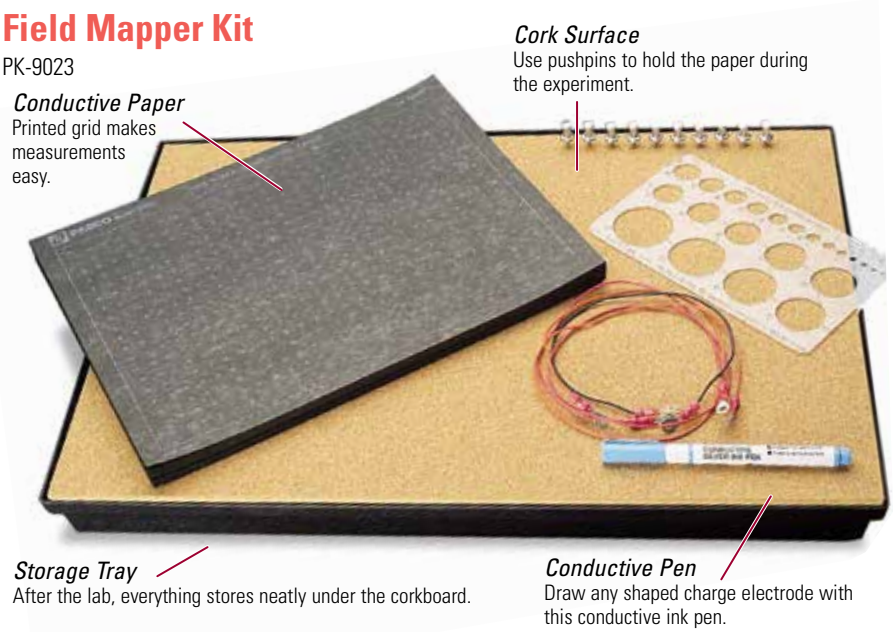
Conductive Ink Pen PK-9031B
(limited shelf life of six months; pen is not refillable)

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



Start by investigating standard electrostatic configurations, such as point sources, dipoles, and capacitors. Then go further. You might, for example, investigate whether a person is safe in a car, under a tree, or on top of a flag pole in a thunder storm. Or you might create an electrostatic model of fluid flow to show that water flows fastest in the narrowest portion of a hose.

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
2. Plot the equipotentials
3. Plot the electric field

Features

- Complete kit
- Complete manual
- Measure electric fields directly
- Measure potentials directly
- No mess
- Inexpensive
- Easy storage

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.

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

Order Information

Field Mapper Kit PK-9023

Required:

Basic Digital Multimeter ..... SE-9786A p. 216
(or any voltmeter with at least a 10 MΩ input impedance)

Power Supply ..... SE-8587 p. 244
(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

Special Conductive Ink Pen

PK-9031B

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

**Price may fluctuate with the price of silver.*

Resistance Apparatus

EM-8812

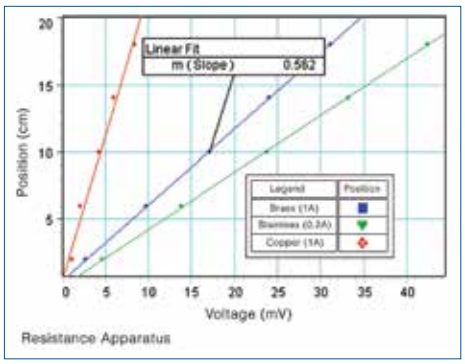
- Slide-wire potentiometer
- Measure resistance and resistivity
- Four wire diameters, five wire materials

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.

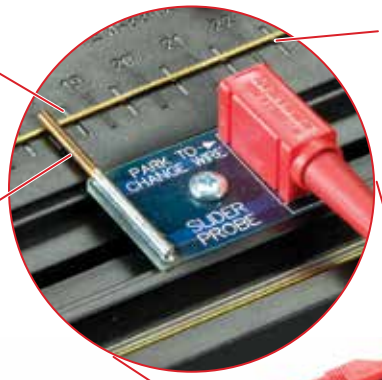


Graph shows voltage drop across various lengths for three different material wires. The slope of the line (along with wire diameter and current) is used to calculate the resistivity of the material.

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.

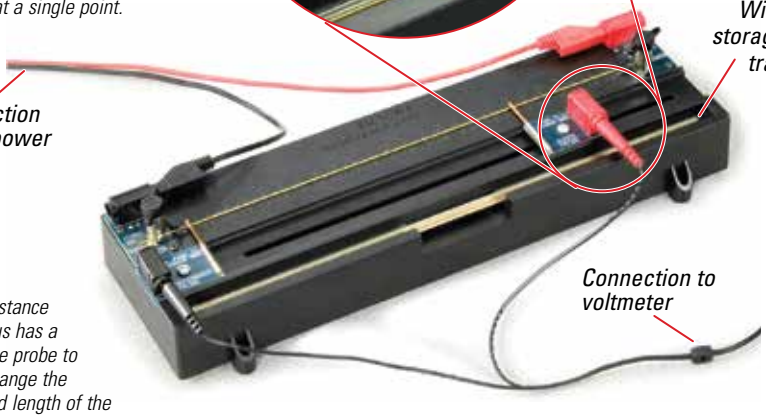
Slide-wire probe
Spring-loaded wire probe slides easily along the wire, making contact at a single point.



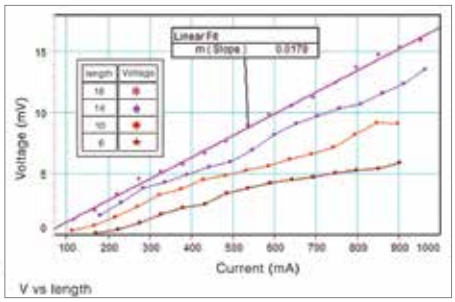
Wire storage tray

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 this experiment, the 850 Universal Interface produces a 10 sec 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.

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)



Order Information

Resistance Apparatus	EM-8812	
Shown in use with:		
850 Universal Interface	UI-5000	p. 26
Voltage Sensor	UI-5100	p. 54
2 m Patch Cord Set	SE-9415A	p. 226
Recommended:		
Galvanometer Sensor	PS-2160	p. 57
Replacement Wires	EM-8813	

PASCO Modular Circuits

Basic Modular Circuits Kit

EM-3535

Essential Physics Modular Circuits Kit

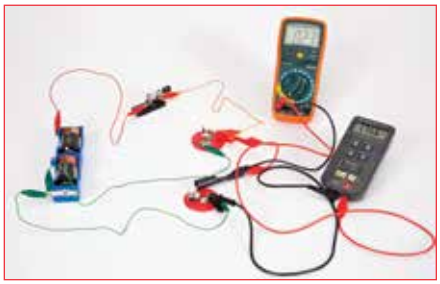
EM-3536

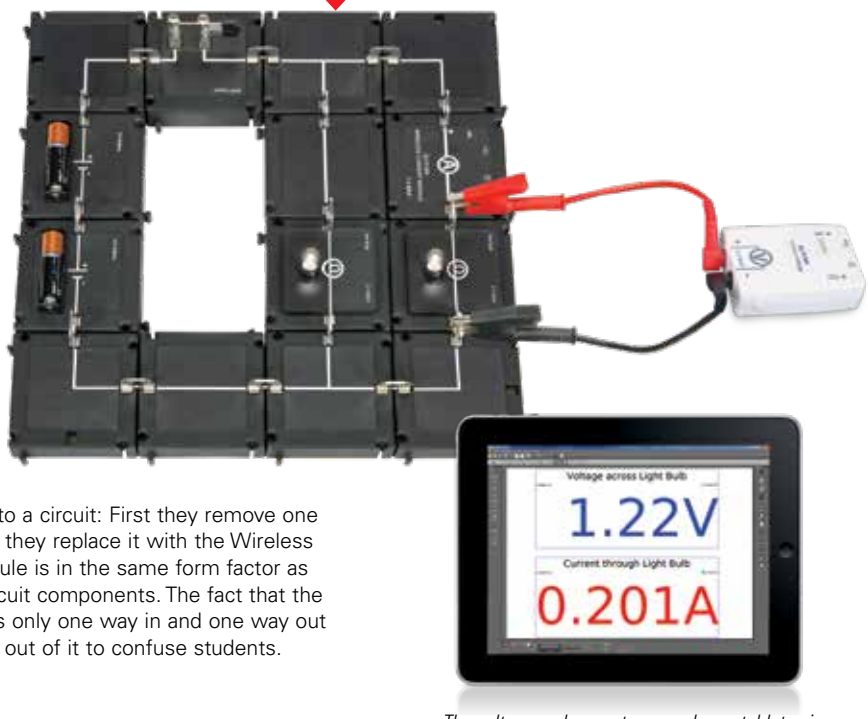
- Puts learning first
- Eliminates confusing wires
- Easy-to-connect modules

These circuit modules are designed specifically for introductory circuits classes. For students who have never wired a circuit, this modular system makes it easy for them to see the layout because it ends up looking like a circuit diagram.

Each module connects mechanically to another by sliding the tabs into each other. It works on any tabletop. No special surface is required. To electrically connect two modules, students insert a jumper clip, which emphasizes that an electrical connection has been made. The large size of the modules (8 cm x 8 cm) enables all the students around the table to see and understand the completed circuit.

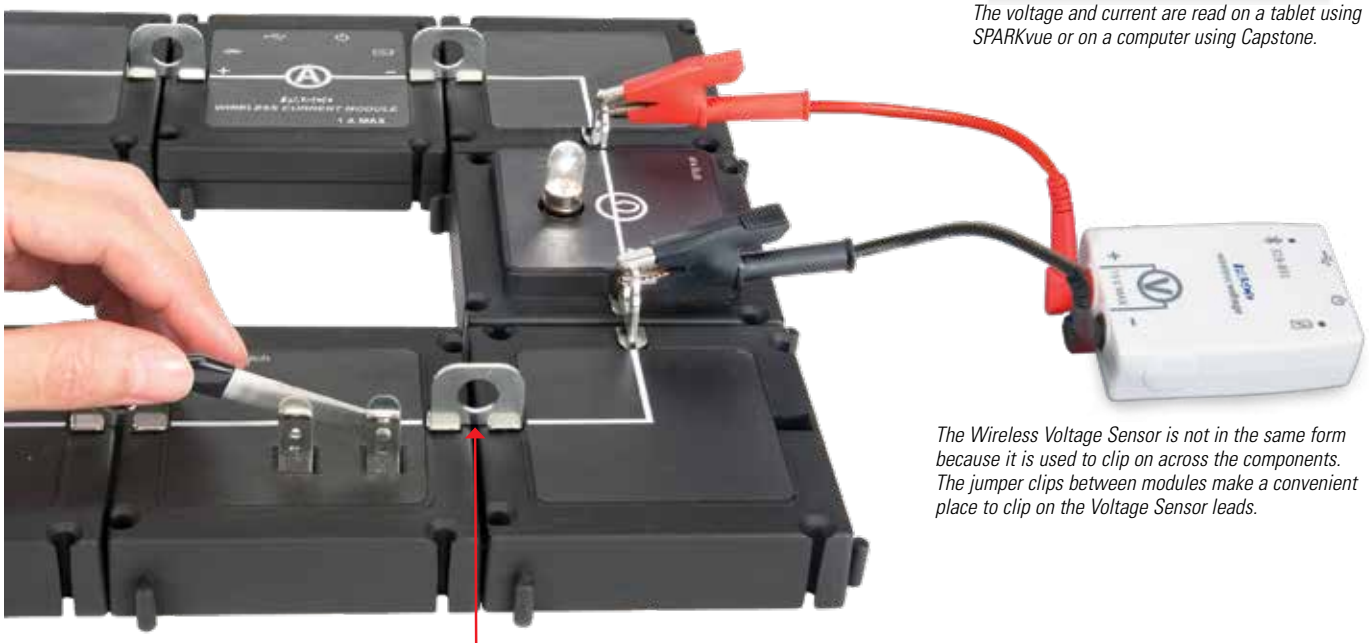
Believe it or not, these two circuits are the same. Which would be easier for your students to understand?





The voltage and current are read on a tablet using SPARKvue or on a computer using Capstone.

Students learn the correct way to insert an ammeter into a circuit: First they remove one of the straight wire modules from their circuit and then they replace it with the Wireless Current Sensor Module. Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components. The fact that the Current Sensor is wireless helps the pedagogy: There is only one way in and one way out of the Current Sensor. There are no extra wires coming out of it to confuse students.

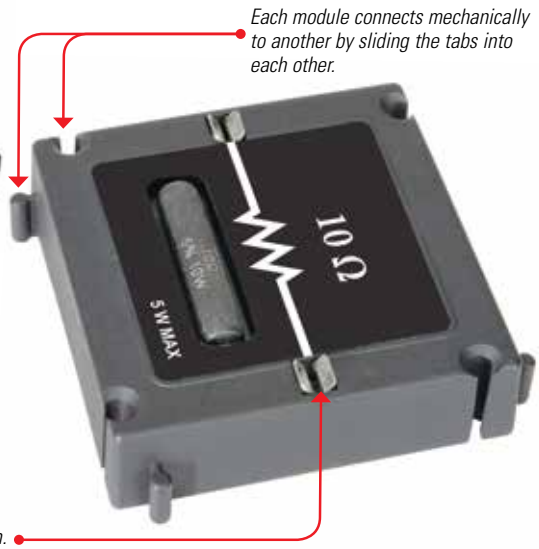


The Wireless Voltage Sensor is not in the same form because it is used to clip on across the components. The jumper clips between modules make a convenient place to clip on the Voltage Sensor leads.

To electrically connect two modules, students insert a jumper clip, which emphasizes that an electrical connection has been made.



Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components.



Wireless Current Sensor Module EM-3534 (included in EM-3536) Specifications

- **Two ranges:** ±1A, ±0.1A
- **Resolution:** 0.2mA (±1A range); 0.02mA (±0.1A range)
- **Bluetooth® sampling rate of 1 kHz**
- **Higher speed sampling via USB**
- **Includes remote logging**

See Expansion Pack (EM-3540) on page 220 for extra modules and replacement parts.

There are two kits.

The Basic Kit has enough modules to do the five basic experiments listed below. The Essential Kit has more modules, includes the Wireless Current Sensor Module and Wireless Voltage Sensor, and has 12 experiments.

Basic Circuit Kit Experiments

- Ohm's Law
- Series/Parallel Circuits
- Batteries and Bulbs Circuits
- Switches/Open/Closed Circuits
- Electric Power and Energy

Essential Circuit Kit Experiments

- Ohm's Law
- Series/Parallel Circuits
- Kirchhoff's Laws
- Batteries and Bulbs Circuits
- Switches/Open/Closed Circuits
- Electric Power and Energy
- Electromagnets
- Electromagnetic Induction
- RC and RL circuits
- Variable Resistance
- LED Circuits
- Electric Motors

Includes

Module	Basic EM-3535	Essential EM-3536
Straight	4	5
Corner	4	4
Resistor	2	3
Light Bulb	2	3
Tee	2	2
Battery Holder *(batteries not included)*	2	2
SPST	1	1
Capacitor	1	1
Spring Clips	1	1
Inductor	0	1
Motor	0	1
LED	0	1
Potentiometer	0	1
SPDT Switch	0	1
Bar Magnet	0	1
Wireless Voltage Sensor	0	1
Wireless Current Sensor Module	0	1
Extra Jumpers	15	15
Loose Components for Spring Clips	5	5
Gratnells® Case	1	1
Experiments (download)	5	12



Each kit comes in a Gratnells® case with trays that organize the modules.

Order Information

Basic Modular Circuit Kit EM-3535
Essential Physics Modular Circuit Kit EM-3536
Required:
2 AA Batteries
Required for EM-3536:
PASCO Capstone Software
or SPARKvue Software ..... See pages 18-20
Also available separately: .....
Wireless Current Sensor Module EM-3534
Wireless Voltage Sensor PS-3211

Modular Circuits Expansion Pack

EM-3540

This expansion pack supplies extra modules found in both the Basic and *Essential Physics* Modular Circuits Kits (EM-3535 and EM-3536). It also includes a Banana Jack Terminals module for powering your circuits with an external power supply or signal generator. It also includes a storage case with custom foam insert.



Includes

- Spring Clips (1)
- Straight (2)
- Tee (2)
- Corner (2)
- Light Bulb (1)
- Battery Holder (1) (battery not included)
- Jumper Clips (15)
- Banana Jack Terminals (1)
- Gratnells® Storage Case

Coming soon!
Check pasco.com for availability.

Order Information

Modular Circuits Expansion Pack	EM-3540	
Recommended:		
Basic Modular Circuits	EM-3535	pp. 218-219
Essential Physics Modular Circuits	EM-3536	pp. 218-219
Replacements:		
Replacement Bulbs for Modular Circuits (Qty 25)	EM-3541	
Replacement Jumper Clips (Qty 15)	EM-3542	

Resistors for Determining Temperature Coefficient

Determine the temperature coefficient for the resistivity of various materials. Measure the change in resistance of these wire-wound resistors as they are immersed in different temperature non-conductive liquids (boiling or ice water or liquid nitrogen). The wire is wound on Plexiglas® tubes that are fitted with sockets for safety plugs. We recommend an ohmmeter that can read to 0.01 Ω (such as SE-8792, see order information below).





Specifications

Dimensions: 20 x 180 mm diameter

The resistance values below are measured at 20°C:

Copper, approx. 1.8 Ω
Constantan, approx. 46.7 Ω
Nickel, approx. 8.7 Ω

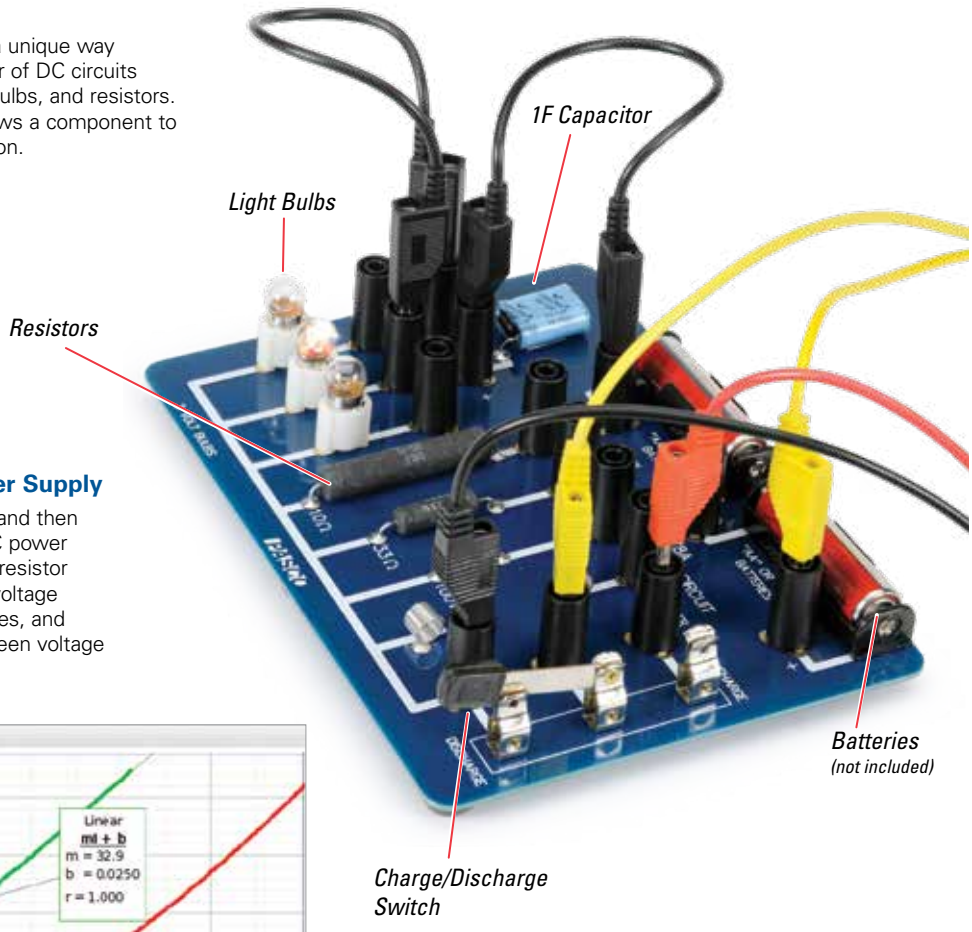
Order Information

Resistors for Determining Temp Coefficient/Copper	SF-7213	
Resistors for Determining Temp Coefficient/Constantan	SF-7214	
Resistors for Determining Temp Coefficient/Nickel	SF-7215	
Required:		
Digital LCR Meter	SE-8792	p. 251

Charge/Discharge Circuit

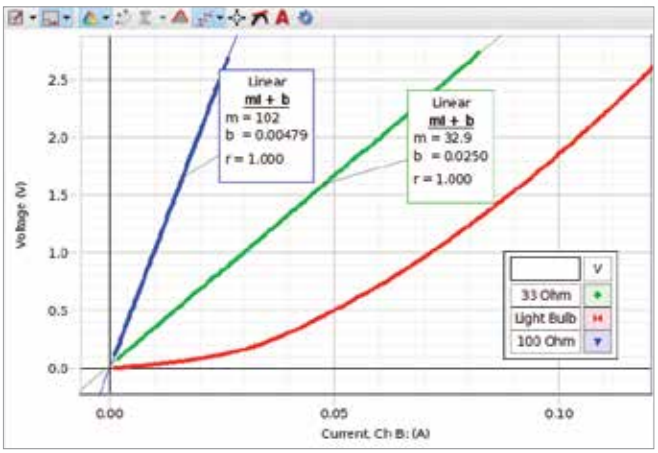
EM-8678A

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.

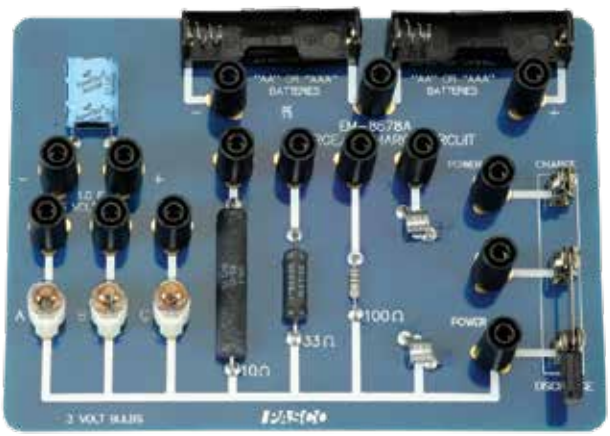


Works Like a Variable DC Power Supply

Charge the capacitor using batteries and then the capacitor will act as a variable DC power source as you discharge it through a resistor or light bulb. Students measure the voltage and current as the capacitor discharges, and they can graph the relationship between voltage and current for various components.



Voltage vs. Current for a 33 Ω resistor, a 10 Ω resistor, and a light bulb. Note the non-linearity for the bulb. Data was recorded in PASCO Capstone using a 550 Universal Interface, Voltage Sensor (UI-5100) and a Wireless Current Sensor (PS-3212).



Includes

- 1 Farad Capacitor
- #14 Light Bulbs (3)
- 10 Ω Resistor
- 33 Ω Resistor
- 100 Ω Resistor
- Battery Holders (uses AA or AAA; batteries not included)
- Double-Throw Knife Switch
- Instruction Manual

Order Information

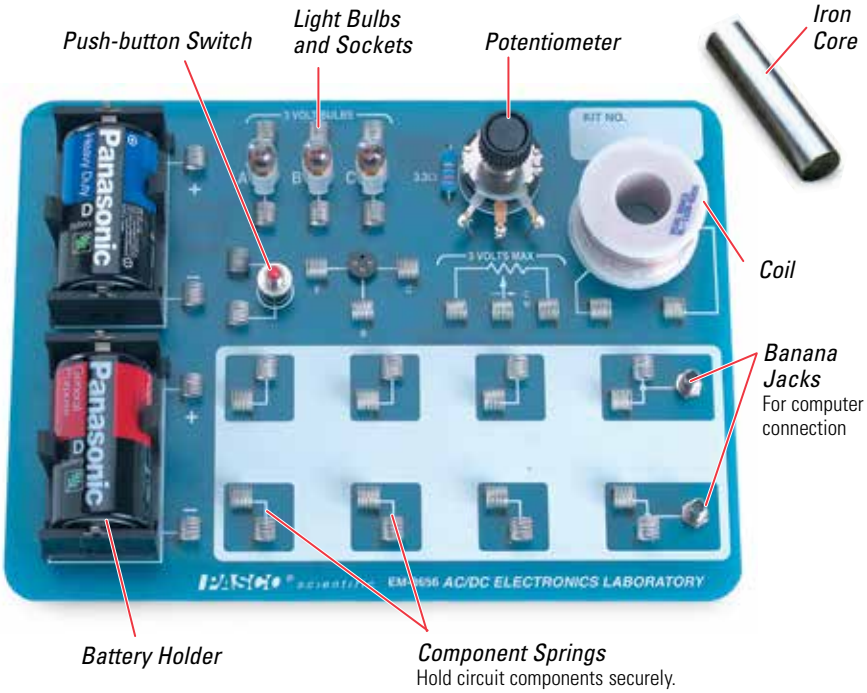
Charge/Discharge Circuit	EM-8678A	
Recommended:		
#14 Light Bulbs (25 pack)	EM-8627	p. 228
4-pack "AA" Batteries (not included)		
Wireless Current Sensor	PS-3212	p. 11
Wireless Voltage Sensor	PS-3211	p. 11
PASCO Capstone Software		pp. 70-73

AC/DC Electronics Laboratory

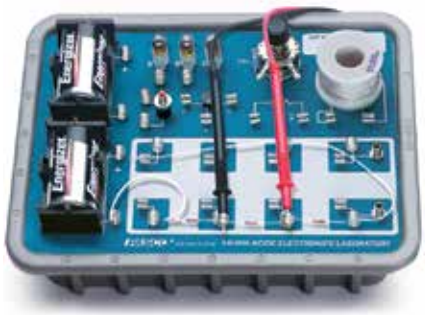
EM-8656

- 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 an 850 or 550 or as a stand-alone unit with batteries. The storage tray holds all included components, reducing the chance of losing capacitors, resistors, etc. Two D batteries (not included) are required for stand-alone use.

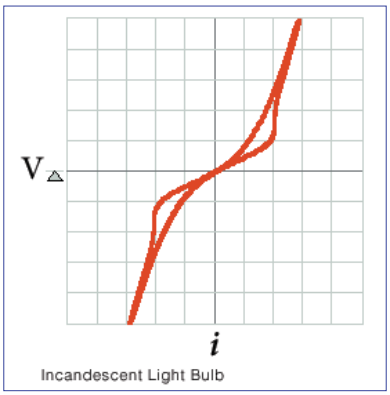


Experiments



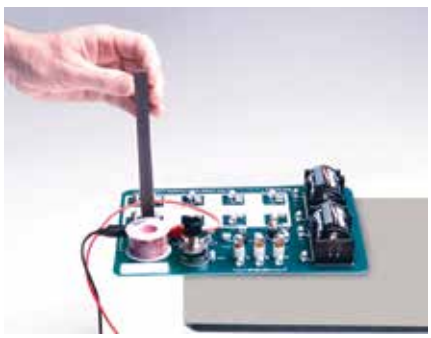
The AC/DC Electronics Laboratory can be used as a stand-alone electricity learning center.

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.

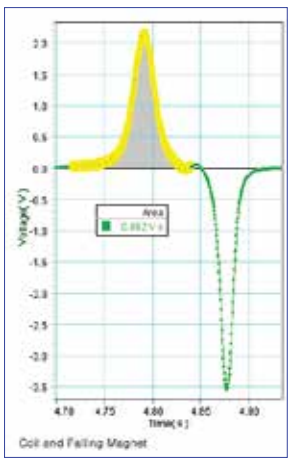


Incandescent Light Bulb

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

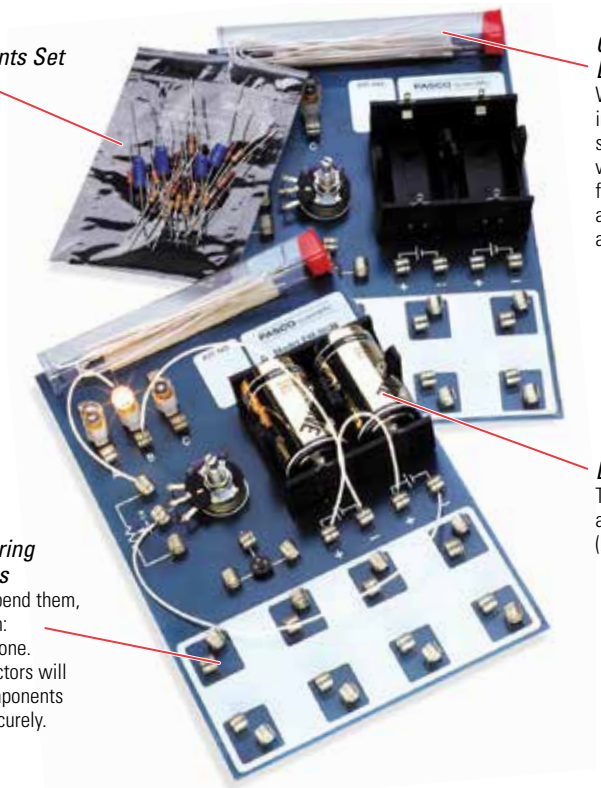
Electronic Components – AC/DC Electricity..... EM-8668

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
Basic Digital Multimeters (2) ..... SE-9786A p. 250
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

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?

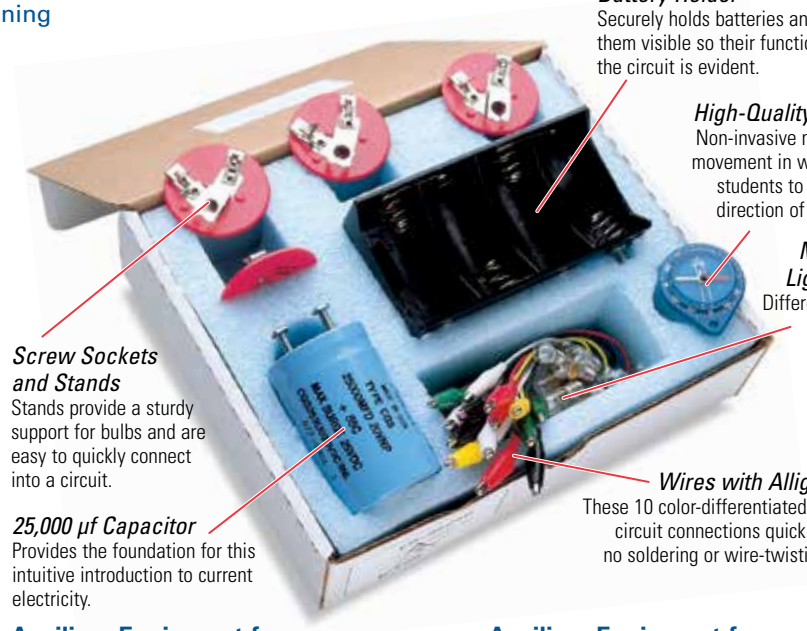
To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

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.



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 V, 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. 232

Capacitor (0.1 F) EM-8655
(Minimum of two each per class)

Primary and Secondary Coils ..... SE-8653A p. 236
(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

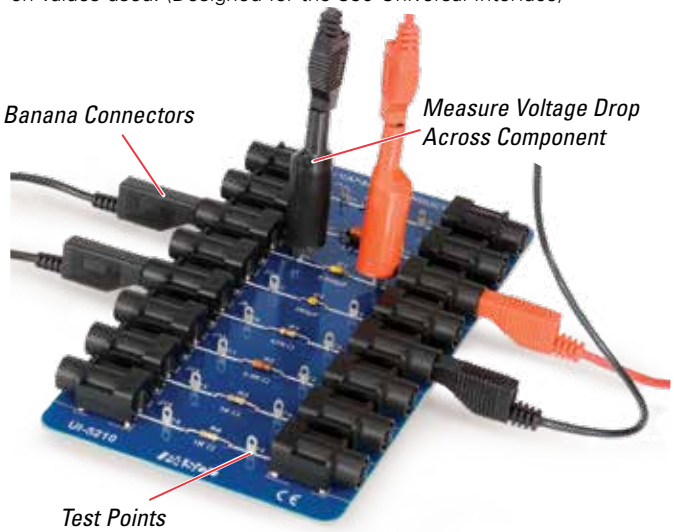
Liquid-filled Compasses (5 pack) EM-8631A

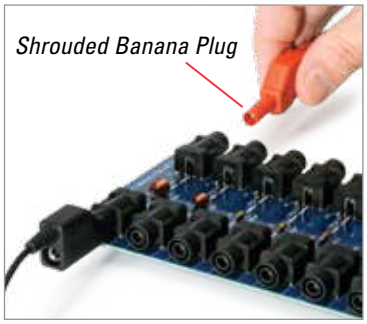
Capacitors (0.025 F, 2 pack) EM-8632

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. (Designed for the 850 Universal Interface)





The circuit board accepts patch cords with shrouded banana terminals.



Shown in use with 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
- Four resistors: 47 kΩ, 3.3 kΩ, and two 1.0 kΩ.

Order Information

Resistor Capacitor Inductor Network UI-5210

RLC Circuit

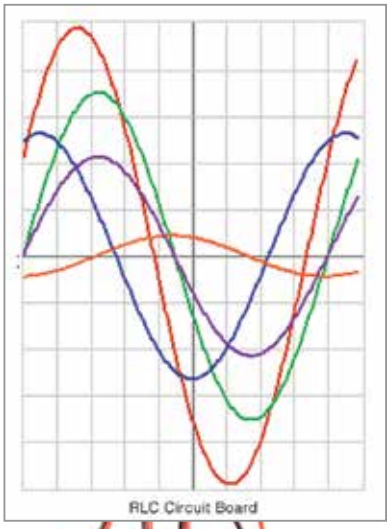
CI-6512



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.

Phase relationships can be studied between voltage across the capacitor, resistor, and inductor.





The 550 or 850 Interface can measure current and voltage as well as provide power to the RLC Circuit.

Order Information

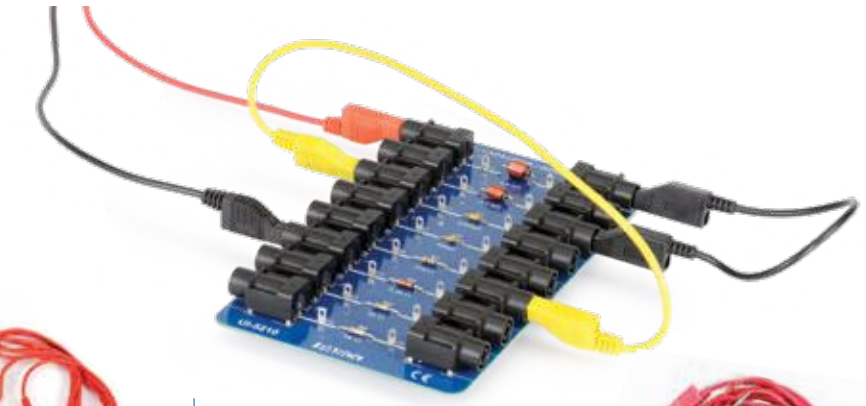
RLC Circuit CI-6512

Patch Cords

Banana plug cord sets *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.

Shown in use with UI-5210 circuit board.
See page 225 for more information.



2 Meter Patch Cord Set

SE-9415A

Two each of black and red; 2 m long



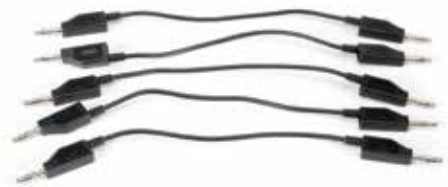
Order Information

2 Meter Patch Cord Set SE-9415A

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

Short Patch Cords

SE-7123

30 cm long, two each red, yellow, blue, black



Order Information

Short Patch Cords (set of 8) SE-7123

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

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

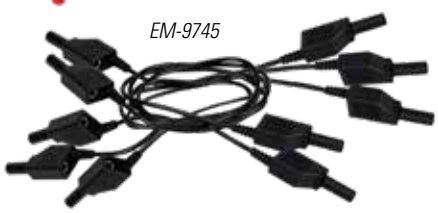
EM-9740, EM-9745

75 cm long, five black or five red. Terminals are shrouded banana plugs. Maximum rating: 600 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

Shrouded Alligator Test Leads

PS-3544

(Set of 2)

These test leads are included with the Wireless Voltage Sensor (PS-3211). They can also be used with the Wireless Current Sensor (PS-3212).

Includes one red and one black lead.



Order Information

Shrouded Alligator Test Leads (set of 2) PS-3544

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)



EM-8655:
(0.1 F) Electrolytic, bipolar, 10 V capacitor with screw terminals, 4.5 cm diameter, 14 cm long.

EM-8632:
(0.025 F) Electrolytic, bipolar, 25 V capacitor with screw terminals, 5 cm diameter, 8 cm long. Contains two capacitors.

SE-8626:
(1.0 F) Electrolytic, bipolar, 5 V capacitor.

Order Information

Capacitors
0.1 F EM-8655
0.025 F (2 pack) EM-8632
1.0 F SE-8626

Circuit Components

Use these stand-alone components to build your own circuits.



Investigate series and parallel combinations of bulbs and batteries using components detailed below.

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

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

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

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

Replacement Bulbs

EM-8679 (5 pack)



The Replacement Bulbs (5 pack) is a replacement part for the:

- Series/Parallel Circuit (EM-8677)
- Introductory Optics System (OS-8500)

Order Information

Replacement Bulbs (5 pack) EM-8679

Voltaic Cell

SE-7249

- Learn how batteries work
- Includes different types of electrodes



A basic student voltaic cell set is ideal for demonstrating the characteristics of battery cells. Set includes one plastic cell, complete with a screw-on plastic ring, two adjustable electrode holders, porous ceramic cup and ten electrodes (one each of aluminum, nickel, tin, graphite, iron, and copper, and two each of lead and zinc).

Electrolyte (such as vinegar) is not included.

Order Information

Voltaic Cell SE-7249
Suggested:
Basic Digital Multimeter..... SE-9786A

Basic Digital Multimeter

SE-9786A



This basic meter includes all functions and ranges needed for most introductory lab work.

Features

- 20 A 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

Precision Digital Multimeter, Component Tester, and Thermometer

SB-9631B



This is an excellent general purpose multimeter that 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 kΩ, 20 kΩ, 200 kΩ, 2 MΩ; ± (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.

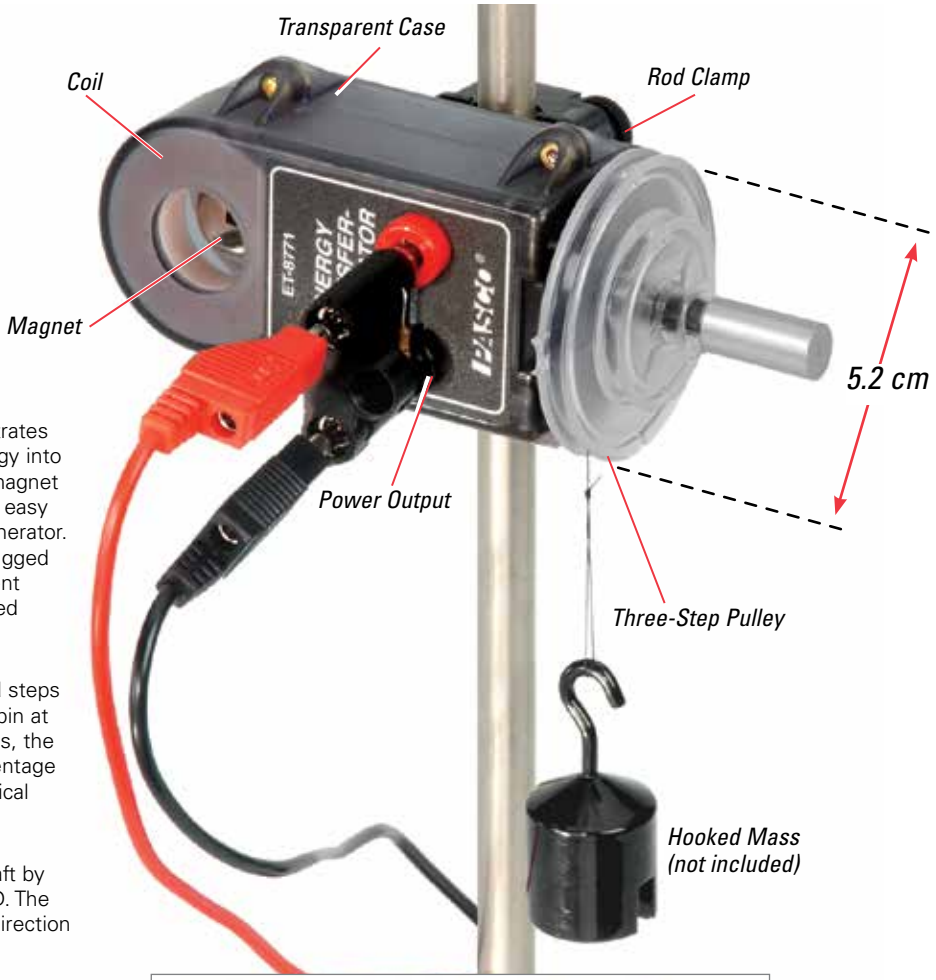
Order Information

Precision Digital Multimeter..... SB-9631B
Replacement Supplies:
Thermocouple Probe..... SB-9632

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



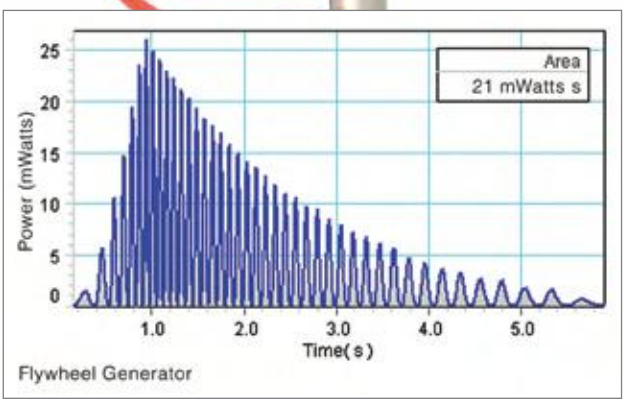
PASCO's Energy Transfer Generator demonstrates the conversion of gravitational potential energy into electrical energy as a falling weight turns a magnet between two coils. The open design permits easy identification of the essential parts of the generator. The supplied lamp or load resistor can be plugged 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.

Case Dimensions: 8.7 x 4.4 x 3.6 cm





Includes

- Generator with three-step pulley
- Red-green LED mounted on plug
- 100-ohm load resistor mounted on plug
- Spool of thread

Order Information

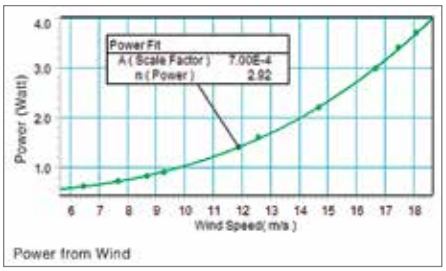
Energy Transfer Generator	ET-8771B	
Recommended:		
2 Meter Patch Cord Set	SE-9415A	p. 226
Hydro Accessory	ET-8772	p. 231
Hooked Mass Set	SE-8759	p. 197
Large Rod Base	ME-8735	p. 186
Steel Rod (90 cm)	ME-8738	p. 186
No Bounce Pad	SE-7347	p. 194
Required for use with PASPORT:		
Voltage/Current Sensor	PS-2115	p. 56

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.





Includes

- Fan
- Mounting hardware

Order Information

Energy Transfer Wind Turbine.....ET-8783
Required:
Energy Transfer Generator.....ET-8771B

Energy Transfer Hydro Accessory

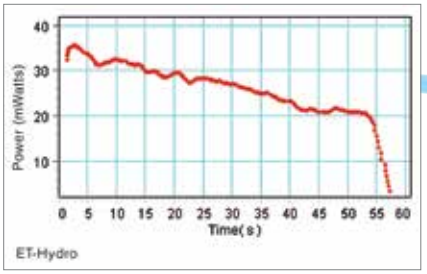
ET-8772

- 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. 195
Large Rod Base	ME-8735	p. 186
Steel Rod (90 cm)	ME-8738	p. 186
Three-Finger Clamp	SE-9445	p. 188
1000 ml Beaker (6 pack)	SE-7288	p. 195

Demonstration Motor/Generator Set

NEW

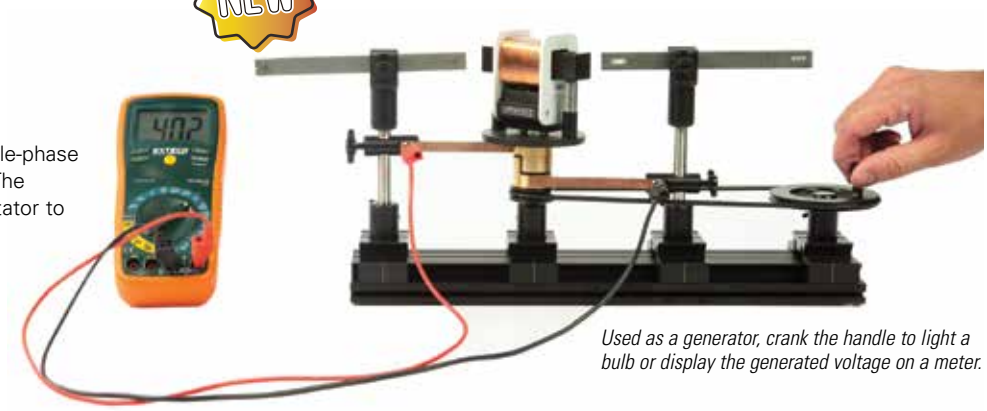
SF-7216

- Hand-crank generator
- AC and DC generators
- DC motor

This sturdy kit clearly demonstrates single-phase AC and DC generators and DC motors. The brushes can be adjusted on the commutator to convert the generator from AC to DC.

Includes

- Coil holder with commutator
- Coil, 800 windings
- Laminated core
- Commutator contact spring (2)
- Base rail: 37 cm long
- Carrier with 10 mm diameter hole (4)
- Magnet mount (2)
- Bar magnets (2): 100 x 10 x 10 mm
- Manual drive pulley
- Drive belts, set of 4 different
- Instructions



Used as a generator, crank the handle to light a bulb or display the generated voltage on a meter.



Use a DC power supply (or 850 Universal Interface output) to power the DC motor.



Order Information

Demonstration Motor/Generator Set	SF-7216	
Required:		
DC Power Supply	SE-9720A	p. 244
or		
850 Universal Interface	UI-5000	p. 26
Patch Cords	SE-9750	p. 226
Basic Digital Multimeter	SE-9786A	p. 250

Mini Generator

SE-8645



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) *(see below)*	SE-8626
Light Bulb Sockets (10 pack)	EM-8630
Light Bulbs #50 7.5 V (25 pack)	EM-8814

Capacitor (1 Farad)

SE-8626 (1.0 F)



Electrolytic, bipolar, 5 1.0 F capacitor. Charge up this capacitor with the Mini Generator and then let go of the crank. The handle will continue to rotate in the same direction as the capacitor discharges.

Order Information

1.0 F Capacitor	SE-8626

Ring Launcher

EM-8817

- Electromagnetic induction
- Shoots ring 2 meters high
- Improved design with thermal shutoff

This Ring Launcher has been optimized to maximize safety by enclosing all wiring inside the case. A thermal shutoff switch protects the coil by preventing overheating.

Includes a coil with a bulb that lights by induction when the coil is placed over the launcher core. Also includes five rings: one split aluminum ring that will not launch, one copper ring, one shorter aluminum ring, and two regular length aluminum rings.

A classic demonstration

In this demo, an aluminum ring is propelled straight up by the Lorentz force that arises from the interaction between the alternating magnetic field of the coil and the current induced in the ring.

For great demo ideas using the PASCO Ring Launcher, check out James Lincoln's AAPT video. James explains how the Ring Launcher works and walks you through all the classic demonstrations.

https://www.youtube.com/watch?v=G0sTOcyhcFM



Ring Launcher design ideas contributed by Carl Schneider and John Ertel from the U.S. Naval Academy.



EM-8817 Includes

- Launcher
- Coil with Light Bulb
- Split Aluminum Ring
- Aluminum Ring (2)
- Short Aluminum Ring
- Copper Ring





Lighting a bulb connected to a coil by induction; coil and bulb are included in Ring Launcher Accessories.

Order Information

Ring Launcher with Accessories (120 VAC only)	EM-8817
Also available:	
Ring Launcher without Accessories	EM-8661
Replacement:	
Ring Launcher Accessories	EM-8662

Magnetic Demonstration System

EM-8644B

Demonstrate:

- Magnetic damping
- Diamagnetism and paramagnetism
- Magnetic force on a current-carrying wire swing

This all-in-one demonstration system includes the Variable Gap Magnet (EM-8618) and the Magnetic Force Accessory (EM-8642A), both on the opposite page.



Includes

- Variable Gap Magnet
- Pole Pieces
- Three aluminum paddles (solid, slotted, closed slotted)
- Glass rod
- Aluminum rod
- Wire swing
- Special mounting rod



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 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 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.

Order Information

Magnetic Demonstration System	EM-8644B	
(Includes EM-8618 and EM-8642A)		
Required:		
Power Supply (18 V DC, 5A)	SE-9720A	p. 244
or		
Mini-Generator	SE-8645	p. 232
Base and Support Rod	ME-9355	p. 186
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 226

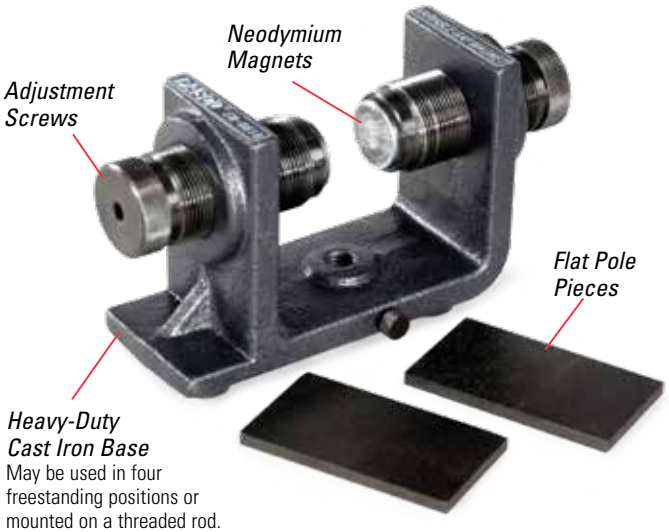
Variable Gap Magnet

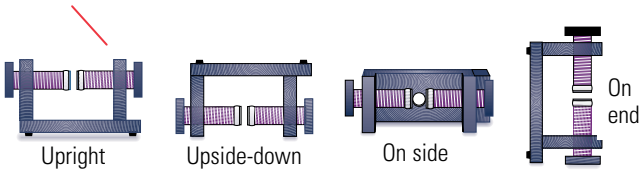
EM-8618

- 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 to mount on a support rod, which provides 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.





Order Information

Variable Gap Magnet EM-8618
(Includes Variable Gap Magnet with Pole Pieces)

Magnetic Force Accessory

EM-8642A

Includes

- Three aluminum paddles (solid, slotted, closed slotted)
- Glass rod
- Aluminum rod
- Wire swing
- Special mounting rod



Order Information

Magnetic Force Accessory EM-8642A

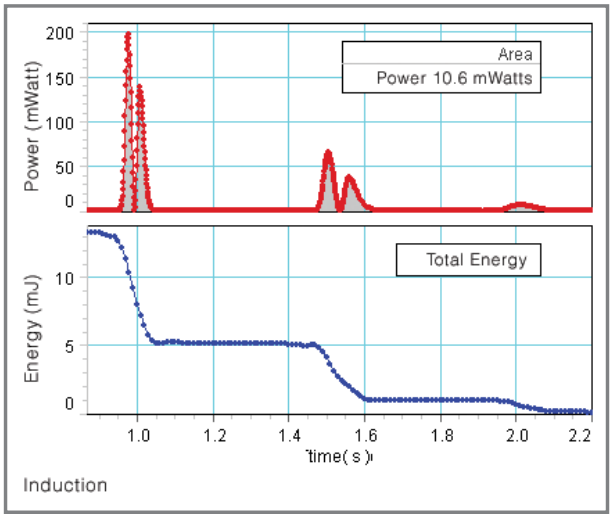
Induction Wand

EM-8099

See EX-5541A Faraday's Law of Induction Experiment on page 367.

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, 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 vs. Time plot.

Includes

- Wand with screw
- Resistive load



Order Information

Induction Wand EM-8099

Coils and Cores

Complete Coil Set

SF-8617



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 more in-depth experiments and demonstrations, use a computer with PASCO's 850 Universal Interface (pp. 26-27).

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)

Order Information

Basic Coil Set SF-8616
Complete Coil Set SF-8617
Individual parts sold separately (see chart above).

Primary and Secondary Coils

SE-8653A

- Study transformer theory with this set of nested coils.
- Drop a magnet through the outer coil to demonstrate induction.



Outer Coil: 2920 turns; length 11 cm; 2 cm ID
Inner Coil: 235 turns; length 12 cm; 1 cm ID
Soft Iron Core: 0.96 cm diameter

Order Information

Primary and Secondary Coils SE-8653A

Economy Primary and Secondary Coils

NEW

SE-8722

Outer Coil: 1100 turns; length 11.4 cm; 4.7 cm ID
Inner Coil: 210 turns; length 10.9 cm; 1.7 cm ID
Iron Core: 1.6 cm diameter
Shielded Banana Jacks



Order Information

Economy Primary and Secondary Coils..... SE-8722

Air Core Solenoid

SE-7585

This air core solenoid produces a uniform magnetic field (200 gauss at 5 A).



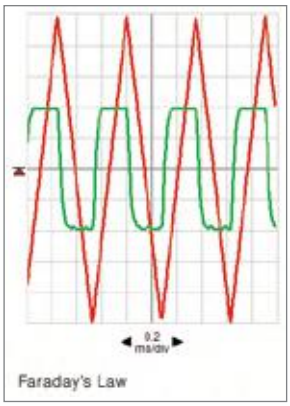
Coil: 550-570 turns (16 AWG); length 11.4 cm; 5.5 cm ID; 13.5 cm OD
Max Current: 5 A

Order Information

Air Core Solenoid..... SE-7585

Field and Detector Coils





A 5 V 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. 235
850 Universal Interface		pp. 26-27
or		
Low Voltage AC/DC Power Supply	SF-9584B	p. 246
and:		
Function Generator	PI-8127	p. 249

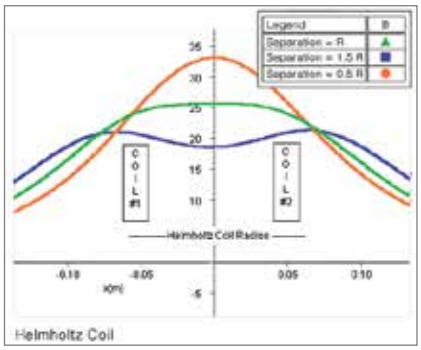
Helmholtz Coils

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

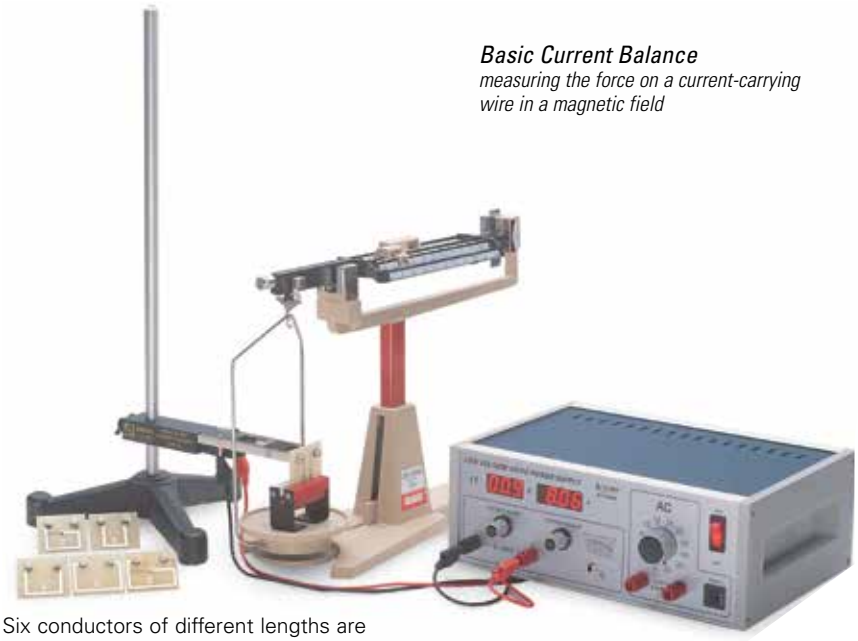
Force on Current-carrying Wires

Basic Current Balance

SF-8607

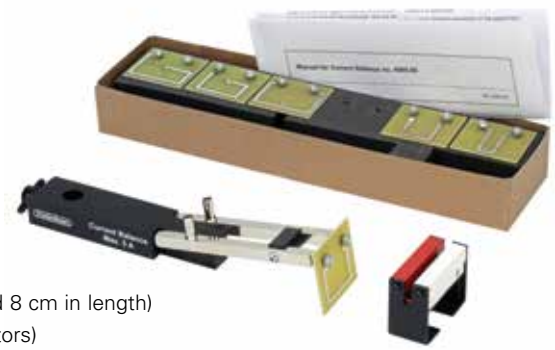
- Measure force vs. current, wire length, magnetic field, and angle
- Use a gram balance to measure force

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

- Iron Yoke (holds magnets)
- Removable Magnets (six)
- Six Conductors (1, 2, 3, 4, 6 and 8 cm in length)
- Mount (to hold position conductors)

Order Information

Basic Current Balance	SF-8607	
Required:		
Ohaus Balance	SE-8725	p. 196
Power Supply	SF-9584B	p. 246
Base and Support Rod	ME-9355	p. 186
Recommended:		
Basic Digital Multimeter	SE-9786A	p. 250
Tesla Meter	SF-7579A	p. 242
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 226

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

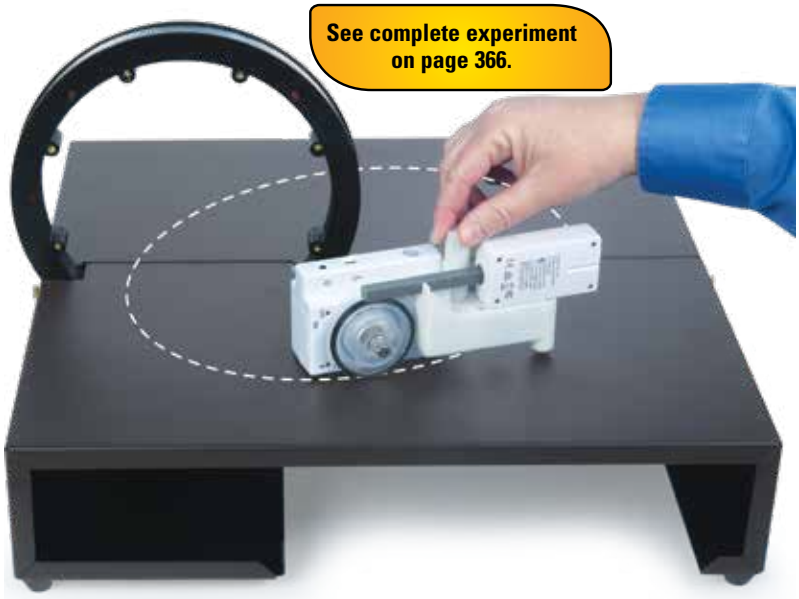
Ampere's Law Accessory

EM-6720

NEW

- Verify Ampere's Law
- Plot magnetic field tangent to path
- Closed integral is area under B vs. Distance plot
- Choose to enclose current in path or not

See complete experiment on page 366.

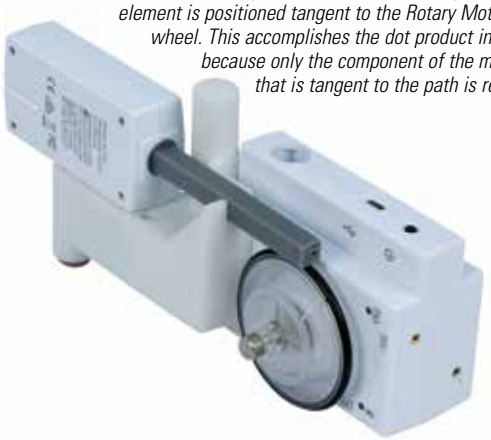


Students can verify Ampere's Law experimentally by graphing the magnetic field strength that is tangent to the path taken along a closed path that encloses a current source.

The magnetic field strength is measured with a Wireless Magnetic Field Sensor which rides on a Rotary Motion Sensor. The student pushes the Rotary Motion Sensor, which rolls on its wheel, along a closed path.

If you traverse a path that does not enclose any current source, the area under the curve is zero. The magnetic field of the Earth or any nearby source is measured but they will cancel out in a closed loop that encloses no current.

The Wireless 3-Axis Magnetic Field and Rotary Motion sensors allow students to move in any shaped path without wires getting wrapped around the coil. Students can choose any path they want; you don't have to follow a circular path because the sensors are recording the field tangent to any path.

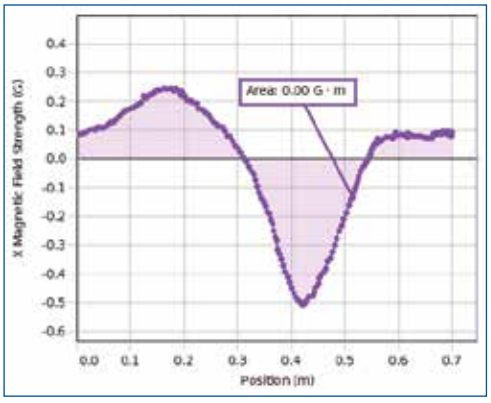


The key to making this work is that the Magnetic Field Sensor element is positioned tangent to the Rotary Motion Sensor's wheel. This accomplishes the dot product in Ampere's Law because only the component of the magnetic field that is tangent to the path is recorded.

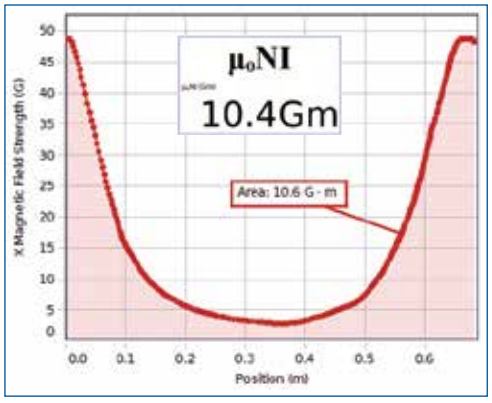
Ampere's Law

$$\oint \vec{B} \cdot \vec{dl} = \mu_o NI$$

Area under B vs. Distance curve = μ_0 (# of coil turns enclosed in path) (Current)



No current enclosed: Area is zero.



Current enclosed: Area is $\mu_0 NI$.

Includes

- Aluminum Table (46 cm x 46 cm x 11 cm)
- Sensor Bracket



Coming soon!
Check pasco.com for availability.

Order Information

Ampere's Law Accessory	EM-6720	
Required:		
Wireless 3-Axis Magnetic Field Sensor	PS-3221	p. 13
Wireless Rotary Motion Sensor	PS-3220	p. 9
Field Coil (500-turn)	EM-6723	p. 237
PASCO Capstone Software	pp. 70-73	

Determine the Charge and Mass of the Electron

Electron Charge-to-Mass Ratio System

SE-9629

See page 299.



Millikan Oil Drop Apparatus

AP-8210A

See page 298.



Laplace Force Demo with Magnet

NEW

SF-7279

- Demonstrates the forces on a current-carrying wire in a magnetic field



When the conducting rod is placed on the rails and a current (maximum 10 A) runs through the rails, the rod will be affected by a force, making it roll perpendicular to the magnetic field along the rails.

The apparatus consists of a pair of rails with 4 mm diameter terminals. The conductor consists of a bar with plastic discs that is placed across the rails. The included alnico Horseshoe Magnet (SF-7225) is used as a magnet.

Rails: 15.5 cm long; 5 cm apart

Includes

- Laplace Force Demonstration (SF-7261)
- Horseshoe Magnet (SF-7225)

Order Information

Laplace Force Demo with Magnet..... SF-7279
Required:
DC Power Supply ..... SE-9720A p. 244
Banana Cords
Available separately:
Laplace Force Demonstration SF-7261
(Includes rails and movable conductor shown above; magnet not included.)
Horseshoe Magnet..... SF-7225

Horseshoe Magnet

NEW

SF-7225



This Alnico Horseshoe Magnet includes a steel keeper.

Dimensions: 8.0 x 12.5 x 3.0 cm

Field Strength: 600 gauss at pole surface

Order Information

Horseshoe Magnet.....SF-7225

Lenz's Law Demonstrator

MG-8600



Magnet 6 cm long
19.8 mm OD



Drop a mass through the 1.5 m 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. See the difference in weight as the magnet falls through the tube.

MG-8600 includes:

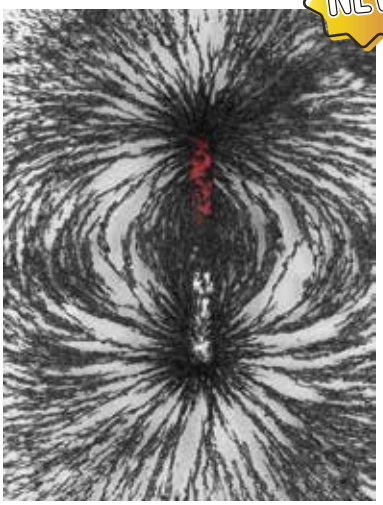
- Lenz's Law Magnet
- Unmagnetized Slug
- 1.5 m Aluminum Tube (2 cm ID, 0.28 cm wall)
- 10-turn Rectangular Coil
- Attachment Bracket for Spring Scale
- Ohaus Spring Scale 10N

Order Information

Lenz's Law Demonstrator.....MG-8600

Iron Filings

SE-7723



Iron filings sprinkled over a bar magnet instantly make the magnetic field visible.

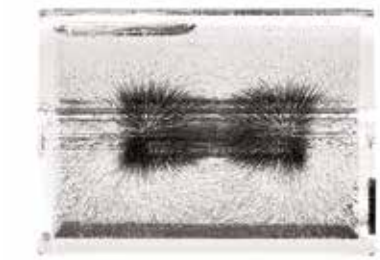


Order Information

Iron Filings (0.25 kg)..... SE-7723

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. 242

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. It has a 4.5 cm diameter liquid-filled plastic case.

Order Information

Liquid-Filled Compasses (5 pack)..... EM-8631A

Replacement part for CASTLE Kits (EM-8624A and EM-8654)

Plotting Compass

SE-8680



(Appearance may vary.)

Includes 20 compasses (19 mm diameter).



Order Information

Plotting Compass (20 pack)..... SE-8680

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.





Order Information

Magnaprobe (1)..... SE-7390

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

Magnetism Supplies

Horseshoe Magnet

NEW

SF-7225



This Alnico Horseshoe Magnet includes a steel keeper.

Dimensions: 8.0 x 12.5 x 3.0 cm

Field Strength: 600 gauss at pole surface

Order Information

Horseshoe Magnet..... SF-7225

Cow Magnets (Pair)

NEW

SE-7722



These strong smooth magnets are convenient for showing magnetic induction by moving one through a coil connected to an ammeter. As the name suggests, the primary purpose of these magnets is to collect metal objects in a cow's first stomach to prevent internal damage.

Length: 7.5 cm

Field Strength: 1400 gauss at pole surface

Order Information

Cow Magnets (Pair)..... SE-7722

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

Tesla Meter

SF-7579A

- 0–2 Tesla range
- Range autoscaling



A 6-12 V 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: 110 V AC to 9 V 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-7579A

Zero Gauss Chamber

EM-8652



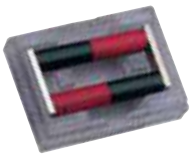
This double-walled, high permeability metal chamber produces a zero gauss field within the chamber. By placing the Magnetic Field Sensor probe into the chamber and pushing the "Tare" button, the sensor may be zeroed. Highly recommended for measurement of Earth's magnetic field.

Order Information

Zero Gauss Chamber..... EM-8652

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

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

DC Programmable Power Supply

PI-9880

- 1 A 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.

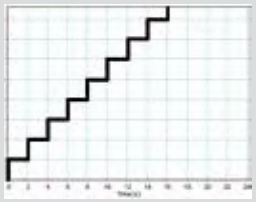
There are both coarse and fine adjustment knobs. As a safety factor, a maximum current and a maximum voltage can be set to protect your students' external circuits. The output is voltage-regulated but not current regulated.

The power supply is connected to AC power using a universal power adapter.

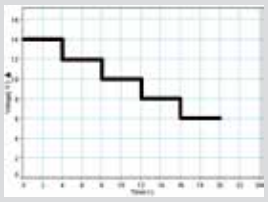


Small and lightweight; 12 cm x 13 cm x 5.5 cm high and approximately 300 g.

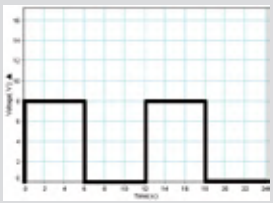
Available Functions:



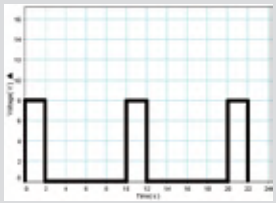
Step Voltage Up



Step Voltage Down from Max to Min



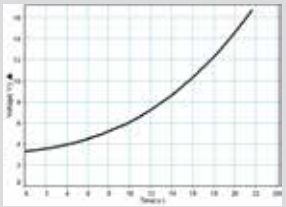
Cycle On and Off



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

DC Power Supplies

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 Meters: Voltage and current; LED

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

Constant Current Mode:

- Output Current: 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)

Includes

- Instruction Manual
- Test Lead

Order Information

Power Supply (18 VDC, 5 A) SE-9720A

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; Backlit LCD

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: <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

Student Power Supply (18 V) SE-8828

Triple Output Power Supply

SE-8587

- 0-30 VDC at 0-3 A
- Fixed 5 V and 12 V outputs
- Digital voltage & current meters
- Overload and short circuit protection
- Constant voltage or current



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) with easy snap terminals. 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; 3 digits; LCD

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

Fixed Output Voltage: 5 V at 0.5 A continuous; 1 A max. 12 V at 0.5 A continuous; 1 A max.

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

Power Supply (30 VDC, 6 A)

SE-9721A

- 0-30 VDC at 0-6 A
- 0.01% high regulation
- Constant voltage or current



This single output linear DC power supplies is suitable for high-end precision bench top applications. Low load and line regulation for both constant voltage and constant current mode ensure reliable, predictable output. Overload and reverse polarity protection as well as internal selection for dynamic or constant load are standard.

Specifications

Digital Meters: Voltage and current: 3 1/2 digits; 0.5" LED display

Constant Voltage Mode:

- Output Voltage: continuously variable, coarse and fine control
- Line Regulation: ≤0.01% ±5 mV
- Load Regulation: ≤0.01% ±5 mV
- Ripple and Noise: ≤1 mV rms 5 Hz -1 MHz

Constant Current Mode:

- Output Voltage: continuously variable, coarse and fine control
- Line Regulation: ≤0.2% ±3 mA
- Load Regulation: ≤0.2% ±3 mA
- Ripple: ≤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)

Includes

- Instruction Manual
- Test Lead

Order Information

Power Supply (30 VDC, 6 A) SE-9721A

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



Appearance may vary.

Here is a versatile and reliable supply for experiments requiring medium to high voltages at relatively low currents, such as the Millikan Oil Drop experiment. 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 V supply is internally connected to the negative terminal of the 500 V 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



Appearance may vary.

This Kilovolt DC Power Supply is used for electron tubes and electrostatics.

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

AC/DC Power Supplies

AC/DC Power Supply 12 V 3 A

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



Appearance may vary.

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.

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: 20.3 x 20.5 x 11.7 cm

Order Information

AC/DC
Power Supply SF-9581

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



Appearance may vary.

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

Tunable DC Power Supply 6 A

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

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 300)	X			X
Franck-Hertz (page 297)	X	X		X
e/m (page 299)		X	X	

Connect to a 550 or 850 Interface:

These instruments can be used stand-alone by reading the digital displays. However, they have special data collection ports that connect a 550 or 850 Universal Interface (see pp. 26-28) 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 a 550 or 850 analog port with the special cable (included).

Order Information

8-Pin DIN 1.8 m Male-to-Male Extension Cable..... UI-5219

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%

Includes cords to connect to the 550 and 850.

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%

Includes cords to connect to the 550 and 850.

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 0 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 (Pico-ammeter)

SE-6621

- Measures picoamp currents
- Six ranges from 10^{-8} A to 10^{-13} A



Includes cords to connect to the 550 and 850.

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

Function Generators

Student Function Generator

SF-7208

- Sine, triangle, square waves
- 7.5 V peak at 1 A



This affordable alternative to the advanced Function Generator PI-8127 covers the most common experiments.

The function generator is operated with three buttons: Waveform, Frequency, and Amplitude. There is a single output, provided with 4 mm safety sockets. The frequency is displayed on the LCD display.

The output can easily drive a speaker or vibrator with ample amplitude for resonance. The frequency range extends well beyond the audible range. The lowest frequencies are suitable for slow-motion AC experiments.

Specifications

Waveforms: sine, triangle, square
Distortion (sine): <0.25% (20 Hz to 20 kHz); <1% (0.05 Hz to 50 kHz)
Frequency Range: 0.05 Hz to 50.00 kHz
Frequency Deviation: <0.05 % (for f >10 Hz)
Frequency Drift: <0.005 %
Amplitude: 0 to 7.5 V peak (15 V p-p; 5.3 V RMS)
Maximum Current: >1 A peak (overload protected)
Supply Voltage: 12 V (1.5 A) (adapter included)
Accessories: BNC to insulated clips

Order Information

Student Function Generator.....SF-7208

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 W up to 100 kHz to drive speakers
- Sweep mode
- Step mode



Appearance may vary.

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 utilize 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 effortlessly drives 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

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

- 0.001 Hz to 150 kHz
- Programmable frequency sweep
- 10 V at 1 A
- 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





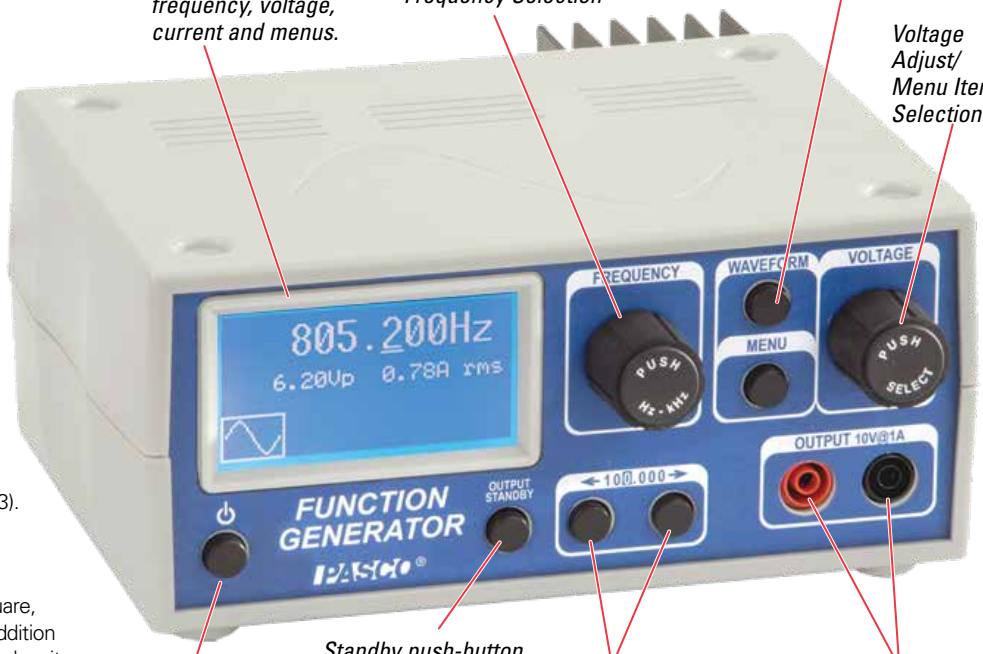
Menu driven selection makes the Function Generator intuitive to use.



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

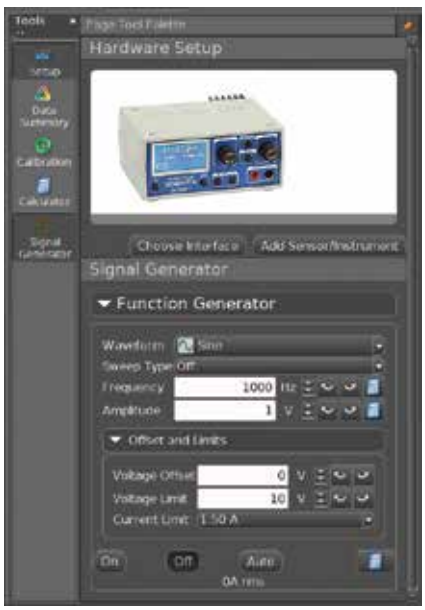
Upgradable Firmware

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. 70-73).

Features

The Function Generator outputs sine, square, triangle, positive and negative ramps in addition to DC. It's powerful output, 1 A at 10 V, 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, provided the peak voltage does not exceed 10 V.
- **Frequency Sweep:** Sweep between any two frequencies at a selectable rate.



Use the Function Generator as a stand-alone or connect it 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

Digital Storage Oscilloscope

SB-9621A (100 MHz)

- 2-Channel 100 MHz bandwidth
- 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



This 2-channel oscilloscope is designed to meet educational demands. With fast waveform process capability, more advanced triggering functions, and lightweight design, this oscilloscope is an excellent replacement for an analog scope.

Via the USB Device port, the user can easily build a remote control program to manipulate the machine, storing data directly into a flash drive for further analysis.

Several acquisition modes and 27 auto measurement functions help the user accurately measure waveform properties.

A total of 15 waveforms can be saved into the internal memory for later recall and display, and two saved reference waveforms plus two live waveforms can be shown on the screen at the same time for comparison.

Specifications

Bandwidth: 100 MHz, 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 Oscilloscope
100 MHz SB-9621A

Basic Digital Multimeter

SE-9786A



This basic meter includes all functions and ranges needed for most introductory lab work.

Features

- 20 A 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

Precision Digital Multimeter, Component Tester, and Thermometer

SB-9631B



This is an excellent general purpose multimeter that 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 kΩ, 20 kΩ, 200 kΩ, 2 MΩ; ± (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

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-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 W 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 W 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 kΩ/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%

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 kΩ/170 Ω/17 Ω

Accuracy: ±2%

Order Information

Heavy-Duty
Galvanometer SF-9500A

Ripple Tank

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

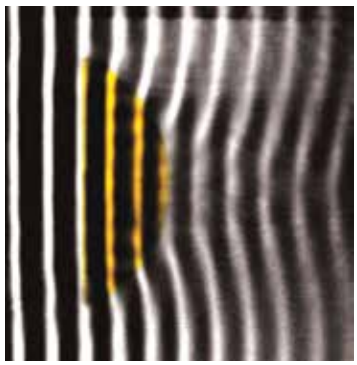
The redesigned Ripple Tank System is easier to use, more reliable, and more affordable. The strobe and rippler are controlled by the same unit, and a new feature makes it possible to introduce a small frequency difference between the strobe and the rippler to make the waves appear to move slowly. A simple 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.

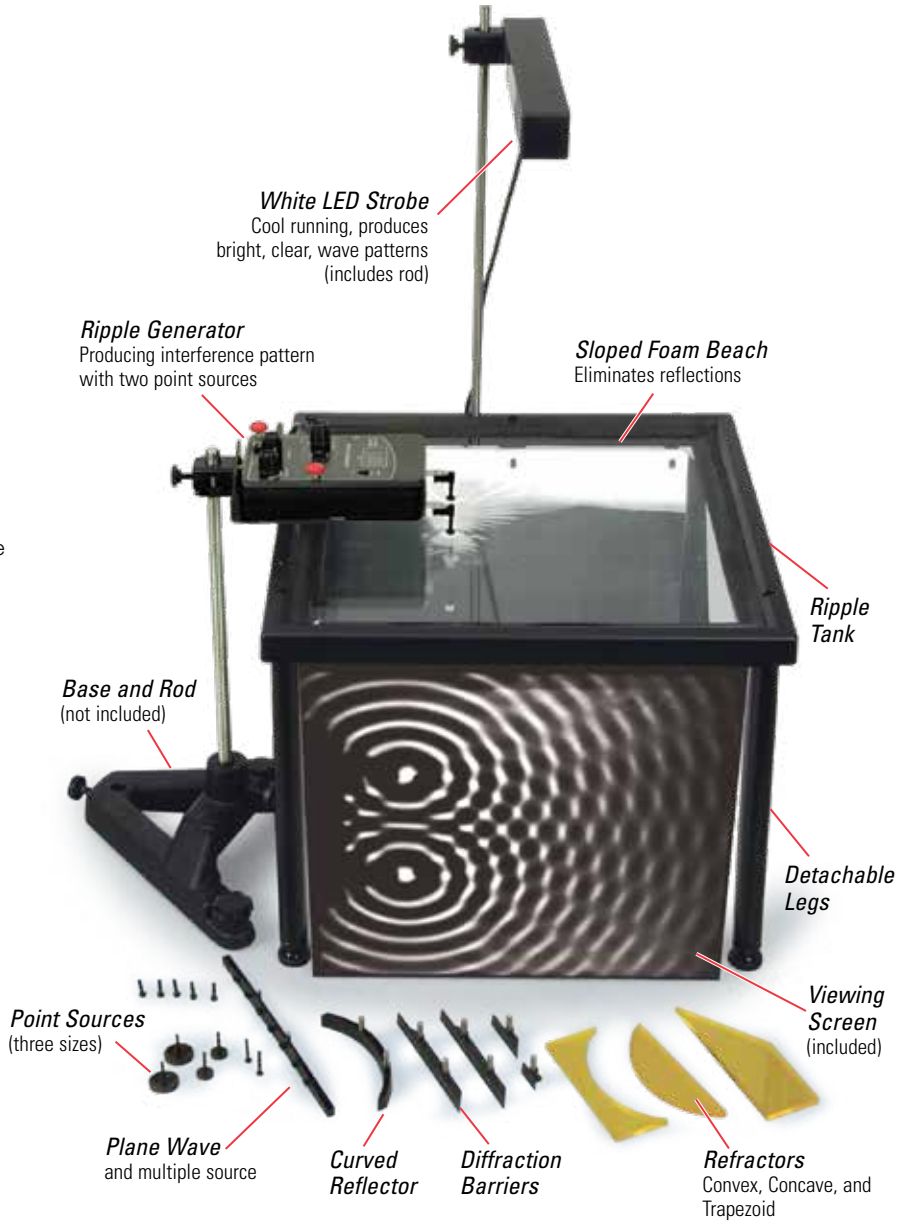
The new light source is a white LED that remains cool during operation and produces a bright, clear wave pattern. The light can be used as a strobe or in steady mode.

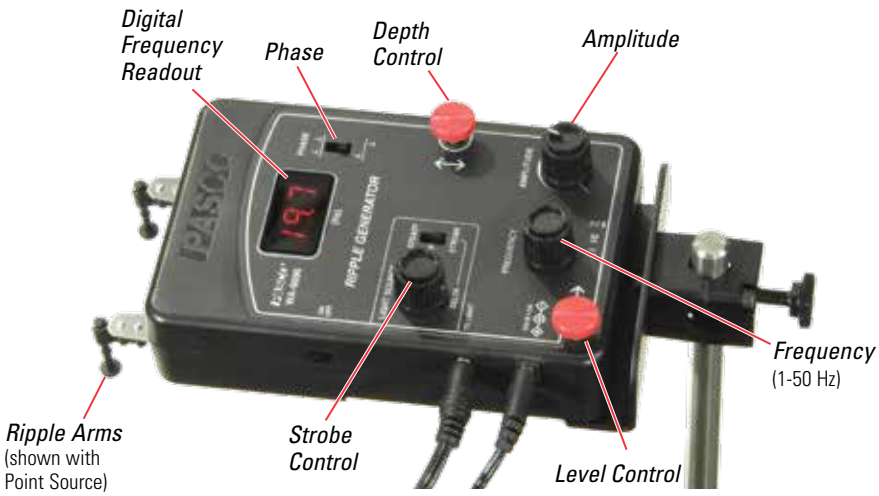
Typical Applications

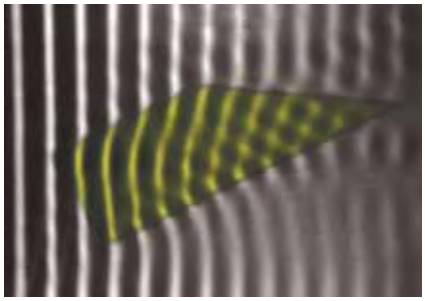
- Speed of Wave Propagation
- Superposition of Waves
- Effects of Varying Water Depth
- Reflection, Refraction, and Diffraction



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.



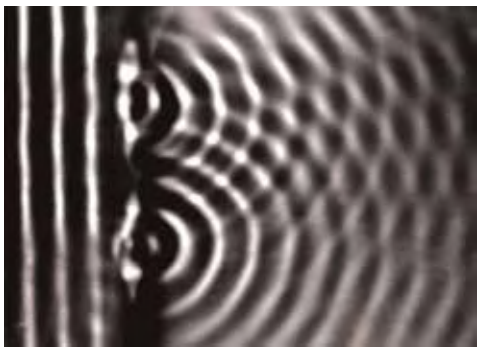




Refraction occurs at the boundaries of this rhomboid shape.



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. 186
90 cm Rod	ME-8738	p. 186
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 L Plastic Beaker
- Pipette
- Clear Plastic Ruler
- Water Resistant Storage Box for Entire System

See specifications 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)

See specifications 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

See specifications at left.

Order Information

Ripple Tank Optics WA-9898

Ripple Tank Screen and Mirror

WA-9881

Includes

- Screen and mirror

Order Information

Ripple Tank Screen and Mirror WA-9881

Standing Waves

String Vibrator

WA-9857A

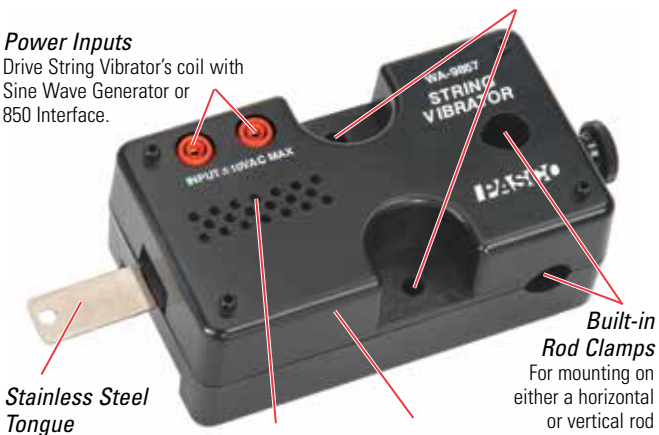
- Great tool for mechanical wave demonstrations
- Uses magnetic field to drive flexible tongue

The String Vibrator transforms mechanical wave demonstrations into 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.

Includes

- String Vibrator Unit
- Wave Cord (3 meters) (not shown)





Order Information

String Vibrator	WA-9857A
Required:	
Sine Wave Generator	WA-9867

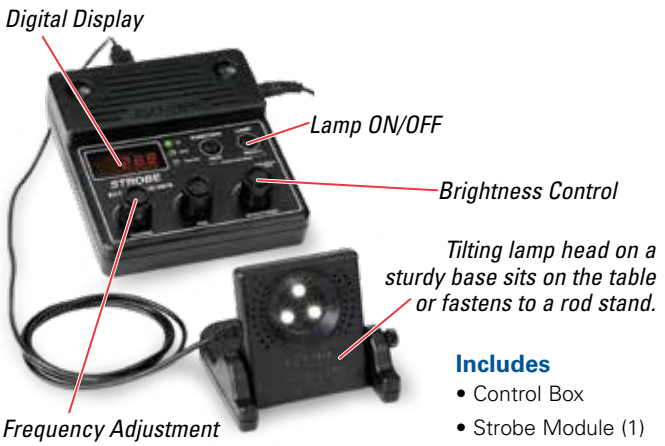
Strobe

ME-6978

- 1 Hz to 500 Hz
- Variable intensity
- Low cost
- External trigger

This 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.





Includes

- Control Box
- Strobe Module (1)

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

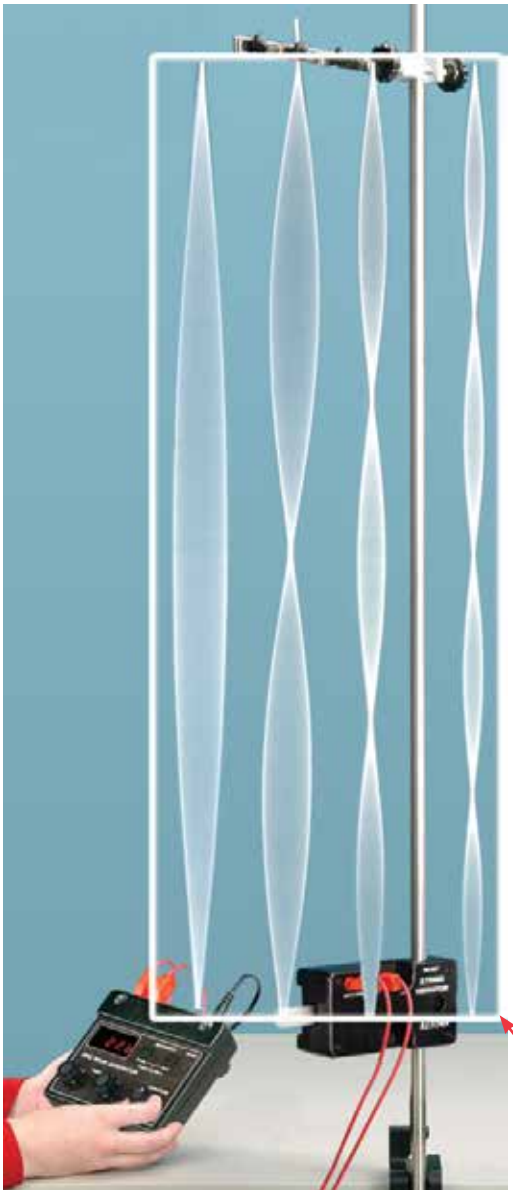
Order Information

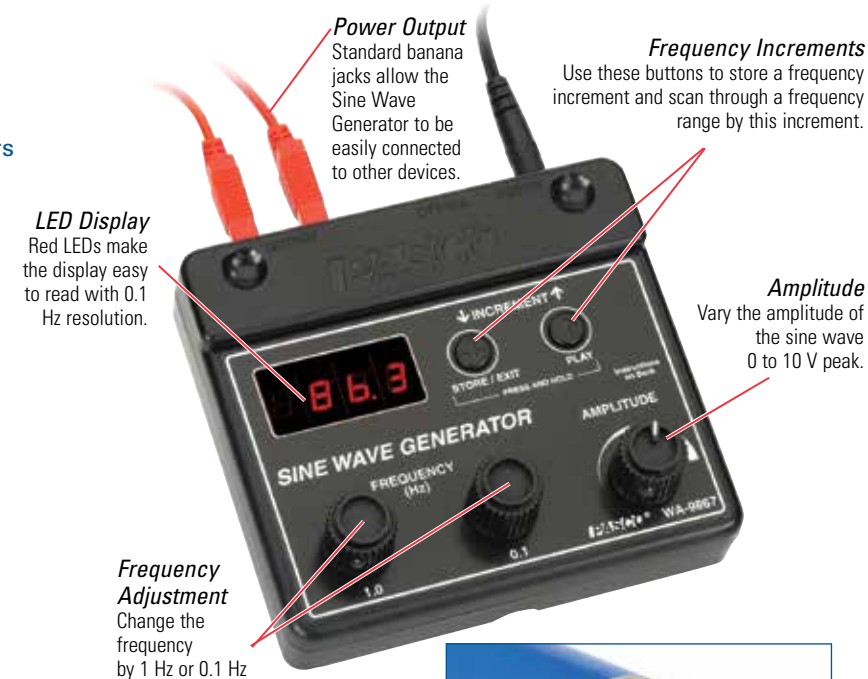
Strobe	ME-6978	
Additional Strobe Module	ME-6982	
Shown in use with:		
String Vibrator	WA-9857A	p. 186
25 cm long Steel Rod (2) (threaded)	ME-8988	p. 189
Aluminum Table Clamp (2)	ME-8995	
Sine Wave Generator	WA-9867	
Multi-Clamp	ME-9507	

Sine Wave Generator

WA-9867

- Sine wave output up to 800 Hz
- Ideal for driving speakers and wave drivers
- Auto-scan of resonant frequencies







High Power Output
To drive speakers

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: 15 VDC 2A



Order Information

Sine Wave Generator	WA-9867	
Recommended:		
String Vibrator	WA-9857A	p. 254
Mechanical Wave Driver	SF-9324	p. 256
Open Speaker	WA-9900	p. 258
Economy Resonance Tube	WA-9495	p. 258
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 226

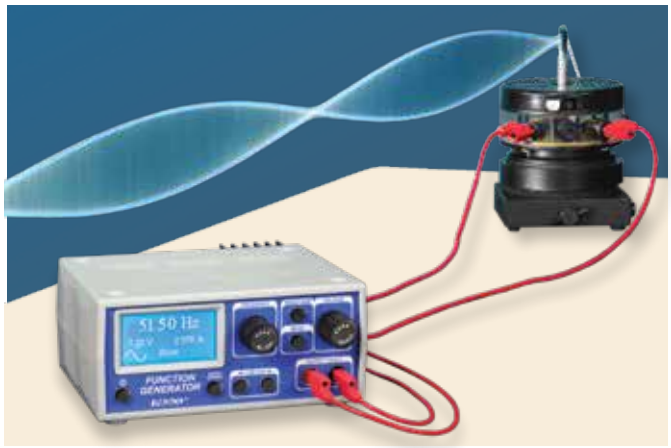
Mechanical Waves

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; see below.

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 at 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. 226
Plus one of the following function generators:		
Sine Wave Generator	WA-9867	p. 255
Function Generator	PI-8127	p. 249
850 Universal Interface	UI-5000	p. 26
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. 226
Recommended:		
Slot String Holder (set of 4)	SF-9322	p. 257
Hole String Holder (set of 4)	SF-9323	p. 257

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.



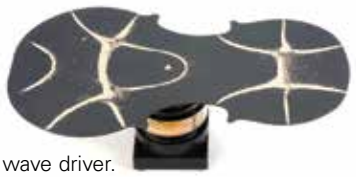
Longitudinal waves can be easily demonstrated with the Longitudinal Wave Spring.

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.

Order Information

Violin Chladni Plate SE-7319

Chladni Plates Kit

WA-9607



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 that 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.

WARNING! This product can expose you to crystalline silica, which is known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Order Information

Chladni Plates Kit WA-9607

Mechanical Wave Driver Accessories

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

4 mm diameter banana plugs fit into shaft of Wave Driver (SF-9324).



Slot (set of 4)
SF-9322



Hole (set of 4)
SF-9323

Order Information

Slot String Holder (set of 4)..... SF-9322
Hole String Holder (set of 4)..... SF-9323

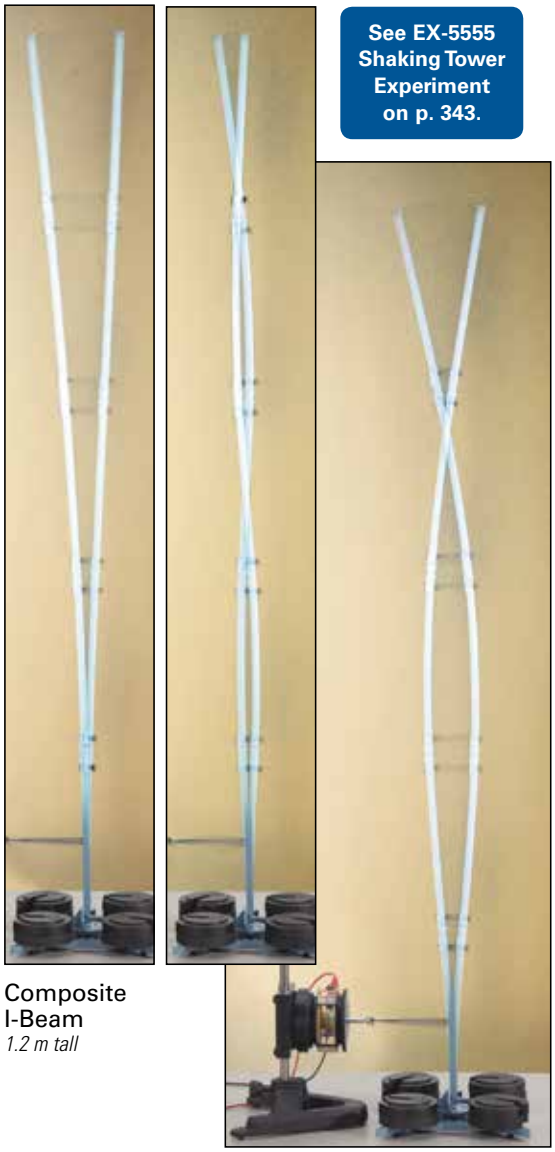
Structures Resonance

Structures System

PASCO's Structures System is ideal 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.

The long plastic I-Beam is constructed of components from the Advanced Structures Set (p. 151). It is driven using the Mechanical Wave Driver and the Function Generator (PI-8127), demonstrating the three lowest harmonics.

See EX-5555 Shaking Tower Experiment on p. 343.



Composite I-Beam
1.2 m tall

Order Information

Advanced Structures Set.....	ME-6992B	p. 151
Large Slotted Mass Set.....	ME-7566	p. 197
45 cm Stainless Steel Rod.....	ME-8736	p. 186
Large Rod Base.....	ME-8735	p. 186

Resonance

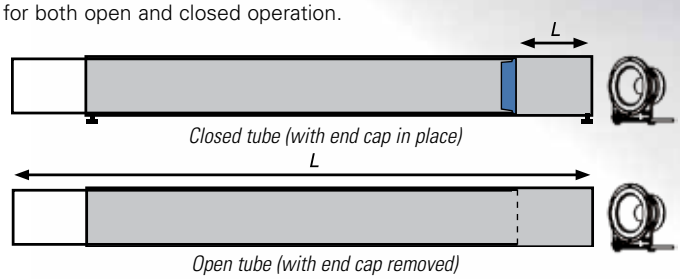
Demonstrate Acoustic Resonance

Economy Resonance Tube

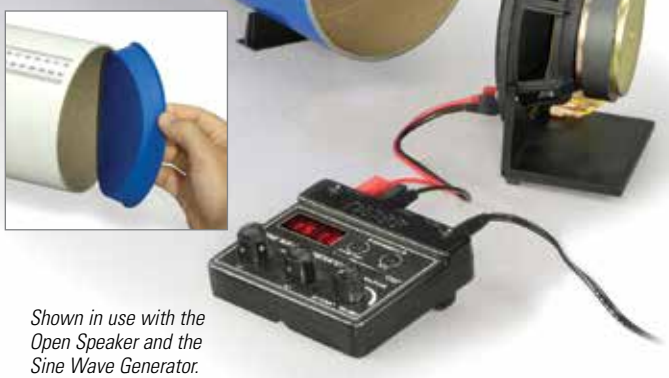
WA-9495



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.



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.

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. 255
2 Meter Patch Cord Set	SE-9415A	p. 226

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 W (max)

Order Information

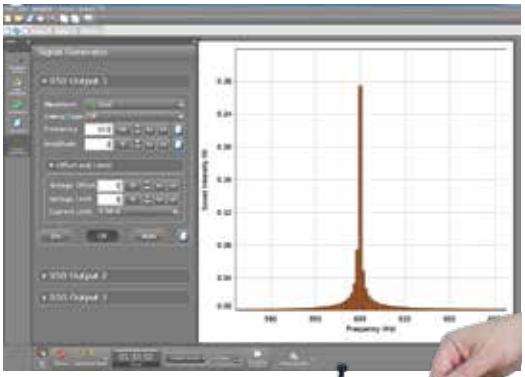
Open Speaker	WA-9900

Resonance Air Column with Speaker

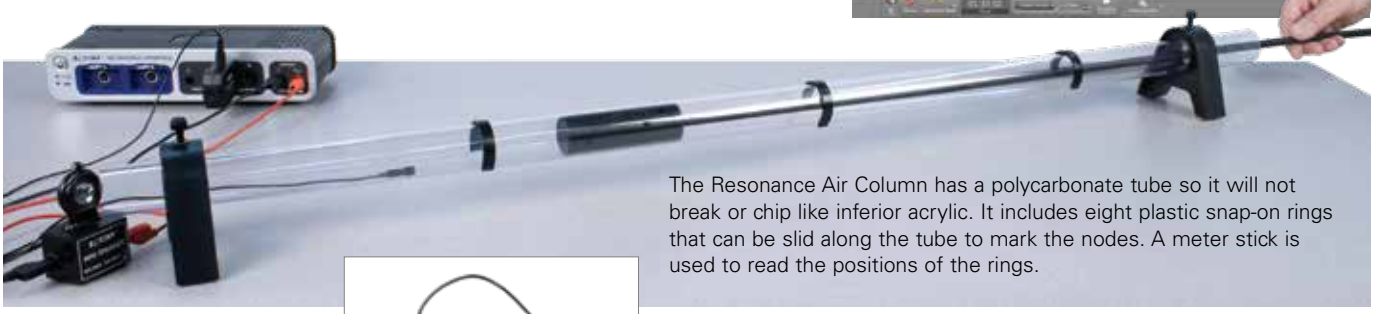
WA-9594

- 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 550 Universal Interface to drive the speaker. The FFT display of the Sound Sensor data shows the tube's resonant response.



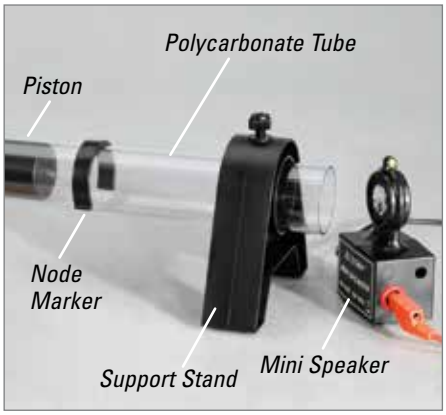
The Resonance Air Column has a polycarbonate tube so it will not break or chip like inferior acrylic. It includes eight plastic snap-on rings that can be slid along the tube to mark the nodes. A meter stick is used to read the positions of the rings.

The new Sound Sensor (UI-5101) has a microphone on a 1.4 m long wire so it can be used to find the nodes inside the Resonance Air Column.





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.



WA-9594 includes
- Resonance Air Column (WA-9606)
- Mini Speaker (WA-9605)

WA-9606 includes
- Tube and plunger,
- Node markers (8)
- Detachable stands (2)



Shown: WA-9594

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

Order Information

Resonance Air Column with Speaker	WA-9594	
Resonance Air Column (without speaker)	WA-9606	
Shown in use with:		
550 Universal Interface	UI-5001	p. 26
Sound Sensor	UI-5101	p. 60
Tuning Fork Set	SE-7342	p. 263
2 Meter Patch Cord Set	SE-9415A	p. 226
Meter Stick (6 pack)	SE-8827	p. 192

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), an 850 Universal Interface (UI-5000), or a 550 Universal Interface (UI-5001). It is also useful as a stand-alone speaker for doing interference demonstrations. Two Mini Speakers acting as 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

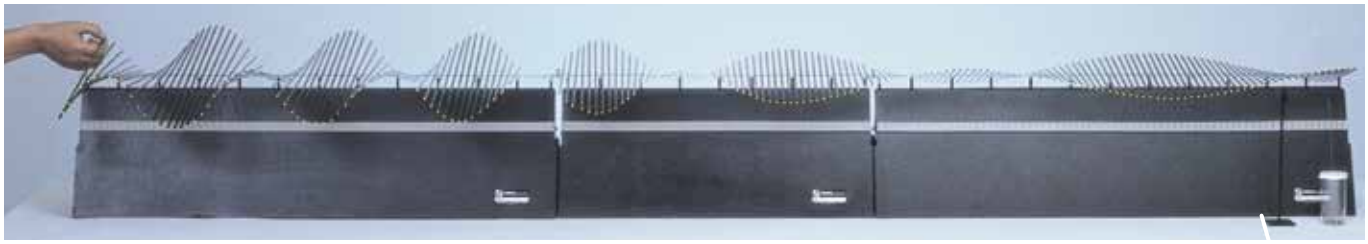
Transverse Waves

Complete Wave Motion Demonstrator

SE-9600

- Produces slow-moving, high-amplitude transverse waves
- Demonstrates all basic wave phenomena

The PASCO Complete 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

SE-7125

- Sinusoidal driver
- Reproducible pulse
- Digital readout



The Wave Motion Actuator sinusoidally drives the Complete Wave Motion Demonstrator (above). 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:

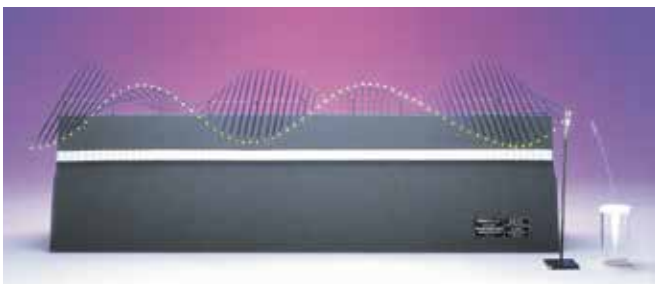
- Wave propagation velocity
- Wave reflection boundary conditions
- Wave interference and standing waves

Order Information

Wave Motion Actuator SE-7125

Single Section Wave Motion Demonstrator

SE-9601



A-frame design collapses for easy storage.

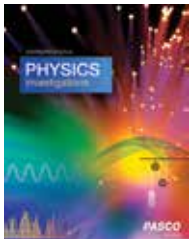
Includes

- 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

Comprehensive Physics Investigations Lab Manual



EP-6326

Are you looking for more hands-on physics labs? The *Comprehensive Physics Investigations Lab Manual* includes over 40 labs and activities, seven of which are for Oscillations, Waves & Sound.

Oscillations, Waves & Sound Labs

- Oscillators
- Resonance
- Waves
- Interference
- Resonance and Sound
- Design a Musical Instrument

Best of all, digital access to these **Online Teacher Resources** is included with purchase of the lab manual:

- Word and PDF versions of the lab instructions
- Student worksheets (blackline masters) in Word and PDF formats
- Answer keys in Word and PDF formats
- Sample Data
- Labs for SPARKvue

Equipment

Oscillations, Waves and Sound Kit

EP-3578

Perform experiments to study wave properties, amplitude, wave length, frequency, resonance, and period.

Includes

- Steel Transverse Wave "Snakey" Spring (1.8 m)
- Extra-large Steel Longitudinal Wave "Slinky" Spring
- 25 cm Extension Spring
- Pendulum/Spring Hanger
- Resonance Lever
- 1"-diam. Aluminum Pendulum Ball
- Resonance Tube
- Tuning Forks (4)
- Forces Accessories
- Tripod
- Gratnells® Storage Tray



Order Information

Oscillations, Waves, and Sound Equipment Kit EP-3578
Comprehensive Physics Investigations Lab Manual..... EP-6326

Bell Jar

SE-7725

This thick glass bell jar with base plate includes an electric bell on a rubber mount to demonstrate that sound does not propagate in a vacuum. Remove the air from the jar and the sound from the bell gradually fades.



Specifications

Vacuum Pressure for Bell Jar: <= -0.06 MPa
Bell Voltage: 3 V DC
Bell Jar: 6.5" dia. x 9.75" tall (inside: dia. 6.25" x 8" tall)
Base: 8" dia. x 1.5" high



Includes

- Glass bell jar
- Vacuum base plate
- Gasket
- Hose
- Battery-operated electric bell (removable)

Order Information

Bell Jar SE-7725
Required:
2 AA batteries
Vacuum Pump..... SE-7726

Vacuum Pump

SE-7726



- 15 mTorr vacuum
- Pump the air out of a bell jar
- Use with Coin and Feather Tube (page 129)

This reasonably priced vacuum pump can obtain a vacuum down to 15 mTorr.

Features

- 1/2 HP, 1725/1425 RPM capacitor start motor with thermal overload protection
- 1/2" x 1/4" x 3/8" intake port
- 21-ounce (680 cc) oil capacity
- 2 stage direct drive to achieve deep 15-micron vacuum
- Lighter weight finned aluminum housing reduces heat during operation
- All metal construction including all brass fittings
- Completely field-repairable
- UL listed; made in the USA
- 24-month warranty

Coming soon!
Check pasco.com for availability.

Order Information

Vacuum Pump..... SE-7726

Wave Media

Sound Pipe

SE-7724





When students spin these pipes over their heads, the pipe produces an audible tone similar to that produced by blowing across the mouth of a bottle. As the pipe is spun faster, the resonant frequency increases. Five different frequencies can be achieved. Four pipes of various colors are included.

Coming soon!
Check pasco.com for availability.

Order Information

Sound Pipe SE-7724

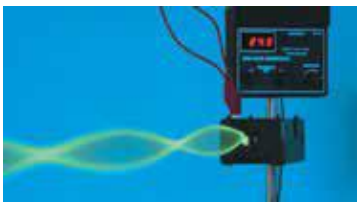
Glow String (2 pack)

SE-8690



String color may vary.

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

⚠WARNING
CHOKING HAZARD
Small parts. Not for children under 3 years.

Order Information

Glow String (2 pack) SE-8690

Snakey

SE-7331



This extra-long metal spring is ideal to study 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.



Easily create clear standing wave patterns.

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

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

Singing Rods

SE-7301

These rods emit a VERY LOUD pure tone when stroked. The nodes are marked on these rods to indicate where you should hold the rod. Standing longitudinal waves are set up in the rod by stroking the rod with your fingers (coated with the included rosin). Investigate the effects of different lengths and holding the rod at different nodes.



Includes

- Two Aluminum Rods
  Approx. length: 20" (500 mm) and 30" (750 mm).
- Bag of crushed rosin to lightly coat your fingertips

Order Information

Singing Rods SE-7301
Replacement Supplies:
Rosin Bag SE-6659

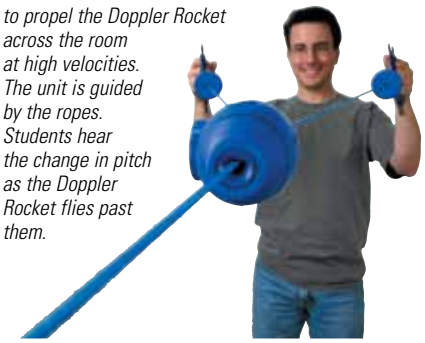
Doppler Rocket

WA-9826

- Experience the frequency shift of sound waves
- Easily generate high velocity motion
- Rugged construction



Fly 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 m)
- Handles (4)
- Handle Cushions (4)
- Battery (9 V)

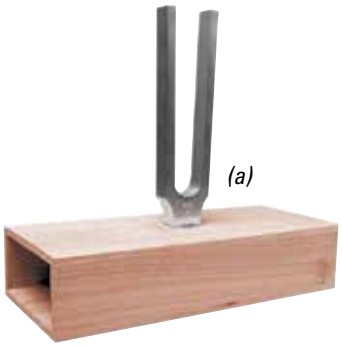


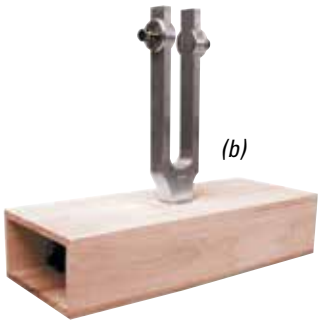
Order Information

Doppler Rocket..... WA-9826

Sympathetic Resonance Box Set

SE-7345





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 Capstone software and a sound sensor (UI-5101) to measure the sound waves and beat frequencies created by these resonance boxes.

Includes

- Hardwood resonance box with a 256 Hz A4 tuning fork (a)
- Hardwood resonance box with an adjustable tuning fork (b)

Order Information

Sympathetic Resonance Box Set SE-7345

Recommended:

Sound Sensor UI-5101

850 Universal Interface..... UI-5000

PASCO Capstone..... pp. 70-73

Tuning Fork Set

SE-7342



The tuning fork has long been the tool of choice to help 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

Tuning Fork Technical Set

SE-7728



This tuning fork set consists of six aluminum tuning forks: 125, 250, 500,1000, 2000, 4000 Hz. The frequencies are stamped on the forks.



Order Information

Tuning Fork Technical Set..... SE-7728

Basic Optics System

OS-8515C

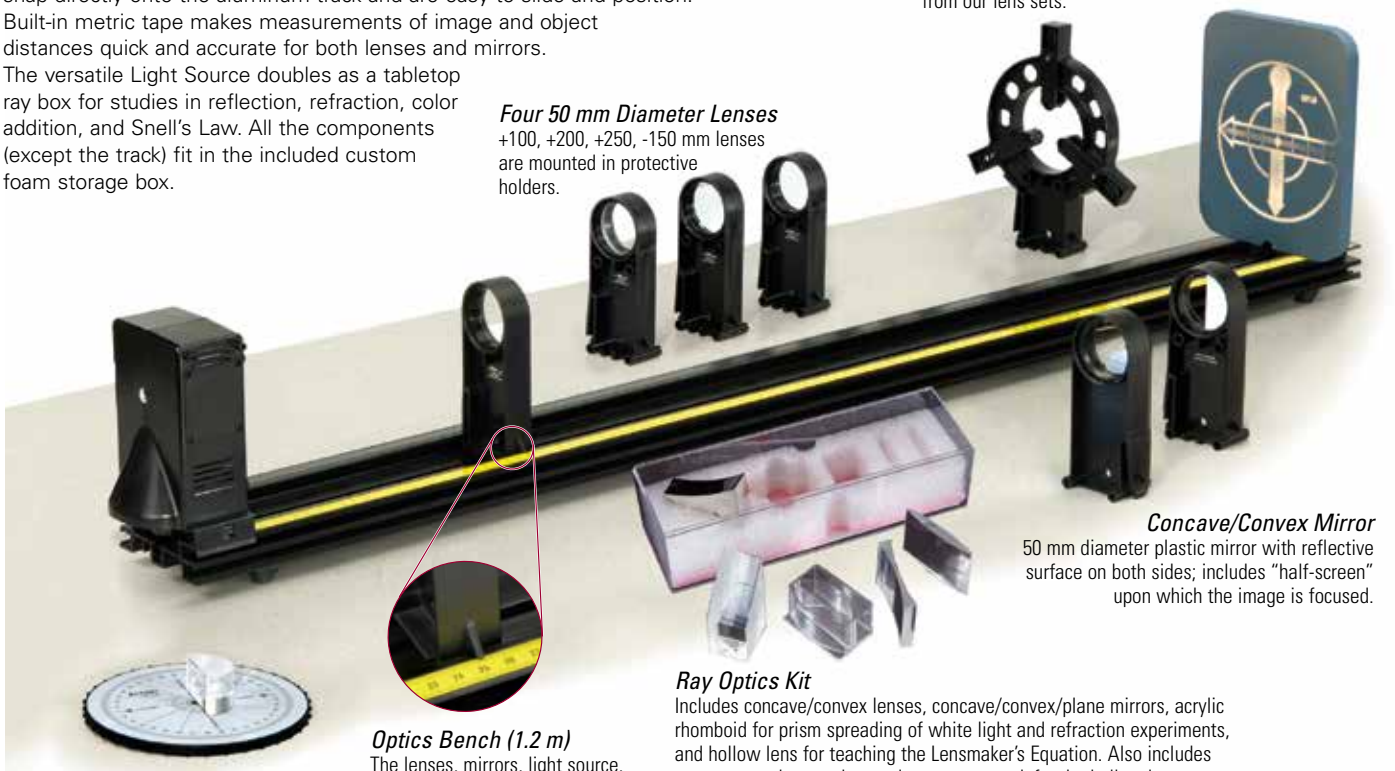
- Geometric and ray optics
- Concave and convex lenses
- Concave/convex mirror

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.

Viewing Screen
White plastic screen snaps into the optics bench and the position of the screen can be read directly on the bench scale.

Adjustable Lens Holder
Use your own lenses (from 19 mm to 75 mm in diameter) or choose from our lens sets.

Four 50 mm Diameter Lenses
+100, +200, +250, -150 mm lenses are mounted in protective holders.

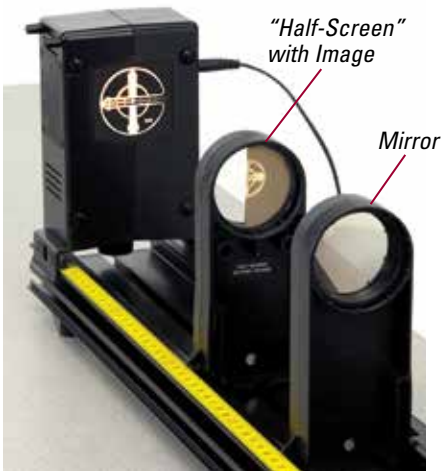


Concave/Convex Mirror
50 mm diameter plastic mirror with reflective surface on both sides; includes "half-screen" upon which the image is focused.

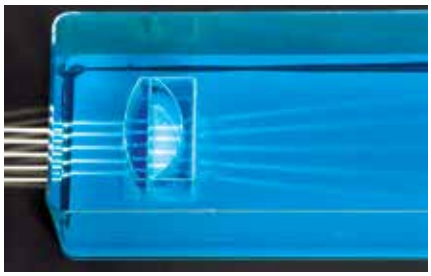
Ray Optics Kit
Includes concave/convex lenses, concave/convex/plane mirrors, acrylic rhomboid for prism spreading of white light and refraction experiments, and hollow lens for teaching the Lensmaker's Equation. Also includes storage tray that can be used as a water tank for the hollow lens.

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.

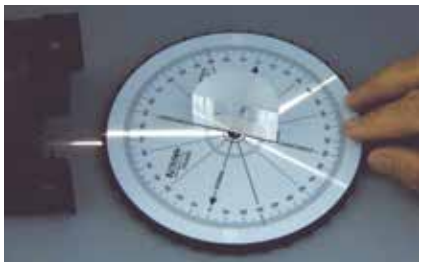
Ray Table
Two-piece construction allows the table to be rotated to study Snell's Law or the Law of Reflection. Includes D-shaped acrylic lens.



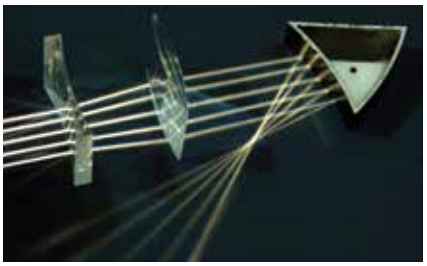
Light Source: Has a lighted crossed arrow target with metric scale for focusing images through lenses or for use with the concave mirror.



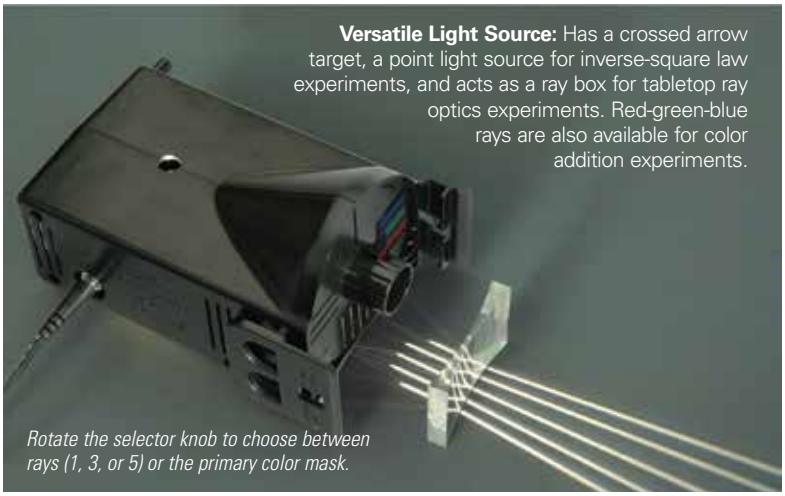
The storage tray is used to create a "hollow" air-filled convex lens. Note that the rays diverge.



Ray Table in use showing both the reflected and refracted rays

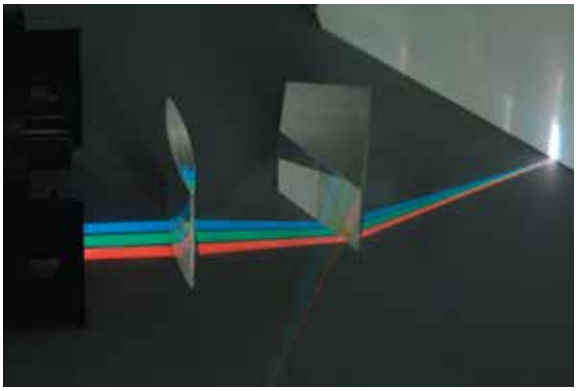


Components from the Ray Optics Kit showing refraction and reflection



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.

Included Basic Optics System Experiments

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 pp. 267-268).



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

System Components

pp. 266-269





Color Mixer

p. 270





Lens Sets

pp. 267-268





System Accessories

pp. 267-268
272-273



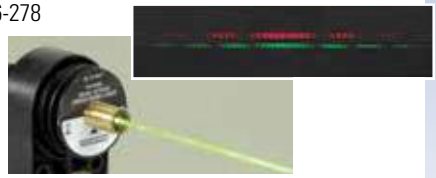
Human Eye Model

pp. 274-279



Diffraction

pp. 276-278



Dynamics Track Optics

p. 280



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 in 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

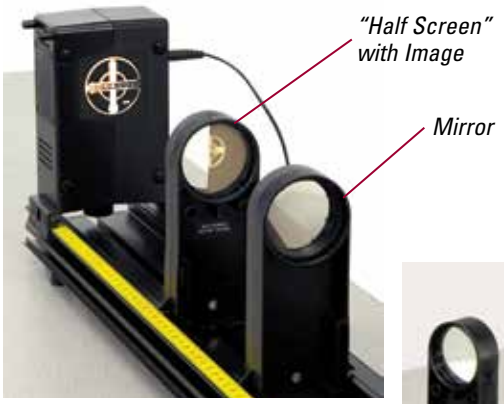
Ray Optics Kit OS-8516A

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. This 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

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 to control the amount of light that reaches the viewing screen.

The ƒ-number is designated as ƒ / #, where # equals the focal length of the lens (f) divided by the diameter of the aperture (D). Example uses a +100 mm lens.

ƒ-Number	*Aperture Diameter (mm)*
ƒ / 4	*25.0*
ƒ / 5.6	*17.7*
ƒ / 8	*12.5*
ƒ / 11	*8.8*
ƒ / 16	*6.3*
ƒ / 22	*4.4*



The Peripheral Mask passes light through the center only.

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.



Peripheral Mask shown mounted on +250 mm lens



The Center Mask passes light through an outside ring.

Includes

- Aperture Disk and Holder
- Spherical Aberration Attachments

Order Information

Aperture Accessories OS-8524

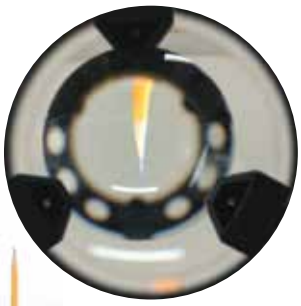
Adjustable Lens Holder

OS-8474

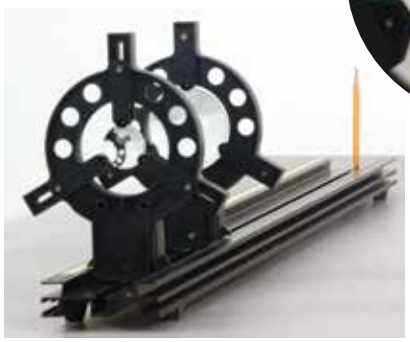
The Adjustable Lens Holder for the Basic Optics System is designed for use with lenses and mirrors with diameters between 19 mm and 75 mm.

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.





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.

Order Information

Adjustable Lens Holder OS-8474

Lens Holder Set

OS-8522

These holders for the Basic Optics System are an excellent way to permanently mount 50 mm diameter lenses.

Just push in the two retaining rings to hold the lens in place.



Order Information

Lens Holder Set (2 pack) OS-8522

Basic Optics Accessories

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.

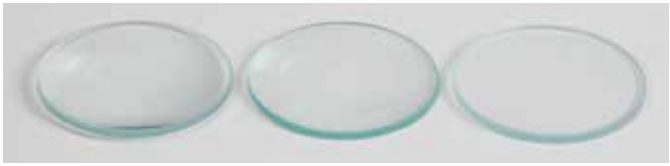
Focal Length (mm)	Description	Focal Length (mm)	Description
+1000	double convex	-1000	double concave
+300	double convex	-200	double concave
+150	double convex	-150	double concave

Order Information

50 mm Diameter Lens Assortment SE-7581

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 on page 267.

Order Information

Geometric Lens Set OS-8466A

Lens Sets

Basic Optics Geometric Lens Set (set of 2)

(+200, +100 mm) OS-8456

Accessory Lens Set (set of 2)

(+250, -150 mm) OS-8519



Each lens is mounted in a lens holder for protection and easy storage. The lens holder clips directly to the Basic Optics Track.

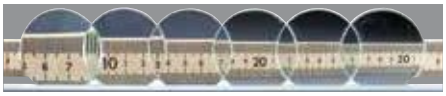
Order Information

Basic Optics Geometric Lens Set (set of 2) OS-8456

Accessory Lens Set (set of 2) OS-8519

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

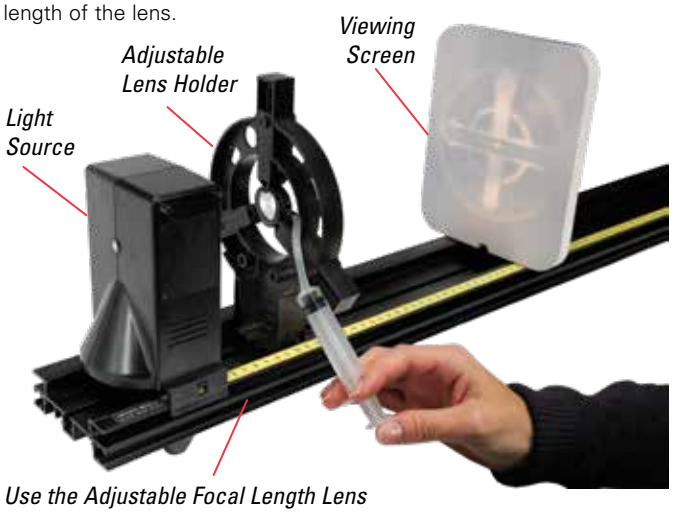
Order Information

Ground Glass Lenses (set of 6) SE-9013

Adjustable Focal Length Lens

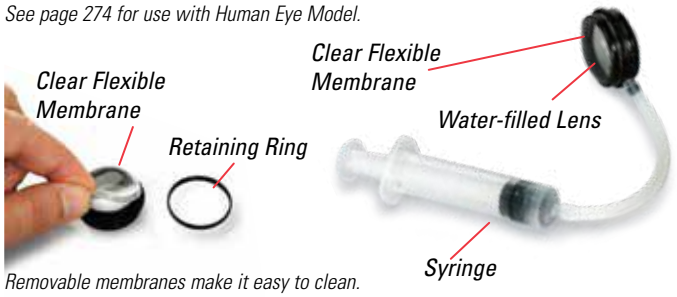
OS-8494

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 274 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. 264

Basic Optics Viewing Screen

OS-8460



This white plastic screen is used with the Basic Optics System. 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 280) for use with a Dynamics Track.

Order Information

Basic Optics Viewing Screen OS-8460

Basic Optics Spares Kit

OS-8510



All parts are organized in a plastic case for easy storage.

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).

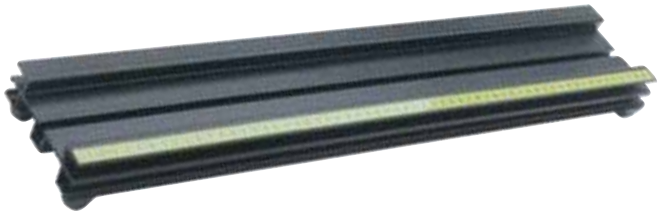
Includes

- 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

Optics Benches



60 cm Optics Bench

OS-8541

This 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.

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
Shown in use with:
Small Round Base with Rod ME-8270

Color Mixer

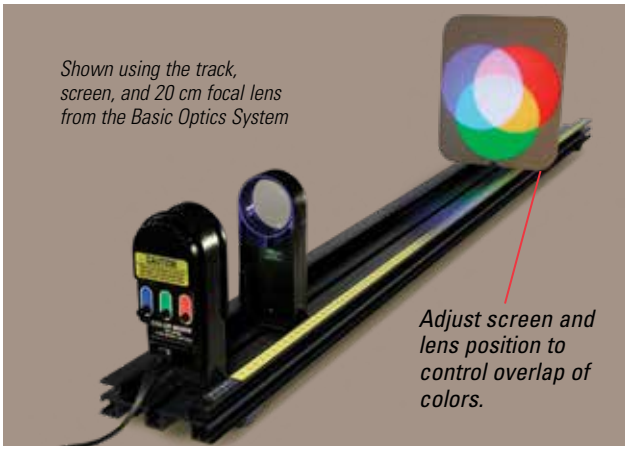
OS-8496

- 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, handheld, or clip it directly to the Basic Optics Track.



Includes

- Tri-color light source
- Power supply

Order Information

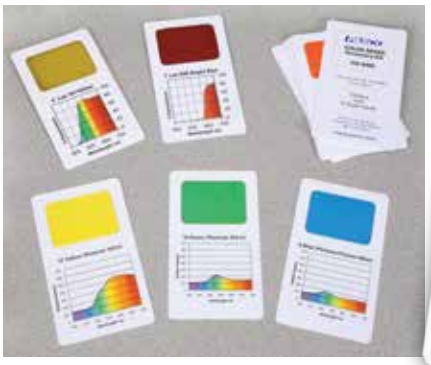
Color Mixer OS-8496

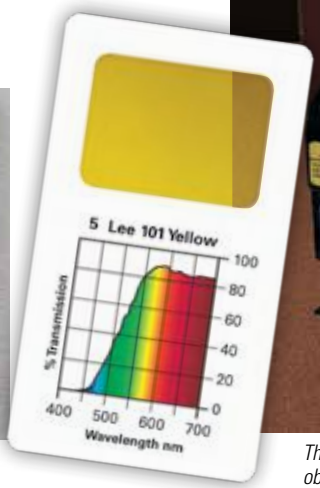
Color Mixer Accessory Kit

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.

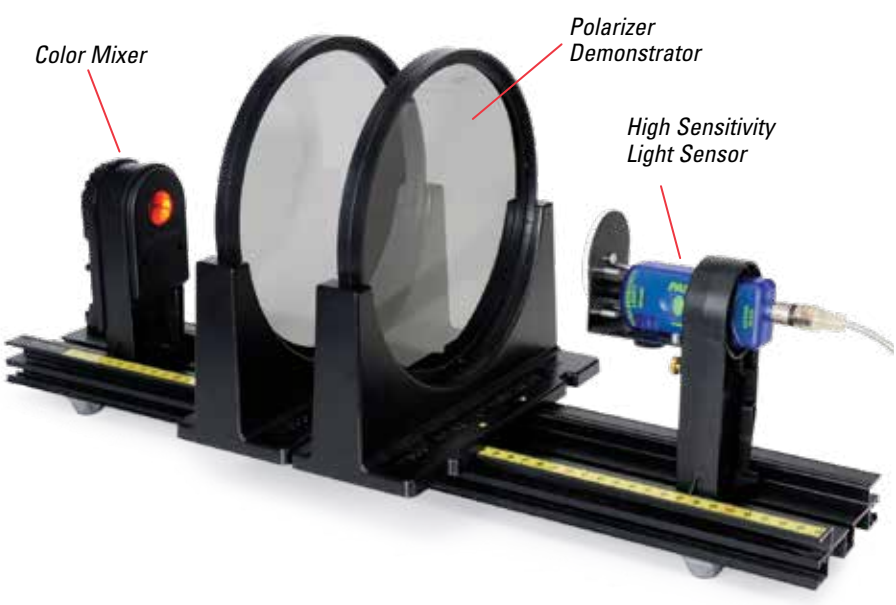
Order Information

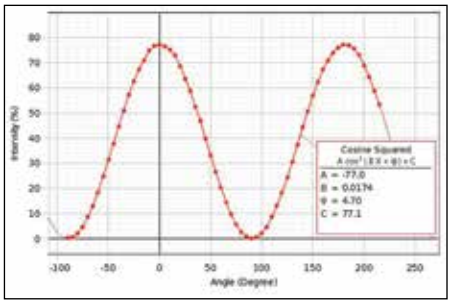
Color Mixer Accessory Kit OS-8495

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	
Shown in use with:		
Optics Bench (60 cm)	OS-8541	p. 269
Aperture Bracket	OS-8534A	p. 279
Color Mixer	OS-8496	p. 270
High Sensitivity Light Sensor	PS-2176	p. 53

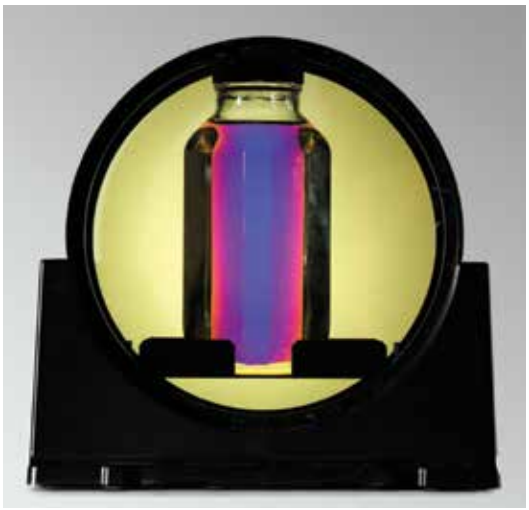
Polarizer Demonstrator Accessory

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 as the axis of polarization of different colors rotates to different angles.



Demo with Karo® corn syrup shows 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

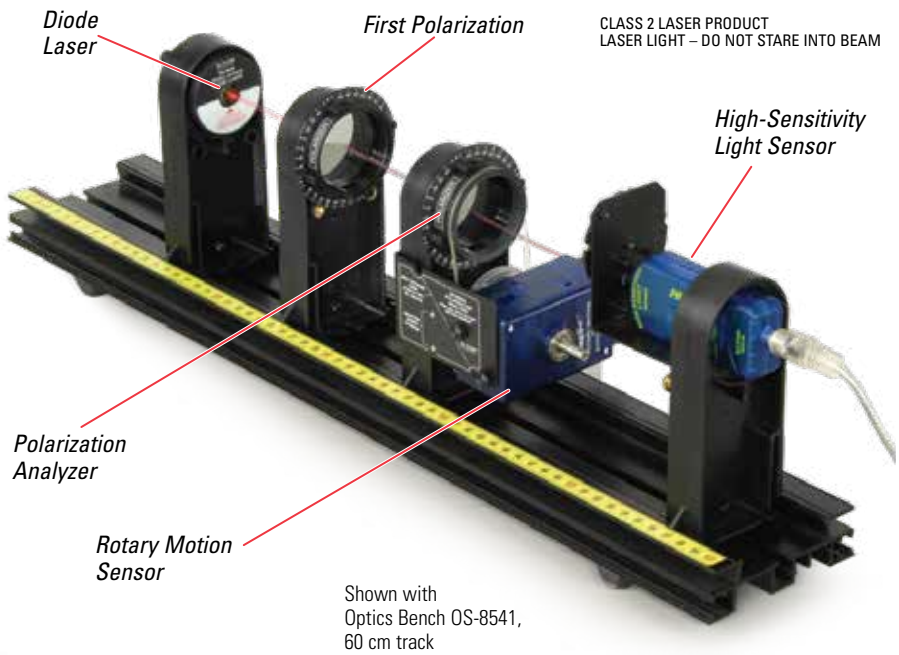
Polarizer Demonstrator Accessory	OS-8172	
Required:		
Polarizer Demonstrator	OS-9477A	
Suggested:		
Color Mixer	OS-8496	p. 270

Polarization

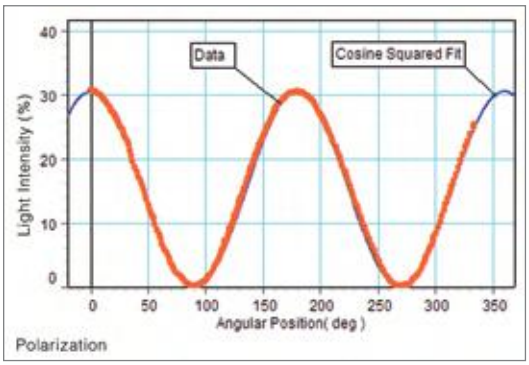
Polarization Analyzer

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-8541. 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 Optics Bench 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.



Includes

- Polarizer Disks (2)
- Polarizer Holder
- Aperture Bracket
- Accessory Holder with Mounting Bracket
- Accessory Holder for Aperture Bracket
- Retarder Disk

Order Information

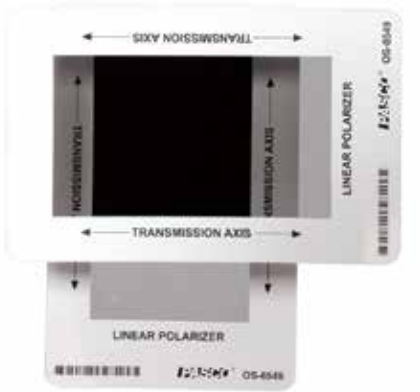
Polarization Analyzer	OS-8533A	
Required:		
Rotary Motion Sensor	PS-2120A	p. 33
High-Sensitivity Light Sensor	PS-2176	p. 53
Basic Optics System	OS-8515C	p. 264
Diode Laser	OS-8525A	p. 279

See page 374 for complete experiment.

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 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.



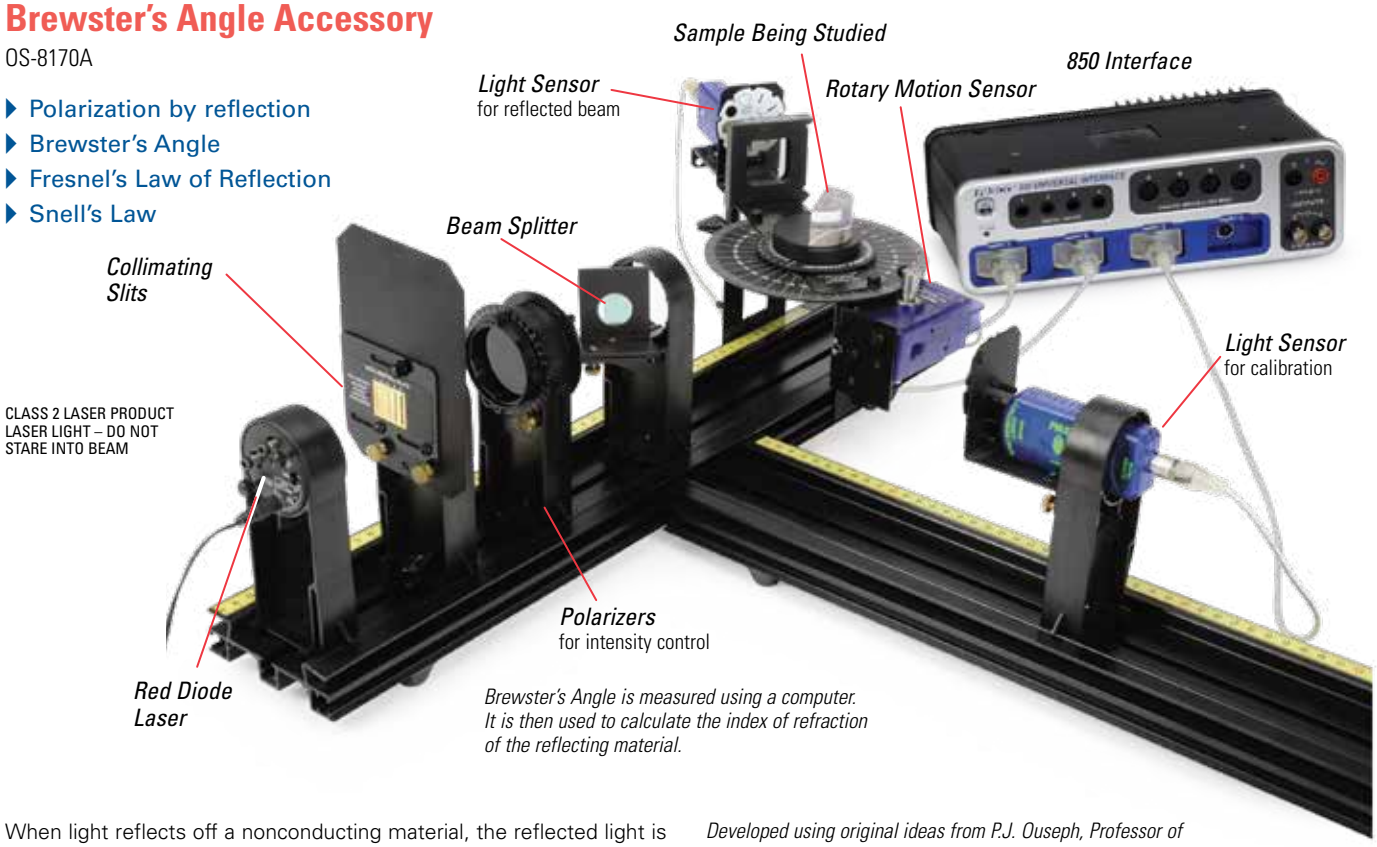
Order Information

Polarizer Set OS-8473

Brewster's Angle Accessory

OS-8170A

- Polarization by reflection
- Brewster's Angle
- Fresnel's Law of Reflection
- Snell's Law

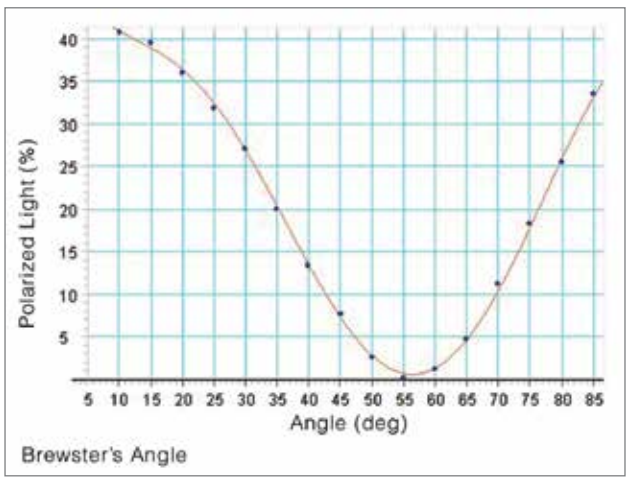


Brewster's Angle is measured using a computer. It is then used to calculate the index of refraction of the reflecting material.

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 semicircular 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 vs. 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.

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).*



The intensity of the reflected polarized light as a function of the incident angle; see Brewster's Angle Experiment on page 375.

Includes

- Acrylic semicircular lens
- Lens platform
- Polarizers (2) with holder
- Analyzing polarizer
- Beam splitter



Order Information

Brewster's Angle Accessory OS-8170A
Beam Splitter (only) OS-8171

For other required equipment, see the Brewster's Angle experiment EX-5544A on page 375.

Optics of the Human Eye

Human Eye Model

OS-8477A

- Classic eye model at an affordable price
- 3-D working model of the human eye



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.
- **Movable Retina:** Three positions 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 it with the Basic Optics System and Eye Model Bracket on page 275.

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)

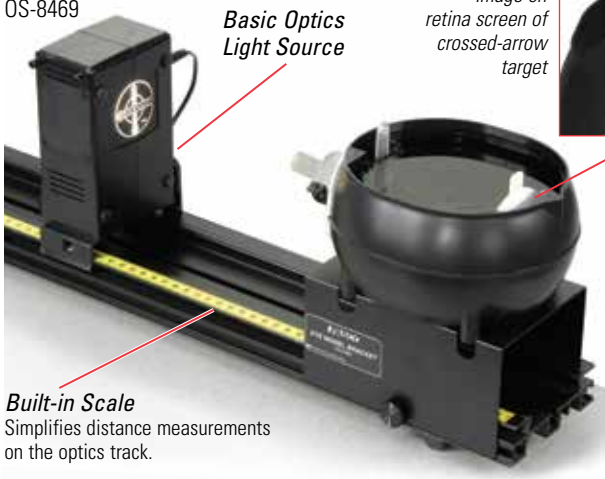
Dimensions: 15 cm x 17 cm x 10 cm high

Order Information

Human Eye Model	OS-8477A	
Recommended:		
Basic Optics Light Source	OS-8470	p. 264
Human Eye Replacement Set (includes lenses, screen, and pupil)	OS-8476	
Optics Caliper (set of 5)	OS-8468	p. 275

Eye Model Bracket

OS-8469



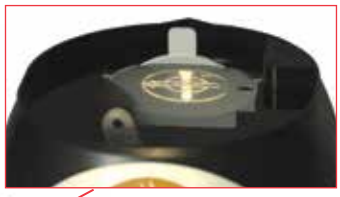


Image on retina screen of crossed-arrow target

The Eye Model Bracket allows the Human Eye Model to be used with the Basic Optics System (OS-8515C). 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 are shown with a telescope made using two Adjustable Lens Holders (OS-8474) and accessory lenses (see page 268). 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

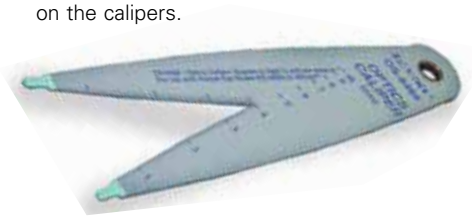
Eye Model Bracket OS-8469
Shown in use with:
Basic Optics System OS-8515C
Human Eye Model OS-8477A

Optics Caliper

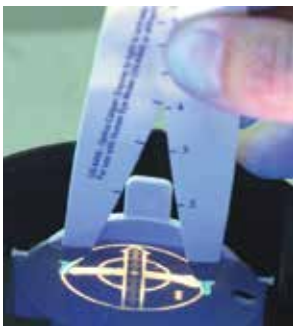
OS-8468

- 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 are activated using a UV light source.

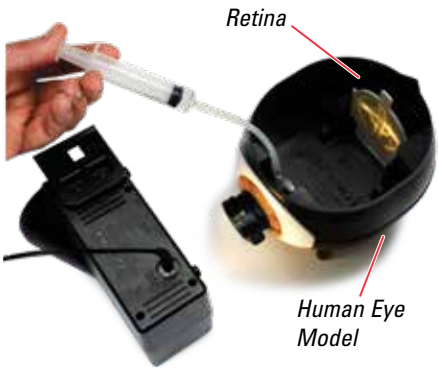
Order Information

Optics Caliper (set of 5) OS-8468

Adjustable Focal Length Lens

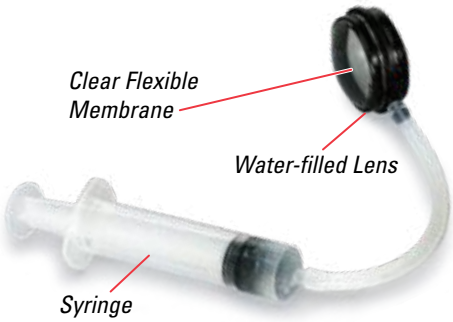
OS-8494

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 268 for use with Basic Optics System.





Removable membranes make it easy to clean.



Includes

- 10 mL Syringe
- 1ft. Silicon Tubing
- Lenses (2)

Order Information

Adjustable Focal Length Lens OS-8494
Shown in use with:
Human Eye Model OS-8477A

Diffraction

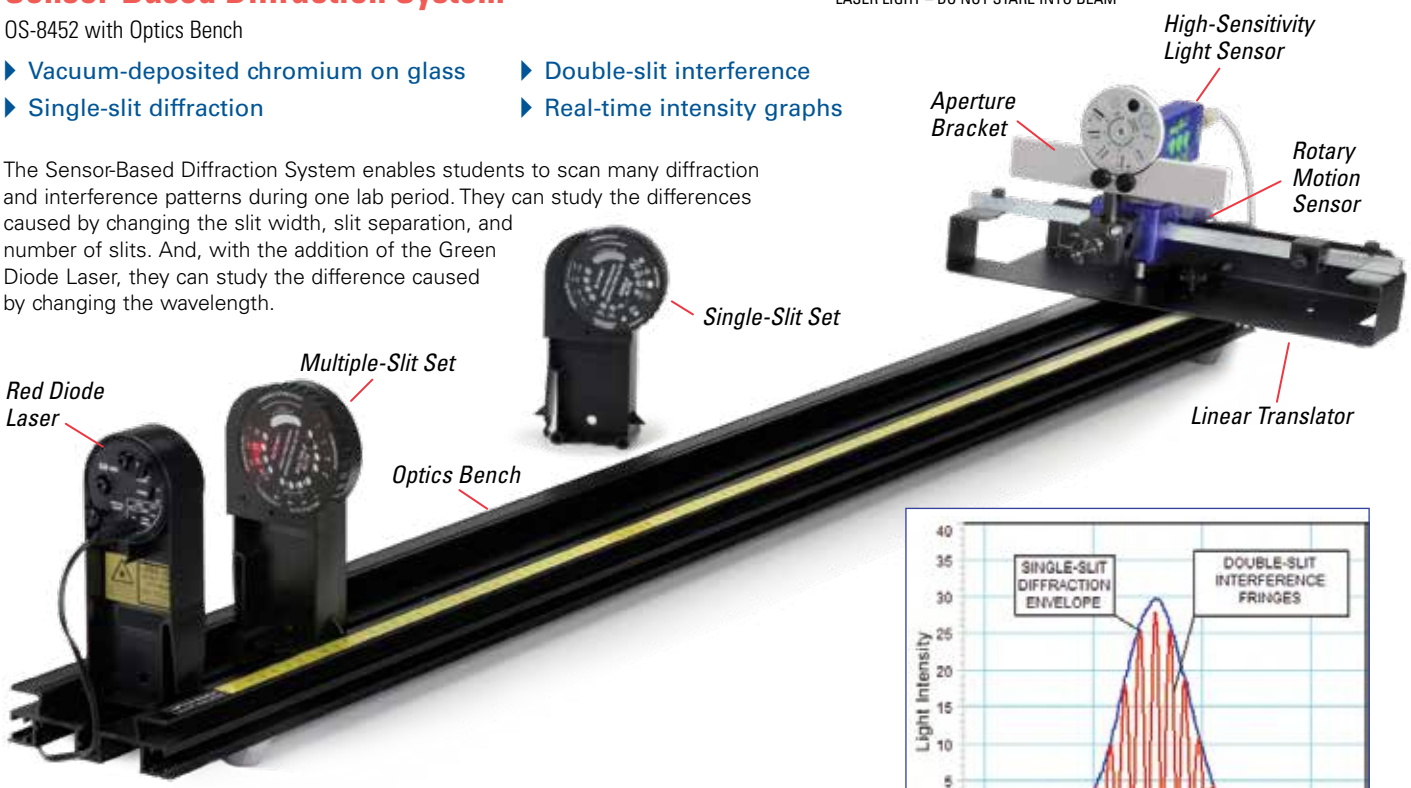
Sensor-Based Diffraction System

OS-8452 with Optics Bench

- Vacuum-deposited chromium on glass
- Single-slit diffraction
- Double-slit interference
- Real-time intensity graphs

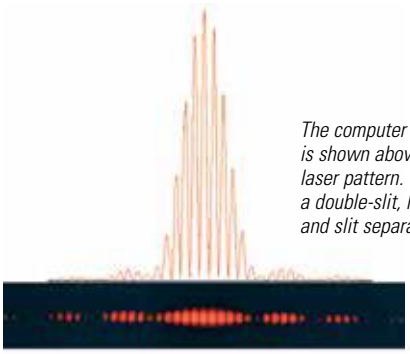
CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

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.

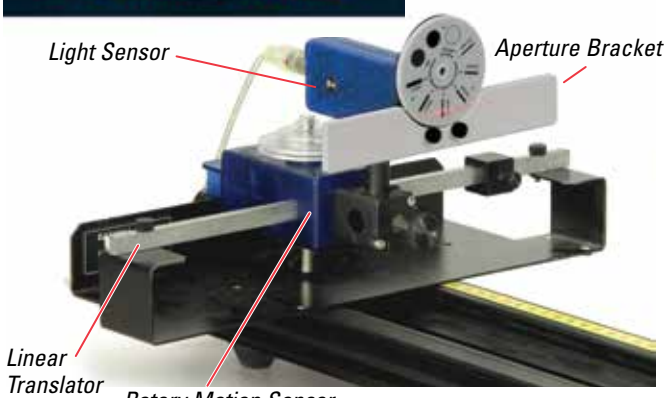


Scanning with the Linear Translator (on page 279): In this unique scanning system, the diffraction pattern is scanned using a light sensor attached to a Rotary Motion Sensor. As the wheel on the Rotary Motion Sensor is rotated by hand, the Rotary Motion Sensor moves along a gear rack (called the Linear Translator). Students make the association between the diffraction pattern they see and the real-time graph of the light intensity vs. 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 Set (OS-8453)

For components and accessories, see pages 278-279.

Order Information

Sensor-Based Diffraction
(with Optics Bench) OS-8452
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-8458B p. 279

Diffraction Optics Kit

OS-8531A

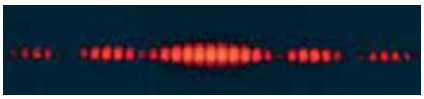
Add this kit to the Basic Optics System to allow the investigation of a wide variety of diffraction slit patterns. The slits are constructed using vacuum-deposited chromium on glass. The following patterns are included:

- 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



Single Slit Pattern (a = 0.04 mm)

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM



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.

Red Diode Laser

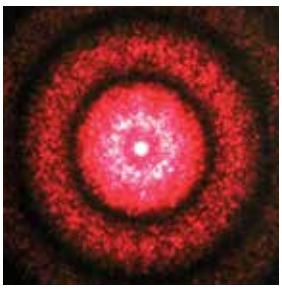
4-Slit Pattern (a = 0.04 mm, d = 0.125 mm)

Single/Double Slit Comparison

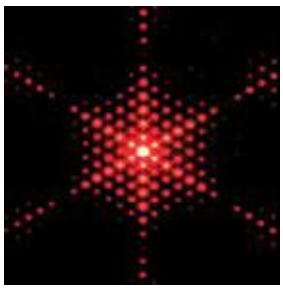


Easy Laser Alignment.
The laser beam can be aimed through the slits using two thumb screws. Once the beam is aligned, either the laser or the slits can be removed from the optics bench and returned to the bench without re-aligning the beam.

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

Includes

- Red Diode Laser (OS-8525A)
- High Precision Diffraction Slit Set (OS-8453)



For components and accessories, see pages 278-279.

Order Information

Diffraction Optics Kit	OS-8531A
Required:	
120 cm Optics Bench	OS-8508
Basic Optics Viewing Screen	OS-8460
Recommended:	
Green Diode Laser	OS-8458B p. 279

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 275 for more information.*

Order Information

Optics Caliper (Set of 5)	OS-8468

Diffraction Components

High-Precision Diffraction Slits

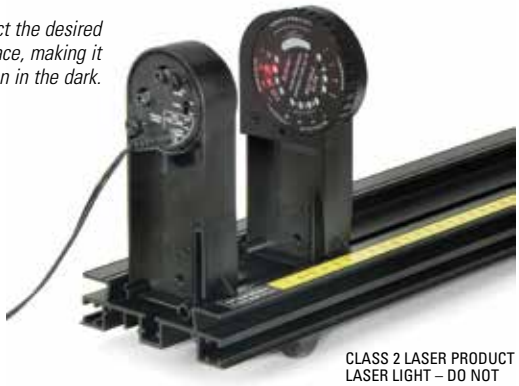
OS-8453

- 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, which locks 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.



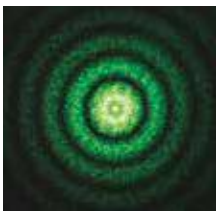
CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

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.

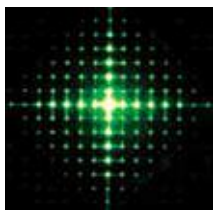


Single-Slit Diffraction Pattern

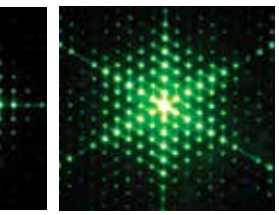




The Circular Diffraction pattern has the same dimensions for both the dots and the holes.



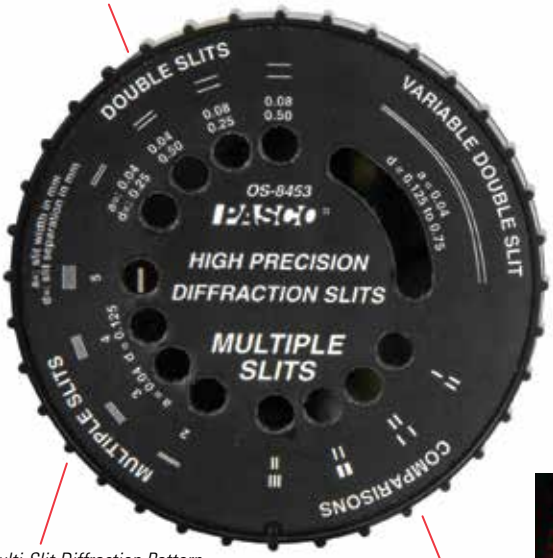
The diffraction geometry represents the structure of the Square and Hex patterns.



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.



Double-Slit Diffraction Pattern

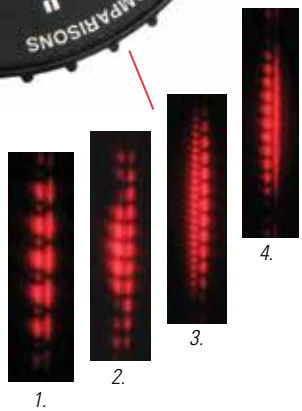


Multi-Slit Diffraction Pattern



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. 264
Diode Laser – Red	OS-8525A	p. 279
Diode Laser – Green	OS-8458B	p. 279

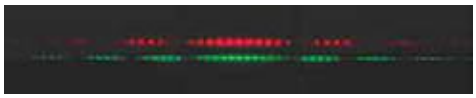
Diode Lasers – Basic Optics

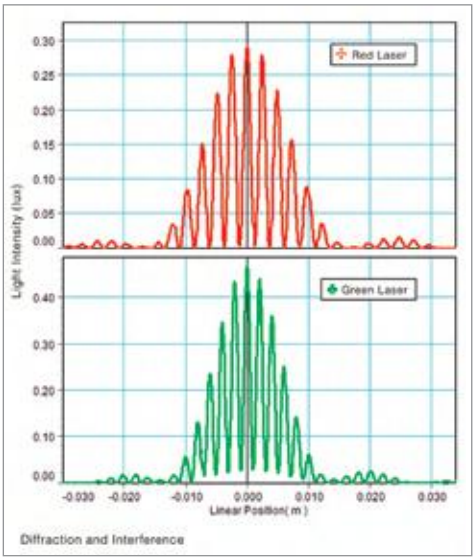
OS-8525A (Red)

OS-8458B (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 red wavelength 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); 515 nm (OS-8458A)
Power Supply: 9 V adapter (included)

Order Information

Diode Laser – Red OS-8525A
Diode Laser – Green OS-8458B

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

Order Information

Linear Translator OS-8535A

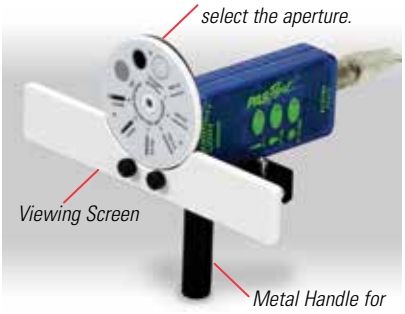
Aperture Bracket

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
10% transmittance diffuser





Includes

- Aperture Bracket with Screen
- Metal Handle
- Accessory Holder

Order Information

Aperture Bracket OS-8534A

Dynamics Track Optics

Dynamics Track Optics Kit

OS-8471A

- Turns your dynamics track into an optics bench
- Use with 1.2 m 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 266-279 for more components.



Typical Experiments

1. Focal Length and Magnification of a Thin Lens
2. Telescope
3. Microscope
4. Shadows
5. Virtual Images

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

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-9493
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

Comprehensive Physics Investigations Lab Manual

EP-6326

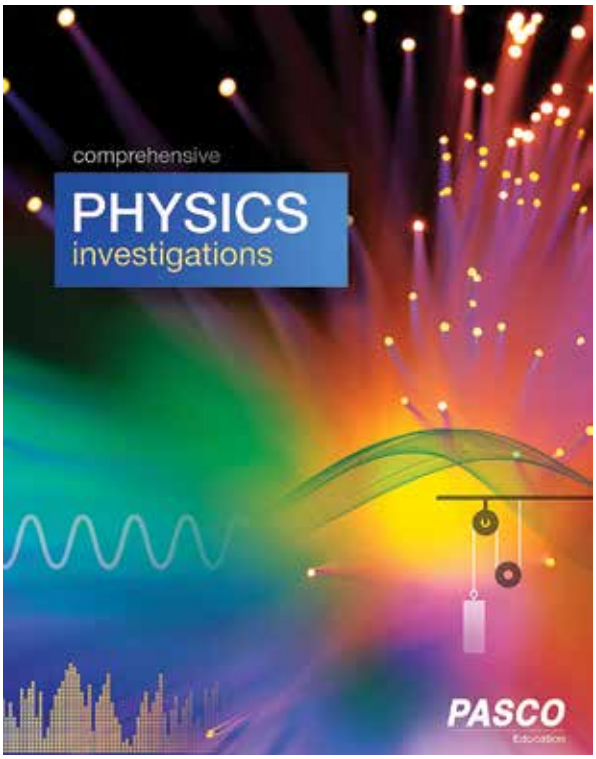
Are you looking for more hands-on physics labs? The *Comprehensive Physics Investigations Lab Manual* includes over 40 labs and activities, seven of which are for Light, Color, and Optics.

The Light, Color, and Optics labs in the Lab Investigations Manual include the following:

- Magnification of Mirrors and Lenses
- Reflection in a Plane Mirror
- Refraction of Light
- Creating Real and Virtual Images with Lenses
- Image Formation for a Convex Lens
- Build a Microscope and Telescope
- Phosphorescence

Best of all, digital access to these **Online Teacher Resources** is included with purchase of the lab manual:

- Word® and PDF versions of the lab instructions
- Student worksheets (blackline masters) in Word® and PDF formats
- Answer keys in Word® and PDF formats
- Sample data
- Labs for SPARKvue



Equipment

Light, Color, and Optics Kit

EP-3558

The Light, Color, and Optics Kit is a complete laboratory for learning about light, color, and optical technology. Three 50-mm optics snap onto the track and slide easily. The light source makes a perfect illuminated "object" for optics experiments, and the fixed spacing of the colored LEDs makes it easy to observe and measure image properties such as magnification, inversion, and brightness.

Includes

- 1.2 m aluminum track
- 50 mm optics mounts (3)
- Rechargeable light source
- AC adapter/charger
- Refraction tank
- Triangular prism
- Phosphorescent plastic
- 50 mm convex lens - 10 cm f.l.
- 50 mm convex lens - 20 cm f.l.
- 50 mm convex lens - 50 cm f.l.
- 50 mm concave lens - 20 cm f.l.
- 50 mm convex mirror - 20 cm f.l.
- 50 mm concave mirror - 50 cm f.l.
- 50 mm screen
- 50 mm diffraction grating
- Eyeglasses





Lens holders mount to PASCO tracks.

Order Information

Comprehensive Physics Investigations Lab Manual EP-6326

Light, Color, and Optics Kit EP-3558

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 in front of the light source to vary the number of rays produced.



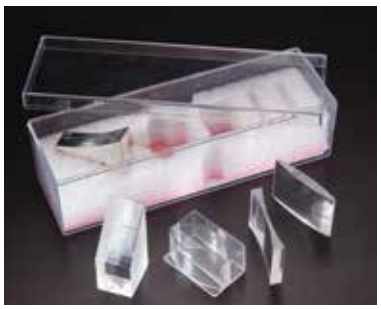
Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.

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

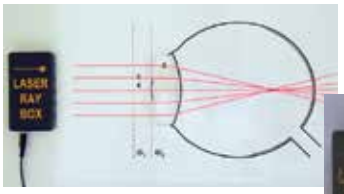
Ray Optics Kit OS-8516A

Ray Optics Laser System

SE-8506

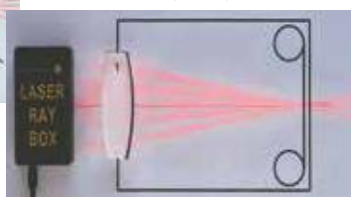
CLASS 2 LASER PRODUCT
LASER LIGHT –
DO NOT STARE INTO BEAM

- No need to dim the lights
- Wide variety of optical components
- Templates simulate real-world optical devices



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.



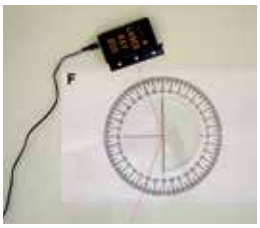
This demonstrations optics set uses a Laser Ray Box that has bright, well-defined rays because it uses lasers rather than an incandescent light source. The Laser Ray Box projects five parallel laser beams onto any flat surface. It contains five 1 mW diode lasers (wavelength 635 nm). The laser beams are 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.



The included protractor template can be used to demonstrate refraction.



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

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.

Order Information

Ray Optics Laser System SE-8506
Laser Ray Box (alone) SE-8505

Mirage

SE-7302

These two concave mirrors create a real image of any object you place at the bottom. The image appears at the opening in the top and when students try to touch it, they find that it is only an image, not the real thing!





Includes

- Concave mirror (14 cm diam.)
- Plastic frog

Coming soon!
Check pasco.com for availability.

Order Information

Mirage SE-7302

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

Convex Mirror

SE-7574

Concave Mirror

SE-7573

Virtual and real images are formed with these large, curved mirrors. Diameter is 60 cm. Stand is included.





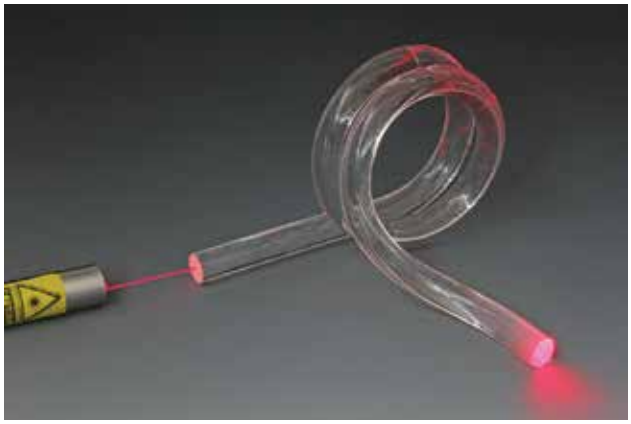
Order Information

Demonstration Convex Mirror SE-7574
Demonstration Concave Mirror SE-7573

Optical Fiber Model

SF-7201

This bent acrylic rod simulates the operation of optical fibers. The laser beam undergoes repeated total internal reflections and is emitted at the other face of the rod as a divergent beam.



Specifications

Dimensions: 50 cm length and 1.0 cm diameter, with two windings of approx. 5 cm diameter.

Order Information

Optical Fiber Model SF-7201
Required:
Laser Pointer (Red) SE-9716C

Spectrometer

PASCO Wireless Spectrometer

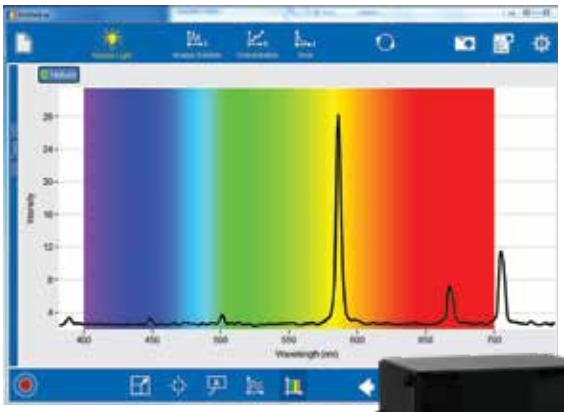
PS-2600

For iOS, Android™, Computers, and Chromebooks™

Now includes Spectrometry 2.0 functionality!

- Measure intensity, absorbance, transmittance, and fluorescence.
- Works on all computing platforms
- Bluetooth® or USB connectivity
- Includes free award-winning Spectrometry software





Helium spectrum



Shown using the optional Fiber Optic Cable (shown below)

winner! 2016 AWARDS OF EXCELLENCE TECH&LEARNING

//CODiE// 2017 SIIA CODiE WINNER

bett AWARDS 2017 FINALIST

Specifications

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

You can perform these labs with the Wireless Spectrometer:

- Emission Spectra of Light
- Absorbance Spectra
- Beer's Law
- Kinetics
- Fluorescence





Includes

- PASCO Spectrometer
- 10 cuvettes
- Spectrometry software (on opposite page)

Order Information

PASCO Spectrometer..... PS-2600

Fiber Optic Cable

PS-2601

Required for External Light Sources



Order Information

Fiber Optic Cable.....PS-2601

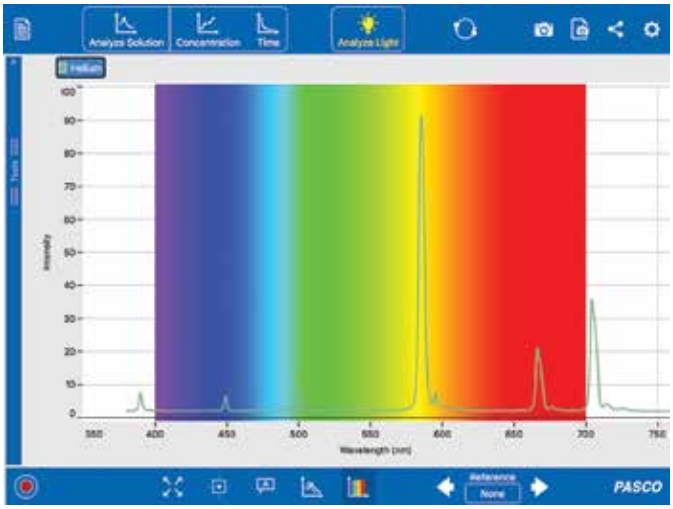
PASCO's Free Spectrometry Software Puts Learning First

PASCO's award-winning software for iOS, Android™, Computers, and Chromebooks*

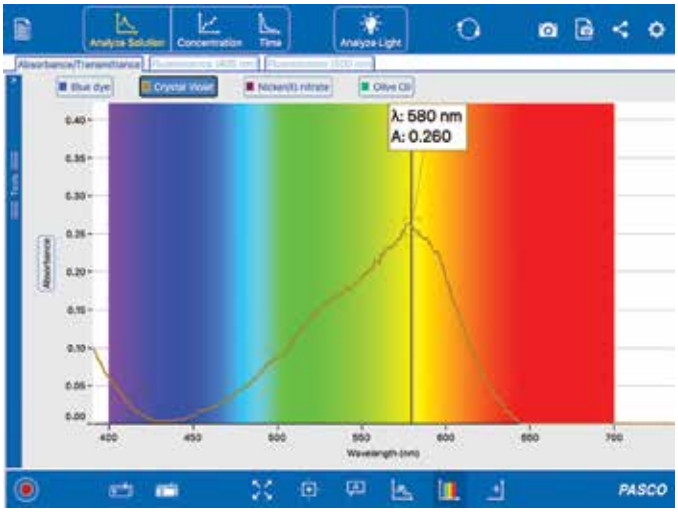
- Designed by teachers
- Specialized software specifically targets spectrometry activities
- Program guides students through the four common types of spectrometer uses
- Calibration routine is made obvious

The four specially targeted activities are:

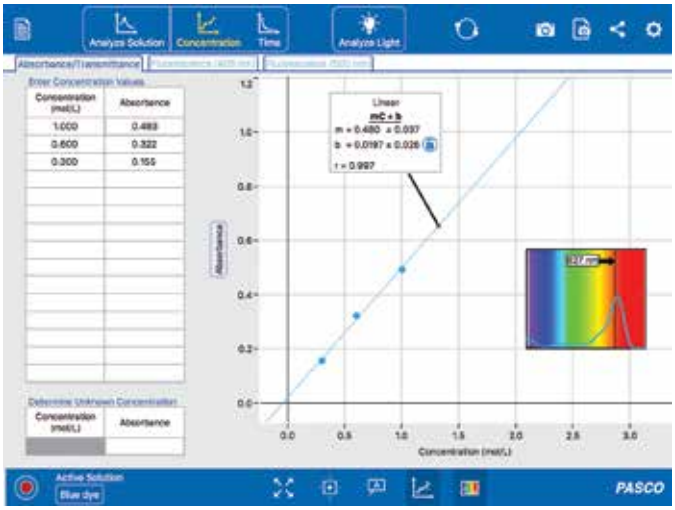
1. Analyze light sources with the optional fiber optic cable.
2. Analyze the absorbance, transmittance, and fluorescence of colored solutions.
3. After the analysis wavelength is set, you can easily create calibration curves and determine the unknown concentration.
4. Observe the kinetics of a reaction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



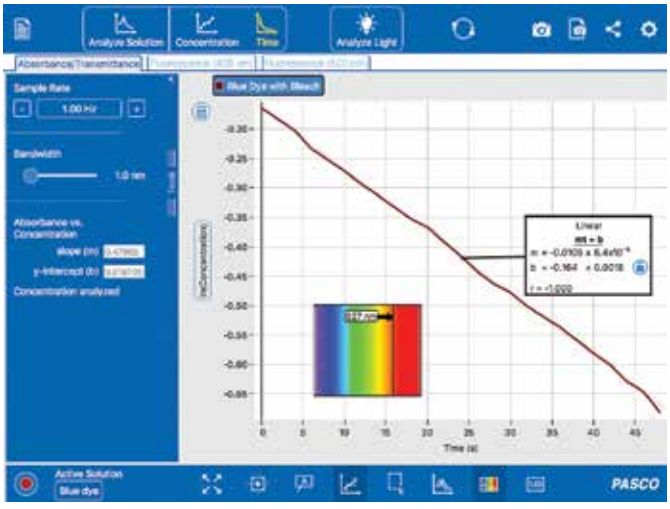
Analyze light sources with the optional Fiber Optic Cable.



Full visible spectrum analysis of solutions



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



Quickly plot calculations of Concentrations vs. Time to determine the order of the reaction.

The Wireless Spectrometer comes with **PASCO's FREE award-winning Spectrometry software**.

- Windows® and Mac® versions included with purchase.
- FREE for iOS, Android™, and Chrome™
- Designed specifically for introductory spectrometry experiments.

Download at **pasco.com/downloads**

Our list of compatible Chromebooks is expanding rapidly. Check* **pasco.com/compatibility *for the latest updates.*

Spectrophotometer

Educational Spectrophotometer System

OS-8450 (PASPORT) OS-8539 (ScienceWorkshop)

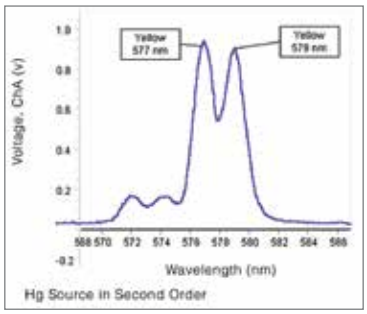
Educational Spectrophotometer Accessory Kit

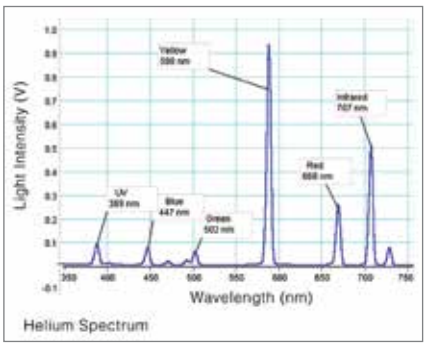
OS-8537

- Analyze and graph spectral lines
- Explore relationships 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.

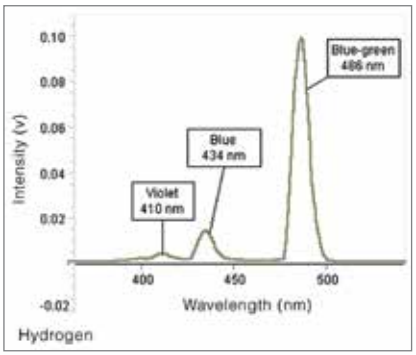
When the Spectrophotometer is used with PASCO Capstone™ software, students can explore the relationship between angle, wavelength, and intensity, and graph the spectral lines from discharge tubes. Lines from mercury, sodium, helium, neon, krypton, and argon can be plotted. Even the lines of the Balmer series in hydrogen can be detected.

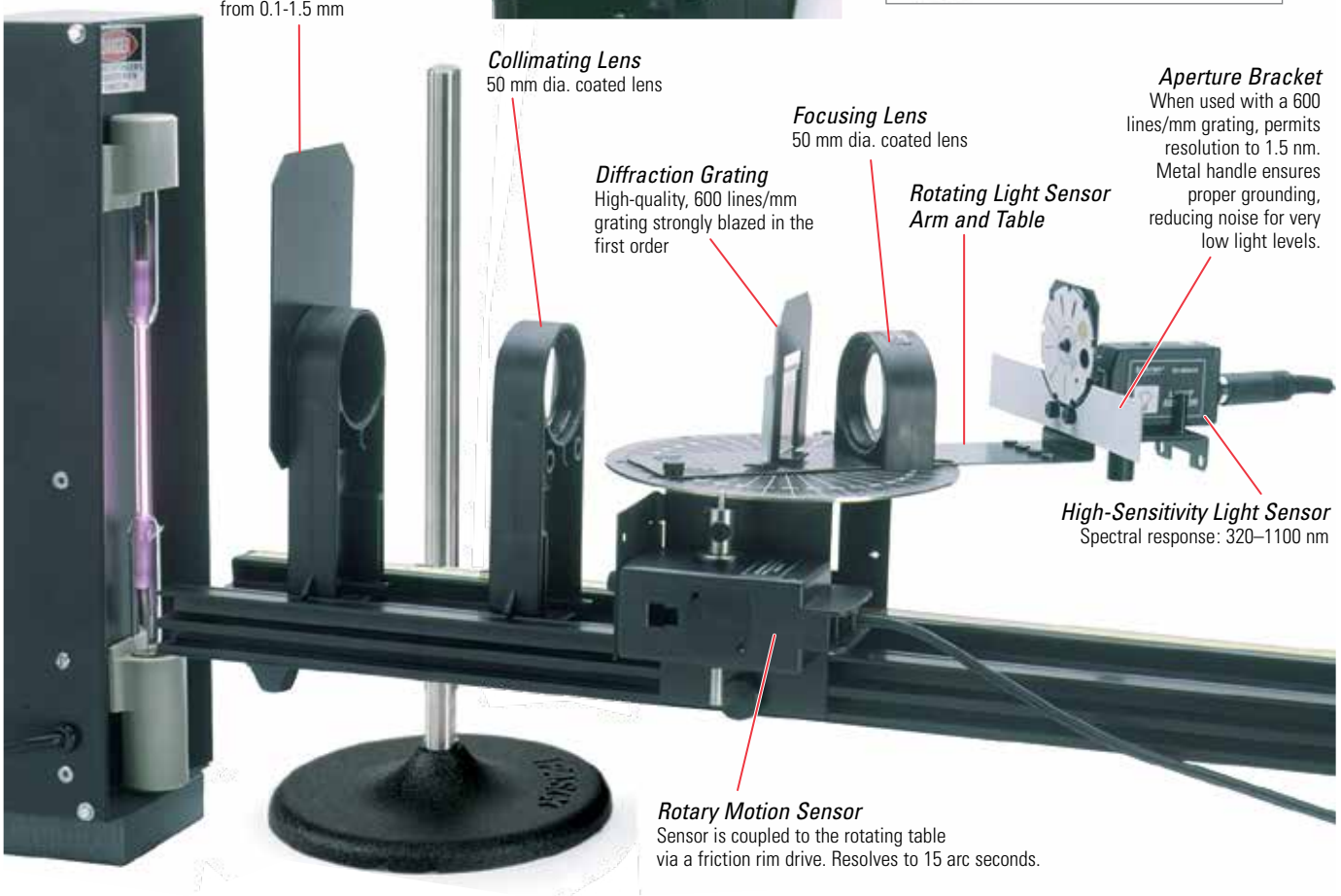




Typical Spectrum Graphs







Collimating Slits
Set of five slits ranging from 0.1-1.5 mm

Collimating Lens
50 mm dia. coated lens

Focusing Lens
50 mm dia. coated lens

Diffraction Grating
High-quality, 600 lines/mm grating strongly blazed in the first order

Rotating Light Sensor Arm and Table

Aperture Bracket
When used with a 600 lines/mm grating, permits resolution to 1.5 nm. Metal handle ensures proper grounding, reducing noise for very low light levels.

High-Sensitivity Light Sensor
Spectral response: 320–1100 nm

Rotary Motion Sensor
Sensor is coupled to the rotating table via a friction rim drive. Resolves to 15 arc seconds.

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 includes	ScienceWorkshop OS-8539	PASPORT OS-8450
1. Optics Bench (60 cm) OS-8541		
2. Rotary Motion Sensor	CI-6538	PS-2120A
3. High-Sensitivity Light Sensor CI-6604	CI-6604	PS-2176
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		

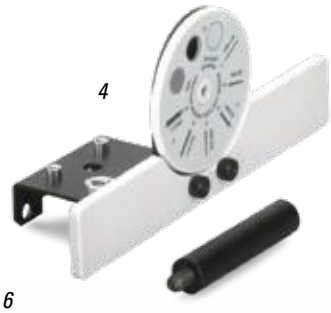
















The Spectrophotometer Accessory Kit (OS-8537) includes

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
PASPORT OS-8450
ScienceWorkshop OS-8539

Educational Spectrophotometer
Accessory Kit OS-8537

For use with PASPORT Sensors, see the Atomic Spectra experiment EX-5546 on page 376.

For adjusting height of optics bench to your light source:

Round Base with Rod ..... ME-8270 p. 186

High-Quality Grating

600 lines/mm SE-9358

The 600 lines/mm grating is strongly blazed in the first order. It has excellent resolving power and produces bright, sharp spectral lines for spectrometer labs or for projecting spectra in lecture demonstrations.



Order Information

High-Quality Grating 600 lines SE-9358

Spectrophotometers

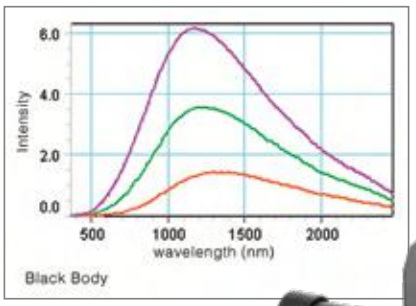
Prism Spectrophotometer Kit

OS-8544

- High-quality prism
- Blackbody light source

Add this kit to the Educational Spectrophotometer System (pages 286-287) to plot blackbody curves. A prism is used to disperse the light (instead of a diffraction grating) so the infrared doesn't overlap the second order visible spectrum.

See the complete Blackbody Radiation Experiment (EX-559A) on page 351.



The classic textbook diagram of the intensity vs. 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.





Includes

- Mounted Prism
- IR Filter
- Blackbody Light Source

Order Information

Prism Spectrophotometer Kit OS-8544
Required for experiment:
Broad Spectrum Light Sensor ..... PS-2150 p. 53
Spectrophotometer System OS-8450
850 Universal Interface ..... UI-5000 p. 26
PASCO Capstone ..... pp. 70-73
Replacement Supplies:
Replacement Bulbs (10 pack) SE-8509

OR components of the system may be ordered separately:
Blackbody Light Source OS-8542
Mounted Prism OS-8543

Student Spectrometer

SP-9268A

- Wide aperture optics
- Precision vernier: resolves one minute of arc
- Durable and precise

Custom Prism/Grating Table
Threaded holes and engraved reference lines for accurate component placement

Vernier Scale
For precision measurements

Collimator
High-quality, large-aperture optics with a 6 mm long slit of adjustable width; the collimator can be independently focused, leveled, and aligned.

Telescope
High-quality, large-aperture optics plus a 15x Ramsden eyepiece with a cross-hair graticule; the telescope can be independently focused and aligned.

Durable Construction
Heavy aluminum castings provide a stable base for delicate measurements and ensure long-term durability.

Precision-Ground Bearings
The main bearings are ground as a single unit, so the movement is exceptionally smooth with virtually no backlash. This is essential for precise positioning.

Magnifier
For reading the Vernier Scale

Dense Flint Glass Prism with Holder

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.
- **Rotating 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 ..... p. 290

UV Beads

SE-7729



Shining an ultraviolet flashlight on UV-sensitive beads causes them to change color.

UV-sensitive beads are white when indoors but change color instantly when exposed to UV radiation. These beads make students aware of UV radiation. Students can explore how much UV there is on a cloudy day and how much UV is blocked by car windows.

Each bead is created with a pigment that changes color as the ultraviolet energy is absorbed. When the UV radiation is removed, the beads will return to their pale white color. This process can be repeated many thousands of times. Each package includes 1000 beads.

Order Information

UV Beads..... SE-7729

UV Flashlight

SE-7730



This ultraviolet flashlight with 51 UV LEDs is great for illuminating UV beads and activating fluorescent materials. The wavelength is centered on 385 nm. Powered by three AA batteries (not included).

Specifications

Wavelength: 385 nm
Length: 14 cm
Bulb Type: 51x UV LED
Bulb Life: 50,000 hours
Battery Requirement: 3 AA (not included)
Battery Life: Approx. 20 hrs on new batteries
Body Material: Machined aluminum with rubber O-rings

Order Information

Coming soon!
Check pasco.com for availability.

UV Flashlight..... SE-7730

Spectral Light Sources

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

Spectral Tube Power Supply and Mount

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 (at left).

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

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

Diode Laser – Basic Optics

OS-8525A (Red) OS-8458B (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)
515 nm (OS-8458B)
Power Supply: 9 V adapter (included)

Order Information

Red Diode Laser	OS-8525A
Green Diode Laser	OS-8458B

Laser Pointers

SE-9716C (Red)
SE-8805A (Green)

- Push-button switch
- Inexpensive



CLASS II LASER PRODUCT
LASER RADIATION – AVOID DIRECT EYE EXPOSURE

Specifications

Source: Laser diode
Power: 5 mW max. (class II)
Wavelength: 645 nm (red pointer)
532 nm (green pointer)
Battery: Alkaline AAA (2 included)
Dimensions: 143 mm x 12.7 mm (red pointer)
151 mm x 13.5 mm (green pointer)

Order Information

Red Laser Pointer	SE-9716C
Green Laser Pointer	SE-8805A

Mini Laser with 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

Laser Alignment Bench

OS-9172



This Laser Alignment Bench connects to the Optics Bench with the included couplers, which leaves the full 1 m length of the Optics Bench free for experimental work.

Order Information

Laser Alignment Bench OS-9172

Modulated Laser (1.5 mW)

SE-9449A

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.



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

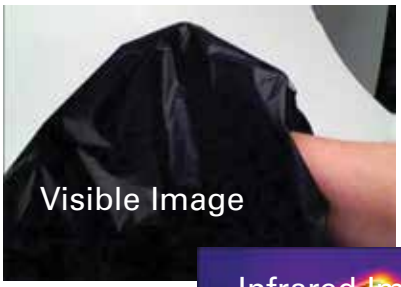
1.5 mW Modulated Laser SE-9449A

Infrared Optics

FLIR C3 Thermal Imaging Camera

SE-7128A

- "See" into the infrared
- Simultaneously record visible and infrared snapshots
- Stream video using FLIR tools
- Record infrared movies in PASCO Capstone
- Determine temperatures from color coding
- WiFi-enabled



The FLIR takes simultaneous visible and infrared images of a hand inside a black garbage bag.



Extend your students' world into the infrared with this full-featured, pocket-sized thermal camera. This infrared camera takes two pictures at once: one in the visible spectrum and one in the infrared. An outline of the visible image is superimposed on the colorized infrared picture for reference. In addition to the color temperature scale, there is a digital readout of the temperature. All of this is offered at a special educator's price.

Consider these activities:

- Check light transmission through different media: Visible light easily passes through acrylic; IR doesn't. Visible light is not readily transmitted through black balloons, but they are transparent in the IR, as are silicon wafers, and black plastic garbage bags.
- Slide a block on the table. We always tell our students that the energy is dissipated as heat. Show them!
- Look at your infrared reflection on a whiteboard.
- Record infrared video in PASCO Capstone and sync to data from thermal experiments.
- Take off your shoes and follow your footsteps by looking at your infrared footprints.
- Evaluate different types of insulation.
- Measure the temperature of ice water.
- Beakers of water with different temperatures (as measured with the camera) come to some easily predictable temperature when mixed together.



The rectangular hole in the heated block (TD-8580A) appears black in visible light, but glows brightly in infrared. This is an example of cavity radiation.



Key Features

1. Light, slim profile
2. Bright 3" touchscreen
3. Built-in LED work light and flash
4. Big snapshot button stores thermal, visible and visible overlay in each JPEG
5. Easy-access on-off button powers up fast
6. USB Micro-B file transfer and data streaming
7. Visible camera
8. Thermal camera



Specifications

3" Touchscreen
IR Sensor: 80 x 60 pixels
Digital Camera: 640 x 480 pixels
Temperature reading at each of the 4,800 pixels
Temperature range: -10°C to 150°C
Accuracy: ±2°C or 2%, whichever is greater
Onboard memory stores 500 sets of jpeg images
USB Micro-B connector
WiFi
Rechargeable Li-ion polymer battery with 2 h operating time
Weight: 0.13 kg (0.29 lb)
Size: (L x W x H): 12.5 x 8.0 x 2.4 cm
Warranty: 2-year warranty on parts and labor
10-year warranty on detector



Includes

- FLIR C3 thermal imaging camera
- Tripod mount
- Power supply/charger
- USB cable
- Research IR software
- Access to FLIR education content with lectures, experiments, and teacher guides

Order Information

FLIR C3 Thermal Imaging Camera SE-7128A

USB Camera Microscope

PS-2343

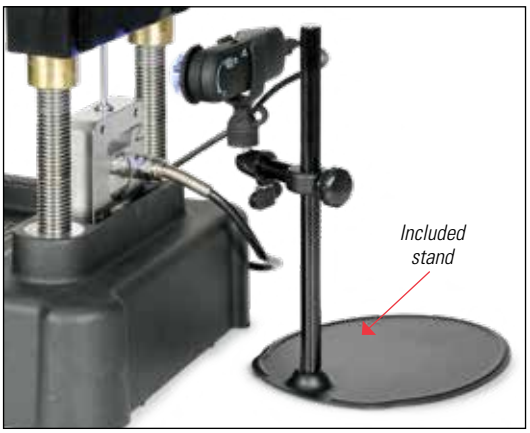
- Use as web camera
- Optical zoom from 1x to 60x
- Built-in LED lights



The versatile USB Camera Microscope 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.



Shown in use with ME-8236 Materials Testing Machine (see page 160). As the tensile sample is being stretched, the force versus time data is graphed in sync with the movie.

Includes

- Camera
- Microscope
- Stand

See the USB Camera Microscope in use with the Universal Gravitational Constant Experiment (EX-5550) on page 331.

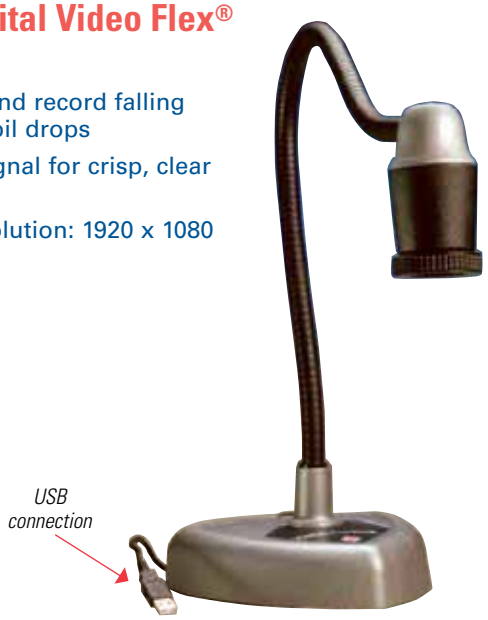
Order Information

USB Camera Microscope.....PS-2343
Suggested Base Supports:
Flex Rod .....ME-8978A p. 187
Small "A" Base .....ME-8976 p. 186
Aluminum Clamp .....ME-8995 p. 189

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

Introductory Michelson Interferometer

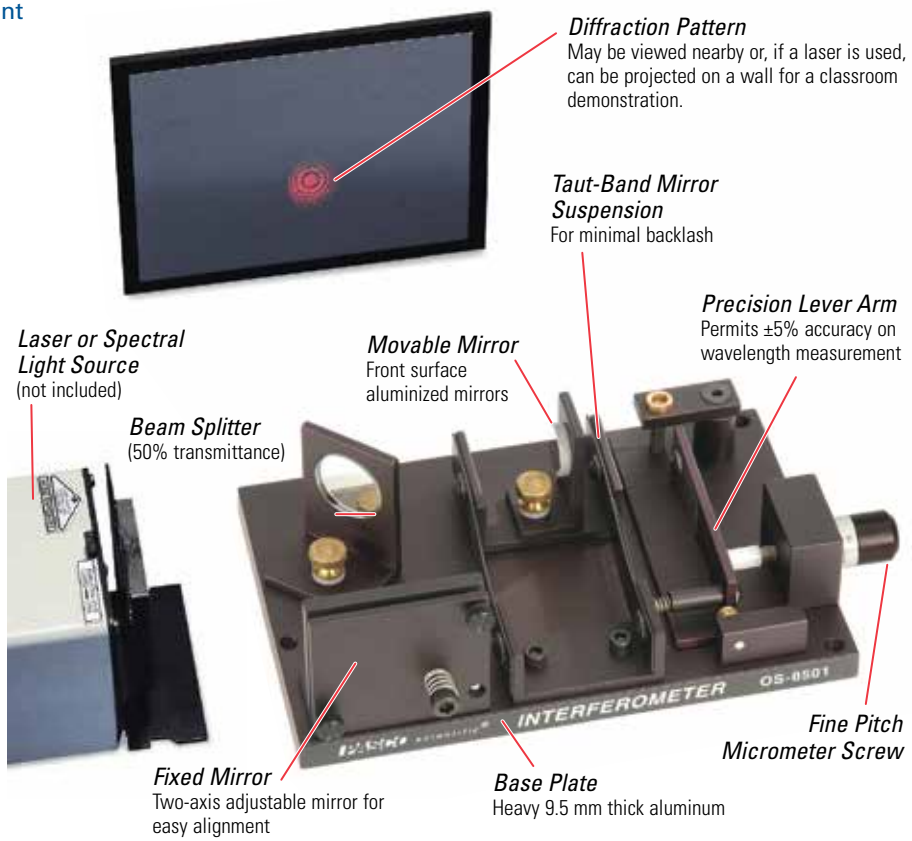
OS-8501

- Micrometer-controlled mirror movement
- Precision, front-surface optics
- Good quality, low price

This interferometer is a precision instrument for the introductory lab. It's easier to use, more compact, and less expensive than PASCO's advanced interferometer (see page 295).

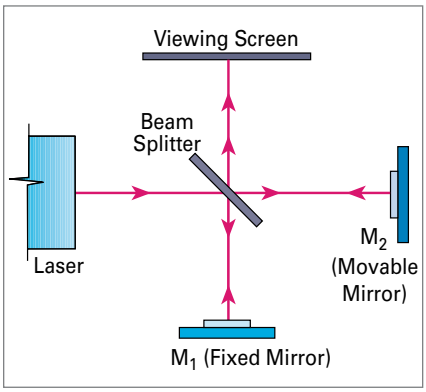
It's capable of measuring the wavelength of monochromatic light with an accuracy of better than 5%. The Michelson Interferometer can also be used for making precise measurements of the index of refraction of air.

The Introductory Michelson Interferometer provides precision interferometry at an economical price (laser and screen not included).



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 setup 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). To download the manual, search for OS-8501 at pasco.com



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 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. 291

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.



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

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

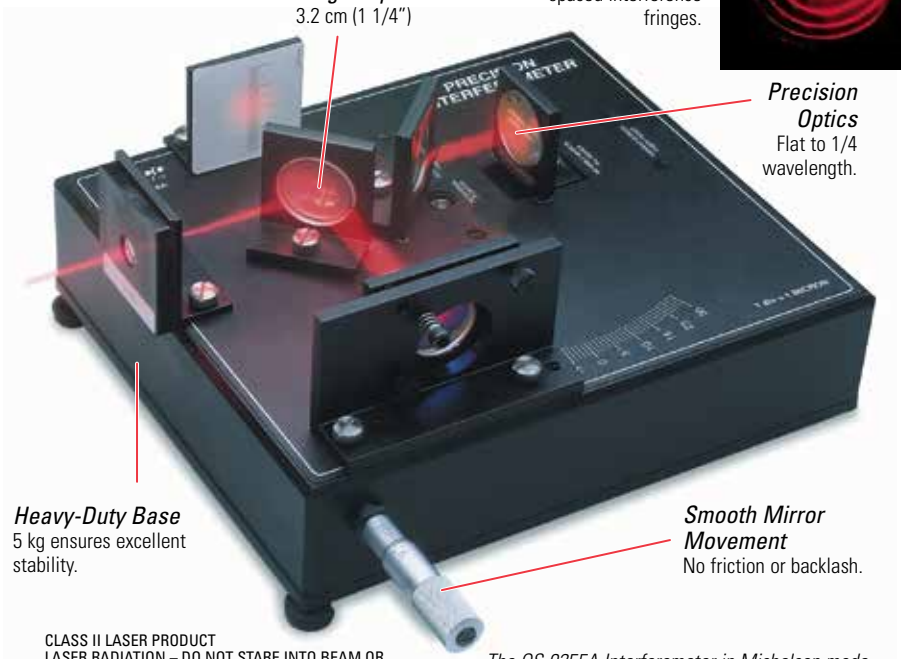
Complete Interferometer System OS-9258B

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 (OS-9256A) (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-9255A: Precision Interferometer
C. OS-9256A: Interferometer Accessories Kit

Systems Component List	***A***	***B***	***C***
Machined base—5 kg	1	1	
Three-point adjustable mirror	1	1	
Mounted beam-splitter	1	1	
Mounted movable mirror	1	1	
Accessory mounts	3	2	1
Viewing screen OS-9138	1	1	
Diffuser OS-9120	1	1	
Double convex lens (18 mm) OS-9132	1	1	
Compensator lens	1	1	
Fitted case	1	1	
Vacuum pump with gauge OS-8502	1		1
Gas cell	1		1
Calibrated polarizer OS-9109	2		2
Glass plate OS-9128	1		1
Rotating component holder	1		1
Twyman-Green lenses OS-9133, OS-9132	2		2
Mini laser with bracket OS-8514	1		
Laser alignment bench OS-9172	1		
Instruction manual	1	1	

Microwave Optics

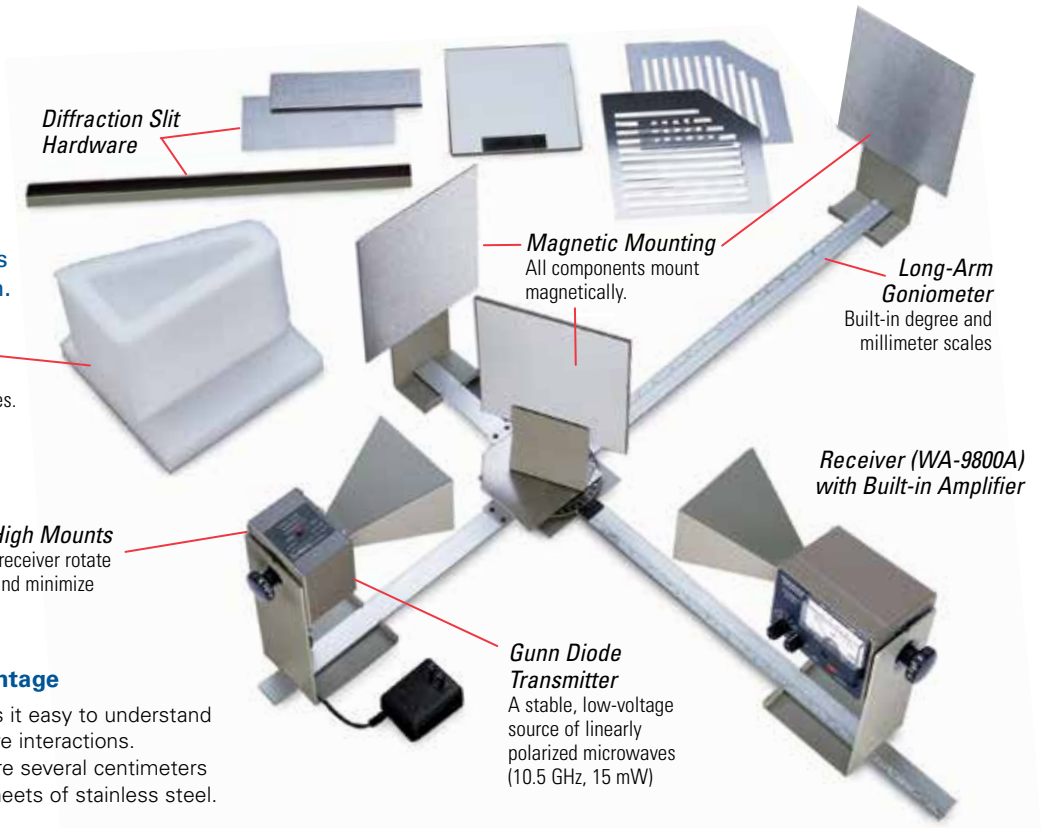
Basic System

WA-9314C

Advanced System

WA-9316A

- Durable construction
- Parts are made of stainless steel or die-cast aluminum.



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

- Basic Microwave Optics System (WA-9314C)
- Microwave Accessory Package (WA-9315)

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

Franck-Hertz Apparatus

SE-9639

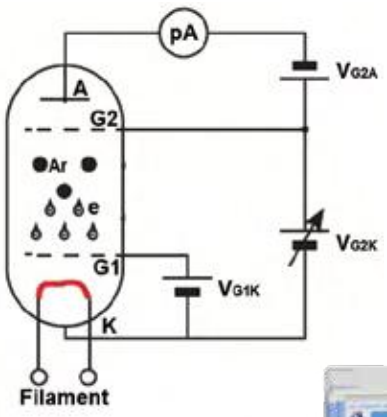
See complete experiment on page 379.

- 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

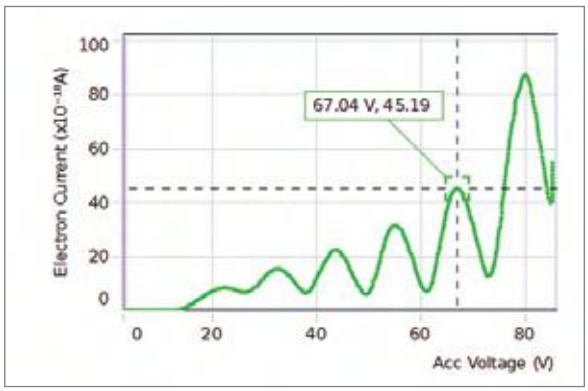
As early as 1914, James Franck and Gustav Hertz discovered in the course of their investigations an energy loss in distinct steps for electrons passing through mercury vapor and a corresponding emission at the ultraviolet line (λ= 254 nm) of mercury. They performed this experiment that has become one 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. Within a very short time, the excited argon electron will 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 247.

Franck-Hertz System (SE-9639) includes:

- Franck-Hertz Tube Enclosure with Argon Tube (SE-9650)
- Tunable DC (Constant Voltage) Power Supply I (SE-6615)
- Tunable DC (Constant Voltage) Power Supply II (SE-9644)
- DC Current Amplifier (SE-6621)
- Red and Black Patch Cords

Order Information

Franck-Hertz System SE-9639
Power supplies & amplifier can be purchased separately. See page 247.
If you already have power supplies, you will need:
Franck-Hertz Tube Enclosure
with Argon Tube SE-9650
Replacement Parts:
Franck-Hertz Argon Tube SE-9645

Millikan Oil Drop Apparatus

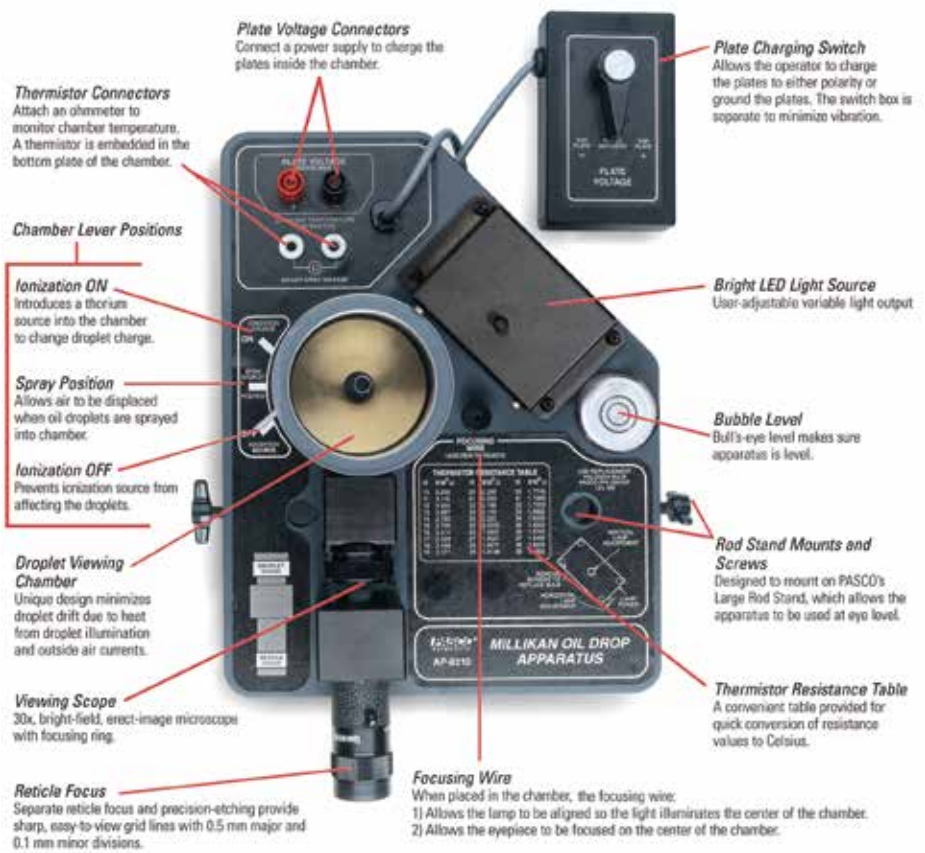
AP-8210A

See complete experiment on page 356.

- 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. 250

High Voltage Power Supply ..... SF-9585A p. 245

Recommended:

For mounting unit at eye level on a standard lab table:

Large Rod Base ..... ME-8735 p. 186

45 cm Steel Rod (2) .... ME-8736 p. 186

Complete System:

Charge of an Electron ..... EX-9929A p. 356

Replacement Parts:

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.



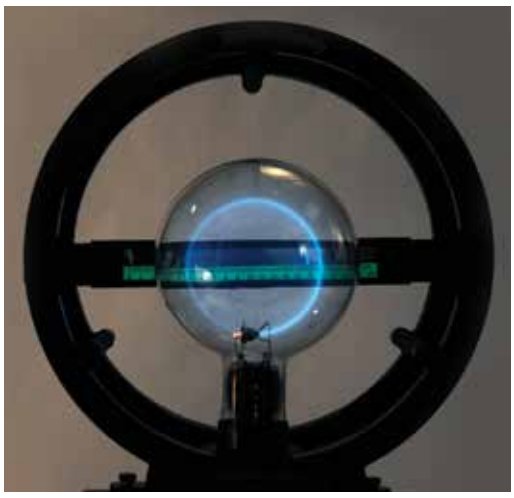
Complete Charge-to-Mass Ratio System includes the power supplies, which can also be used in other experiments (such as Franck-Hertz experiment, see page 303).

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 power supplies, see page 236.

Electron Charge-to-Mass Ratio System (SE-9629) includes:

- Helmholtz Coils *without tube* (SE-9626)
- e/m Tube (SE-9651)
- Tunable DC (Constant Current) Power Supply I (SE-9622)
- Tunable DC (Constant Voltage) Power Supply II (SE-9644)
- 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:	
Replacement Mirror Scale	SE-9649

Photoelectric Effect

Photoelectric Effect System

SE-6609

See complete experiment on page 377.

- 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 vs. 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.

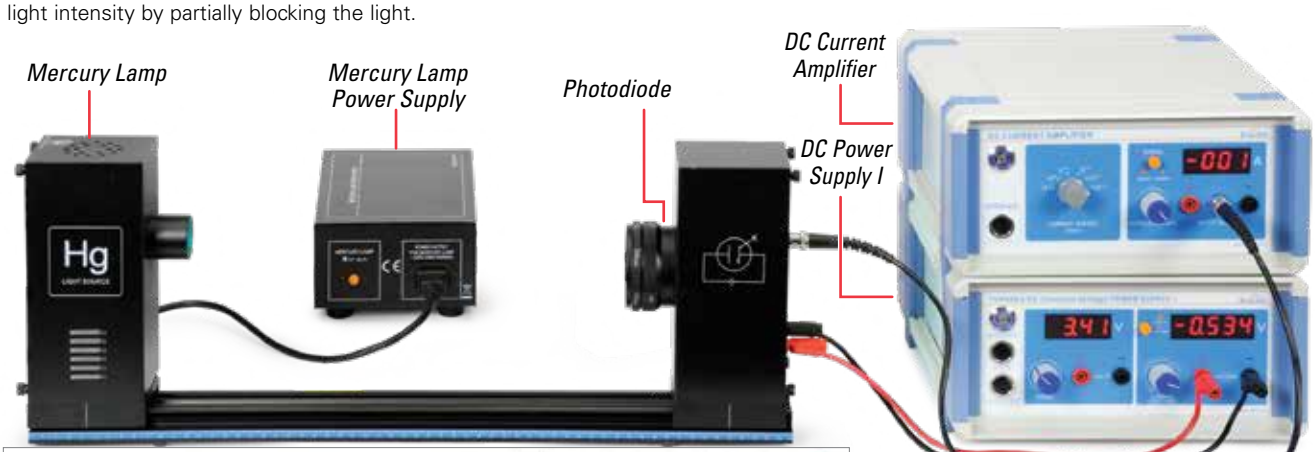
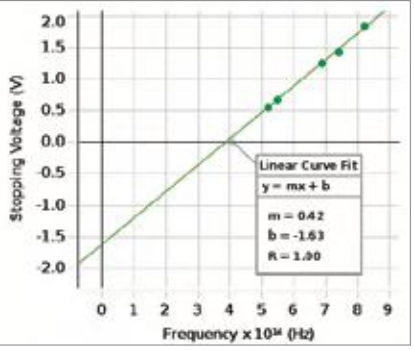


Table I: Photoelectric Effect with 4 mm Aperture

	Run #1 Frequency x 10^{14} (Hz)	Run #1 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 vs. 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. This graph was generated using PASCO Capstone™ software and the 850 Interface.



Can be used with the 850 Interface (UI-5000, see p. 28) and PASCO Capstone

See the complete experiment on page 377.

Power Supply and Current Amplifier specs: See page 247.

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 effect 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 289.*
- 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

Save
Share Instruments in Three Experiments

These three experiments use common power supplies and amplifiers. As long as these experiments are not performed simultaneously, you can save by not duplicating the instrumentation.

1. Photoelectric Effect
Complete Setup SE-6609

2. Frank-Hertz
Complete Setup SE-9639

3. Electron Charge-to-Mass Ratio (e/m)
Complete Setup SE-9629

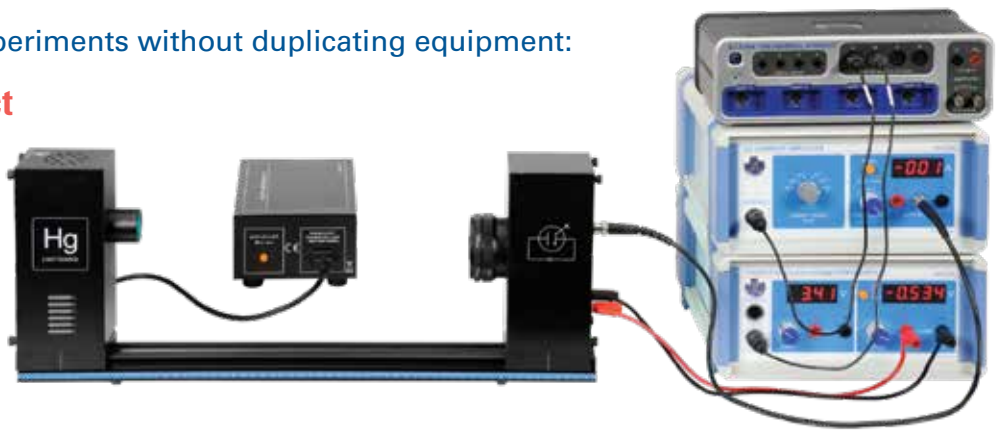
EXPERIMENT	DC Power Supply I	DC Power Supply II	DC (Constant Current) Supply	DC Current Amplifier
Photoelectric Effect	✔			✔
Frank-Hertz	✔	✔		✔
e/m		✔	✔	

To perform these experiments without duplicating equipment:

1. Photoelectric Effect

SE-6609

This complete setup includes two instruments that can be used in the Frank-Hertz and e/m experiments.



2. Frank-Hertz

Add Frank-Hertz Tube
SE-9650



Add DC Power Supply II
SE-9644



3. Electron Charge-to-Mass Ratio (e/m)

Add Hemholtz Coils
SE-9626



Add DC Constant Current Power Supply
SE-9622



Add e/m Tube
SE-9651

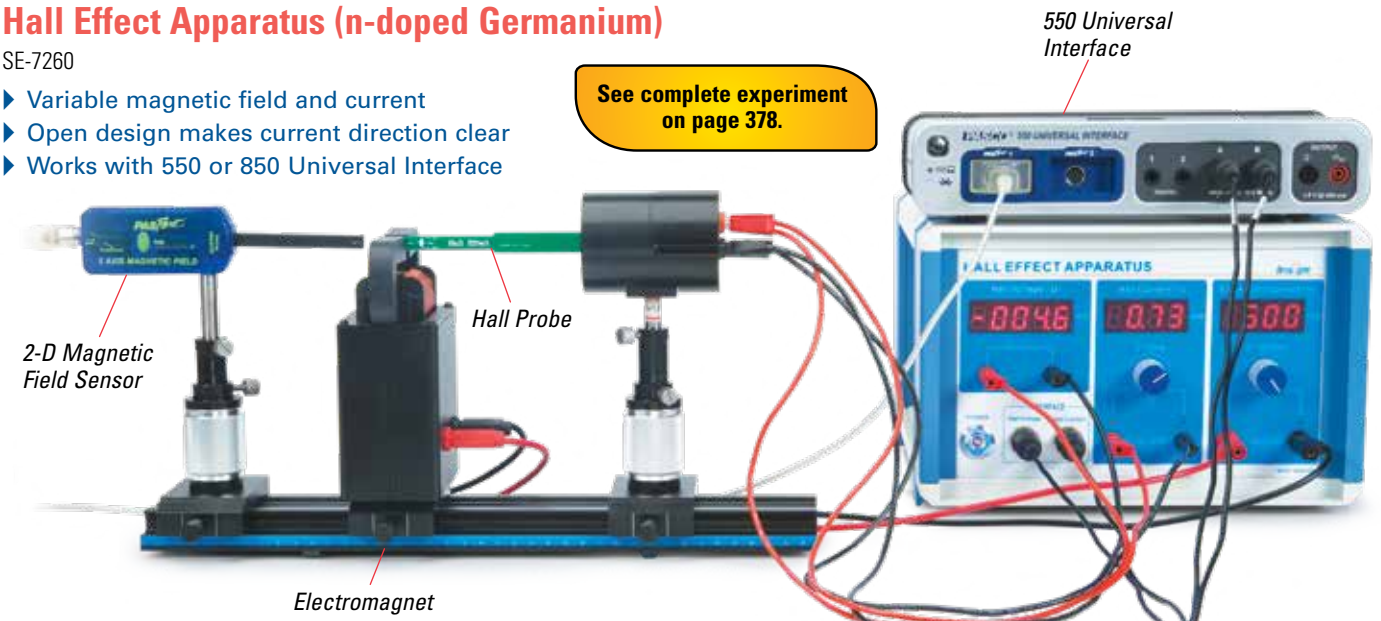


Hall Effect Apparatus (n-doped Germanium)

SE-7260

- Variable magnetic field and current
- Open design makes current direction clear
- Works with 550 or 850 Universal Interface

See complete experiment on page 378.



The Hall Effect experiment (conducted by Edwin Hall in 1879) determines the sign of the charge carriers in current flow. A current can be thought of as a negative charge moving in one direction (Figure 1) or as a positive charge moving in the opposite direction (Figure 2). To determine which it actually is, the semiconductor is immersed in the magnetic field transverse to the direction of flow of current. The moving charge experiences a $q\vec{v}$ x $\vec{B}$ force, causing a charge build-up on one side of the semiconductor (creating an electric field), which in turn leads to a $q\vec{E}$ force. The direction of the electric field will depend on the sign of the charge carriers and the polarity of the Hall voltage across the semiconductor reveals this sign.

The magnitude of the Hall voltage is dependent on the current, the charge carrier density, and the magnitude of the magnetic field. In modern day electronics, the Hall Effect is used to measure the magnitude and direction of magnetic fields.

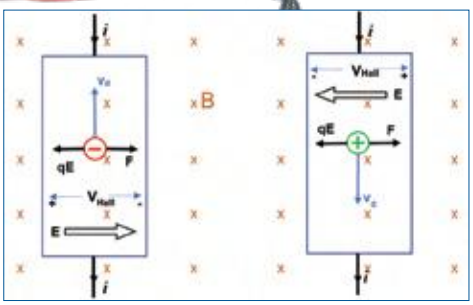


Figure 1 Figure 2

PASCO Advantage

The open design of this Hall Effect apparatus makes it possible for students to see the direction of the current and the magnetic field, enabling them to use the sign of the Hall voltage to deduce the sign of the charge carriers.

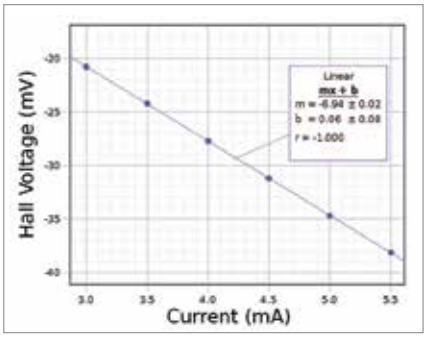


The directions of the current and the voltage probe are clearly marked on the probe that holds the semiconductor.

Specifications

n-Doped Semiconductor Material: GaAs
Hall Sensitivity: ≥150 mV/(mA·T)
U-core Electromagnetic Coil (1000 Turns)
Magnet Space: 10 mm
Magnet Field: 0 to 0.065 T (at 1A)
Excitation Current: 0 to 1 A DC
Hall Voltage: 0 to 1.9999 V
Power Supply Digital Readout for Current, Hall Voltage, and Magnet Current

Using the 550 Universal Interface to record data, this plot of the Hall Voltage vs. the Current was made in PASCO Capstone software. In this case, the magnetic field was held constant and the current through the semiconductor was varied.



Includes

- Hall Probe Unit, n-Semiconductor (GaAs)
- Hall Effect Power Supply
- U-Core Electromagnetic Coil
- Track, Length 40 cm
- Optical Carrier (2)
- Adjustable Post Holder with 9 cm Post (2)
- Banana Cords (6)
- Connecting Cables for 550/850 Interface (2)
- Manual

Order Information

Hall Effect Apparatus SE-7260

Note: This apparatus can be used manually by reading the digital displays. Measuring the magnetic field requires a sensor or other Tesla meter. This apparatus includes connector cables for an 850 or 550 interface so data collection can be automated.

Required:

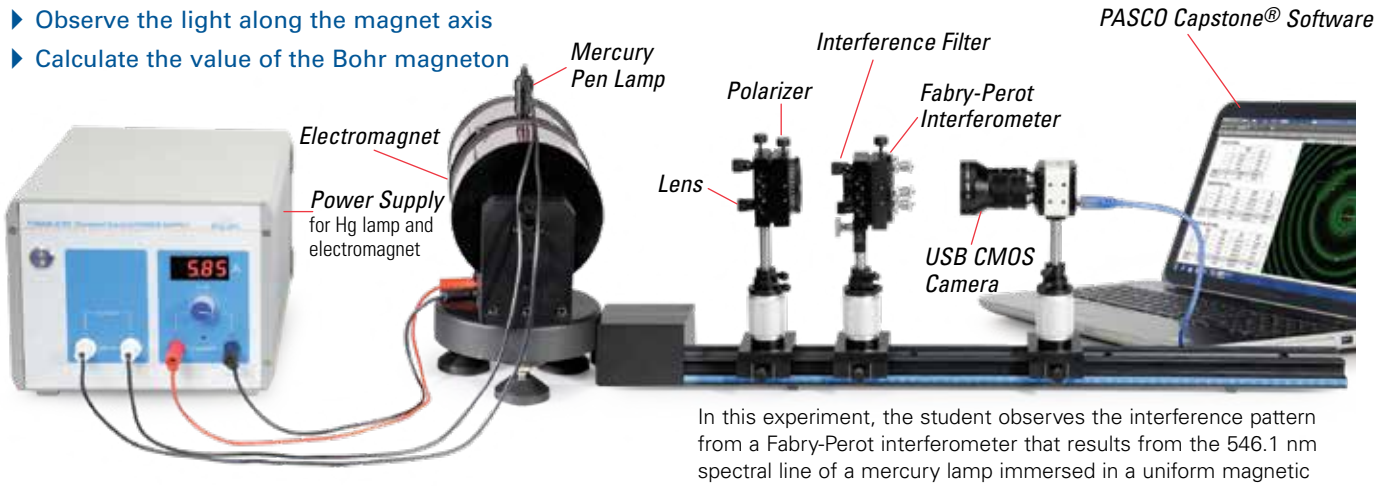
2-Axis Magnetic Field Sensor PS-2162
850 or 550 Universal Interface ..... UI-5000 or UI-5001 pp. 26-28
PASCO Capstone Software ..... pp. 70-73

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

See complete experiment on page 380.



In this experiment, the student observes the interference pattern from a Fabry-Perot interferometer that 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 an aluminum hard case with foam cutouts 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
- PASCO Capstone Single User License.

Order Information

Zeeman Effect	SE-9654	
May be purchased separately:		
Electromagnet	SE-9655	
Tunable DC Power Supply 6A	SE-9656	
Replacement Part:		
Mercury Pen Lamp	SE-9658	
Optional:		
Tesla Meter	SF-7579	p. 242

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

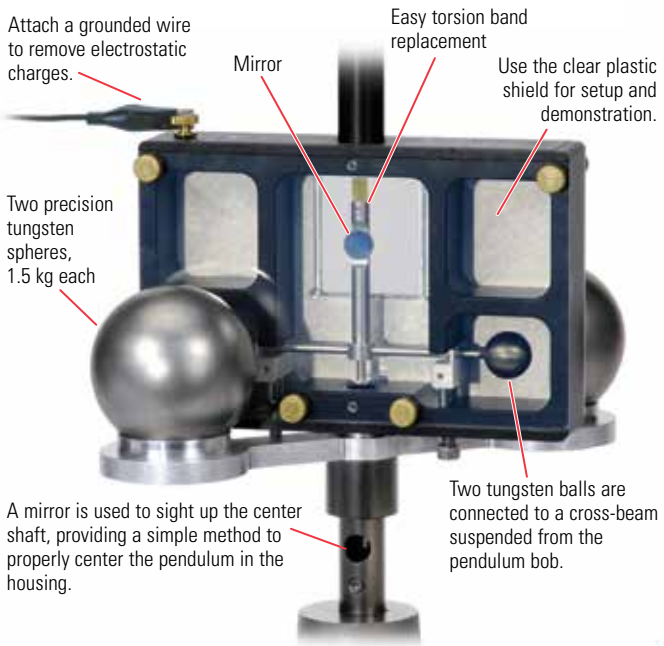
AP-8215A

- Measure the universal gravitational constant in a single lab period
- Adjustment and locking mechanisms decrease lab setup time
- Torsion band easily replaced

Computerized Version:
See the Universal Gravitational Constant experiment (EX-5550) on page 331 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 tungsten 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
- Extra Torsion Band (1)
- Manual

Order Information

Gravitational Torsion Balance	AP-8215A	
Required:		
X-Y Adjustable Diode Laser	OS-8526A	
45 cm Steel Rod	ME-8736	p. 186
Large Table Clamp	ME-9472	p. 189
Replacement Supplies:		
Torsion Bands (2 pack) – Gravitational Torsion Balance	AP-8218	
Gravitational Balls Replacement Set	AP-8219	

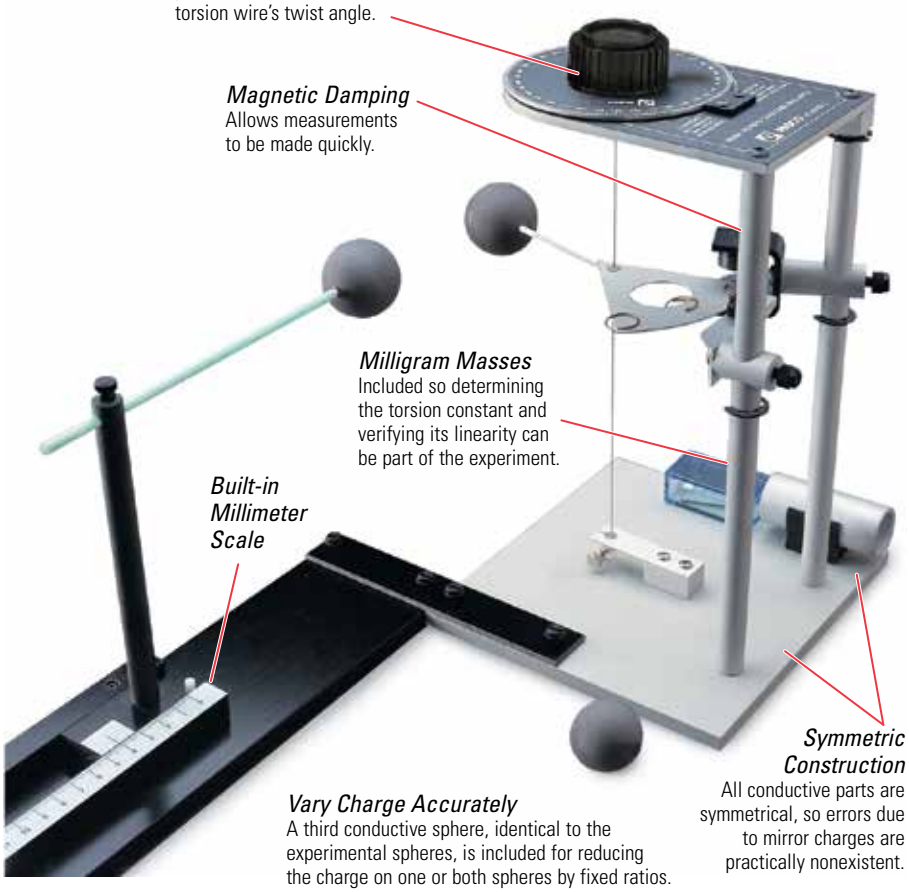
Coulomb's Law Apparatus

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.



Built-in Scale
A degree scale on the torsion balance provides accurate measurements of the torsion wire's twist angle.

Magnetic Damping
Allows measurements to be made quickly.

Milligram Masses
Included so determining the torsion constant and verifying its linearity can be part of the experiment.

Built-in Millimeter Scale

Symmetric Construction
All conductive parts are symmetrical, so errors due to mirror charges are practically nonexistent.

Vary Charge Accurately
A third conductive sphere, identical to the experimental spheres, is included for reducing the charge on one or both spheres by fixed ratios. This method is quick and accurate.

Insulated Track
The calibrated track is designed to minimize mirror charges, which can significantly affect results.

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).

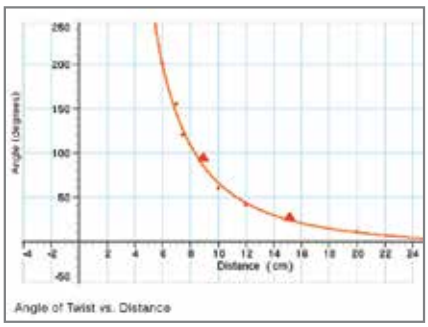
Specifications

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. 245
Basic Electrometer	ES-9078A	p. 214
Faraday Ice Pail	ES-9042A	p. 215
Charge Producers	ES-9057C	p. 215
Complete System:		
Coulomb's Law	EX-9930B	p. 355

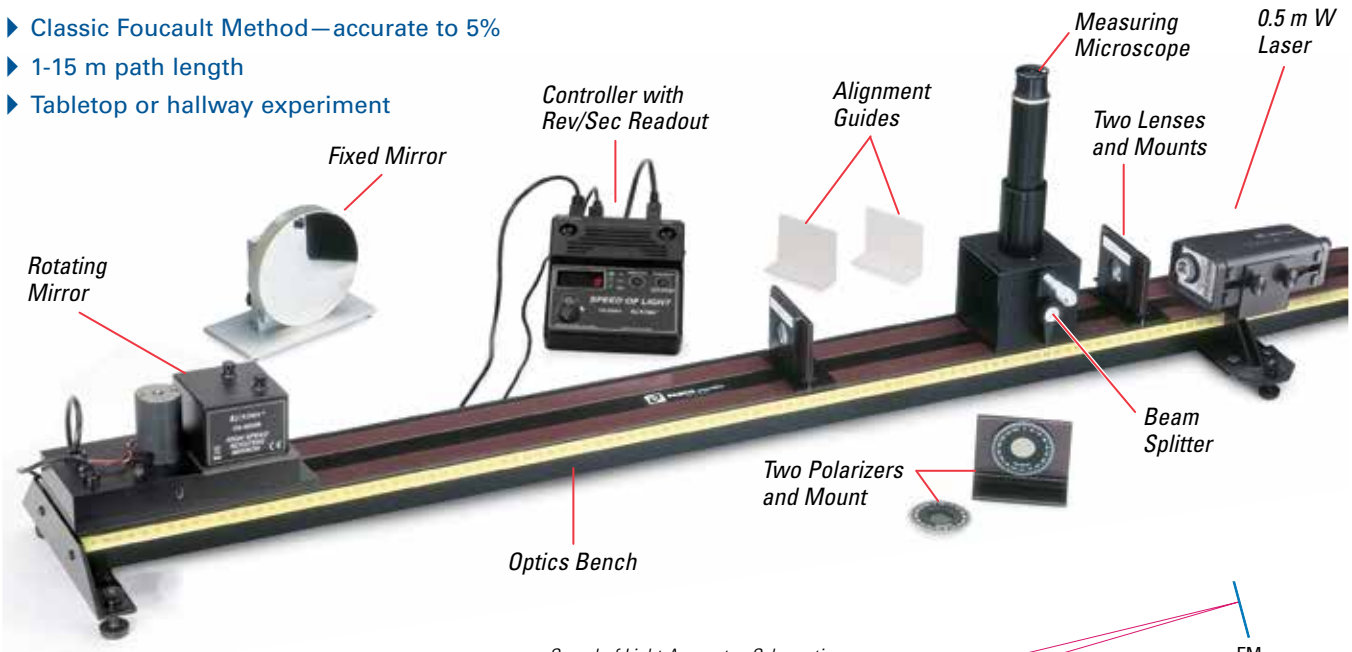
Speed of Light

Complete Speed of Light Apparatus

OS-9261B

CLASS II LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

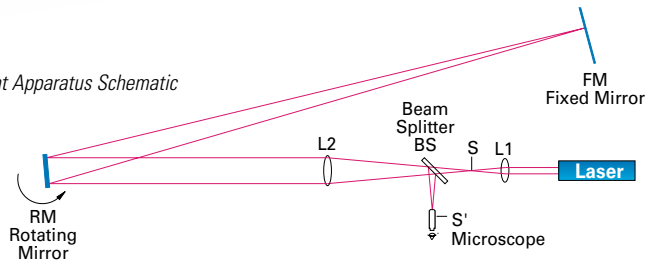
- Classic Foucault Method—accurate to 5%
- 1-15 m path length
- Tabletop or hallway experiment



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.

Speed of Light Apparatus Schematic



OS-9261B includes

- 1 m Optics Bench
- Laser Alignment Bench
- Mini Laser with Bracket
- Double Convex Lens, 48 mm F.L.
- Plano Convex Lens, 252 mm F.L.
- Calibrated Polarizer
- Component Carrier

Order Information

Complete Speed of Light Apparatus	OS-9261B	
Parts available separately:		
Laser Alignment Bench	OS-9172	p. 291
Mini Laser with Bracket	OS-8514	p. 291
Speed of Light Experiment	EX-9932A	p. 371

High Speed Rotating Mirror with Controller

OS-9263B



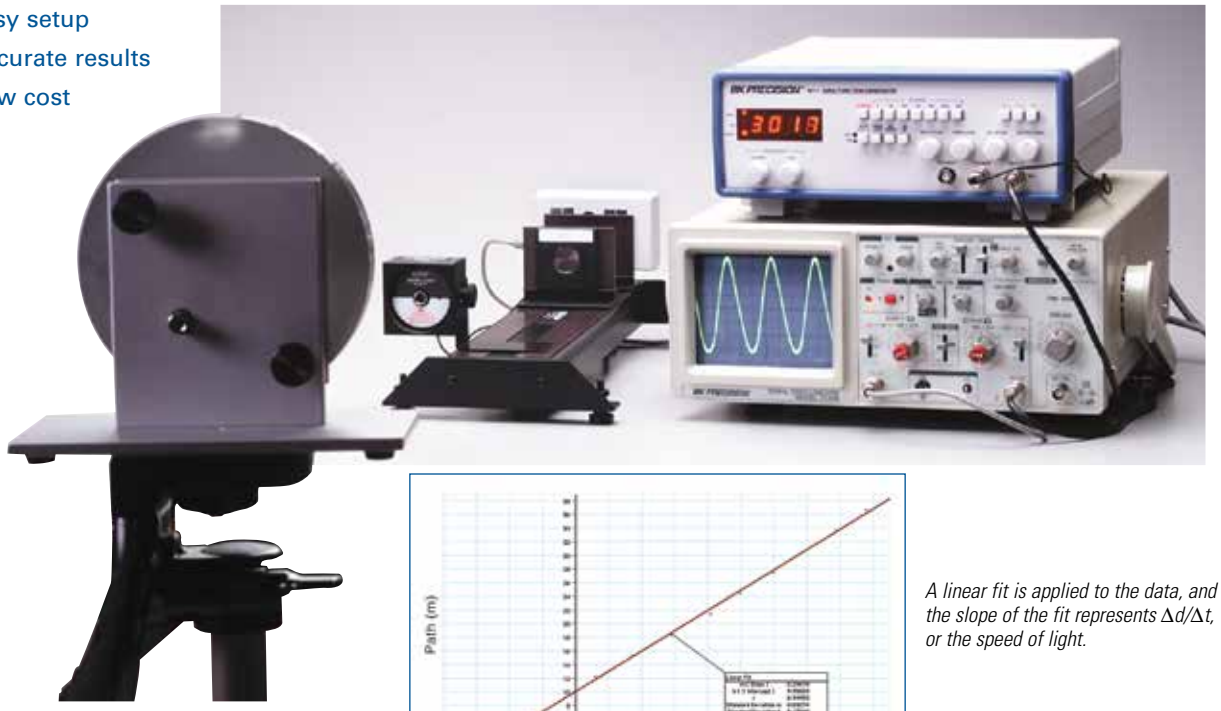
Order Information

High Speed Rotating Mirror with Controller OS-9263B

Laser Speed of Light System

AP-8586

- Easy setup
- Accurate results
- Low cost



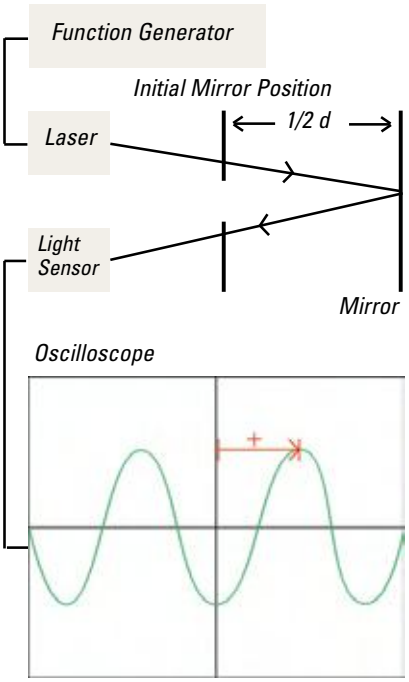
A linear fit is applied to the data, and the slope of the fit represents Δd/Δt, or the speed of light.

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.

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
Digital Oscilloscope..... SB-9621A
Replacement Part:
Speed of Light Diode Laser..... OS-8475

Speed of Light

Speed of Light – Reflector

SF-7203

- Measure the speed of light using short pulses of light
- Unique retro-reflector eliminates alignment problems





To measure the speed of light, pulsed light is reflected off a retro-reflector and the time between the pulse and the received reflection is measured with an oscilloscope. The progressive delaying of light pulses is observed as they travel farther and farther.

How It Works

Very short but powerful pulses of light are emitted from the box. When the light pulses hit the special retro-reflective foil of the reflector, they are directed back toward the source with no need for tedious adjustments. The returning light pulses pass through a beam-splitter and strike a high-speed photodiode, converting the light pulses into electric pulses that are displayed on an oscilloscope. A separate synchronization signal marks the time of pulse emission, so time between emission and return can be timed.

The distance to the retro-reflector is increased a known distance and the resulting increase in return time allows the speed of light to be calculated by simply dividing the distance by the change in time.



Includes

- Pulse-emitter box
- BNC cables (2)
- Retro-reflective screen

Order Information

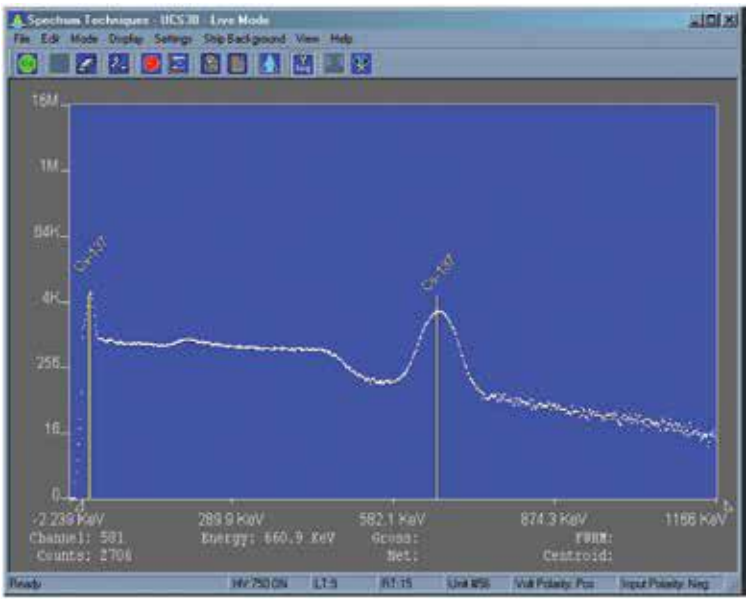
Speed of Light – Reflector	SF-7203	
Required:		
Oscilloscope	SB-9621A	p. 250
Meter Stick	SE-8827	p. 192

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.



Main screen display for Universal Computer Spectrometer

Features

- **Variable Voltage:** A regulated high voltage of 0 to 1280 V is supplied with computer control (1 mA maximum, 5 V increments)
- **Amplifier:** Onboard 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 onboard 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.

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 2x to 1000x

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.



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)

The sources are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations.

Order Information

Advanced Nuclear Spectroscopy System, (Windows) USB*..... SN-7901B

***Note:** Purchased Sources are "Non-Cancellable" and "Non-Returnable".
See Radioactive Source Disclaimer on the Order Information page 398.

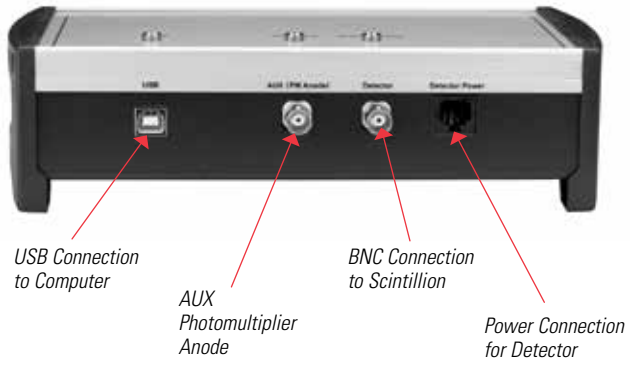
Multi-Channel Analyzer

Multi-Channel Analyzer

SF-7222

- 1024 channels
- Analysis software included





A multi-channel analyzer (MCA) sorts incoming pulses from an energy-sensitive detector (scintillation detector) into a large number of channels according to size. When the counts in the channels are plotted as a function of the channel number, the result is an energy spectrum.

This MCA features 1024 channels, variable analog and digital gain, a variable integration time, and built-in logic to reject "pile up" (a pulse starting on top of the previous one).

The MCA and accompanying software have been specially developed to work with the Scintillation Detector (SF-7223), but an "AUX" input can be used with the anode signal from a traditional photomultiplier tube.

The MCA is powered through a USB connection.

When the MCA is connected to a computer, the included user-friendly software can initiate data acquisition at the press of a button. Default settings for CsI(Tl) and NaI(Tl) scintillation detectors can be retrieved at the press of a button. In the spectrum, one or more energy ranges can be defined where the counts can be summed. Also, the data can be fitted to a Gaussian function. Decay of the counts into a Gaussian peak (or simply into a channel range) can be fitted to an exponential decay function.



Includes

- Multi-Channel Analyzer
- USB Cable

Order Information

Multi-Channel Analyzer SF-7222
Required
Scintillation Detector SF-7223
Computer

Scintillation Detector

SF-7223



This detector is the ideal companion for the Multi-Channel Analyzer (SF-7222). It is powered directly by the MCA unit.

The cesium iodide scintillation crystal used measures 6 x 6 x 15 mm, which provides an exceptional angular resolution, making it an excellent choice for the Compton Scattering Kit (SF-7224).

Energy resolution (full width at half maximum) is approx. 7% at 662 keV (Cs-137) and 5% at 1333 keV (Co-60). The detector's bias voltage is software-controlled (through the MCA) in order to keep the gain independent of temperature.

Order Information

Scintillation Detector SF-7223
Required
Multi-Channel Analyzer SF-7222
Computer

Intermediate Nuclear Laboratory System USB

SN-7900A

- 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. It includes a versatile scaler, a G-M Tube with a mount and trays, and a full set of radioactive sources and absorbers.



Main screen display from LABLINK software

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 read-out 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.

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.
- The rugged and versatile mount is 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

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.

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.



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

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 382.

Compton Scattering

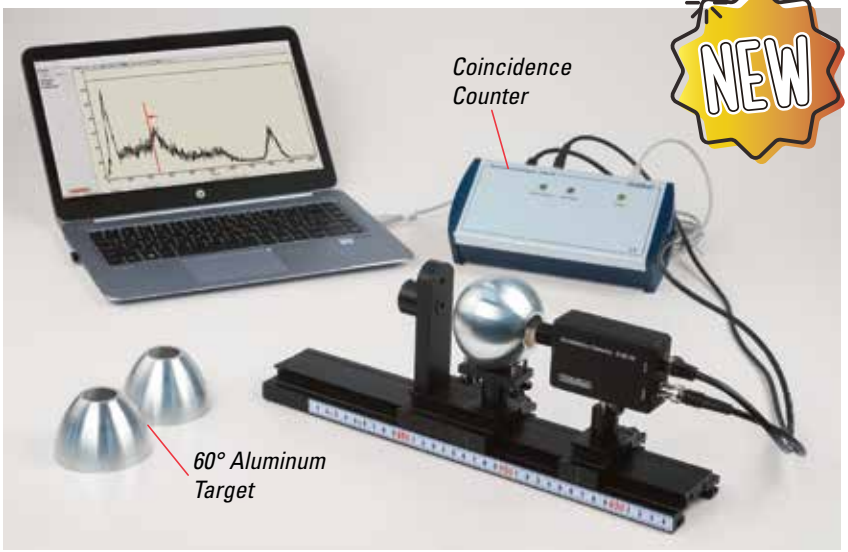
SF-7277

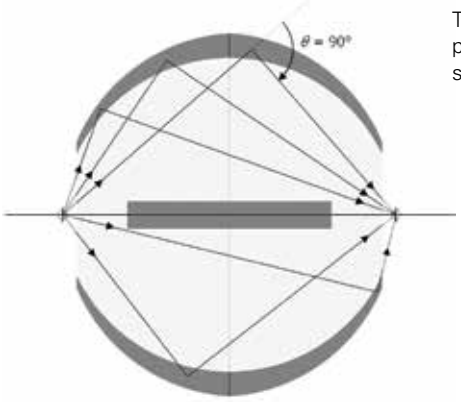
- Scattering of Gamma Radiation
- Particle Nature of Gamma Radiation

The Compton Effect illustrates the particle nature of gamma radiation. When a gamma quantum bounces off an electron, its energy loss depends on the scattering angle.

This kit consists of two pairs of shell-shaped targets and a central holder with adjustment screws and lead absorber. These rotationally symmetrical aluminum targets give a high count-rate for the two fixed scattering angles (approximately 60° and 90°).

With our gamma spectrometer and a standard Cs-137 source, viable difference spectra for both angles can be obtained within an hour. A lead absorber blocks the direct radiation from the source to the detector. Correction for background radiation (including scattered radiation from the table top, etc.) is handled by the included spectrometer software.





The principle behind this device is the old geometric truth that the size of a peripheral angle is defined by the arc it spans. We can then obtain the same scattering angle over a very large solid angle.



There is a rectangular lead absorber in a direct line between the detector and the source. In this picture, half of the 60° aluminum target is shown.

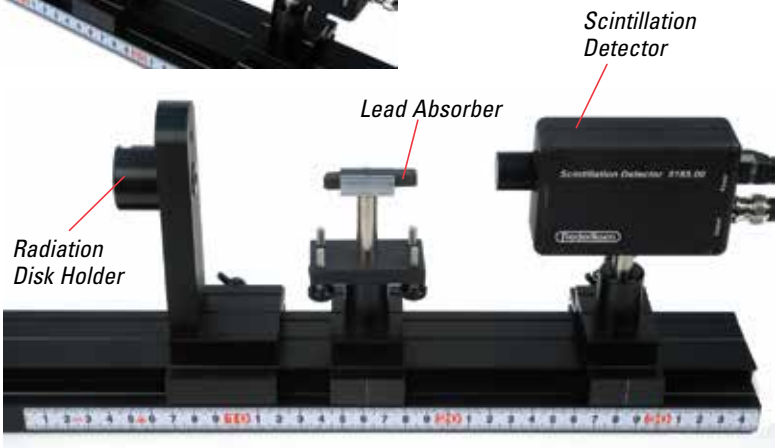
SF-7277 Complete Compton Scattering Includes

- Disk Source Holder (SF-7221)
- Multichannel Analyzer (SF-7222)
- Scintillation Detector (SF-7223)
- Compton Scattering Kit (SF-7224)
- Saddle with diameter 10 mm hole (SF-7262)
- Rail (40 cm long) (SF-7264)
- Analyzing Software

SF-7224 Compton Scattering Kit includes

- Lead Shield Holder
- Aluminum 90° Target
- Aluminum 60° Target





Order Information

Complete Compton Scattering	SF-7277*
Required:	
Cs-137 source	SN-7938
Available separately	
Compton Scattering Kit	SF-7224*

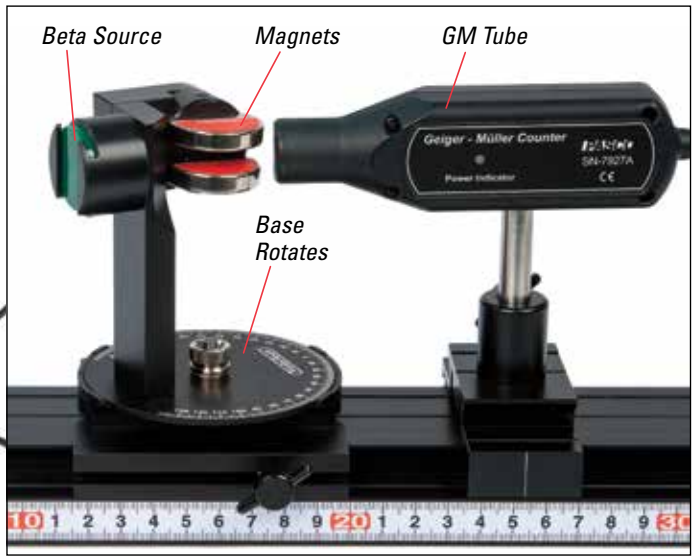
* **WARNING!** This product can expose you to Lead, which is known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Deflection of Beta Particles

SF-7276

- Demonstrate the deflection of beta particles in a magnetic field.





This apparatus can be used on three levels:

1. Qualitative demonstration of the deflection of beta particles in a magnetic field, including the sign of the charge
2. Simple beta spectrum, where the energy is determined by reading from a graph
3. Detailed, relativistic processing of the beta spectrum

The apparatus consists of a pair of permanent magnets with a radioactive source holder. The beta particles are deflected as they pass through the magnetic field. The entire source-and-magnet assembly can be rotated so the deflected beta particles will enter the fixed GM tube. The GM tube can be connected directly to a 550 or 850 Universal Interface (UI-5001 or UI-5000) and the counts can be recorded in PASCO Capstone. Alternatively, the GM tube can be connected to a stand-alone Geiger Counter.

Includes

- Holder for beta disk source (SF-7265)
- Carrier (SF-7262)
- Rail (40 cm long) (SF-7264)

Order Information

Deflection of Beta Particles SF-7276
Required:
Radioactive Source (Sr-90) SN-9796
Radiation Sensor SN-7927A
550 Universal Interface UI-5001
Or
850 Universal Interface UI-5000
Or
Geiger Counter SF-7268
Available separately:
Carrier SF-7262
Rail (40 cm) SF-7264
Holder for Beta Disk Source SF-7265

Alpha Particle Spark Detector

SF-7219

- The alpha radiation can be both seen and heard.
- Clear demonstration of the alpha particle's ionization of the air
- Registers alpha radiation from radioactive minerals

Visualize alpha particles with this spark detector. When alpha particles ionize the air in the spark detector's aperture, sparks can be both seen and heard. The transparent lid allows observation from several different directions.

The spark detector needs to be connected to a high-voltage supply such as SF-9586B. Normal operating voltage is between 2 and 5 kV.

The spark detector can be placed directly on a table or mounted in ordinary stand hardware using the supplied mounting post.

Supplied with instructions and experiment ideas.

Dimensions: 7.5 cm x 13 cm x 5 cm



Order Information

Alpha Particle Spark Detector SF-7219
Required:
Kilovolt Power Supply SF-9586B

Cloud Chamber

Diffusion Cloud Chamber

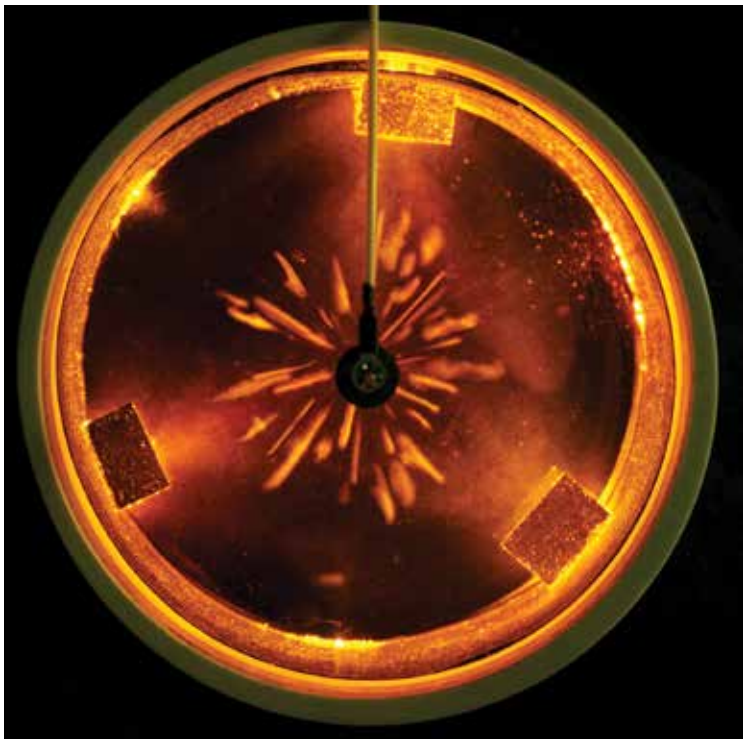
SE-7943

- No dry ice required
- View cosmic rays
- Built-in illumination

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.



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.

Features

- Uses ice water instead of dry ice
- Water circulation pump
- Built-in high voltage (~800 V) power supply to clear the chamber of unwanted ions
- Powered by 12 V DC power adapter
- Built-in LED lamps to illuminate the particle trails

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

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



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).

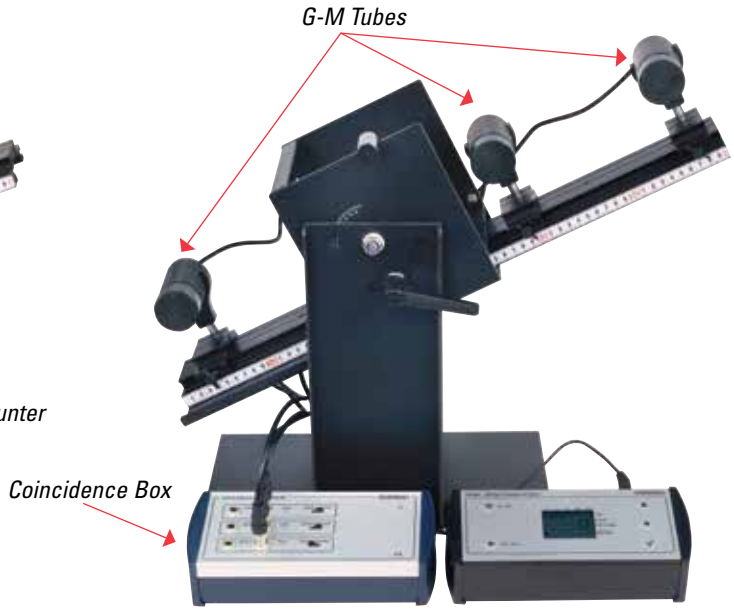
***Note:** Purchased Sources are "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 398.

Complete Muon Observatory

SF-7278

- Detect cosmic rays
- Demonstrate the angular dependence





Shower Mode: Three G-M tubes are clustered together, pointed at the steel absorber sheets.

Telescope Mode: The three G-M tubes are arranged in a line and the telescope angle can be varied to see which angle gives the greatest radiation.

The apparatus can be configured for either Shower Mode or Telescope Mode:

1. In the **Shower Mode** setup, a shower is recorded as a coincidence event from three GM tubes arranged in a triangle. This geometry ensures that no single particle can be detected in all three tubes. Production of showers may be enhanced by allowing the radiation to pass through something that is slightly "thicker" than air (multiple steel plates are used). In shower mode you will typically align the muon observatory vertically. Measurement periods are approximately one day long.
2. In **Telescope Mode** three GM tubes are arranged in a line, and if a muon passes through all tubes in the setup, a pulse is output from the coincidence box. The angle of the telescope can be varied to detect the angular distribution of the muons.



Large Area Geiger Tube (SF-7266): The extra sensitive tube (28.6 mm mica window) is suitable for measurements of radon daughters, naturally radioactive minerals, cosmic radiation and other applications where a greater area of sensitivity, greater solid angle or more sensitive volume are desirable. This tube is supplied with a forked holder with a mounting post.



Coincidence Box (SF-7269): To register coincidence between the three GM tubes, a coincidence box is required. The output from the coincidence box goes to a Geiger Counter (SF-7268), which is set to count with manual start and stop.



Geiger Counter (SF-7268): This Geiger counter can be set to start and stop manually and has a digital readout.

Includes

- Geiger Tube, Large Area (3) (SF-7266)
- USB Communication Adapter (SF-7267)
- Geiger Counter (SF-7268)
- Coincidence Box (SF-7269)
- Muon Observatory (SF-7270)
- Software

Order Information

Complete Muon Observatory	SF-7278
Available separately:	
Muon Observatory	SF-7270
Geiger Counter	SF-7268
Geiger Tube, Large Area	SF-7266
Coincidence Box	SF-7269
USB Communication Adapter for Geiger Counter	SF-7267

Radiation Counters

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. It 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

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

Radiation Counter

SN-7902 (Windows®/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 Windows 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 Windows 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

Handheld GM Counter

SF-7220

NEW

- Sensitive to alpha, beta, and gamma radiation
- Shows rate (µSv/h or counts/second)
- The GM voltage can be adjusted between 400 and 700 V, while the count rate is displayed.
- Displays max, min, and average



The battery-operated Handheld Geiger Counter is a flexible device, specially developed for schools and other educational institutions.

Use the built-in GM tube with protective cap for gamma radiation measurements; remove the cap when working with alpha and beta radiation.

Specifications

Battery: 9 V

Tube Window: Diameter: 9.1 mm; Mica thickness: 1.5 to 2.0 mg/cm2

Sound: Clicks

Measurement Periods: 1, 10, 20, 30, 40, 50, 60 and 100 s

Order Information

Handheld GM Counter.....SF-7220

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).

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 399.

Radioactive Sources

SN-8110



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

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 399.

Radioactive Sources

SN-7972A



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

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 399.

Individual Sources



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*	10 µCi	30.08 years	β,γ	SN-7938
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

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 399.

Gamma Sources

SN-7949A



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

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 399.

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

* **WARNING!** This product can expose you to Lead, which is known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

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

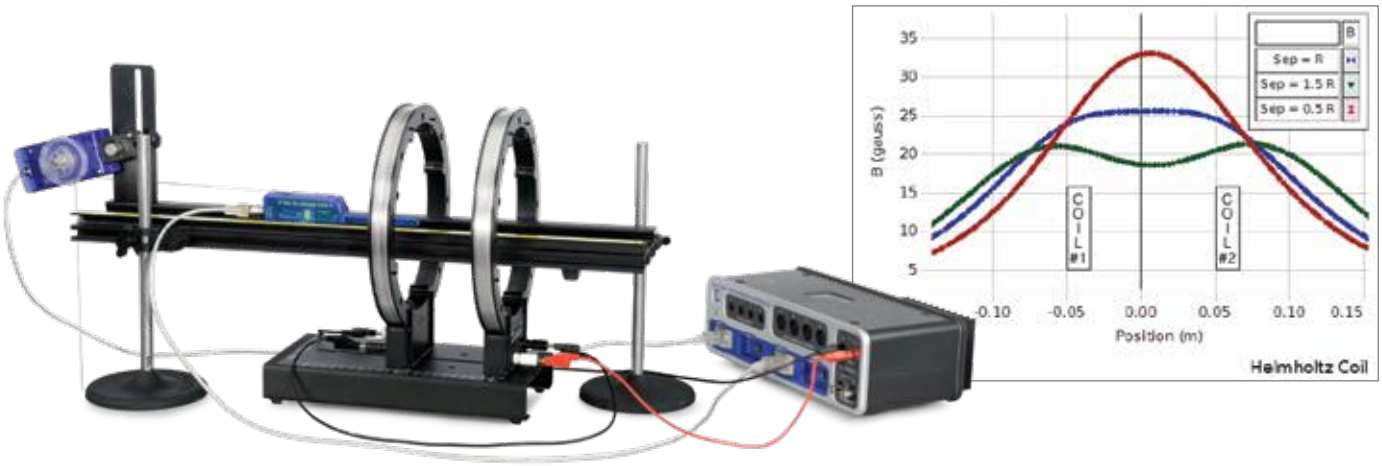
Isotope
Generator Kit* SN-7995A

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on page 399.

Download FREE PASCO Capstone Experiments

Over 60 classic physics experiments for use with PASCO equipment and software

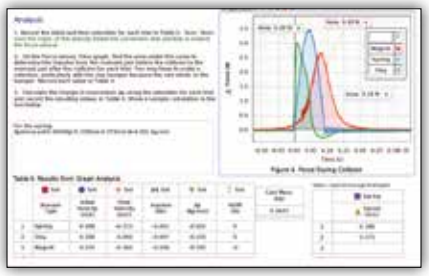
The following pages present classic experiments in physics performed with PASCO apparatus.
Manuals can be downloaded at www.pasco.com. Interfaces and software, where indicated, should be ordered separately.
Everything else is included in the experiment: apparatus, sensors (when needed), and accessories.



Workbooks include all instructions needed to perform the experiment:

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





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.

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Atwood's Machine

EX-5501

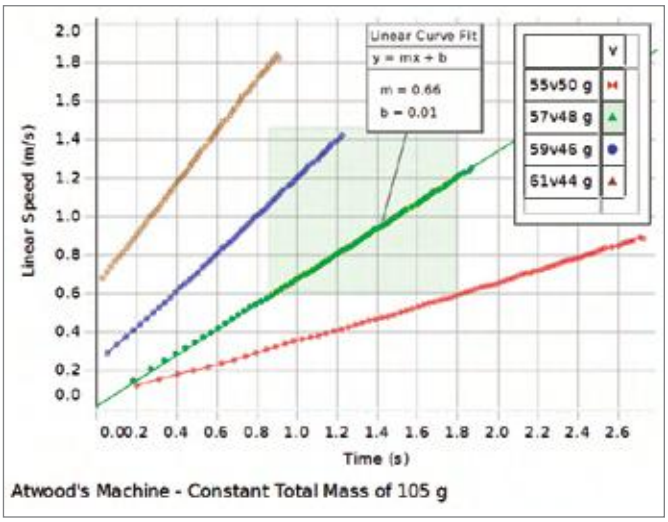
Concepts:

- Newton's Second Law of Motion
- Newton's Second Law of Rotational Motion
- Rotational Inertia

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink with Digital Adapter

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**.

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. 26-28
PASCO Capstone Software ..... pp. 70-73
Balance or Scale ..... p. 196
Calipers ..... SE-8710 p. 192

** This experiment can be performed using the 550 or 850 Universal Interface or AirLink with Digital Adapter.*

Projectile Motion

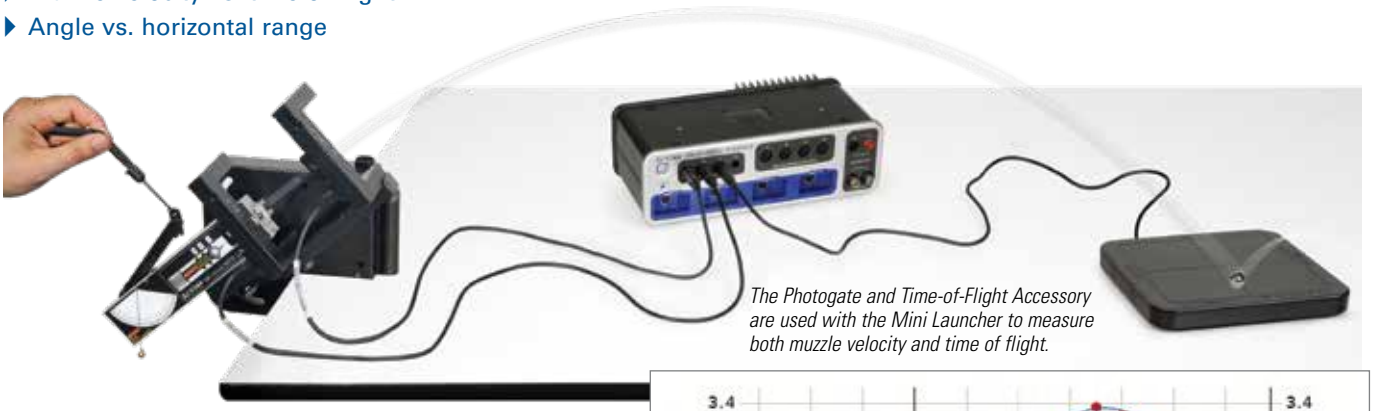
EX-5502

Concepts:

- Independence of x- and y-motion
- Muzzle velocity vs. time of flight
- Angle vs. horizontal range

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface with 2 Digital Adapters
- Any PASPORT interface with 2 ports and 2 Digital Adapters



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

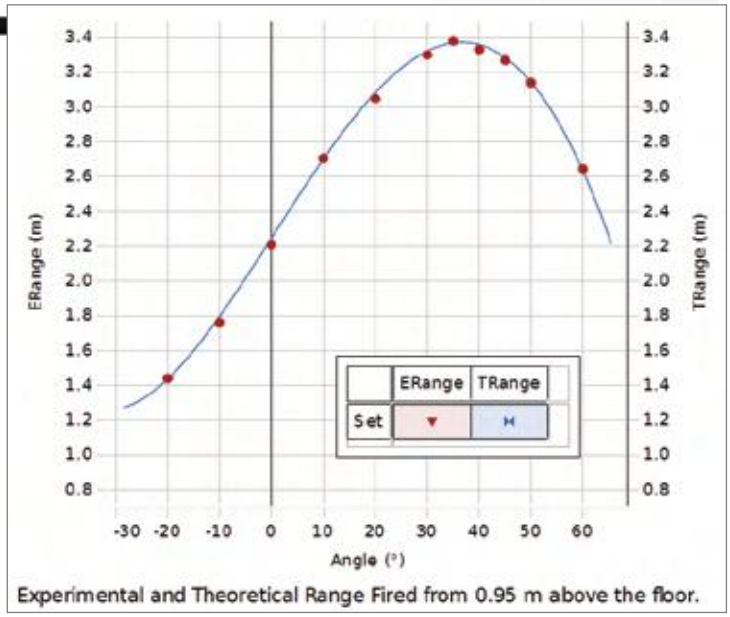
Students fire the projectile at three different velocities from the same height. The Photogate and Time-of-Flight Accessory are used to measure the time of flight at each muzzle velocity. Students are surprised to find that time of flight is not related to muzzle velocity at 0˚ launch angle.

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.

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

• Mini Launcher	ME-6825A
• Time-of-Flight Accessory	ME-6810A
• 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

Order Information

Projectile Motion EX-5502

Required:

850 or 550 Universal Interface* ..... pp. 26-28

PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 850 Universal Interface, the 550 Universal Interface with 2 Digital Adapters, or any PASPORT interface with 2 ports and 2 Digital Adapters.*

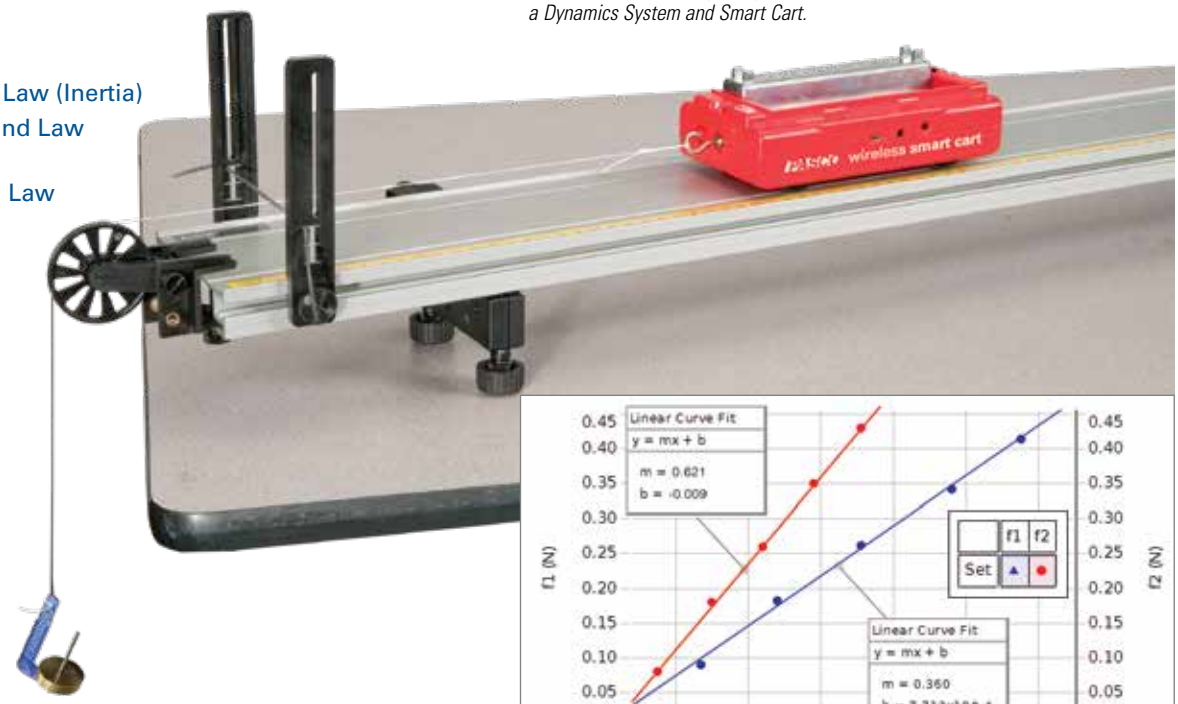
Newton's Laws

▶ No interface required

EX-5503A

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 and Smart Cart.

Force vs. acceleration data for the cart as it experiences changing net force

Method

Students use this collection of equipment to discover or experimentally determine all three of Newton's Laws.

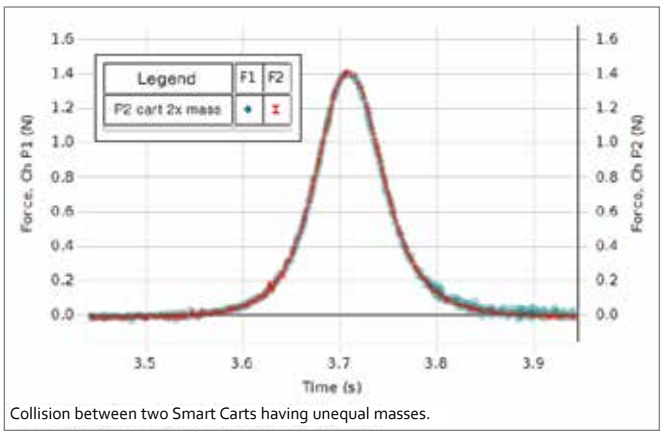
Newton's First Law – Students examine an object's motion to see if it changes when forces are applied or not.

Newton's Second Law – Students use the Smart Cart to discover the relationships between force, mass, and acceleration.

Newton's Third Law – Using two Smart Cart 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

The Smart Cart has all the sensors required, which makes setup very quick and easy. The integration between the probeware and equipment helps students focus on the physics of each experiment.



Collision between two Smart Carts having unequal masses.

Experiment Includes

• Smart Cart (red)	ME-1240
• Smart Cart (blue)	ME-1241
• Cart Mass (set of 2)	ME-6757A
• Dynamics Track Feet (2)	ME-8972
• PASCO Mass and Hanger Set	ME-8979
• Elastic Bumper	ME-8998
• Super Pulley with Clamp	ME-9448B
• 1.2 m Aluminum Dynamics Track	ME-9493
• Friction Block	ME-9807
• 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**.

Order Information

Newton's Laws EX-5503A

Required:

Bluetooth 4.0 enabled computer

PASCO Capstone Software ..... pp. 70-73

Hooke's Law and Energy Stored in a Spring

EX-5504A

Designed for use with any of the following:

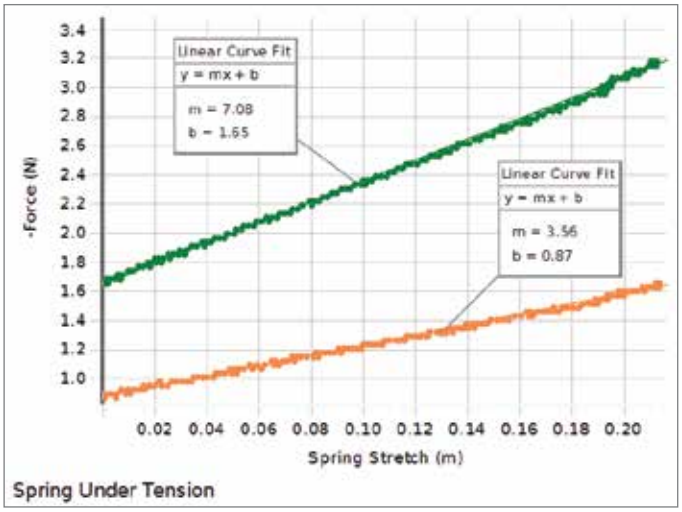
- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports

Concepts:

- Relationship between force and spring deformation
- Investigate both spring compression and extension
- Amount of energy stored in a spring

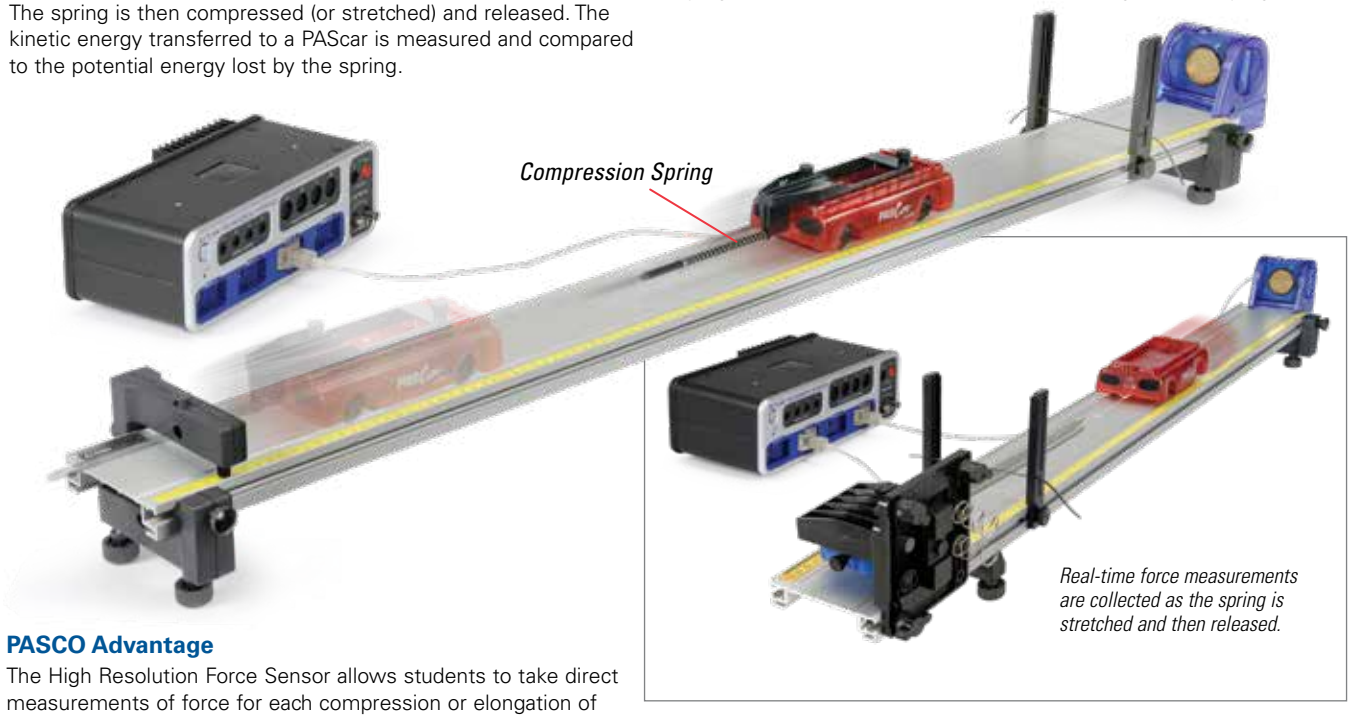
Method

In this experiment, students use a High Resolution 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 High Resolution 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.

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 m PAScar Dynamics System	ME-6955
• Motion Sensor	PS-2103A
• Dynamics Track Spring Set	ME-8999
• High Resolution Force Sensor	PS-2189
• Force Bracket	ME-6622
• Spring Cart Launcher	ME-6843
• Elastic Bumper	ME-8998
• Physics String	SE-8050

Order Information

Hooke's Law and Energy Stored in a Spring EX-5504A

Required:

550 or 850 Universal Interface* ..... p. 26

PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with 2 ports.*

Centripetal Force on a Pendulum

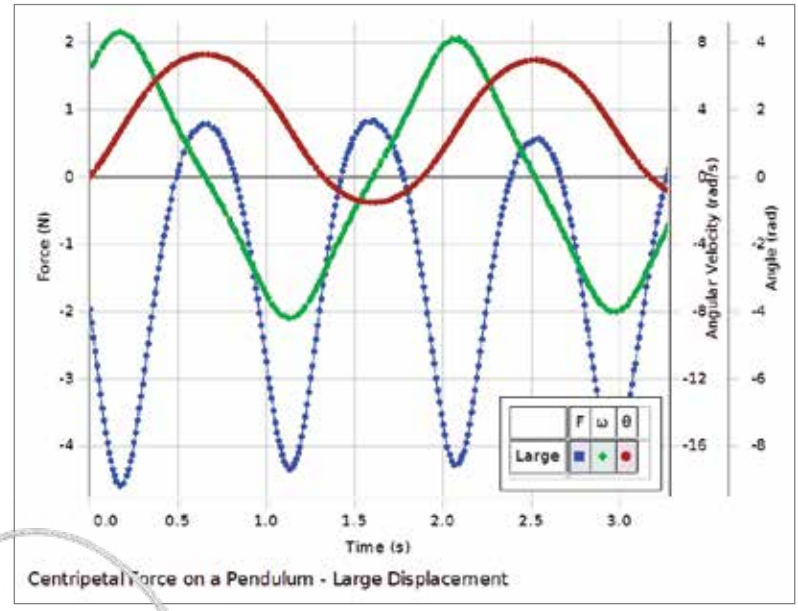
EX-5505A

Concepts:

- Centripetal force
- Angular velocity
- Periodic motion

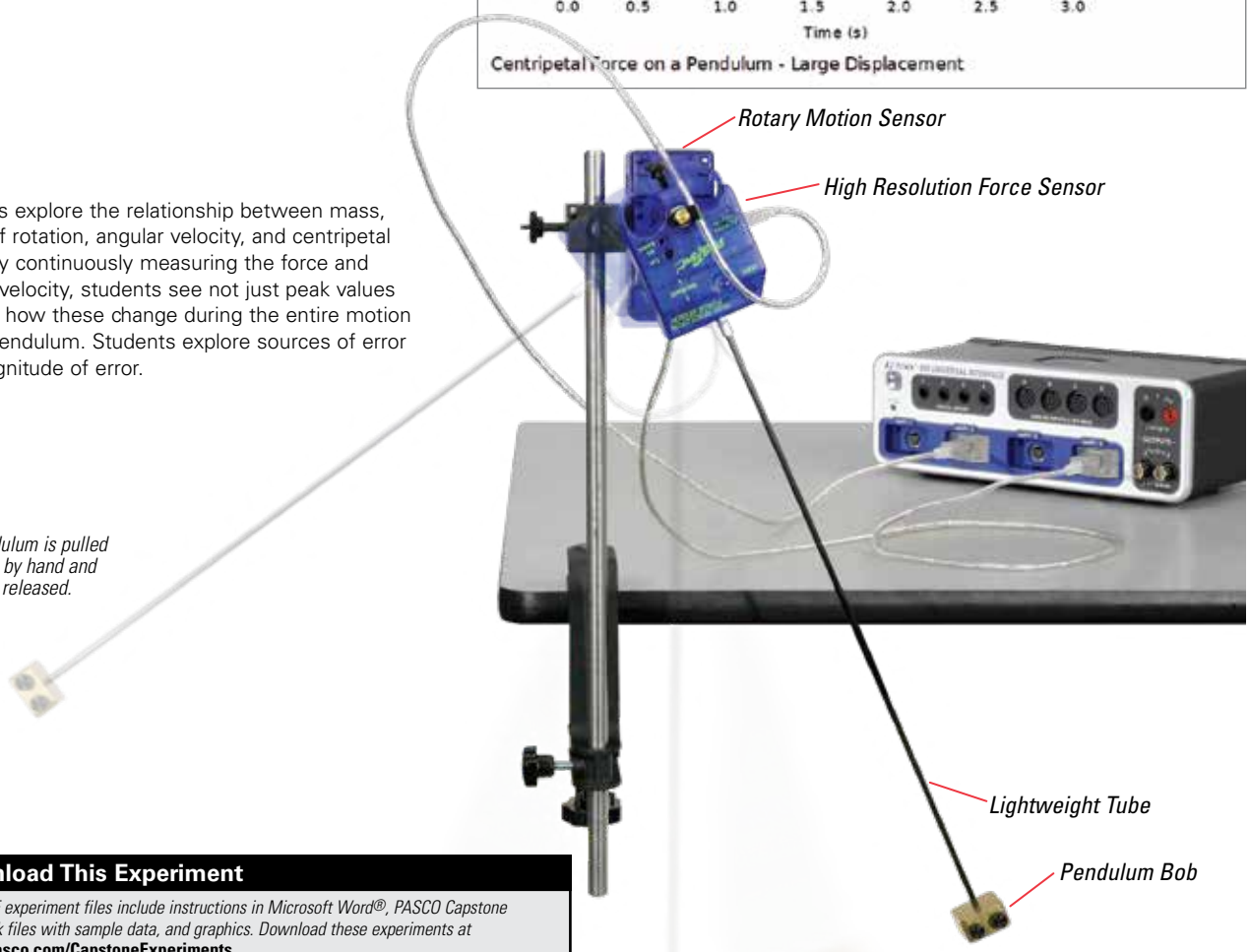
Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports



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**.

Experiment Includes

• High Resolution Force Sensor	PS-2189
• Rotary Motion Sensor	PS-2120A
• Centripetal Force Pendulum	ME-9821
• Aluminum Table Clamp	ME-8995
• Steel Rod 45 cm	ME-8736

Order Information

Centripetal Force on a Pendulum EX-5505A

Required:

550 or 850 Universal Interface* ..... p. 26
PASCO Capstone Software ..... pp. 70-73
Balance or Scale ..... p. 196

** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.*

Centripetal Force

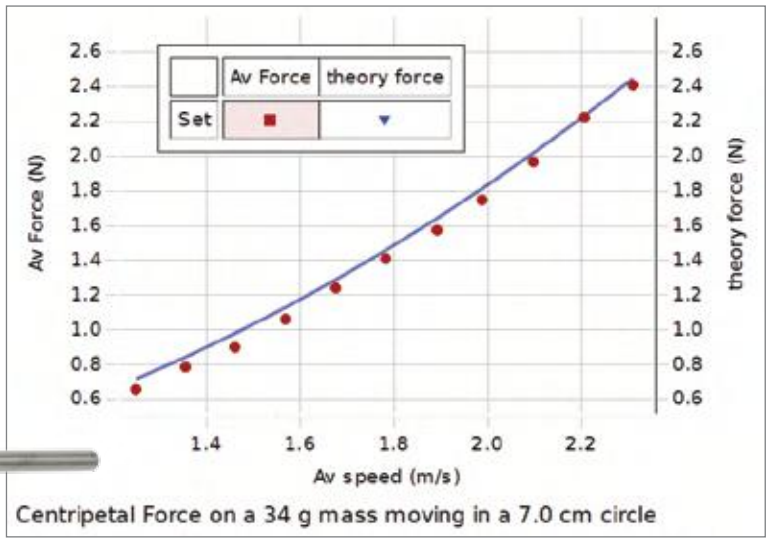
Designed for use with the 850 Universal Interface

EX-5506

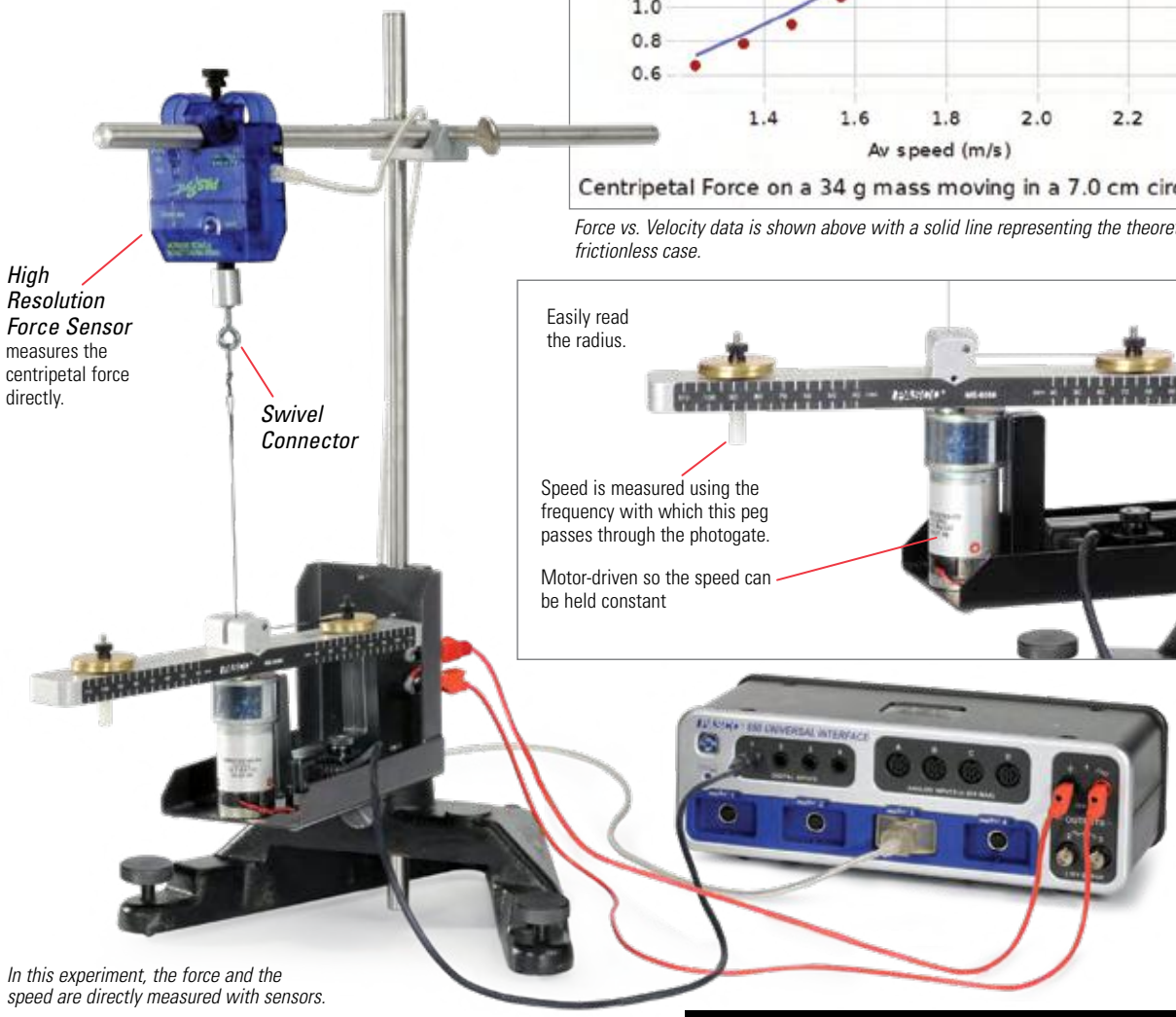
Concept:

- 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.



Force vs. Velocity data is shown above with a solid line representing the theoretical frictionless case.



In this experiment, the force and the speed are directly measured with sensors.

Experiment Includes

• Centripetal Force Apparatus	ME-8088
• High Resolution Force Sensor	PS-2189
• 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
• Red Banana Plug Cord (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**.

Order Information

Centripetal Force EX-5506

Required:

850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Mechanics

Sliding Friction

EX-5508

Designed for use with any of the following:
- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports

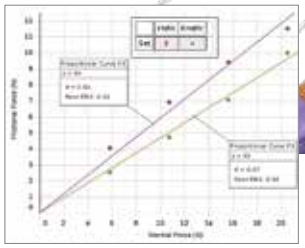
Concepts:

- Relationship between frictional force and normal force
- Coefficients of friction (kinetic and static)

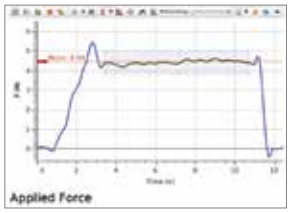
In this experiment, students use a High Resolution Force Sensor to discover frictional forces and their effect on the motion of an object. In addition, the coefficients of friction for various surface combinations can be empirically determined.



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.

Experiment Includes

• Discover Friction Accessory	ME-8574
• High Resolution Force Sensor	PS-2189
• Motion Sensor	PS-2103A
• 500 g Cart Masses (4)	ME-6757
• Physics String	SE-8050

Order Information

Sliding Friction.....EX-5508
Required:
550 or 850 Universal Interface*.....p. 26
PASCO Capstone Software.....pp. 70-73
** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.*

Impulse

EX-5509A

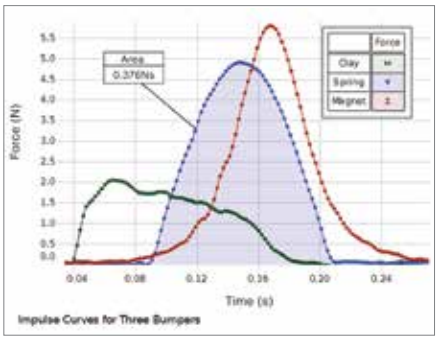
- Designed for use with the Smart Cart
- No interface required

Concepts:

- Impulse: change in momentum
- Impulse: area under a Force vs. 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 vs. Time curve.

A Smart Cart runs down a slightly inclined track with its Force Sensor equipped with either a clay bumper, spring bumper, or magnetic bumper. The cart collides with the endstop. To determine the change in momentum (impulse), the velocities before and after the collision are recorded using the Smart Cart's encoder. To confirm the impulse, the force vs. time is plotted and the impulse is determined by finding the area under the curve.



The Force vs. Time is shown for three different bumpers: clay bumper in green, spring bumper in blue, and magnetic bumper in red.



Magnetic, Spring, and Clay Bumpers



The impulse of a collision is determined by two methods.

PASCO Advantage

Since the PASCO Smart Cart is capable of measuring both force and velocity, it eliminates the need for any external sensor. No interface is required. No wires interfere with the motion because the Smart Cart transmits the data over Bluetooth® 4.0.

Experiment Includes

• Force Sensor Bracket	ME-6622
• PAScar Cart Mass (2)	ME-6757A
• Smart Cart (red)	ME-1240
• Dynamics Track Endstops (2)	ME-8971
• Dynamics Track Feet (2)	ME-8972
• 1.2 m Aluminum Dynamics Track	ME-9493

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

Impulse.....EX-5509A
Required:
Bluetooth 4.0 enabled computer
PASCO Capstone Software.....pp. 70-73
Balance or Scale.....p. 196

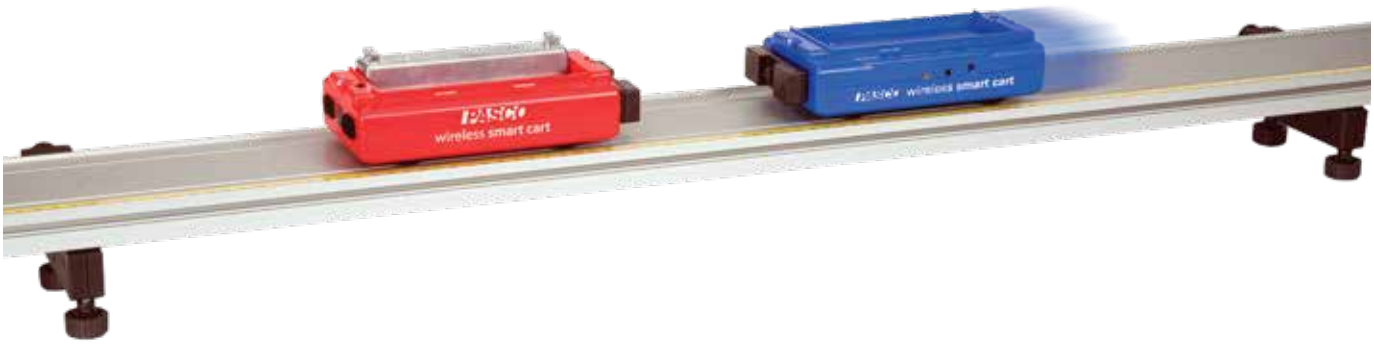
Conservation of Momentum

EX-5510B

- Designed for use with 2 Smart Carts
- No interface required

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

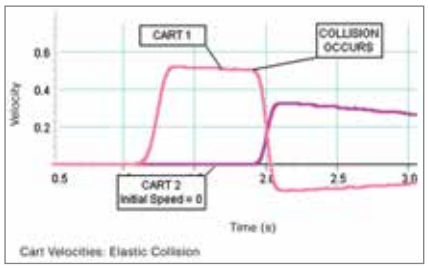


The total momentum and total energy of carts undergoing elastic and inelastic collisions are measured. The values before and after the collisions are compared to verify that momentum is conserved in all collisions, while energy is only conserved in elastic collisions.

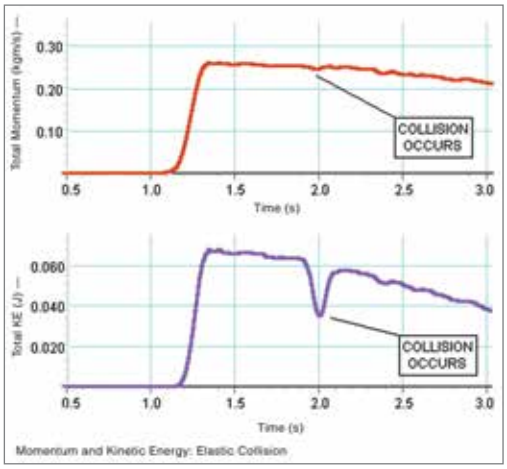
Elastic and inelastic collisions are performed with two dynamics carts of different masses. Magnetic bumpers are used in the elastic collision and Velcro® bumpers are used in the completely inelastic collision. In both cases, momentum is conserved.

Cart velocities are recorded using the encoders inside the Smart Carts. A real-time graph of Velocity vs. 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.



A real-time graph of Velocity vs. Time is obtained for each cart, clearly showing when the elastic collision occurred.



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

• 250 g Stackable Mass (2)	ME-6757A
• Smart Cart (red)	ME-1240
• Smart Cart (blue)	ME-1241
• Dynamics Track End Stops (2)	ME-8971
• Dynamics Track Feet (2)	ME-8972
• Starter Dynamics Track	ME-9493

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 Momentum.....EX-5510B
Required:
Bluetooth 4.0 enabled computer
PASCO Capstone Software..... pp. 70-73
Balance or Scale ..... p. 196

Ballistic Pendulum

EX-5511A

Concepts:

- Modern approach to a classic experiment
- View graph of entire pendulum swing
- Conservation of momentum
- Conservation of energy

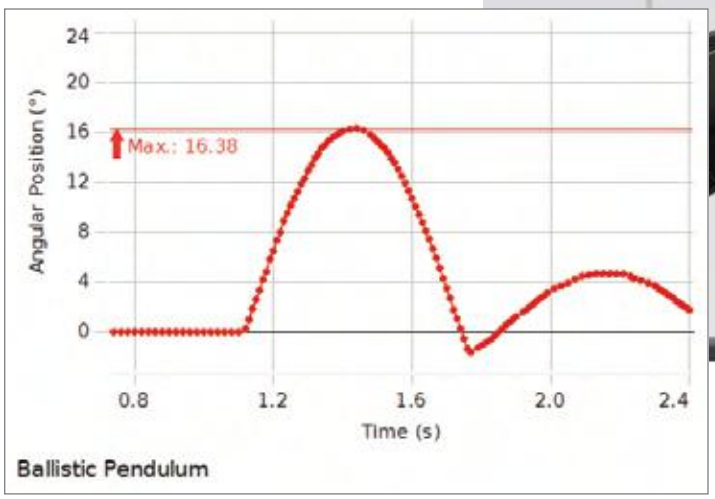
Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink

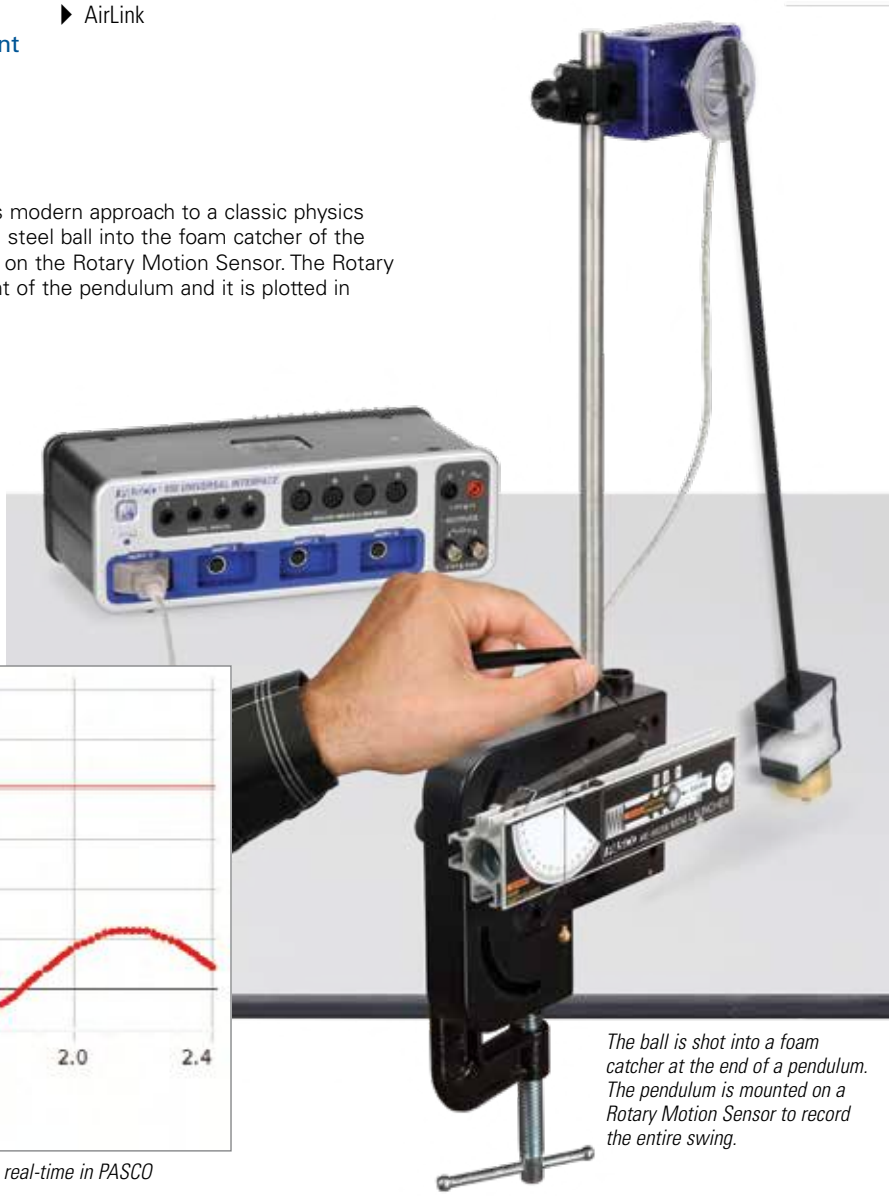
PASCO's Rotary Motion Sensor is the heart of this modern approach to a classic physics experiment. The Mini Launcher (ME-6825B) fires a steel ball into the foam catcher of the Ballistic Pendulum Accessory (ME-6829) mounted on the Rotary Motion Sensor. The Rotary Motion Sensor measures the angular displacement 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.



This graph of the angle of the pendulum vs. time is plotted in real-time in PASCO Capstone. The maximum angle is displayed on the graph.



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.

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

• Rotary Motion Sensor	PS-2120A
• Mini Launcher	ME-6825B
• 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

Order Information

Ballistic Pendulum EX-5511A

Required:

550 or 850 Universal Interface* ..... p. 26

PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

Conservation of Energy

EX-9935

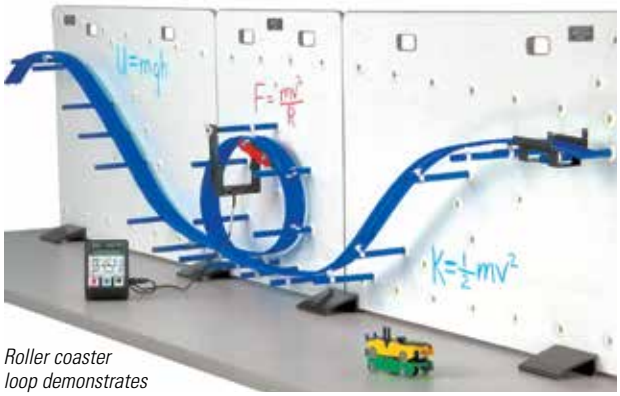
Concepts:

- 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 of 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 whiteboard 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:

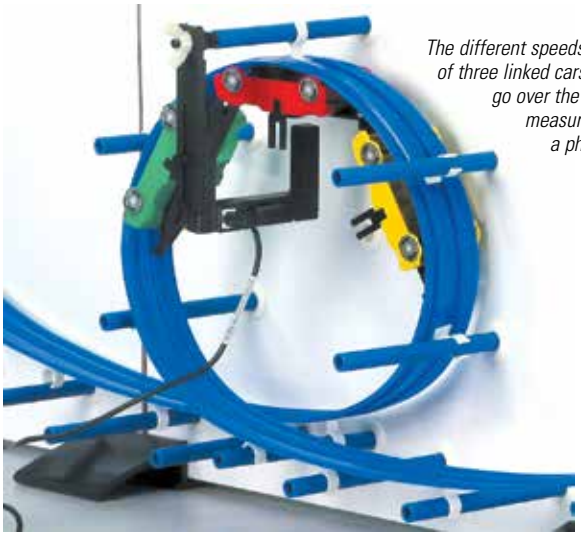
- Speed and height of the Roller Coaster car can be easily measured.
- Loss of energy due to friction is generally only about 5%.
- Cars will withstand repeated drops to the floor.



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.

To Download This Experiment

Search for EX-9935 at **www.pasco.com**

Order Information

Conservation of Energy.....EX-9935

Mechanics

Conservation of Energy II

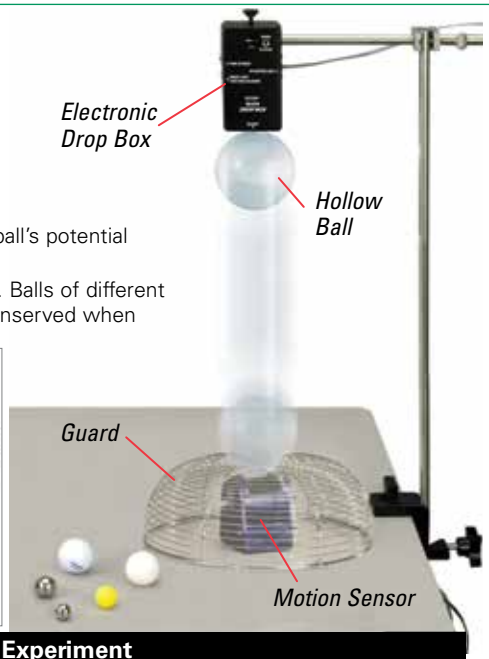
EX-5512

Concepts:

- Potential energy of a falling ball
- Kinetic energy of a falling ball
- Use different size balls to change friction

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink



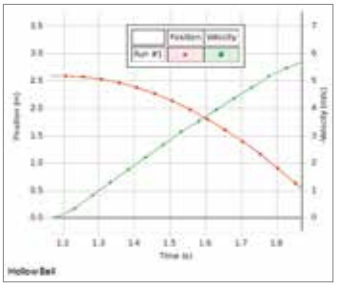
A ball is dropped from rest and its height and speed are recorded using a Motion Sensor. The ball's potential energy and kinetic energy are calculated at various points during the ball's fall.

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.

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

As the ball falls, its height and speed are recorded and displayed in PASCO Capstone software.



Order Information

Conservation of Energy II EX-5512
Required:
550 or 850 Universal Interface* ..... p. 26
PASCO Capstone Software ..... pp. 70-73
** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

Download This Experiment

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Work Energy Theorem

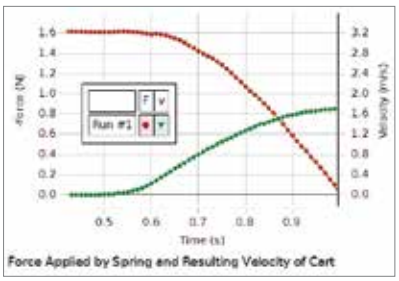
EX-5513A

Concepts:

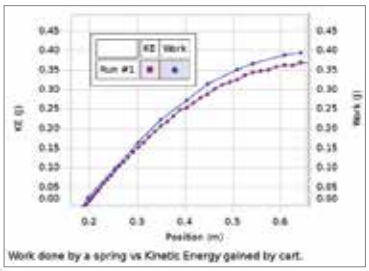
- Kinetic energy
- Potential energy
- Work energy theorem
- Conservation of mechanical energy

Designed for use with any of the following:

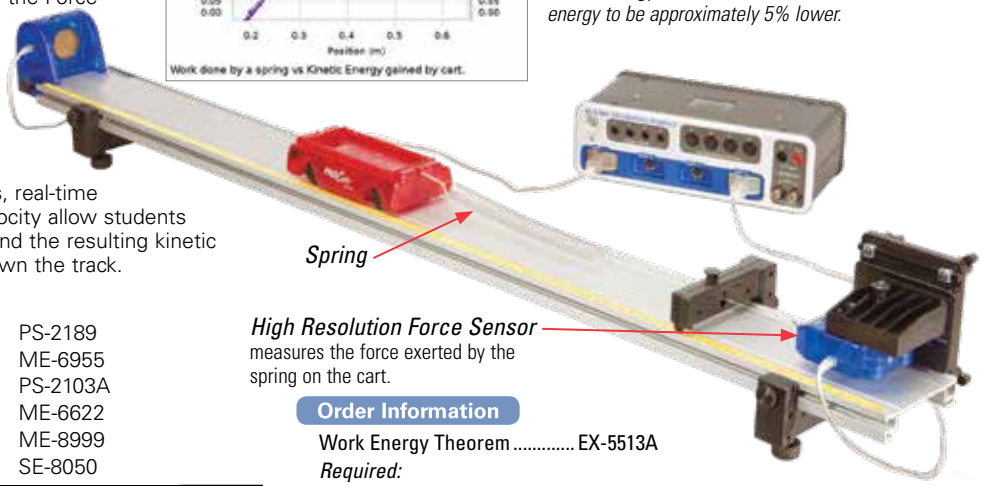
- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports



Work done by friction and ignoring the rotational kinetic energy of the wheels cause the cart kinetic energy to be approximately 5% lower.



The total work done on an object is compared with the change in kinetic energy of the object. Using a High Resolution 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.



High Resolution Force Sensor measures the force exerted by the spring on the 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
• Force Bracket	ME-6622
• Dynamics Track Spring Set	ME-8999
• 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**.

Order Information

Work Energy Theorem EX-5513A
Required:
550 or 850 Universal Interface* ..... p. 26
PASCO Capstone Software ..... pp. 70-73
Balance or Scale ..... p. 196
** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.*

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".

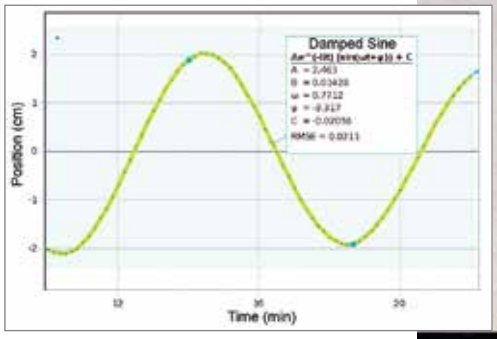
PASCO Advantage

For the first time, the measurement of G using the Cavendish Balance can actually be performed in a three-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.

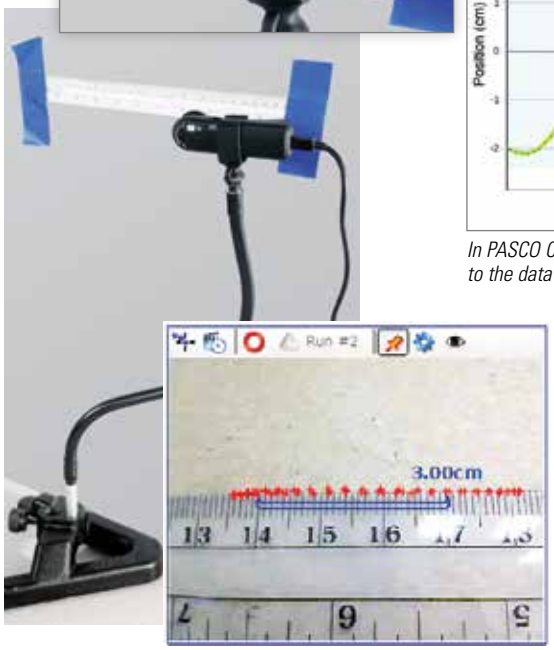




At left, the USB Camera Microscope records the oscillation of the laser beam.



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
• Rods and Clamps	

NOTE: *No interface is required.*

Order Information

Universal Gravitational Constant EX-5550

Required:

PASCO Capstone Software ..... pp. 70-73

Transparent Ruler and Meter Stick

To Download This Experiment

Search for EX-5550 at **www.pasco.com**

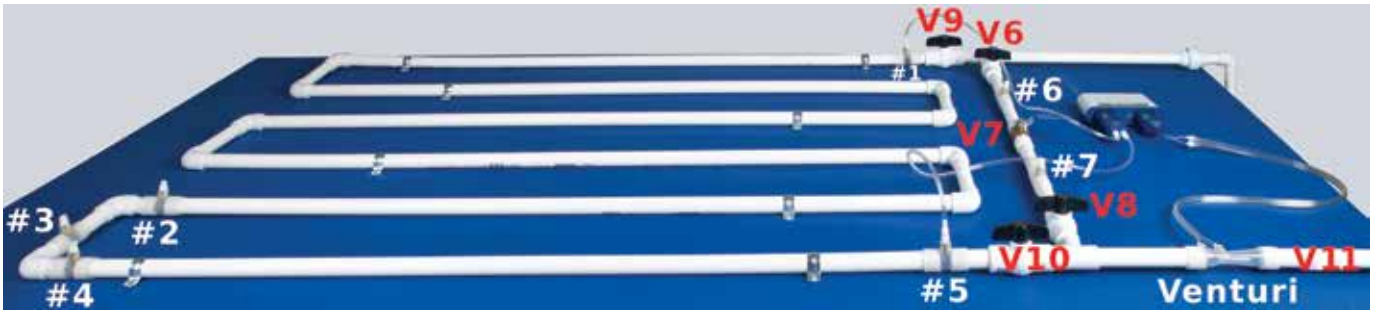
Piping Systems

EX-5553

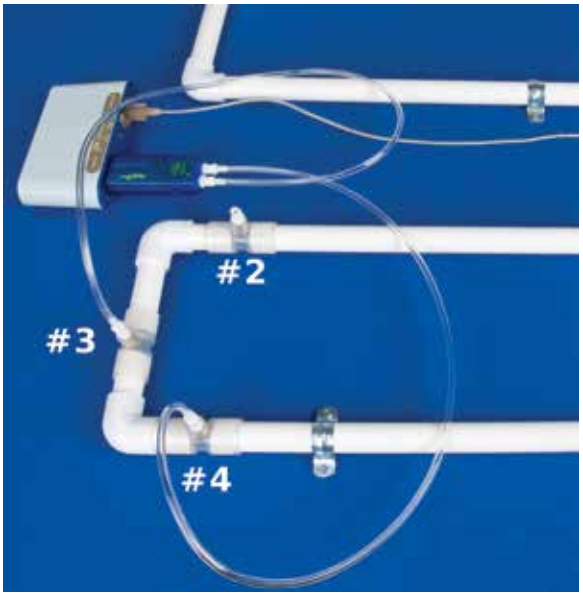
Designed for use with any of the following:
- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports

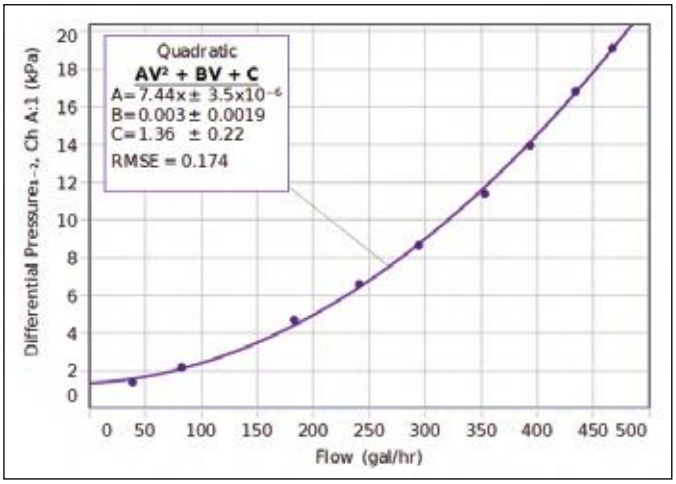
NEW

Concepts:
- Learn how to determine the friction factor.
- Estimate the energy loss of water flowing at a various flow rates through PVC pipe.
- Estimate the energy loss of water flowing through an elbow.
- Estimate the energy loss of water flowing through a valve.



In this experiment, students determine the major losses due to friction in pipes and the minor losses due to elbows and valves. The loss over a long distance is measured between pressure taps #1 and #5 (shown in the picture above). The water velocity is measured using the Venturi tube attached to the General Flow Sensor.





The water velocity is varied to explore the dependence of the losses on velocity (see graph above).

The minor losses due to elbows are found by comparing the pressure at tap #3 and tap #4, as shown at left.

Experiment Includes

• General Flow Sensor	PS-2222
• Venturi Tube	ME-2220
• Dual Pressure Sensor	PS-2181
• Pressure Taps (2 sets of 5 included)	ME-2224
• Fast Temperature Probe	Included in PS-2011
• Water Pump	SE-7727

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**.

Coming soon!
Check pasco.com for availability.

Order Information

Piping Systems Experiment.....EX-5553
Required:
Bucket
Pipe Network (see pasco.com/engineering/pipes for details)
SPARKlink Air Interface.....PS-2011
PASCO Capstone Software.....pp. 70-73
** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.*

Pumping Systems

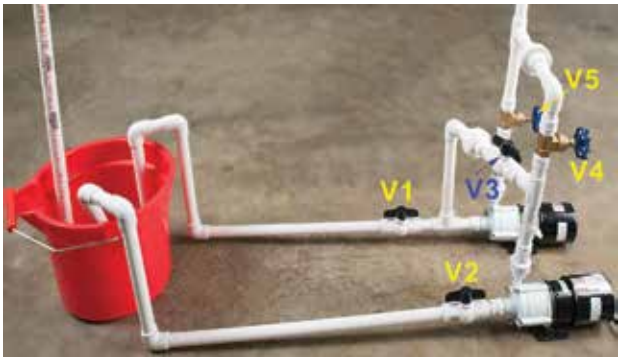
EX-5554

Designed for use with either of the following:
- 850 Universal Interface
- 550 Universal Interface

NEW

Concepts:
- Find the relationship between pump head and flow rate.
- Creating pump performance curves:
  - –Single pump
  - –Pumps in parallel
  - –Pumps in series

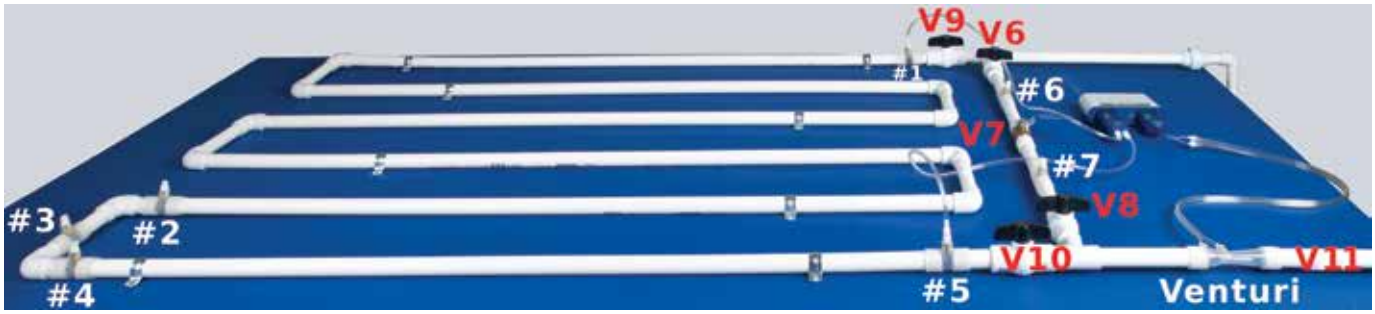
In this experiment, students determine the characteristic curves for two pumps and examine the impact of placing pumps in series and in parallel.



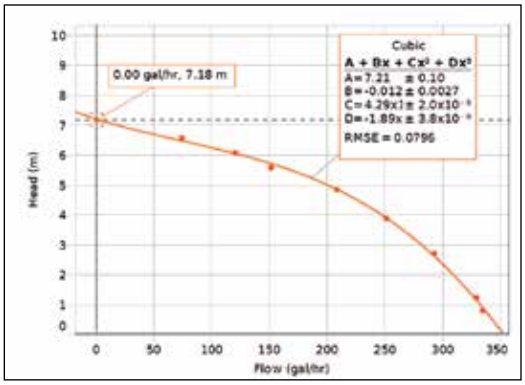
Two pumps are operated separately and then together in series and parallel.



The pressure is measured just above the pump as the water velocity is varied.



For this experiment, the water is pumped through the short section of pipe through valves #6 and #8. The water velocity is measured using the Venturi tube attached to the General Flow sensor. The pressure at the pump is measured for different velocities and a pump curve is created (at right). The maximum head is recorded. Then two pumps are operated at the same time. The effects of pumps in series and in parallel are explored.



Experiment Includes

• General Flow Sensor	PS-2222
• Venturi Tube	ME-2220
• Dual Pressure Sensor	PS-2181
• Pressure Taps (2 sets of 5 included)	ME-2224
• Fast Temperature Probe	Included in PS-2011
• Water Pumps (2)	SE-7727

Coming soon!
Check pasco.com for availability.

Order Information

Pumping Systems Experiment.....EX-5554
Required:
Bucket
Pipe Network (see pasco.com/engineering/pipes for details)
SPARKlink Air Interface.....PS-2011
PASCO Capstone Software.....pp. 70-73

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**.

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.

To Download This Experiment

Search for EX-9909 at **www.pasco.com**

Order Information

Archimedes' Principle..... EX-9909

Rotational Inertia

EX-5516B

Designed for use with any of the following:

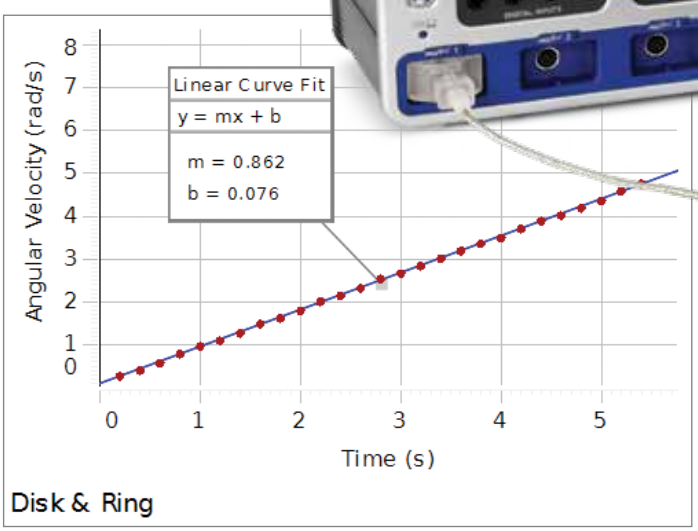
- 850 Universal Interface
- 550 Universal Interface
- AirLink

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 vs. 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 vs. 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.

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.

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

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

Rotational Inertia EX-5516B

Required:

550 or 850 Universal Interface* ..... p. 26
PASCO Capstone Software ..... pp. 70-73
Balance or Scale ..... p. 196
Calipers ..... SE-8710 p. 192

** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

Physical Pendulum

EX-5518A

Designed for use with any of the following:

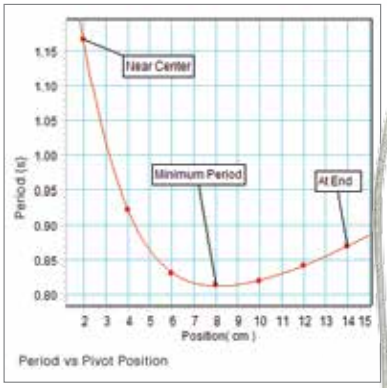
- 850 Universal Interface
- 550 Universal Interface
- AirLink

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.

Center hole is at center of mass.



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

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* ..... p. 26

PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

Conservation of Angular Momentum

EX-5517C

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink

Concepts:

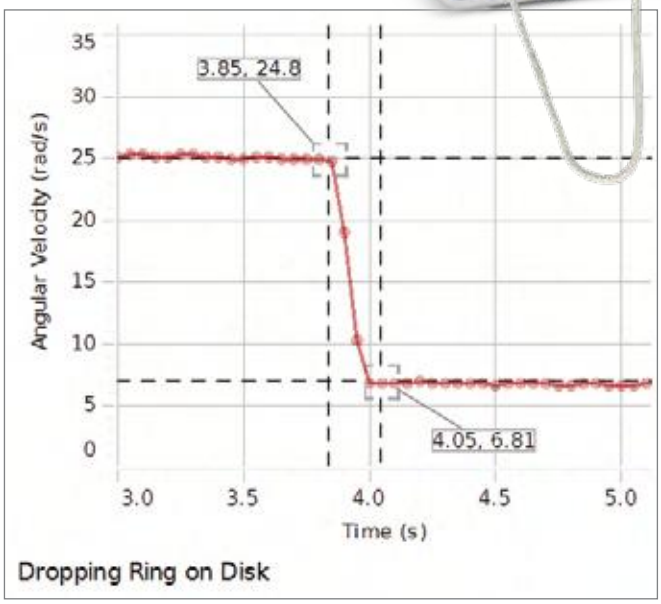
- Conservation of angular momentum during collisions
- Easy determination of before and after points
- Calculation of energy lost during collision

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

Order Information

Conservation of Angular Momentum EX-5517C

Required:

550 or 850 Universal Interface* ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Balance or Scale ..... p. 196

** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

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**.

Variable-g Pendulum

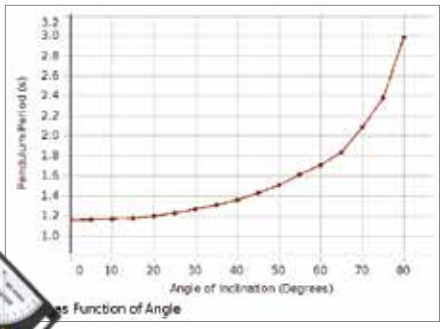
EX-5519A

Designed for use with any of the following:
- 850 Universal Interface
- 550 Universal Interface
- AirLink

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.

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.

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

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

Variable-g Pendulum EX-5519A
Required:
550 or 850 Universal Interface* ..... pp. 26-28
PASCO Capstone Software ..... pp. 70-73
** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

Large Amplitude Pendulum

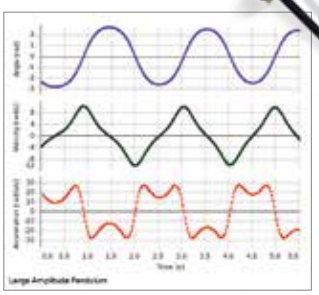
EX-5520A

Designed for use with any of the following:
- 850 Universal Interface
- 550 Universal Interface
- AirLink

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 vs. time to show the difference from the sinusoidal motion of low amplitude oscillations.

The period is measured as a function of the amplitude of the pendulum and compared to theory.



Graphs of angular displacement, velocity, and acceleration vs. time are displayed for a pendulum oscillating with large 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

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

Large Amplitude Pendulum EX-5520A
Required:
550 or 850 Universal Interface* ..... p. 26
PASCO Capstone Software ..... pp. 70-73
** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

Chaos

Designed for use with the 850 Universal Interface

EX-5523A

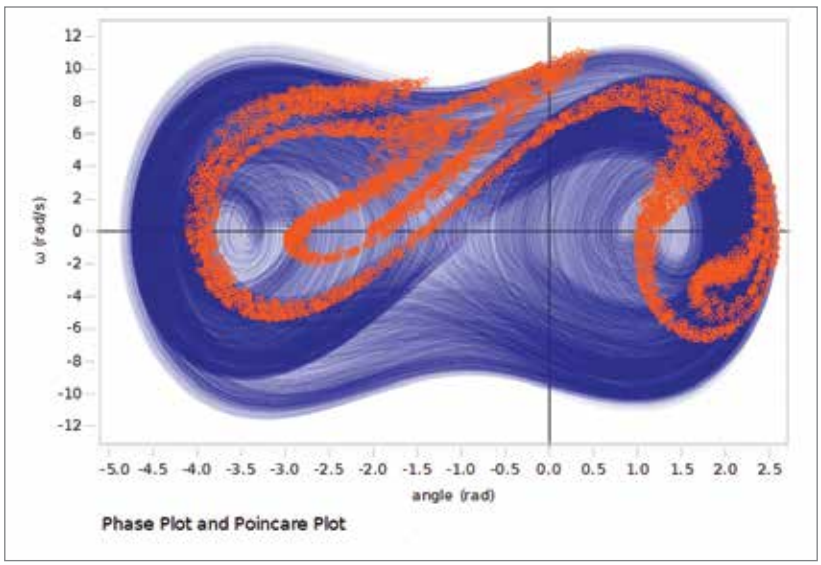
Concepts:

- 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 vs. the displacement angle of the oscillation.

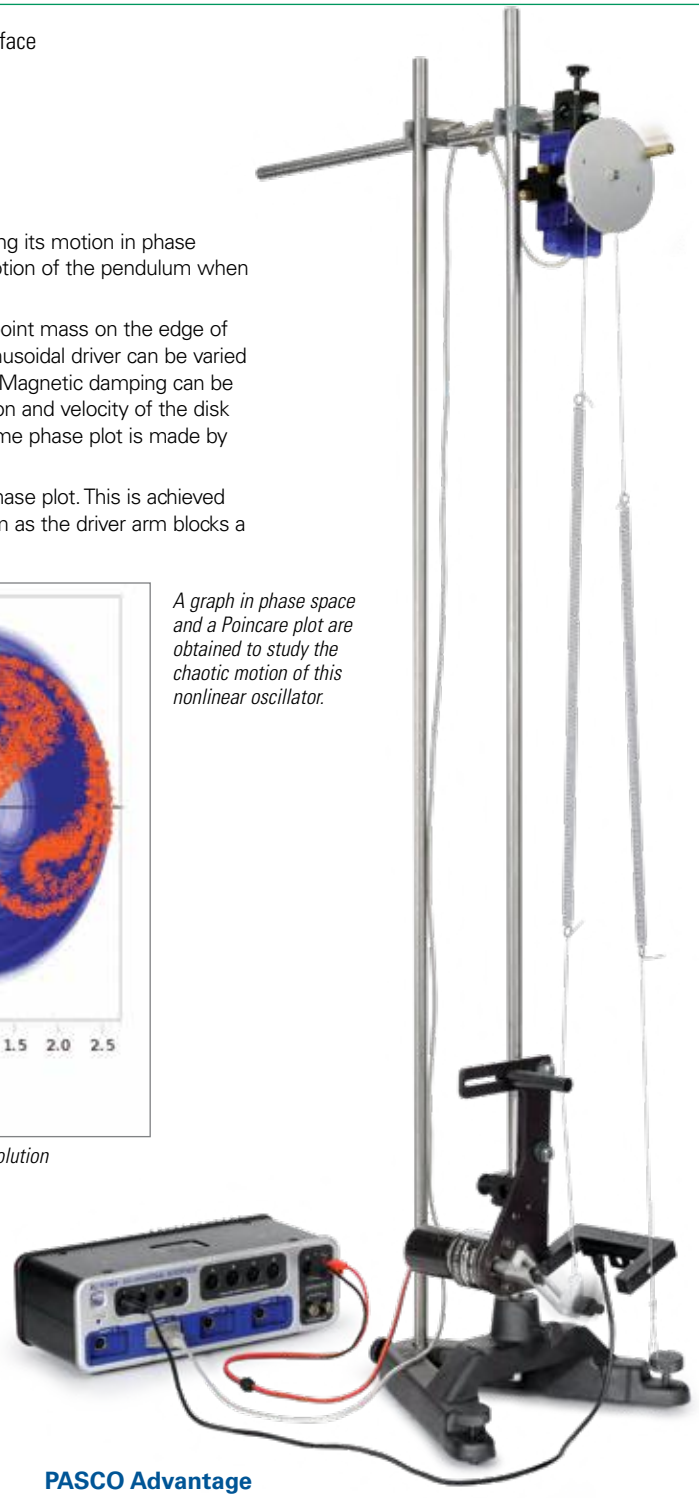
The Poincare plot is also graphed in real time and superimposed on the phase plot. This is achieved by recording the point on the phase plot once every cycle of the driver arm as the driver arm blocks a photogate.



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 vs. position once per revolution of the driver. The purple background is the phase plot.

This phase plot (angular velocity vs. 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

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.

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

Chaos EX-5523A

Required:

850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Oscillations

Driven Damped Cart Oscillations

EX-5551

NEW

Concepts:

- Resonance curves
- Magnetic drag

Designed for use with:

- 850 Universal Interface



Magnets induce currents in the aluminum track and cause a drag force that is proportional to the cart velocity.

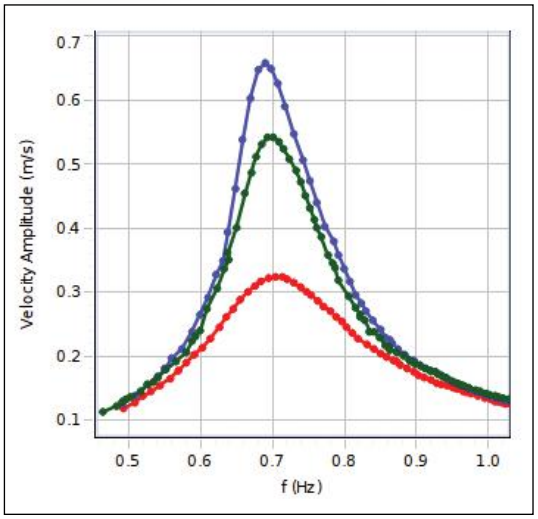


The oscillator consists of a Smart Cart attached to two springs. The damping is provided by magnets mounted on the Smart Cart that cause eddy currents in the aluminum track. The amplitude of the oscillation is plotted vs. the driving frequency for different amounts of magnetic damping. Increased damping is provided by moving adjustable magnets closer to the aluminum track.

$$\frac{d^2x}{dt^2} + \left(\frac{b}{m}\right)\frac{dx}{dt} + \left(\frac{k}{m}\right)x = F_o\cos(\omega t)$$

$$x = \frac{F_o/m}{\sqrt{\left(\omega^2 - \omega_0^2\right)^2 + (b/m)^2\omega^2}}\cos(\omega t - \varphi)$$

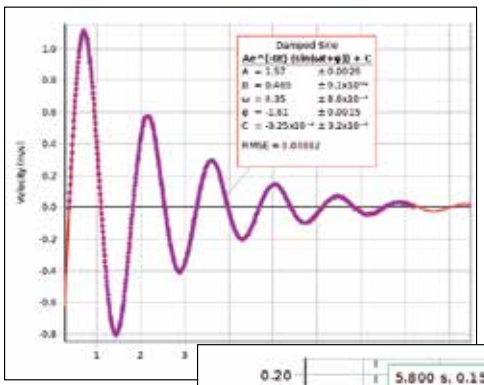
$$\omega = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$$



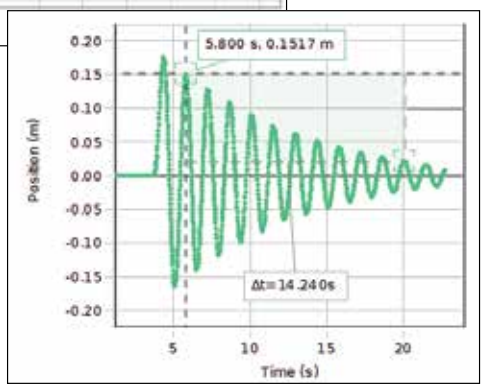
The amplitude of the cart's velocity is plotted vs. the driving frequency. The amount of drag is varied by changing the distance between the magnets and the track.

PASCO Advantage

The Smart Cart wirelessly measures the position and velocity of the cart as well as the magnetic drag, since the magnetic drag bumper is attached to the Smart Cart's force sensor.



In PASCO Capstone, a damped sine wave curve fit is applied to the data to determine the spring constant, period, and damping coefficient.



The period can be directly measured to determine the resonant frequency.

Experiment Includes

• Smart Cart	ME-1240
• Mechanical Oscillator/Driver	ME-8750
• Magnetic Damping Accessory	ME-6828
• Dynamics Spring Set	ME-8999
• Photogate Head	ME-9498A
• Cart Mass (set of 2)	ME-6757A
• 1.2 m Metal Dynamics Track	ME-9493
• Dynamics Track End Stop (2 Pack)	ME-8971
• Dynamics Track Feet (Pair)	ME-8972
• Physics String	SE-8050
Required:	
• Mass Balance	SE-8707
• 850 Universal Interface	UI-5000
• PASCO Capstone	

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**.

Coming soon!
Check pasco.com for availability.

Order Information

Driven Damped Cart Oscillations.....EX-5551
Required:
Mass Balance SE-8707
850 Universal Interface.....UI-5000 pp. 26-27
PASCO Capstone Software..... pp. 70-73

Driven Damped Harmonic Oscillator

EX-5522A

Designed for use with:
- 850 Universal Interface

Concepts:

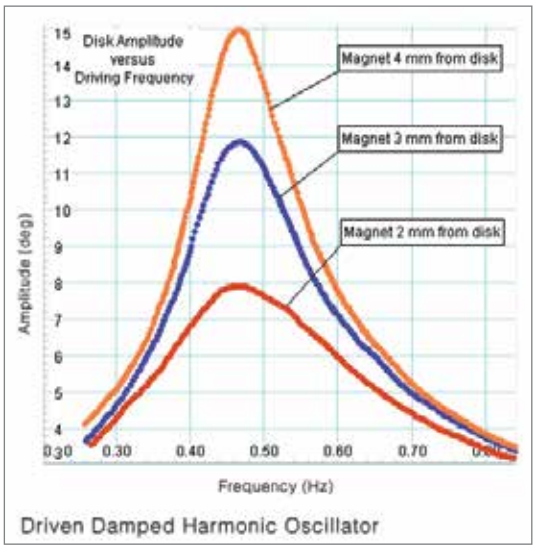
- Resonance curves for an oscillator: amplitude vs. frequency
- Resonant frequency
- Period of a pendulum
- Effect of magnetic damping on shape of resonance curve
- Phase difference between oscillator and driver at low, resonant, and high frequencies

In this experiment, the resonance of a driven damped harmonic oscillator is examined by plotting the oscillation amplitude vs. frequency for various amounts of damping.

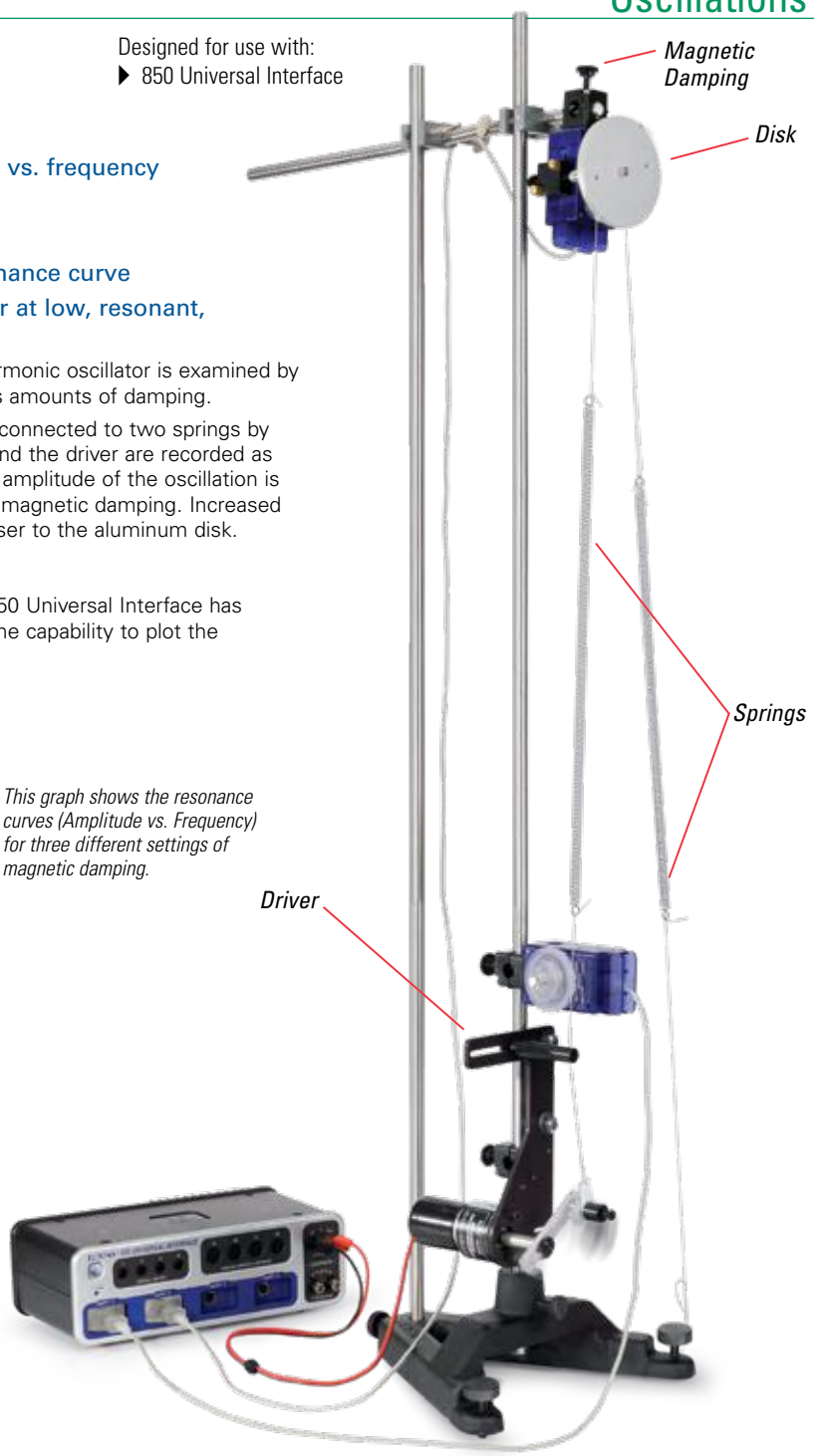
The oscillator consists of an aluminum disk with a pulley connected to two springs by a string. The angular positions and velocities of the disk and the driver are recorded as a function of time using two Rotary Motion Sensors. The amplitude of the oscillation is plotted vs. the driving frequency for 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 vs. the driver frequency in real time.



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

• Rotary Motion Sensor (2)	PS-2120A
• Mechanical Oscillator/Driver	ME-8750
• Chaos/Driven Harmonic Accessory	CI-6689A
• Large Rod Base	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

Order Information

Driven Damped Harmonic Oscillator	EX-5522A	
Required:		
850 Universal Interface	UI-5000	pp. 26-27
PASCO Capstone Software		pp. 70-73
Hooked Mass Set	SE-8759	p. 197
Calipers	SE-8710	p. 192

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**.

Basic Bridges

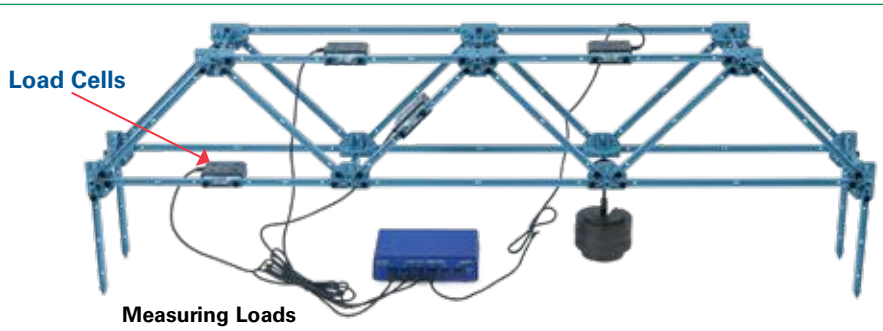
EX-5556

Designed for use with:

- 850 Universal Interface, 550 Universal Interface or AirLink

Concepts:

- Learn about different types of bridges through hands-on exploration.
- Measure the tension/compression in beams for different bridge designs.

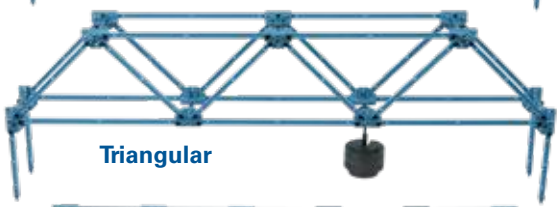


Measuring Loads
Each bridge is loaded by hanging a weight from the bridge. The tension and compression in the I-beams are measured with load cells. The load cells can be moved around to explore the load in every beam in the bridge.

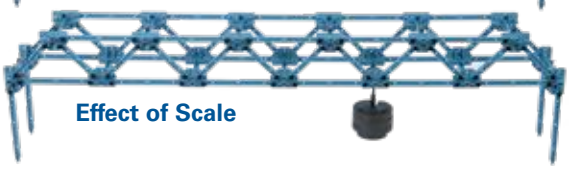
Rectangular Segments
First, students build a bridge with rectangular segments. Of course, bridges are never made this way but students will never understand why until they try it.



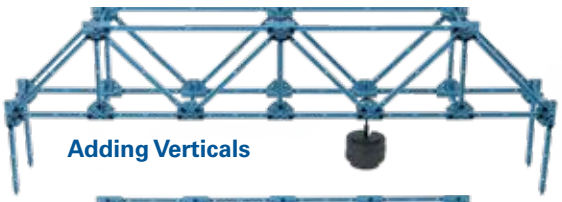
Triangular Segments
Next, students build a Warren bridge with triangular segments. This shows how much stronger triangular segments are than rectangular segments.



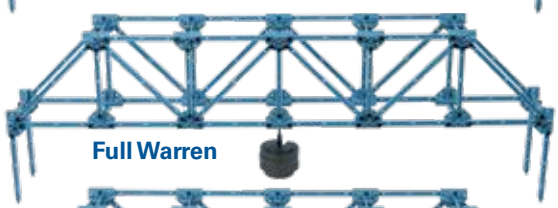
Effect of Scale
Students build a second Warren bridge on a different scale to discover how the forces change in this bridge that has twice the number of segments but spans the same distance.



Effect of Adding Verticals
Verticals are added to the larger Warren bridge. Students will find that the loads do not change when the verticals are added: So why are verticals used?



Full Warren Bridge vs. Pratt Bridge
Additional verticals are added to make a Full Warren bridge. Then the students change the Full Warren to a Pratt bridge. How are the forces different in a Pratt compared to a full Warren?





Experiment Includes

• Truss Set Members (3)	ME-6993
• Truss Set Screws (3)	ME-6994
• #6 I-Beams (1)	ME-7008
• 12 kg Mass Set	ME-7589
• Load Cell Amplifier (1)	PS-2198
• 100 N Load Cells (4)	PS-2200

Download This Experiment

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Coming soon!
Check pasco.com for availability.

Order Information

Basic Bridges EX-5556
Required:
550 or 850 Universal Interface ..... pp. 26-28
OR
AirLink ..... pp. 24
PASCO Capstone Software ..... pp. 70-73

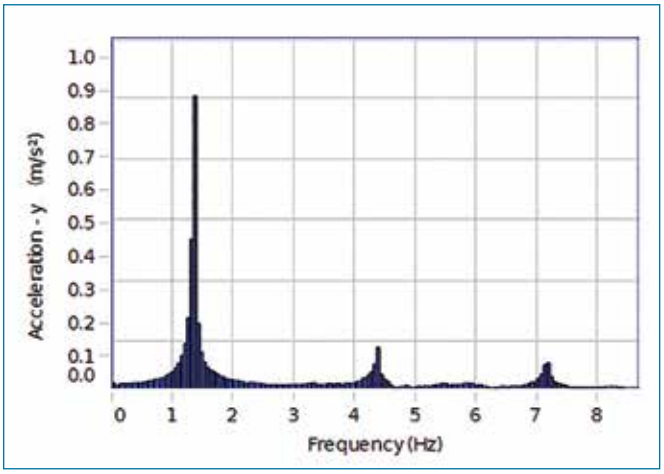
Shaking Tower

EX-5555

Designed for use with:
- 850 Universal Interface or Function Generator

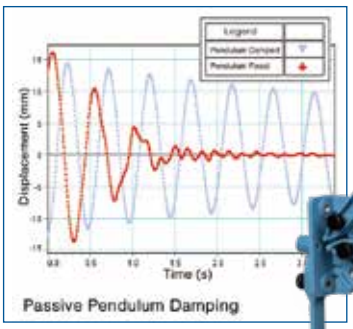
Concepts:
- Explore the resonance modes
- Measure accelerations with wireless sensors
- Demonstrate passive damping

Built from PASCO Structures beams, this tower is made to oscillate in its various resonance modes by a driver attached by a rubber band to the first floor of the tower. Wireless Load Cells with Accelerometers are attached to each floor to record how much shaking each floor experiences.

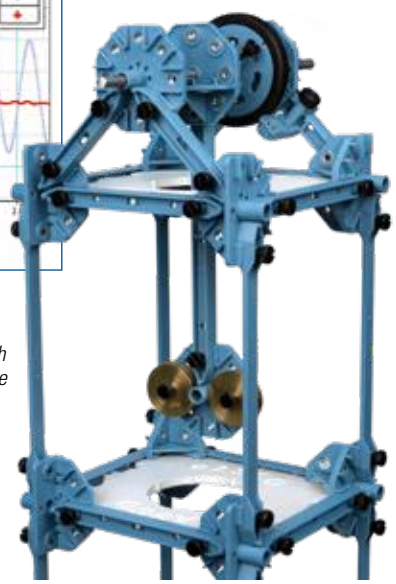


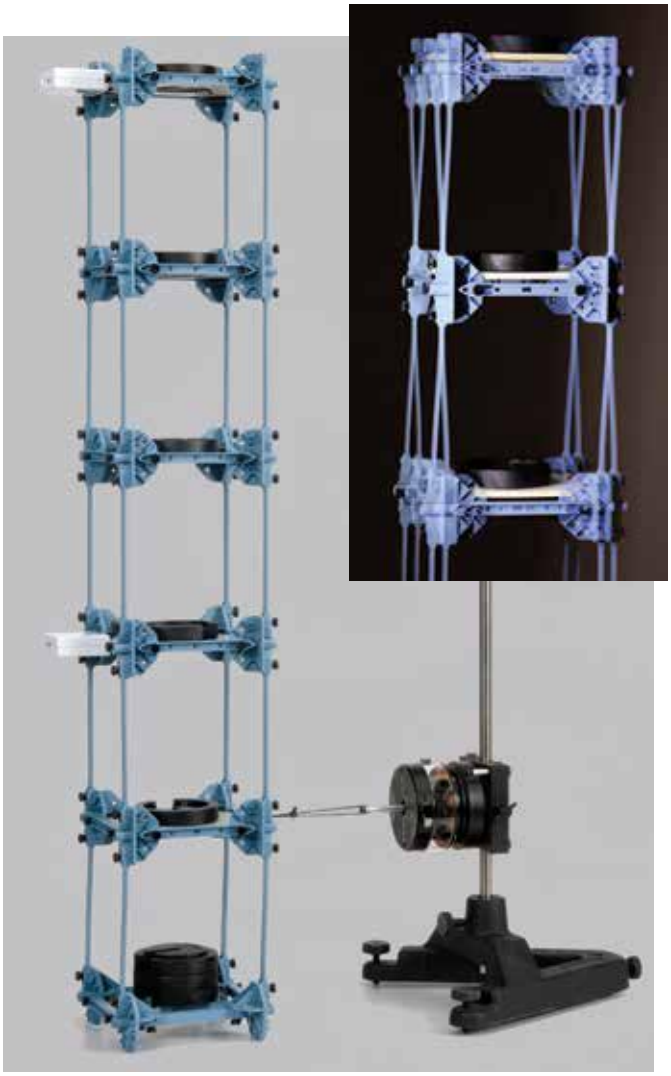
This FFT, generated in PASCO Capstone software, shows the frequency responses of the top Wireless Load Cell/Accelerometer.

In the second part of the experiment, a damping pendulum is installed on top of the tower. In modern buildings, passive damping mechanisms are installed to damp out oscillations during earthquakes. The damping pendulum in this tower quickly stops oscillations.



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.





The tower is shaken by the Mechanical Wave Driver which is powered by an 850 Universal Interface or Function Generator.

Experiment Includes

• Shaking Tower Kit (see p. 153)	ME-7018
• Mechanical Wave Driver	SF-9324
• 2 Meter Patch Cord Set	SE-9415A
• Large Rod Base	ME-8735
• Threaded Rod 25 cm	ME-8988
• Large Slotted Mass Set	ME-7566
• Wireless Load Cells (4)	PS-3216

Download This Experiment

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Order Information

Shaking Tower.....EX-5555
Required:
850 Universal Interface.....pp. 26-28
OR
Function Generator (PI-8127).....pp. 249
PASCO Capstone Software.....pp. 70-73

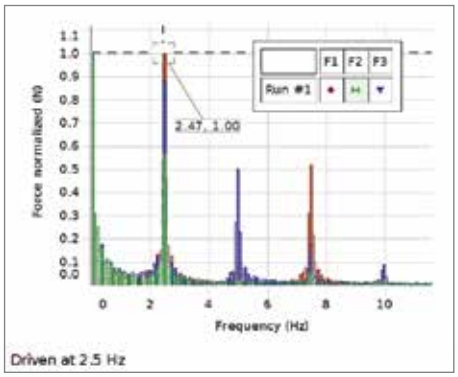
Bridge Vibrations

EX-5548

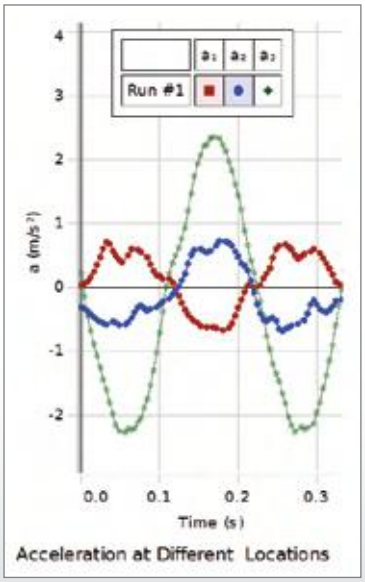
Concepts:

- Resonance in complex systems
- Driven vs. free vibrations

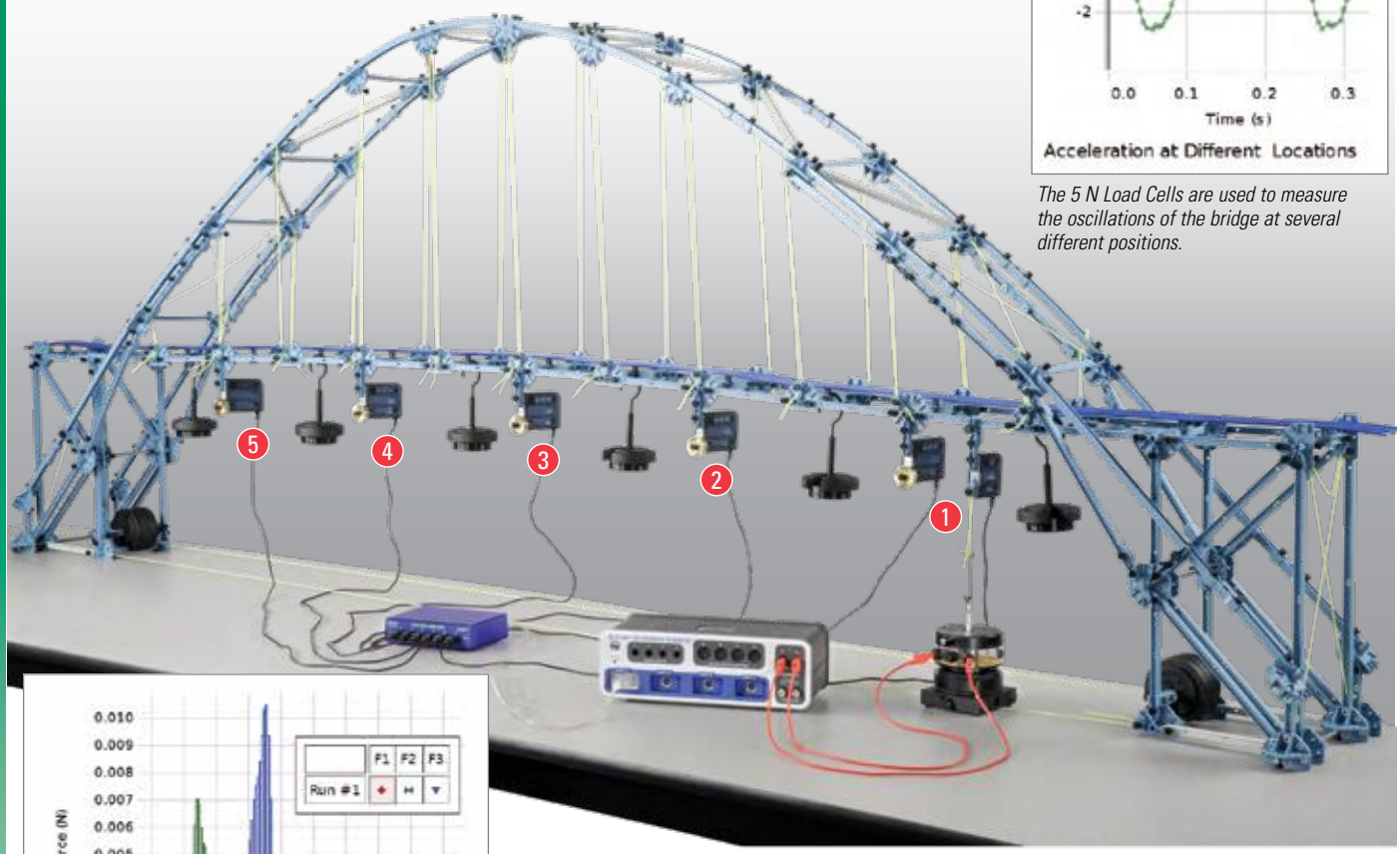
Designed for use with the
850 Universal Interface

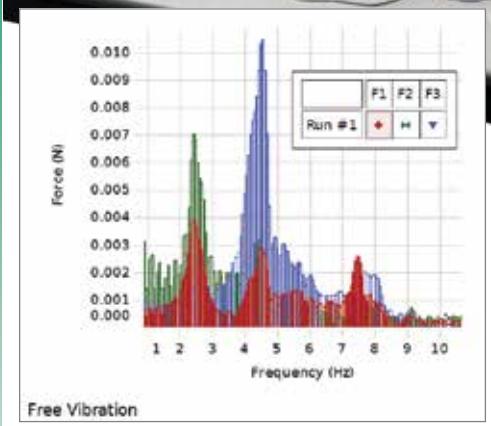


The resonance of the bridge is characterized by driving the bridge at different resonant frequencies. Note how different the amplitudes are at different locations on the bridge.



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. Using PASCO Capstone™, the FFT shows that there are several resonant frequencies. Note how different the amplitudes are at different locations on the bridge.

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

• 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
• Red 4 mm Banana Plug Cords	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

Order Information

Bridge Vibrations EX-5548

Required:

850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Tensile Testing Metals

EX-5557

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink

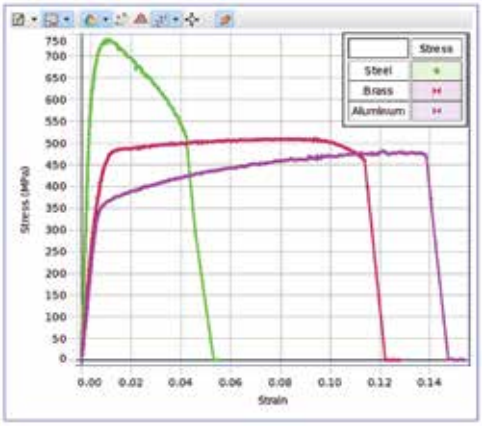
Concepts:

- Young's Modulus
- Yield Strength
- Tensile Strength
- Ductility
- Modulus of Toughness

The three metal tensile samples are made from 1018 Steel, 360 Brass and 2024-T3 Aluminum. The properties measured for these samples include Young's Modulus, Yield Strength, Tensile Strength, Ductility, and Modulus of Toughness. These properties are the same ones found in materials handbooks and databases and are used by engineers to design bridges, buildings, and machines.

1. Measure the slope in the linear portion of the Stress vs. Strain graph to find Young's Modulus for the material.
2. Estimate the Yield Strength by examining the Force vs. Position graph to see where the linear part of the curve ends.
3. Find the maximum stress on the graph to determine the Tensile Strength.
4. Find the maximum strain just before it breaks to determine the Ductility of the material.
5. Take the area under the Stress vs. Strain graph to determine the Modulus of Toughness for the material.

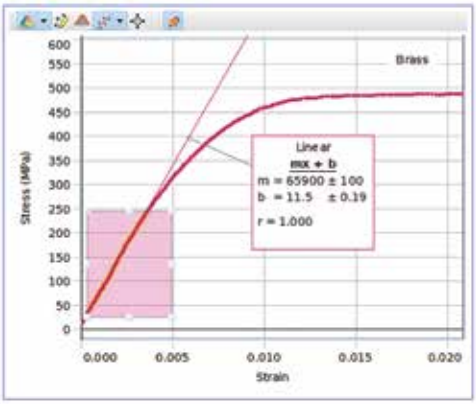




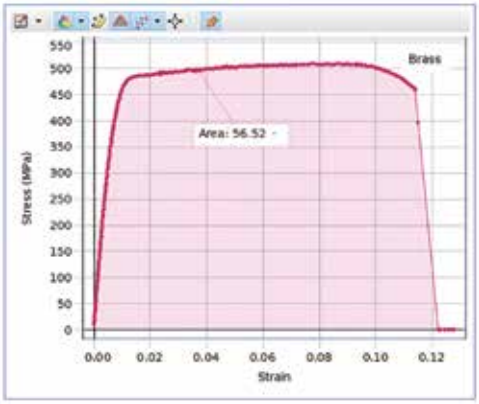
The Stress vs. Strain graph for three metals is displayed in real time and can be played back in PASCO Capstone software.

PASCO Advantage

The hand-cranked Materials Testing Machine allows students to feel the different forces required to break different samples. Data is recorded live and can be played back in PASCO Capstone software.



Young's Modulus for brass is determined from the slope of the line.



The toughness of brass is determined by taking the area under the Stress-Strain curve in PASCO Capstone software.

Experiment Includes

Materials Testing Machine	ME-8236
Tensile Samples (Aluminum, 10 ea.)	ME-8231
Tensile Samples (Brass, 10 ea.)	ME-8232
Tensile Samples (Steel, 10 ea.)	ME-8243
Calipers	SE-8710

Download This Experiment

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Order Information

Tensile Testing Metals EX-5557

Required:

AirLink PS-3200

550 or 850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Materials

Column Buckling

EX-5558

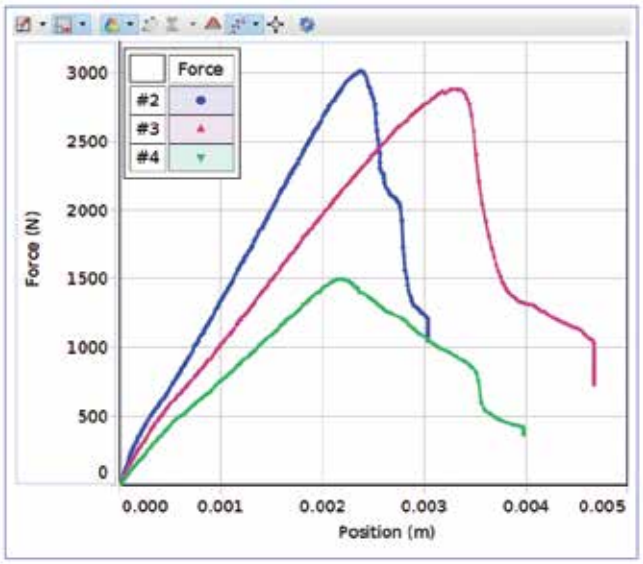
Designed for use with any of the following:

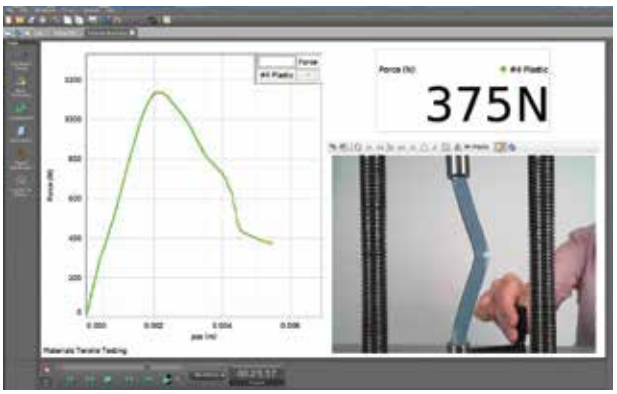
- 850 Universal Interface
- 550 Universal Interface
- AirLink

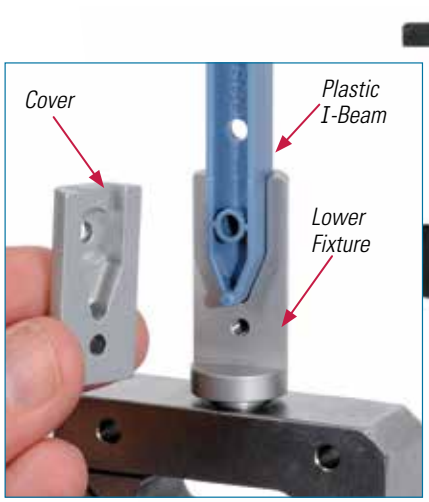
Concepts:

- Column Buckling of I-Beams
- Slenderness Ratio
- Euler Column Equation

In part one, three different length plastic I-beams are tested under compression to investigate their method of failure. The way in which a member fails (buckling or not) is determined by its Slenderness Ratio, and this ratio is calculated for each beam. Topics covered also include the Radius of Gyration and the Area Moment of Inertia.

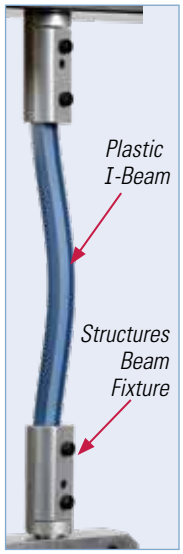






In part two, the critical force is predicted using the Euler Column Equation. When a compressive force is applied to a long straight column, it will elastically compress until a critical force (F_{crit}) is reached, and at this point the column will suddenly buckle. The relationship between this critical load and the column material and geometry is called the Euler Column Equation.

$$F_{crit} = \frac{4\pi^2 EI}{L^2}$$



PASCO Advantage

PASCO Capstone software has the ability to embed live video from a webcam and sync the Materials Tester data to the recorded video. Then you can play back the video along with the data on the graph, stepping through one frame at a time to see the exact breaking point

Experiment Includes

• Materials Testing Machine	ME-8236
• Structures Beam Adapter	ME-8242
• Structures Truss Set I-Beams	ME-6993
• Structures Flat Beam	ME-6987
• Structures Thin I-Beam	ME-7012
• Calipers	SE-8710

Required

- 550 or 850 Universal Interface or AirLink

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Order Information

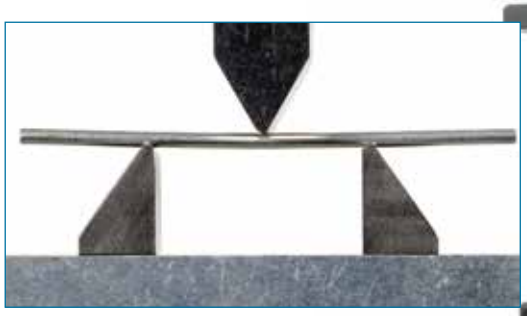
Column Buckling EX-5558
Required:
550 or 850 Universal Interface or AirLink ..... pp. 24-28
PASCO Capstone Software ..... pp. 70-73

3-Point and 4-Point Bending

EX-5559

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink



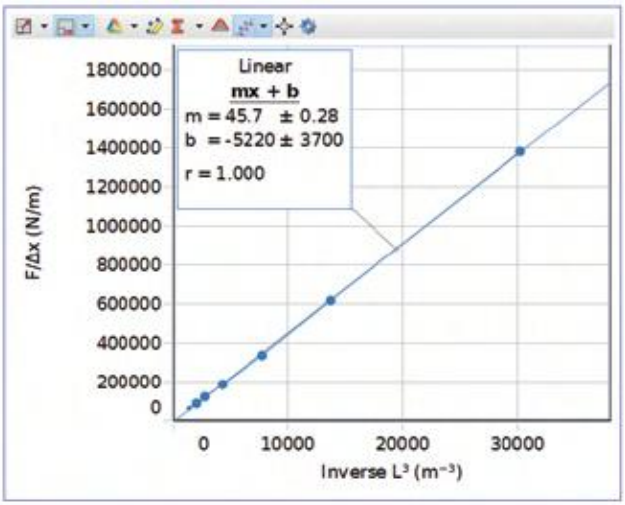
Concepts:

- 3-Point Bending
- 4-Point Bending
- Flexural Elastic Modulus

3-Point Bending

A Three-Point Bend test is performed on a round rod as shown. As a downward force (F) is applied in the middle of the rod, the flex (Δx) is recorded. The ratio (F/Δx) is the effective stiffness of the length of rod being tested.

The distance between the anvils is varied, and the resulting effect on the stiffness of the beam is measured. A graph of the resulting data yields the Flexural Elastic Modulus for the material.



4-Point Bending

A Four-Point Bend Test is performed on the ABS plastic beams from the PASCO Structures System. As a downward force (F) is applied in the middle of the beam, the flex (Δx) is recorded. The ratio (F/Δx) is the effective stiffness of the length of beam being tested, and is measured directly from the slope of the F vs. Δx graph. The Flexural Elastic Modulus for the material is then calculated.



Experiment Includes

• Materials Testing Machine	ME-8236
• Bending Accessory	ME-8237
• Shear Samples	ME-8240
• Structures Flat Beams	ME-6987
• Four-Point Load Anvil	ME-8249
• Calipers	SE-8710

Required

- 550 or 850 Universal Interface or AirLink
- PASCO Capstone software

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

3-Point and 4-Point Bending.....EX-5559

Required:

550 or 850 Universal Interface or AirLink .....pp. 24-28

PASCO Capstone Software.....pp. 70-73

Thermodynamics

Specific Heat

EX-5524A

Concepts:

- Thermal energy
- Equilibrium temperature
- Specific heat

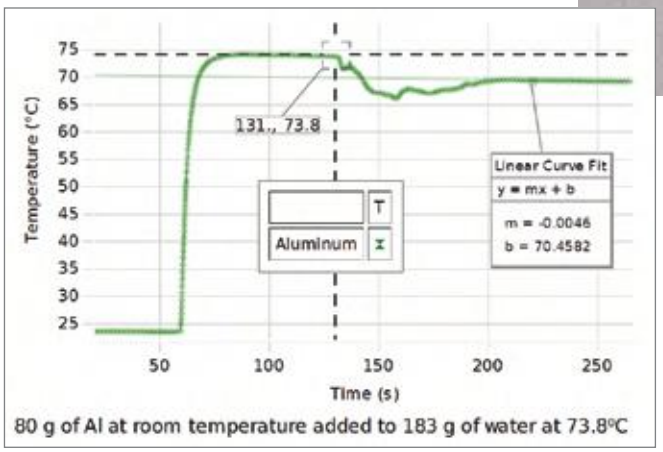
Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink

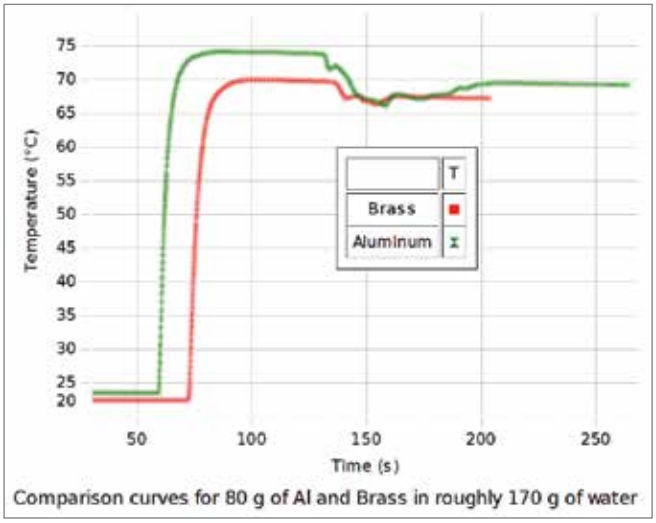


Students learn that materials can be identified using specific heat as a measurable characteristic. A known mass of water is used and the unknown material is placed in the water. The initial temperature of the water and the unknown material are measured. The equilibrium temperature is found and from 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 at approximately 10%.



Comparison of a 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
• Calorimetry Cup with Lid	
• Heater Stirrer	PS-3401
• Balance	SE-8723
• Hot Plate	SE-8830
• Graduated Cylinder, 50 mL	
• 1000-mL Beaker	
• Braided Physics String	SE-8050

Download This Experiment

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Order Information

Specific Heat EX-5524A

Required:

550 or 850 Universal Interface* ..... p. 26

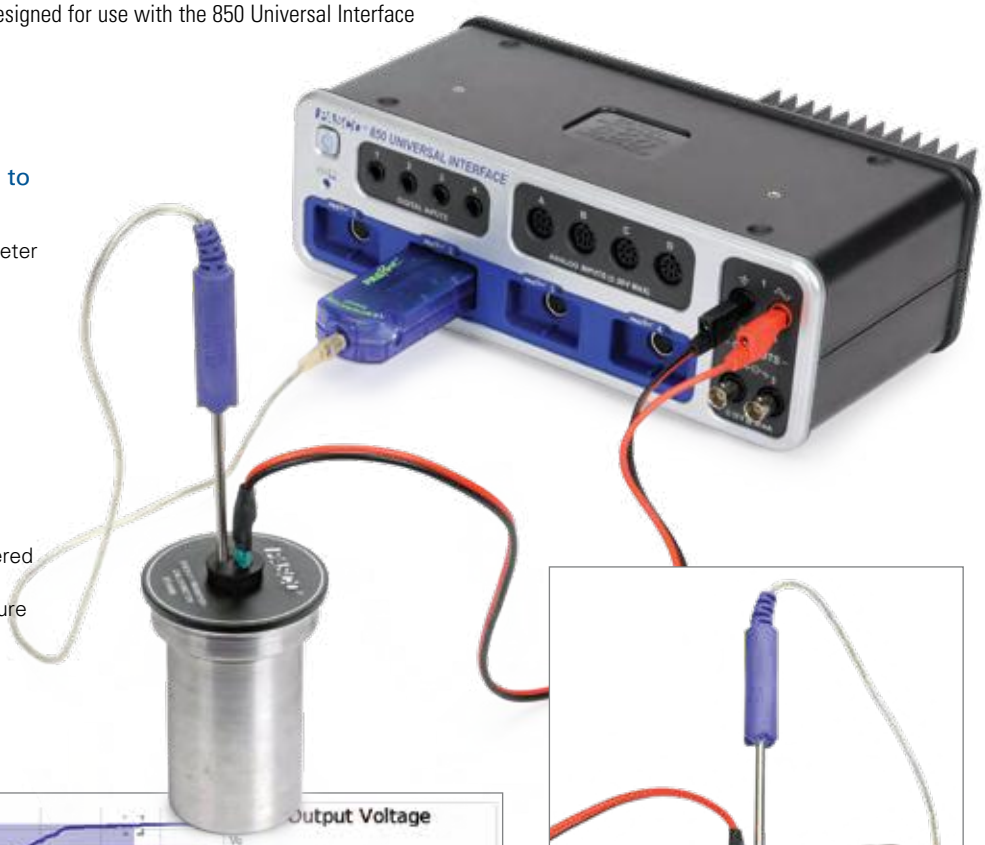
PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

Electrical Equivalent of Heat

EX-5525

Designed for use with the 850 Universal Interface

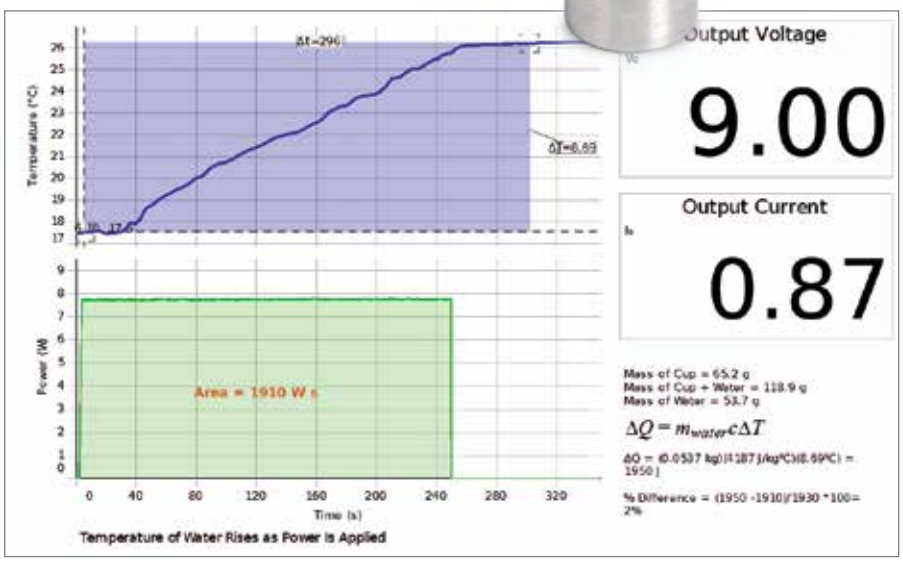


Concept:

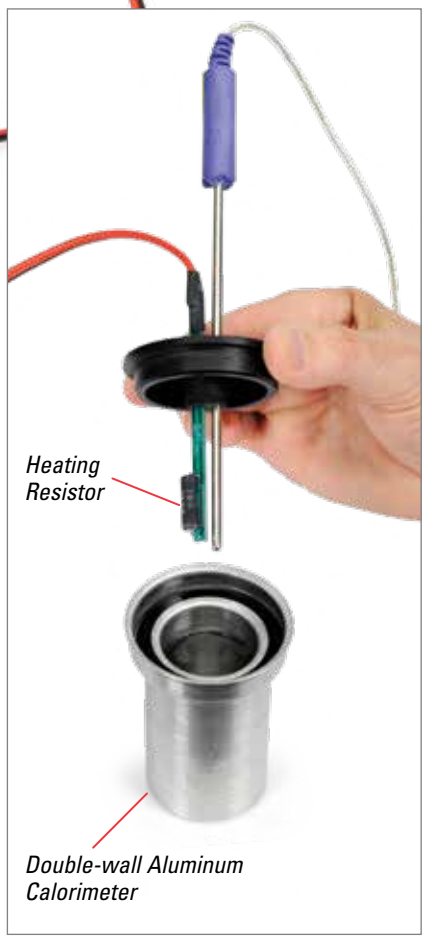
- Compare electrical energy input to changes in internal energy

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 vs. 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 bottom graph displays the power output from the generator and the top graph the increase in temperature. The amount of electrical energy used to heat the water is determined by finding the area under the Power vs. Time curve.



Experiment Includes

• Energy Transfer-Calorimeter	ET-8499
• Temperature Sensor	PS-2125
• Mass Scale	SE-8707

Download This Experiment

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Order Information

Electrical Equivalent of Heat EX-5525
Required:
850 Universal Interface ..... p. 26
PASCO Capstone Software ..... pp. 70-73

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.

PASCO Advantage

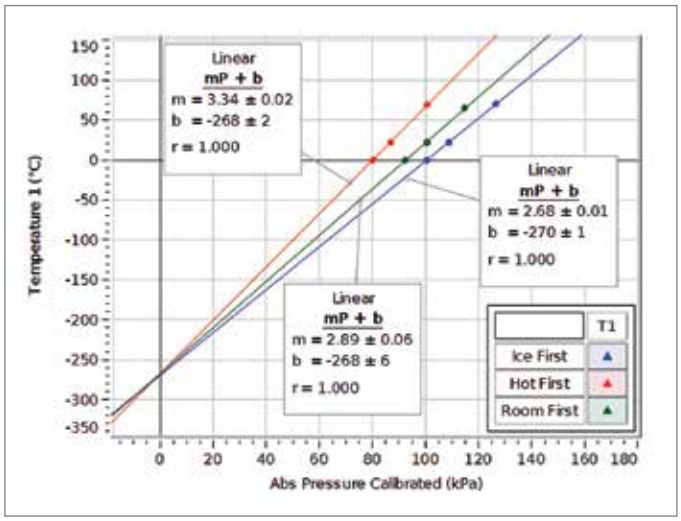
The Ideal Gas Syringe and Absolute Zero Sphere have a thermistor with small mass that responds quickly to temperature changes.

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink



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 vs. Temperature graphs have different slopes corresponding to the different number of moles in the container.



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

• Ideal Gas Law Syringe	TD-8596A
• Pressure/Temperature Sensor	PS-2146
• Absolute Zero Apparatus	TD-8595
• Plastic Containers (2)	ME-7559

Order Information

Ideal Gas Law EX-5527

Required:

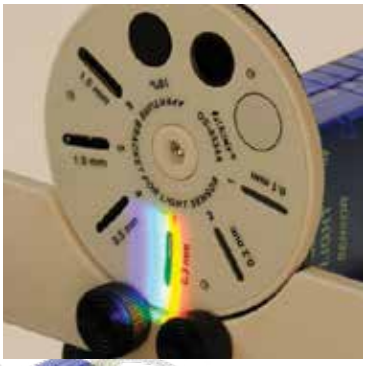
550 or 850 Universal Interface* ..... p. 26
PASCO Capstone Software ..... p. 70-73
Calipers ..... SE-8710 p. 192

** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

Blackbody Radiation

EX-5529A

Designed for use with the 850 Universal Interface

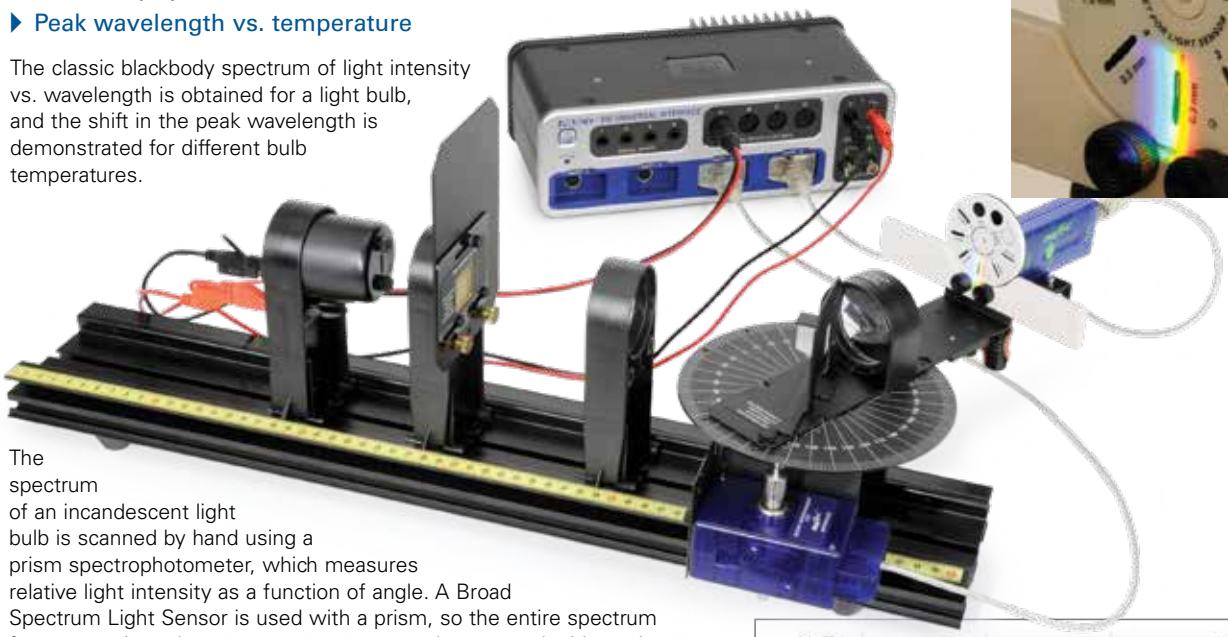


The continuous blackbody spectrum is scanned using a prism spectrophotometer.

Concepts:

- Blackbody spectrum
- Peak wavelength vs. temperature

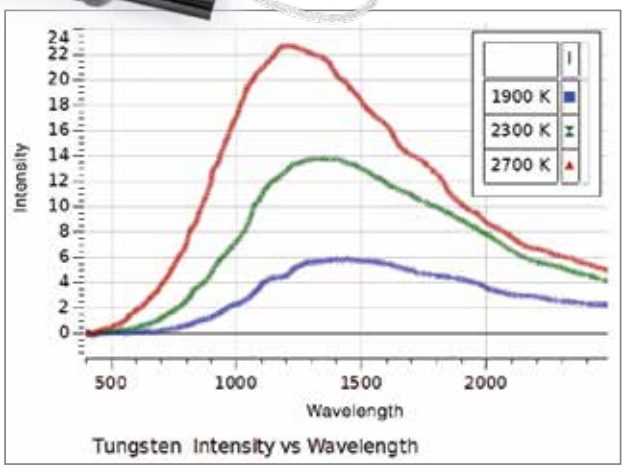
The classic blackbody spectrum of light intensity vs. wavelength is obtained for a light bulb, and the shift in the peak wavelength is demonstrated for different bulb temperatures.



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, which reduces 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 vs. 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 setup 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
• Black Banana Plug Cords (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**.

Order Information

Blackbody Radiation EX-5529A

Required:

850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Heat Engine Cycle

EX-5530B

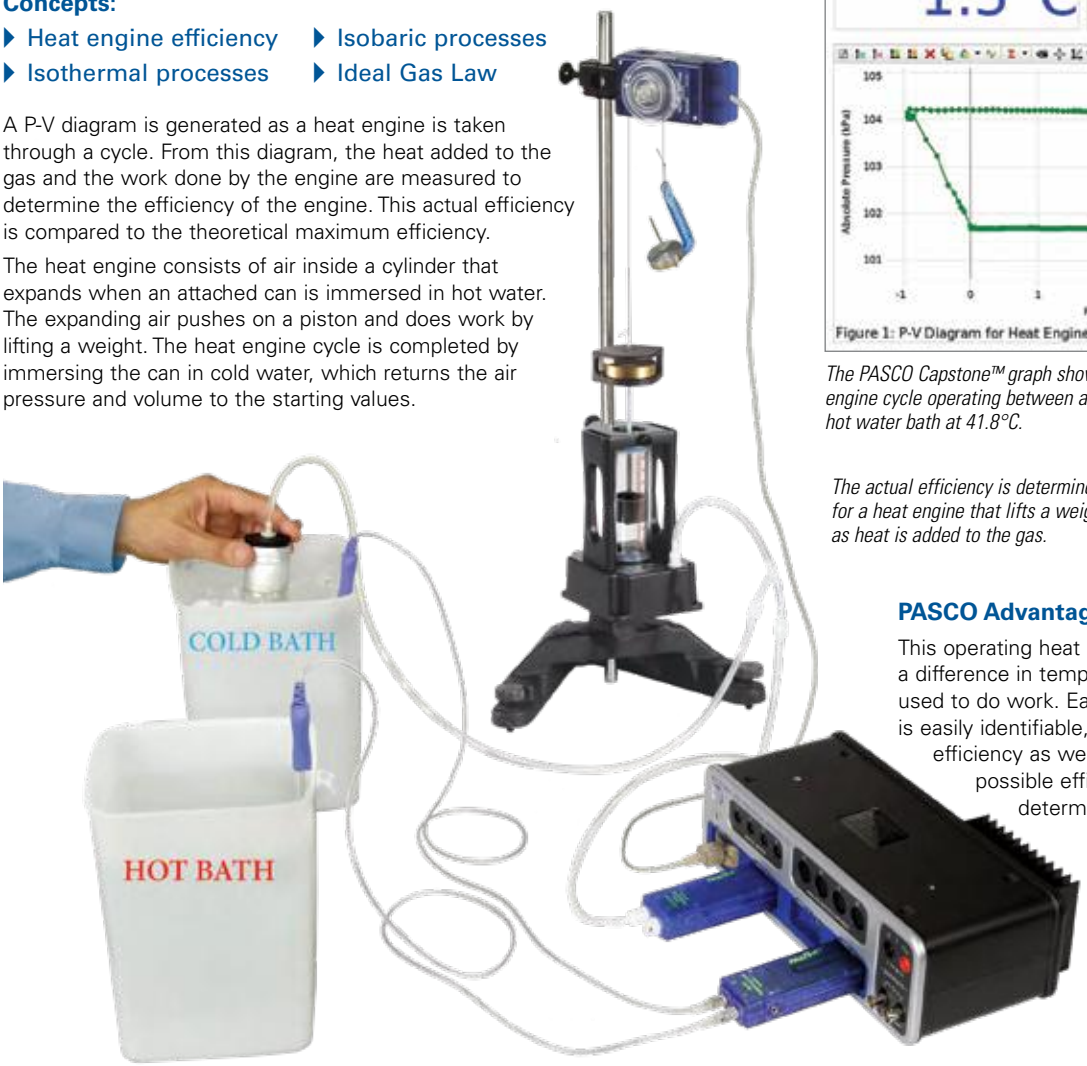
Designed for use with any of the following:
- 850 Universal Interface
- Any PASPORT interface with 3 ports

Concepts:

- Heat engine efficiency
- Isothermal processes
- Isobaric 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.



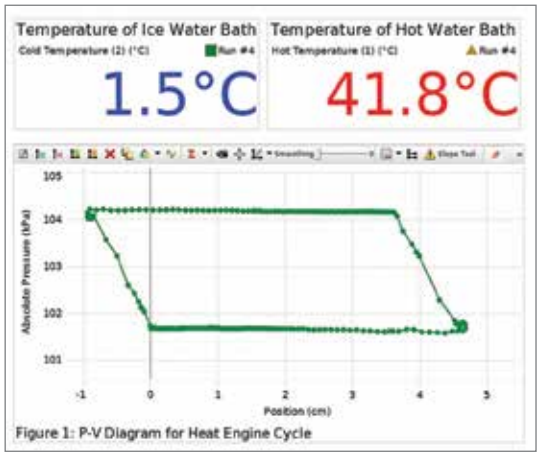


Figure 1: P-V Diagram for Heat Engine Cycle

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**.

Experiment Includes

• Heat Engine/Gas Law Apparatus	TD-8572A
• 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

Order Information

Heat Engine Cycle.....EX-5530B
Required:
550 or 850 Universal Interface*..... p. 26
PASCO Capstone Software..... pp. 70-73
** This experiment can be performed using the 850 Universal Interface or any PASPORT interface with three ports.*

Ratio of Specific Heats

EX-5531A

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- AirLink

Concepts:

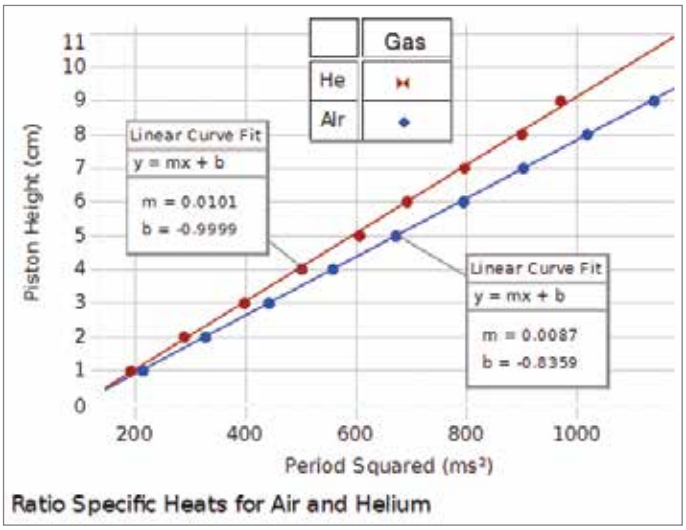
- C_p/C_v for a gas
- Ruchardt's method of measuring the ratio of specific heats
- Adiabatic process

In this experiment, the ratio of specific heat capacities for air is determined using Ruchardt's method of measuring the period of oscillation of the piston in a cylinder filled with air.

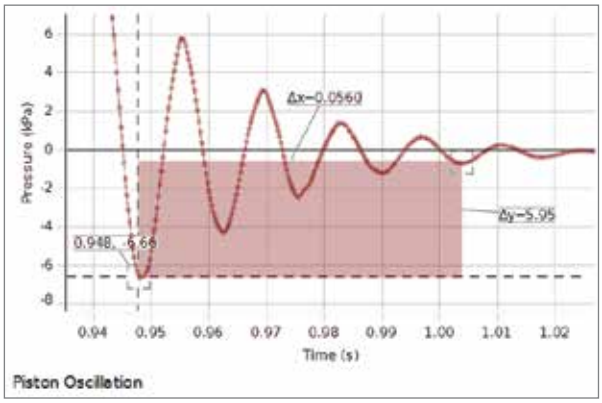
A cylinder is filled with air and a Pressure Sensor is attached. The piston is plucked by hand and allowed to oscillate. The oscillating pressure is recorded as a function of time and the period is determined. The ratio of specific heat capacities is calculated using the period of oscillation, according to Ruchardt's method.

PASCO Advantage

Since the oscillations are plotted, it is easy to accurately measure the period of oscillation.



A plot of the Piston Height vs. the Period Squared 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.

Experiment Includes

• Heat Engine/Gas Law Apparatus	TD-8572A
• Large Rod Stand	ME-8735
• 45 cm Long Steel Rod	ME-8736
• Dual Pressure Sensor	PS-2181

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

Ratio of Specific Heats EX-5531A

Required:

550 or 850 Universal Interface* ..... p. 26

PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or AirLink.*

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**.

Order Information

Electrostatic Charge.....EX-5532

Required:

PASCO Capstone Software.....pp. 70-73

(No interface required.)

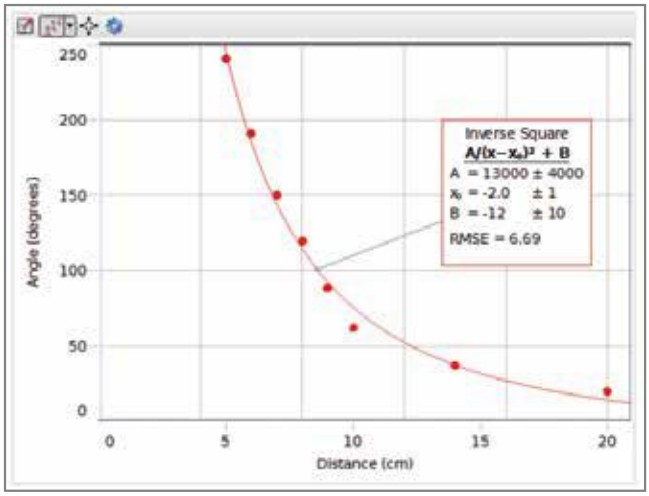
Coulomb's Law

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, and the angle of twist is proportional to the inverse square of the separation of the balls.



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	

To Download This Experiment

Search for EX-9930B at **www.pasco.com**

Order Information

Coulomb's Law.....EX-9930B

(No interface required.)

Charge of an Electron

EX-9929A

Concepts:

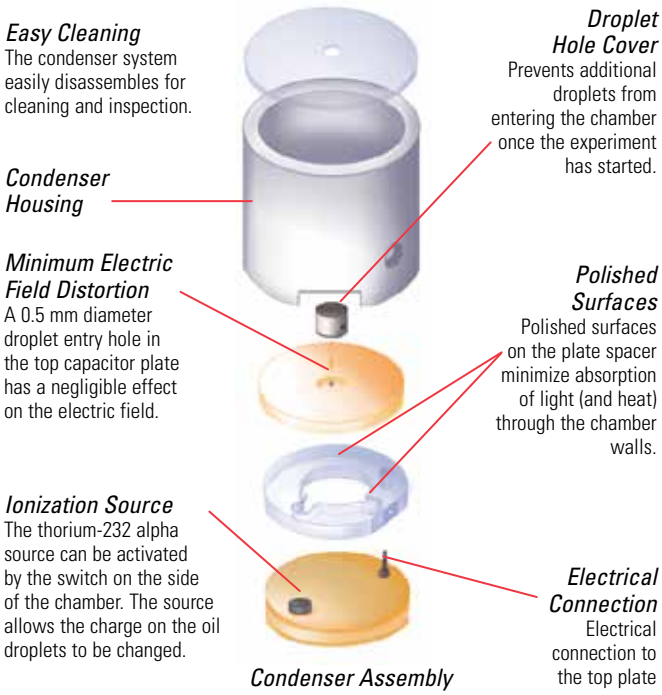
- Accurately measure the charge of a single electron
- Recreate Robert Millikan's historical experiment

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.



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
• Red Banana Plug Cords (5 Pack)	SE-9750
• Black Banana Plug Cords (5 Pack)	SE-9751
• Charge of an Electron Experiment Manual	

To Download This Experiment

Search for EX-9929A at **www.pasco.com**

Order Information

Charge of an Electron EX-9929A

(No interface required.)

Capacitance

EX-5533

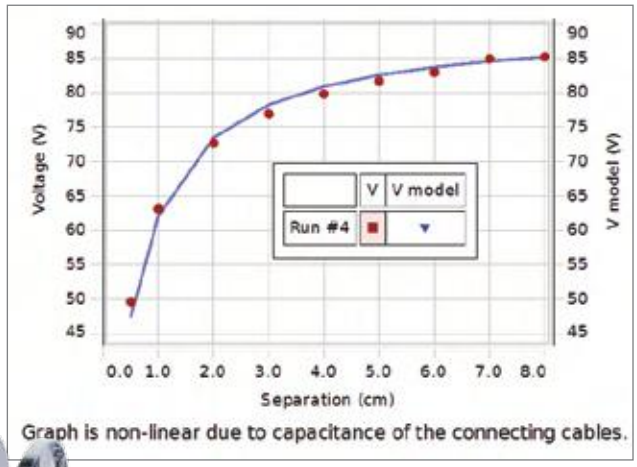
Designed for use with any of the following:
- 850 Universal Interface
- 550 Universal Interface

Concepts:

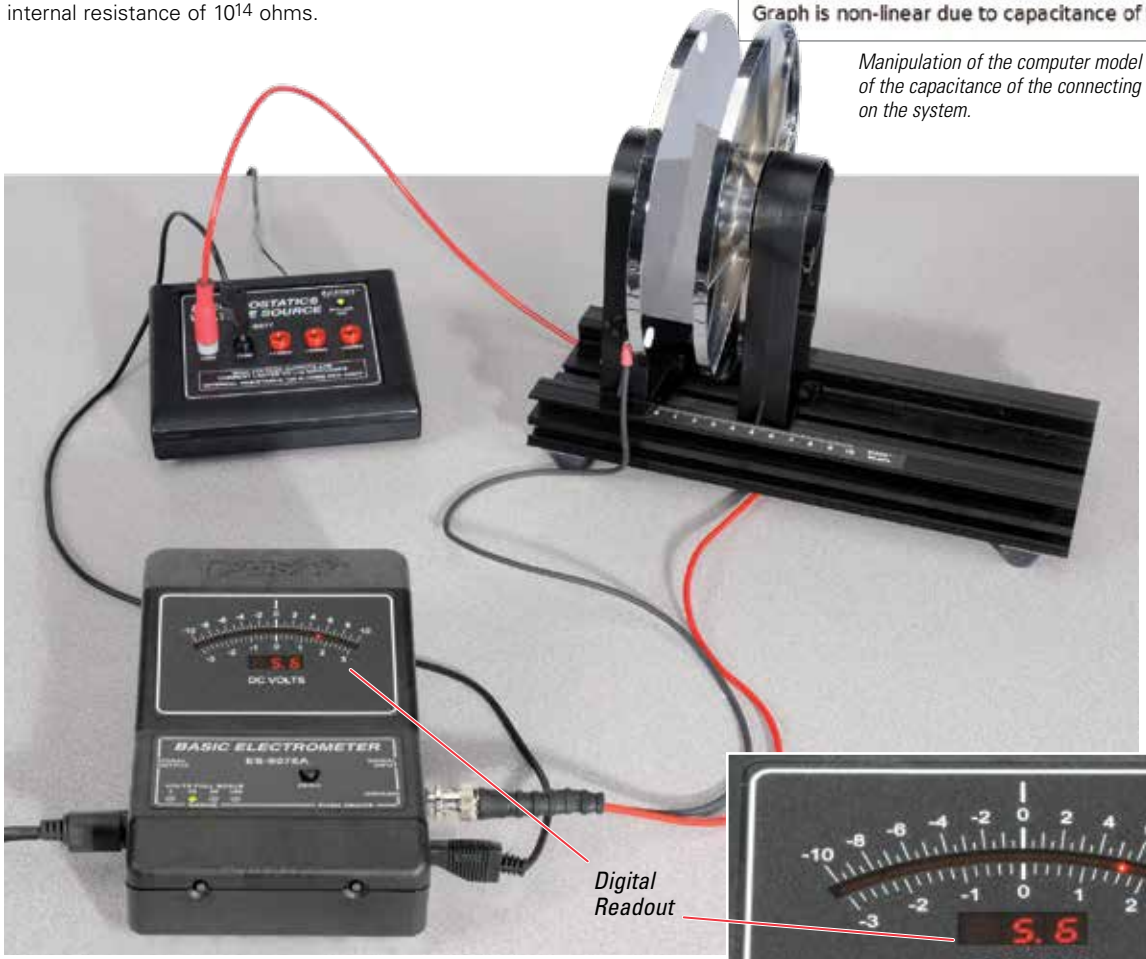
- Capacitance
- Parallel plate capacitor
- Factors affecting capacitance

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.



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**.

Order Information

Capacitance EX-5533

Required:

550 or 850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Electromagnetism

Resistivity

EX-5534

Designed for use with the 850 Universal Interface

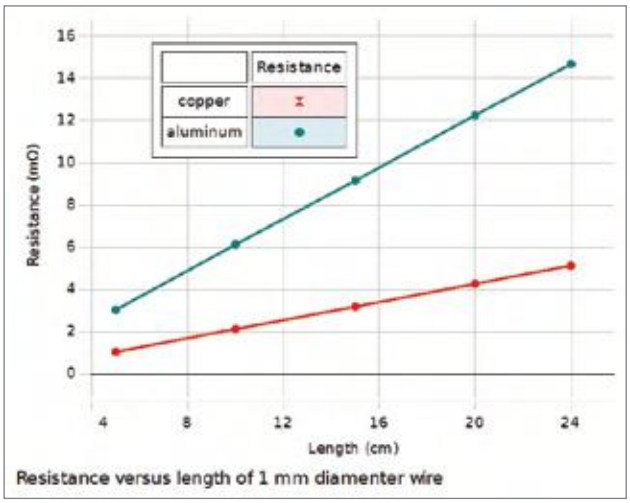
Concepts:

- 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 vs. 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 ..... p. 26
PASCO Capstone Software ..... pp. 70-73
Micrometer ..... p. 192

Ohm's Law

EX-5535

Designed for use with any of the following:
- 850 Universal Interface
- 550 Universal Interface

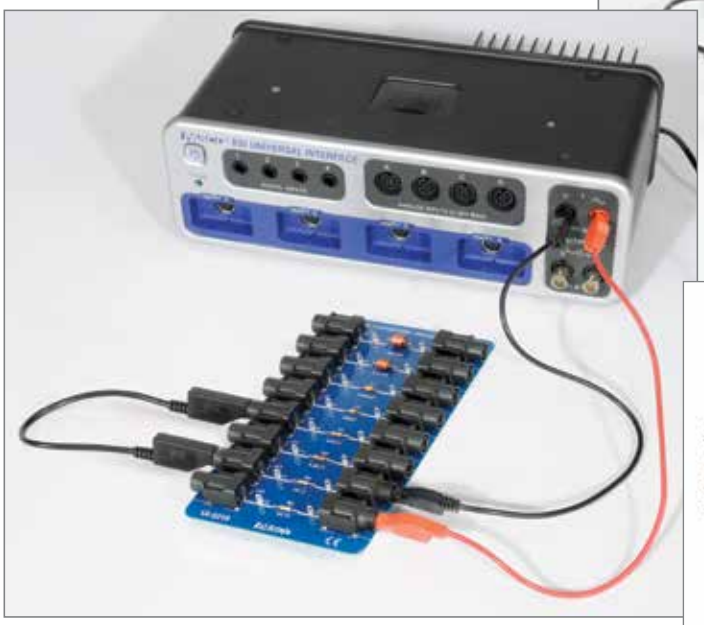
Concepts:

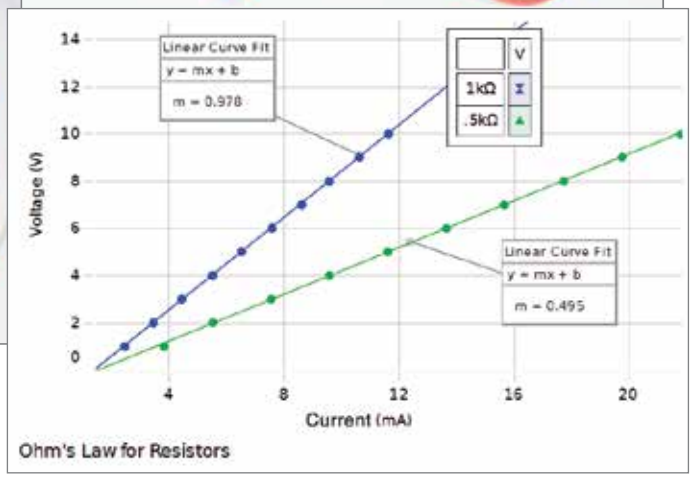
- Relationship between voltage and current

Method

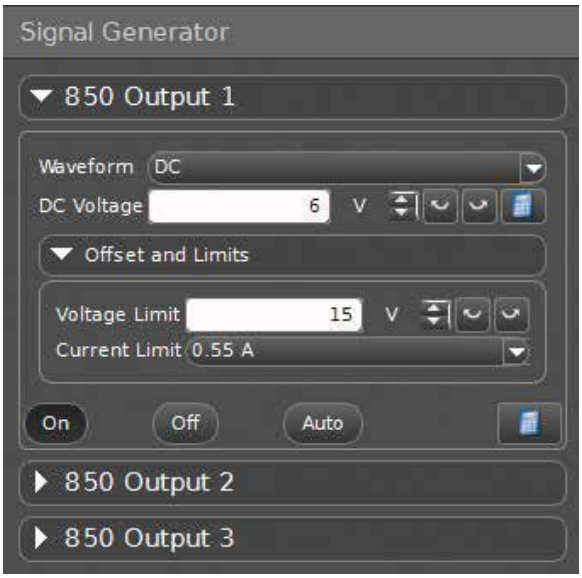
In this experiment, students simultaneously measure both current and voltage for a simple DC circuit. The relationship between current and voltage is explored for different resistors in parallel. Voltage is graphed vs. current to verify Ohm's Law and recognize the physical meaning of slope.







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**.

Order Information

Ohm's Law EX-5535

Required:

550 or 850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Electromagnetism

Kirchhoff's Circuit Law

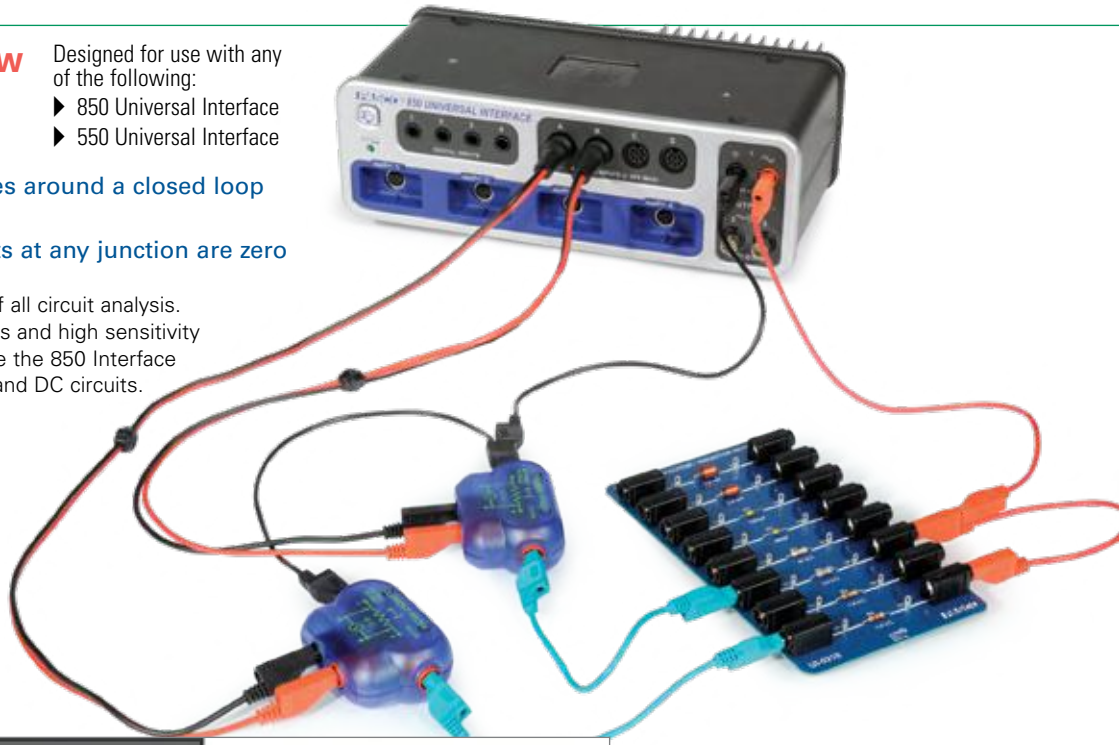
EX-5538

Designed for use with any of the following:
- 850 Universal Interface
- 550 Universal Interface

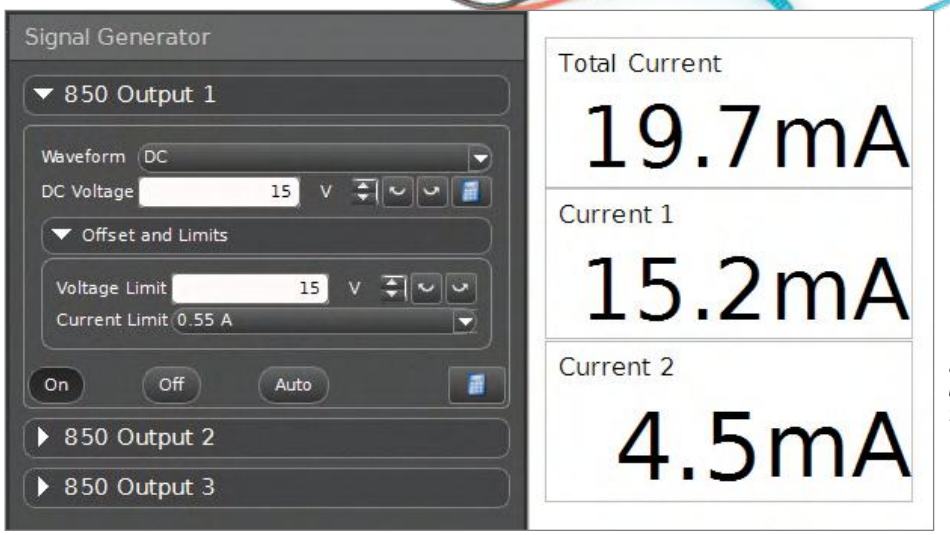
Concepts:

- 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.

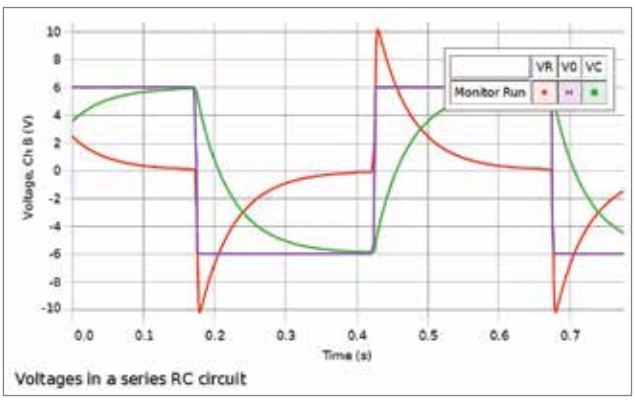


Students control output from the 850 signal generators directly from the user interface in PASCO Capstone.



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:

550 or 850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

RC Circuit

EX-5536

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface

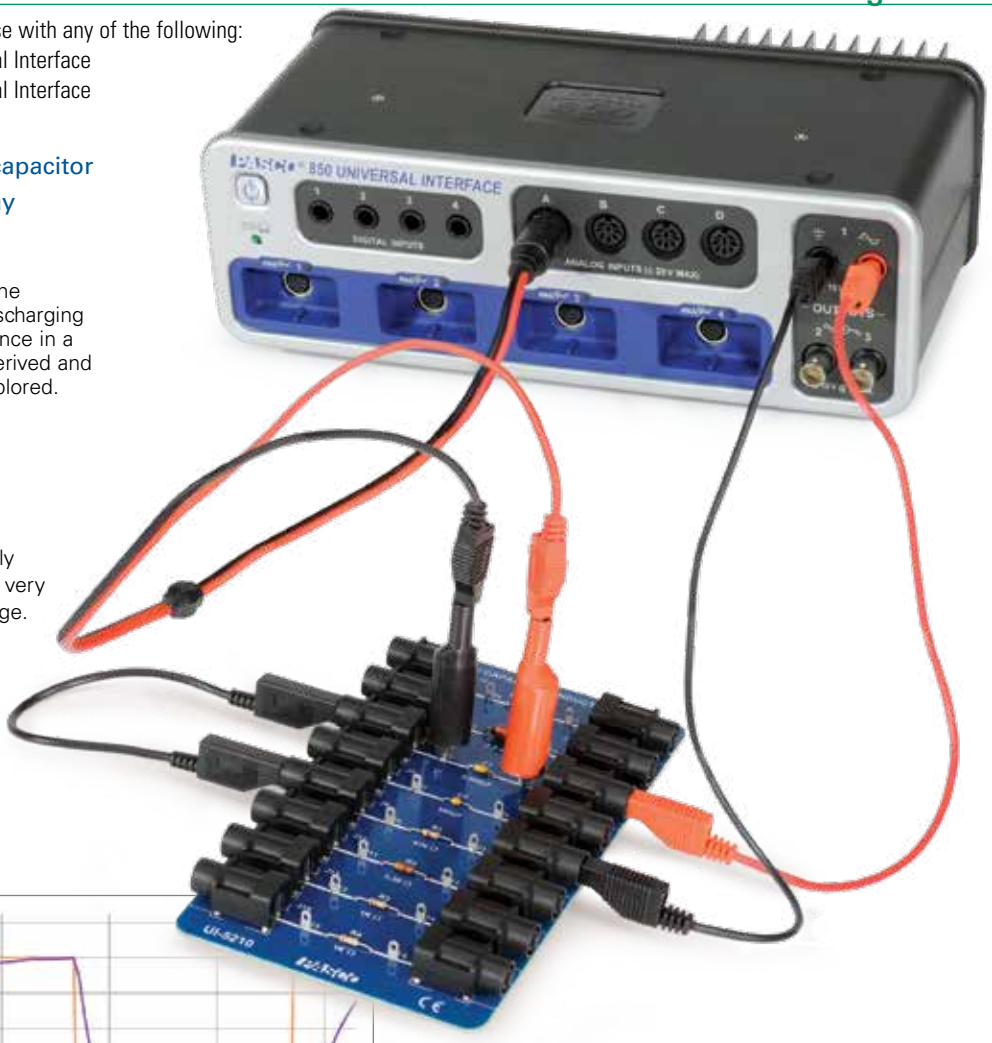
Concepts:

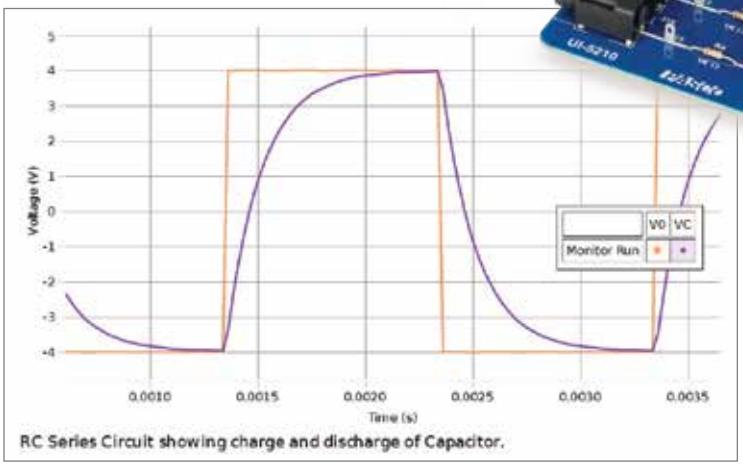
- Charging and discharging a capacitor
- Exponential growth and decay
- Time constants

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

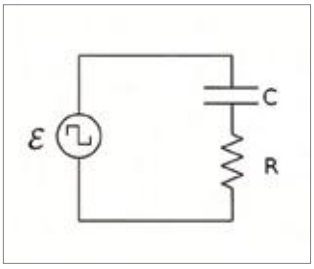
The RC Circuit experiment is extremely simple and transparent to set up. It is very easy to measure the time to half charge. It is also easy to verify that the curve is exponential using the curve-fitting capability of PASCO Capstone software.





RC Series Circuit showing charge and discharge of Capacitor.

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

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

RC Circuit.....EX-5536

Required:

550 or 850 Universal Interface..... p. 26
PASCO Capstone Software..... p. 70-73

LRC Circuit

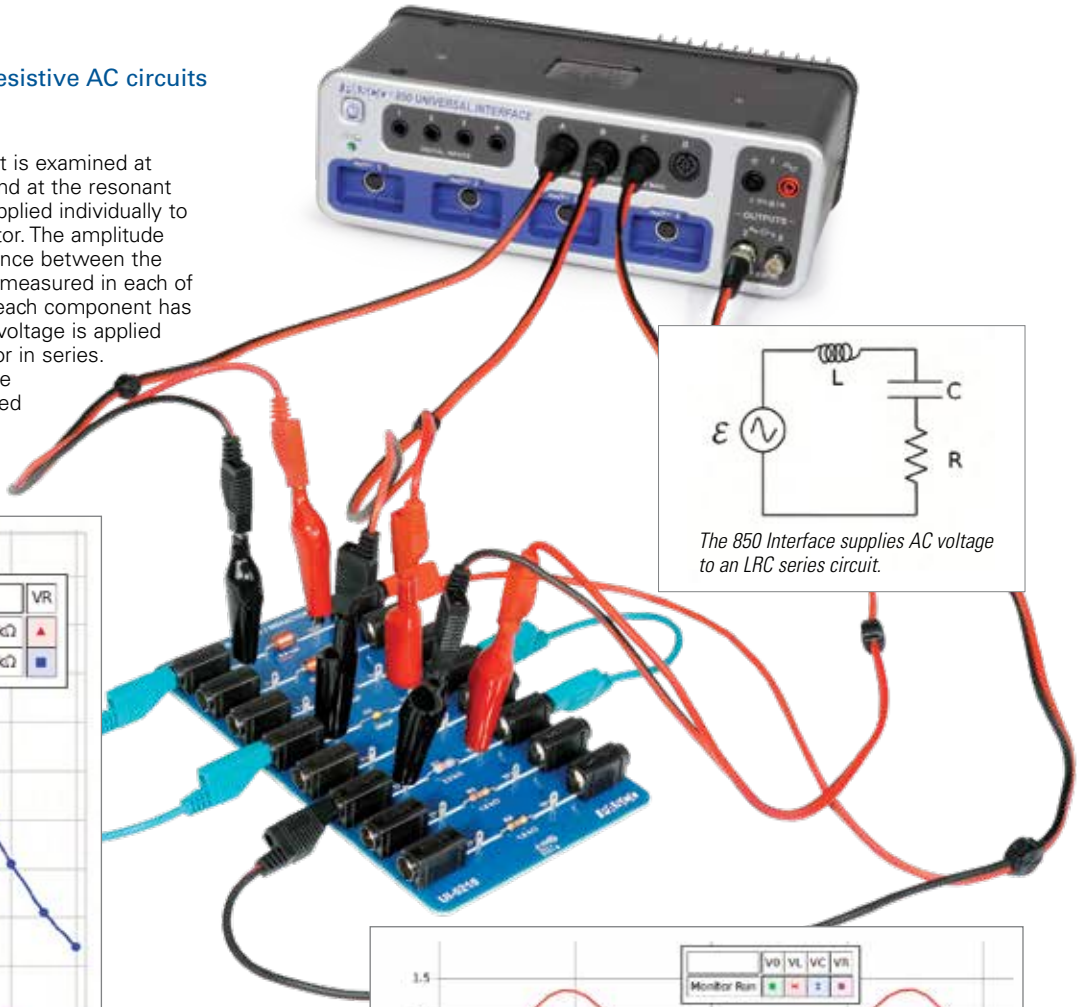
Designed for use with the 850 Universal Interface

EX-5537

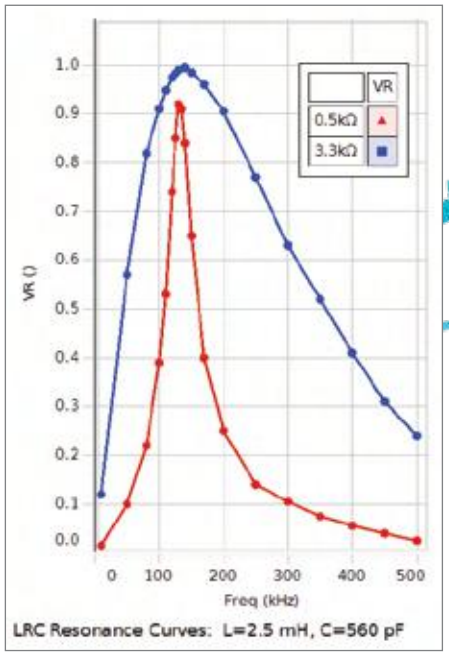
Concepts:

- LC oscillations
- Inductive, capacitive, and resistive AC circuits
- LRC resonant frequency

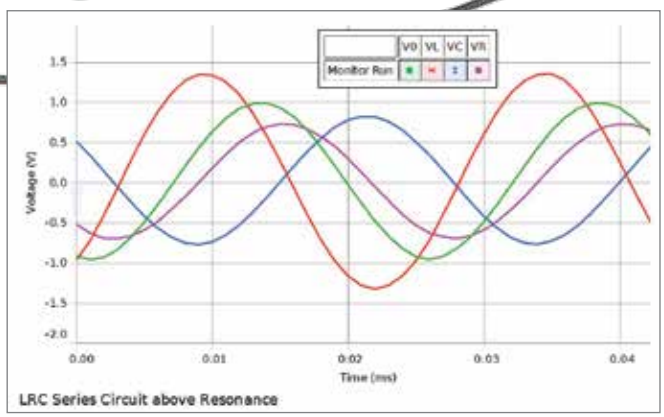
The response of a series LRC circuit is examined at driving frequencies above, below, and at the resonant frequency. A sinusoidal voltage is applied individually to a resistor, a capacitor, and an inductor. The amplitude of the current and the phase difference between the applied voltage and the current 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.



The effect of circuit resistance on peak width is clear and leads to an understanding of how to design a filter for a circuit.



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**.

Order Information

LRC Circuit.....EX-5537

Required:

850 Universal Interface.....p. 26

PASCO Capstone Software.....pp. 70-73

Earth's Magnetic Field

EX-5539A

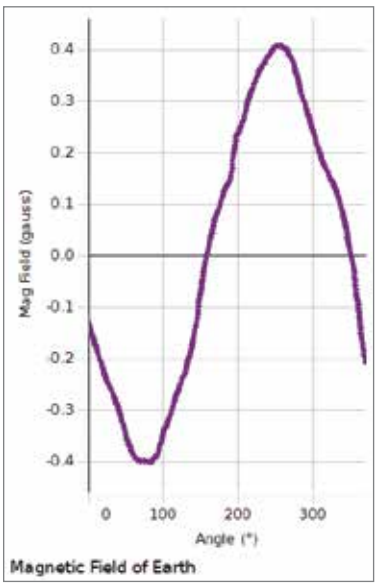
Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports

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 Earth's magnetic field is measured as the Magnetic Field Sensor is rotated 360 degrees in the Earth's field.



The Magnetic Field Sensor is mounted on a Rotary Motion Sensor to measure the magnitude and direction of the Earth's magnetic 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

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

Earth's Magnetic Field EX-5539A

Required:

550 or 850 Universal Interface* ..... p. 26
PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 850 or 550 Universal Interface or any PASPORT interface with two ports.*

Magnetic Forces on Wires

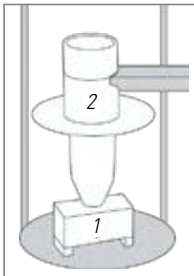
EX-9933

Concepts:

- Examine the relationships between: force and current, force and length of wire, force and magnetic field strength, and force and angle

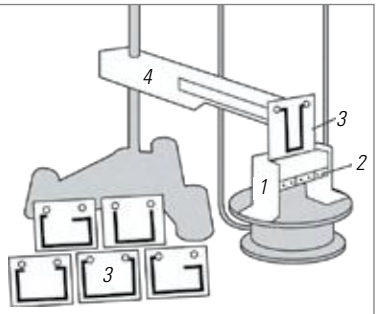


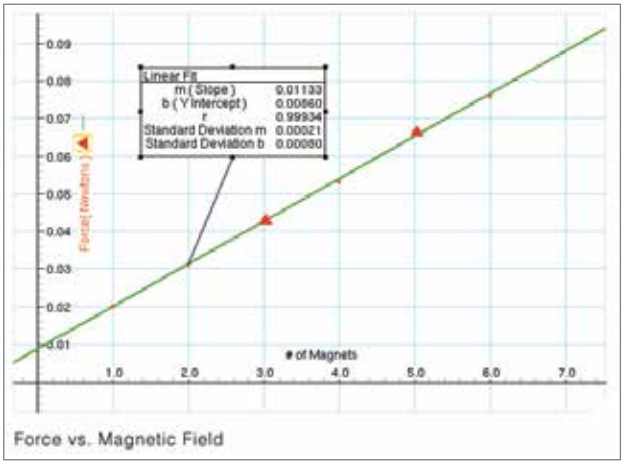




1. *Fixed Magnet with Yoke*
2. *10-turn Rectangular Coil (with a built-in degree scale)*

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)*





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 Forces on Wires Experiment allows students to study the key variables (conductor length, current, magnetic field strength, and angle) that affect magnetic force.

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
• Red Banana Plug Cords (5 pack)	SE-9750
• Black Banana Plug Cords (5 pack)	SE-9751
• Magnetic Forces on Wires Experiment Manual	

To Download This Experiment

Search for EX-9933 at **www.pasco.com**

Order Information

Magnetic Forces on Wires EX-9933

No interface required.

Magnetic Fields of Coils

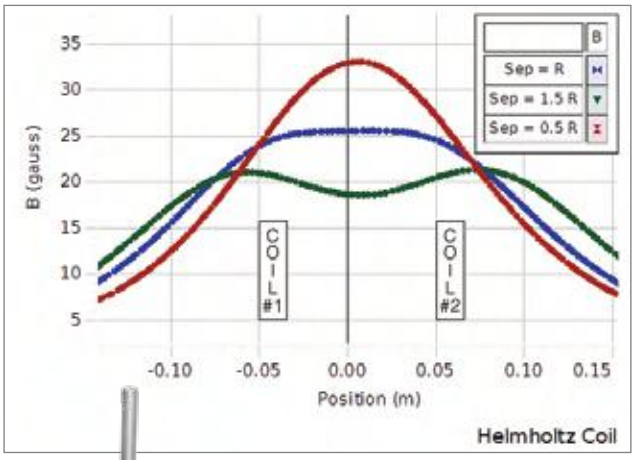
EX-5540A

Designed for use with the 850 Universal Interface

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 vs. 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 vs. 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
• Red Patch Cords (set of 5)	SE-9750
• Black Patch Cords (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
• Round Base with Rod (2 of each)	ME-8270
• 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**.

Order Information

Magnetic Fields of Coils EX-5540A

Required:

850 Universal Interface ..... p. 26

PASCO Capstone Software ..... pp. 70-73

Ampere's Law Experiment

NEW

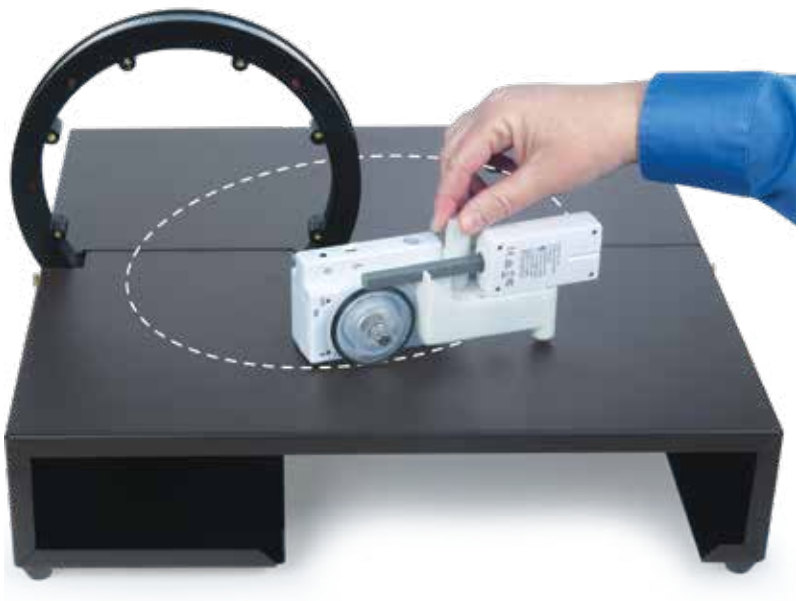
EX-5552

Concepts:

- Verify Ampere's Law
- Plot magnetic field tangent to path
- Closed integral is area under B vs. Distance plot
- Choose to enclose current in path or not

Students can verify Ampere's Law experimentally by graphing the magnetic field strength that is tangent to the path taken along a closed path that encloses a current source.

The magnetic field strength is measured with a Wireless Magnetic Field Sensor which rides on a Rotary Motion Sensor. The student pushes the Rotary Motion Sensor, which rolls on its wheel, along a closed path.



The path taken can be any shape, provided that it is a closed path. The suggested dotted path shown is not marked on the apparatus.

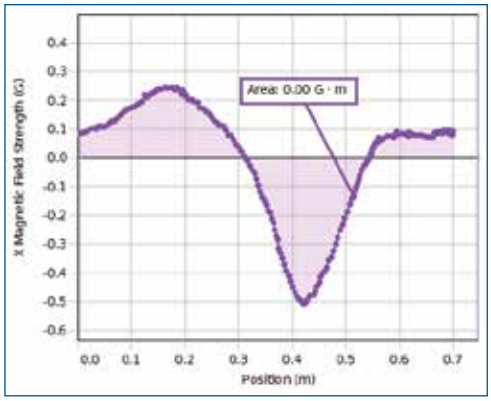
PASCO Advantage

The Wireless 3-Axis Magnetic Field and Rotary Motion sensors allow the students to move in any shaped path without wires getting wrapped around the coil. Students can choose any path they want; you don't have to follow a circular path because the sensors are recording the field tangent to any path.

Ampere's Law

$$\oint \vec{B} \cdot \vec{dl} = \mu_o NI$$

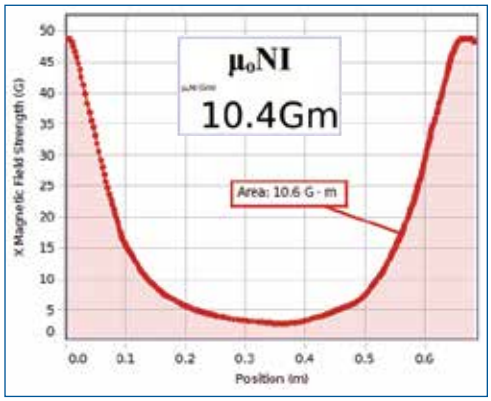
Area under B vs. Distance curve = μ_0 (# of coil turns enclosed in path) (Current)



No current enclosed: Area is zero.

The key to making this work is that the Magnetic Field Sensor element is positioned tangent to the Rotary Motion Sensor's wheel. This accomplishes the dot product in Ampere's Law because only the component of the magnetic field that is tangent to the path is recorded.

If you traverse a path that does not enclose any current source, the area under the curve is zero. The magnetic field of the Earth or any nearby source is measured but they will cancel out in a closed loop that encloses no current.



Current enclosed: Area is $\mu_0 NI$.

Includes

• Ampere's Law Accessory	EM-6720
• Wireless 3-Axis Magnetic Field Sensor	PS-3221
• Wireless Rotary Motion Sensor	PS-3220
• Field Coil (500-turn)	EM-6723
• Zero Gauss Chamber	EM-8652

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

Coming soon!
Check pasco.com for availability.

Ampere's Law.....EX-5552

Required:

PASCO Capstone Software.....pp. 70-73

Faraday's Law of Induction

EX-5541A

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface

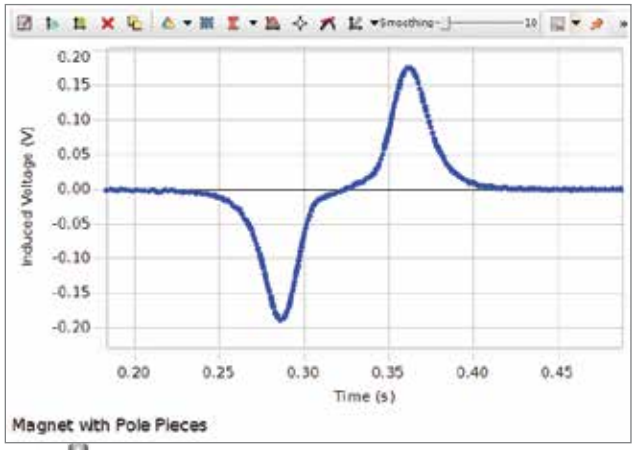
Concepts:

- 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 vs. 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 vs. 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.

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

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

Faraday's Law of Induction EX-5541A

Required:

550 or 850 Universal Interface ..... pp. 26-28

PASCO Capstone Software ..... pp. 70-73

Vibrating String

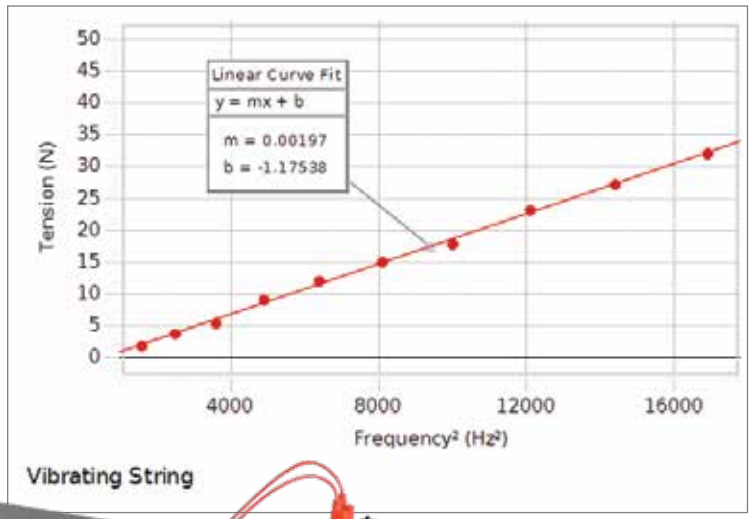
EX-5542

Designed for use with the 850 Universal Interface

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.

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

• String Vibrator	WA-9857
• Physics String	SE-8050
• High Resolution Force Sensor	PS-2189
• Large "C" Clamp	
• Patch Cords (set of 5)	SE-9750
• Tape Measure	SE-8712A

Order Information

Vibrating String..... EX-5542

Required:

850 Universal Interface..... p. 26

PASCO Capstone Software..... pp. 70-73

Waves

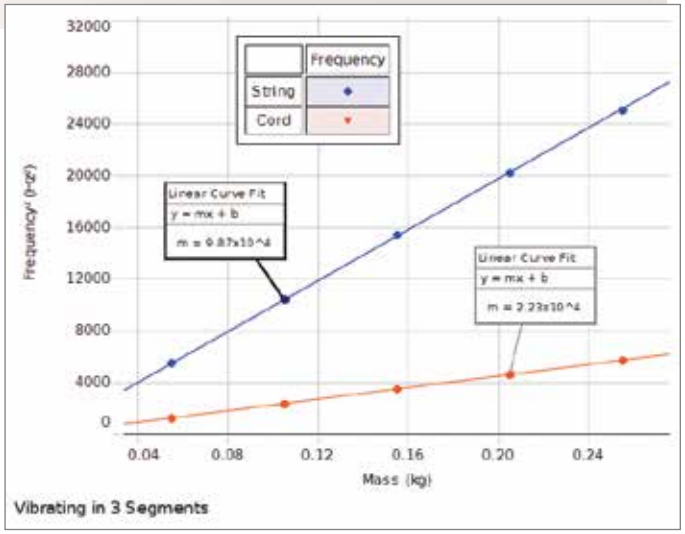
EX-9952

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 vs. open tubes.



Graphs of the square of the frequency vs. 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
• Red Banana Plug Cord Set	SE-9750
• Waves Experiment Manual	

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.

To Download The Manual

Search for EX-9952 at **www.pasco.com**

Order Information

Waves.....EX-9952

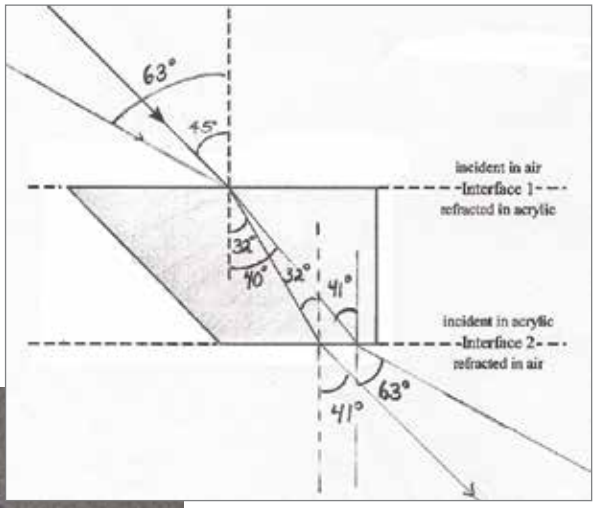
Reflection and Refraction

EX-9987

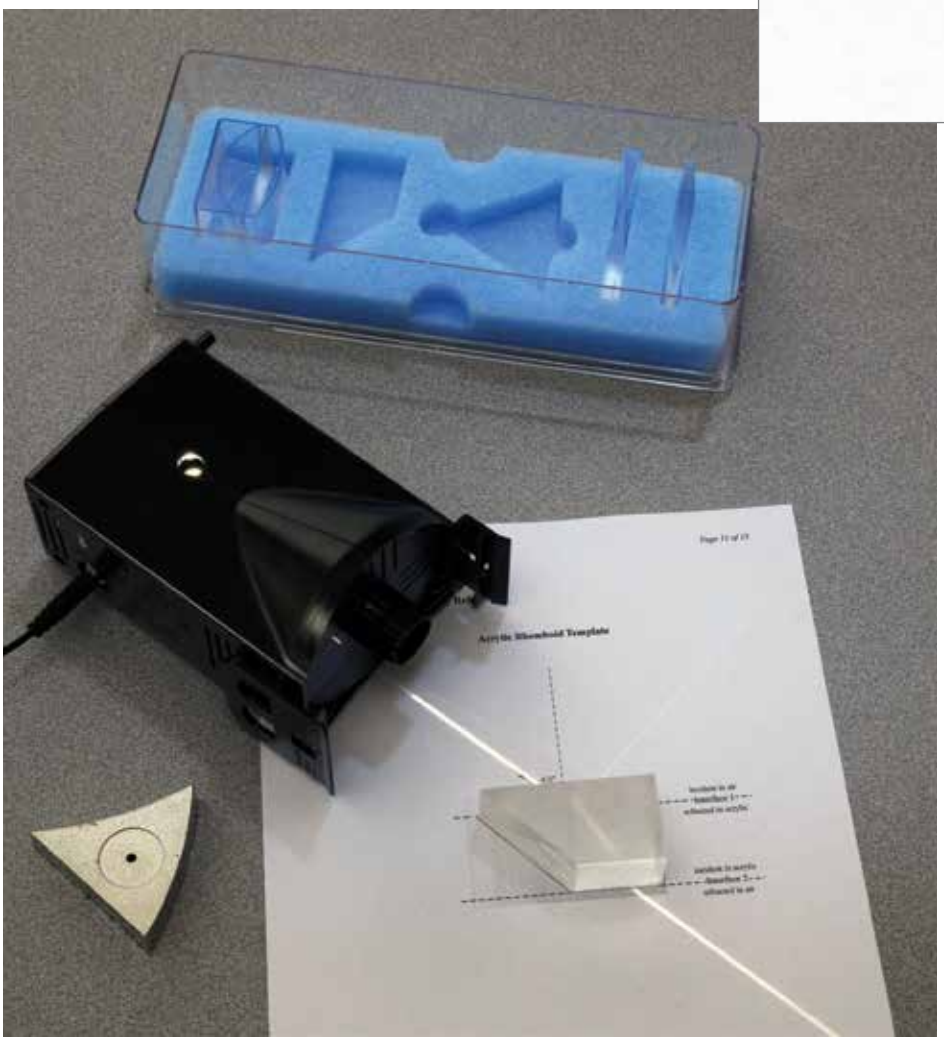
Concepts:

- 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	

Order Information

Reflection and Refraction..... EX-9987

Required:
Protractor and Ruler

To Download The Manual

Search for EX-9987 at **www.pasco.com**

Speed of Light

EX-9932A

CLASS II LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

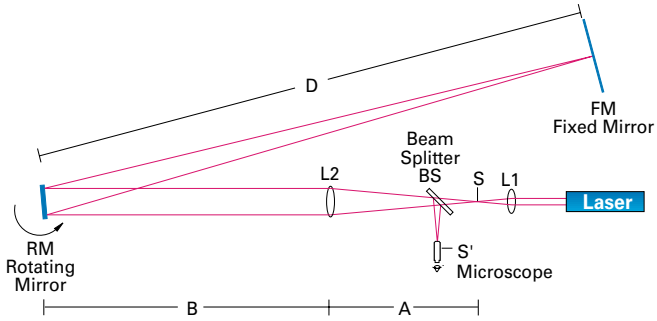
Concepts:

- 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

To Download This Experiment

Search for EX-9932A at **www.pasco.com**

Order Information

Speed of Light.....EX-9932A

Telescope/Microscope

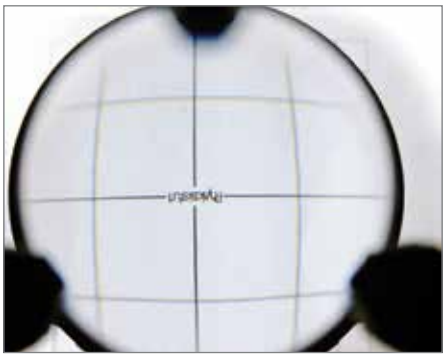
EX-9988

Concepts:

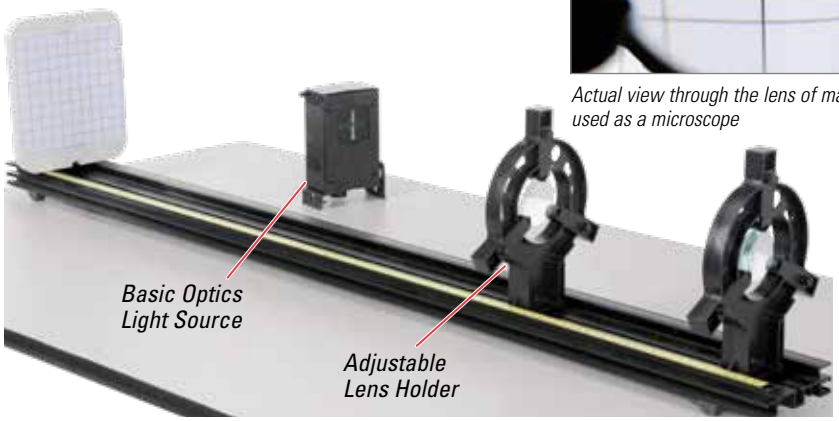
- Multiple lens systems
- Magnification
- Parallax
- Description of images

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.



Actual view through the lens of magnified screen when used as a microscope



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

To Download This Experiment

Search for EX-9988 at **www.pasco.com**

Order Information

Telescope and Microscope EX-9988
Required:
Rubber Bands and Ruler

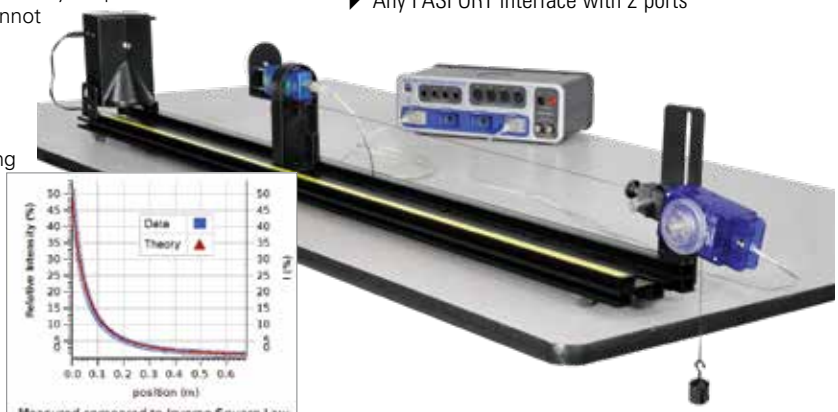
Light Intensity vs. Distance

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.

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports



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.

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

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* ..... p. 26
PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.*

Interference and Diffraction of Light

EX-5545A

Designed for use with any of the following:

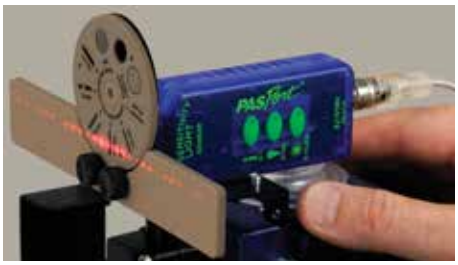
- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports

Concepts:

- Two-slit interference
- Single-slit diffraction
- Multiple-slit minor maxima
- Slit vs. 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.

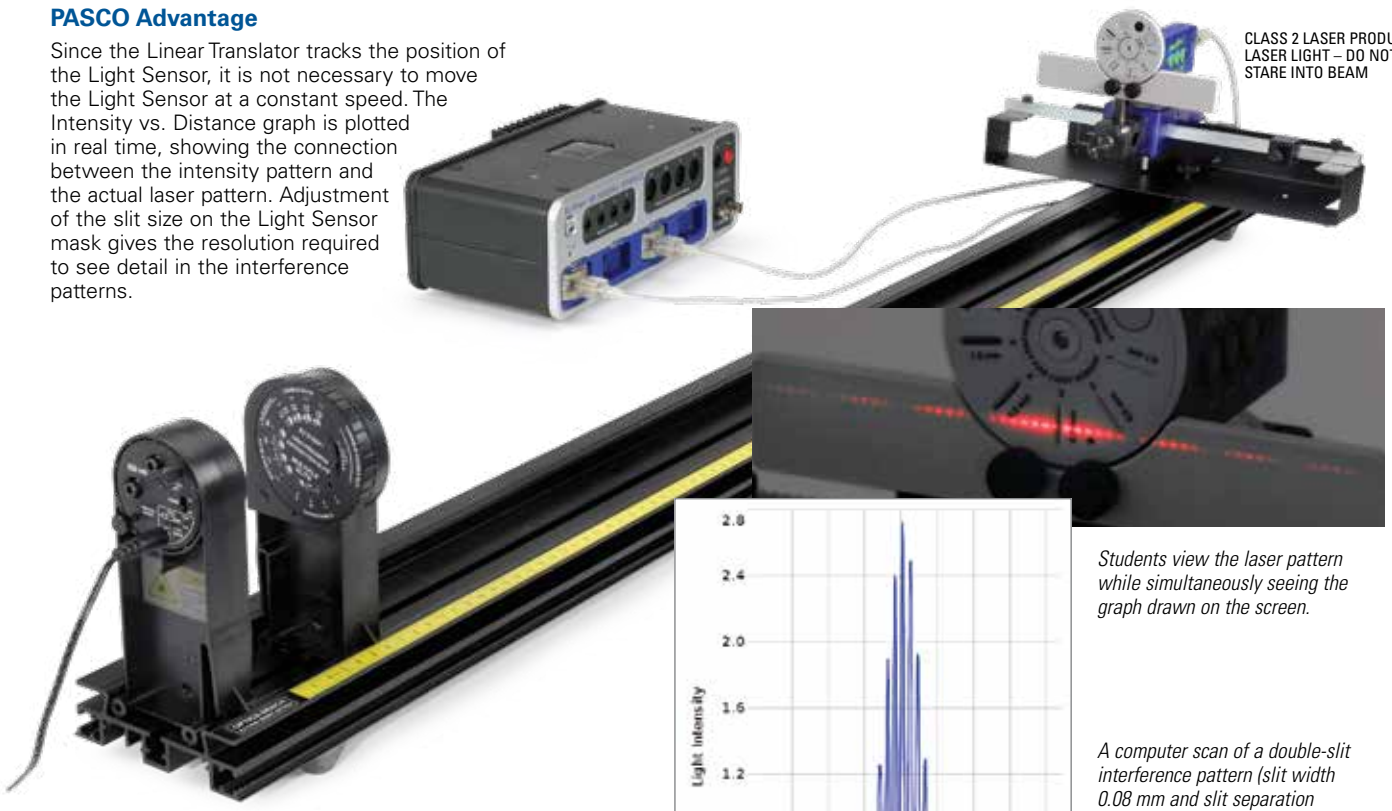
The distances between the central maximum and the diffraction minima for a single slit are measured by scanning the laser pattern with a Light Sensor and plotting light intensity vs. distance. Also, the distances between interference maxima for two or more slits are measured. These measurements are compared 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 vs. 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

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

Interference and Diffraction of Light EX-5545A

Required:

550 or 850 Universal Interface* ..... p. 26

PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.*

Polarization of Light

EX-5543A

Designed for use with any of the following:

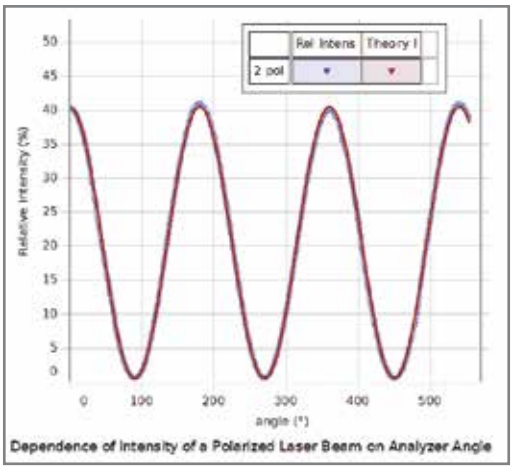
- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports

Concept:

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.

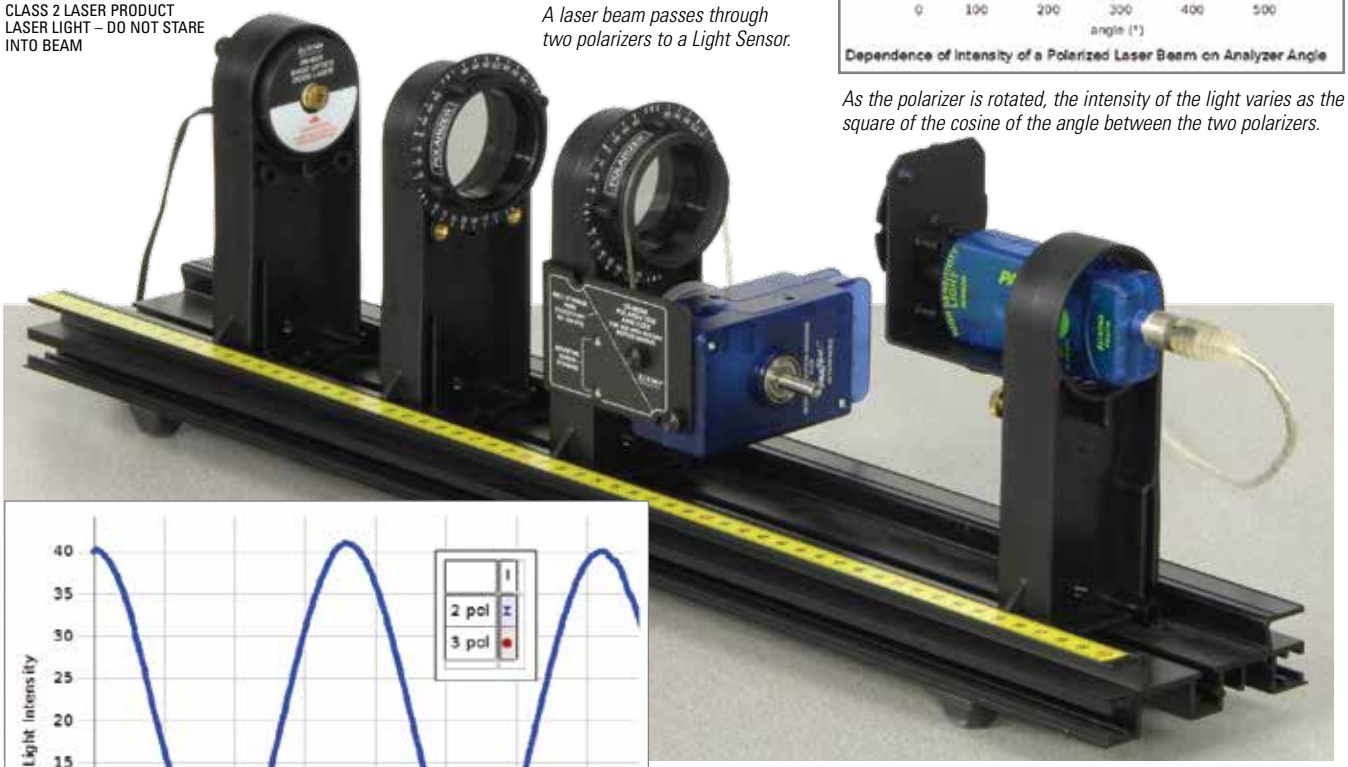
Laser light (peak wavelength = 650 nm) is passed through two polarizers. As the second polarizer (the analyzer) is rotated by hand, the relative light intensity is recorded as a function of the angle between the axes of polarization of the two polarizers. The angle is obtained using a Rotary Motion Sensor coupled to the polarizer with a drive belt. The plot of light intensity vs. 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.

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

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

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

Polarization of Light.....EX-5543A

Required:

550 or 850 Universal Interface*.....p. 26

PASCO Capstone Software.....pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.*

Brewster's Angle

EX-5544A

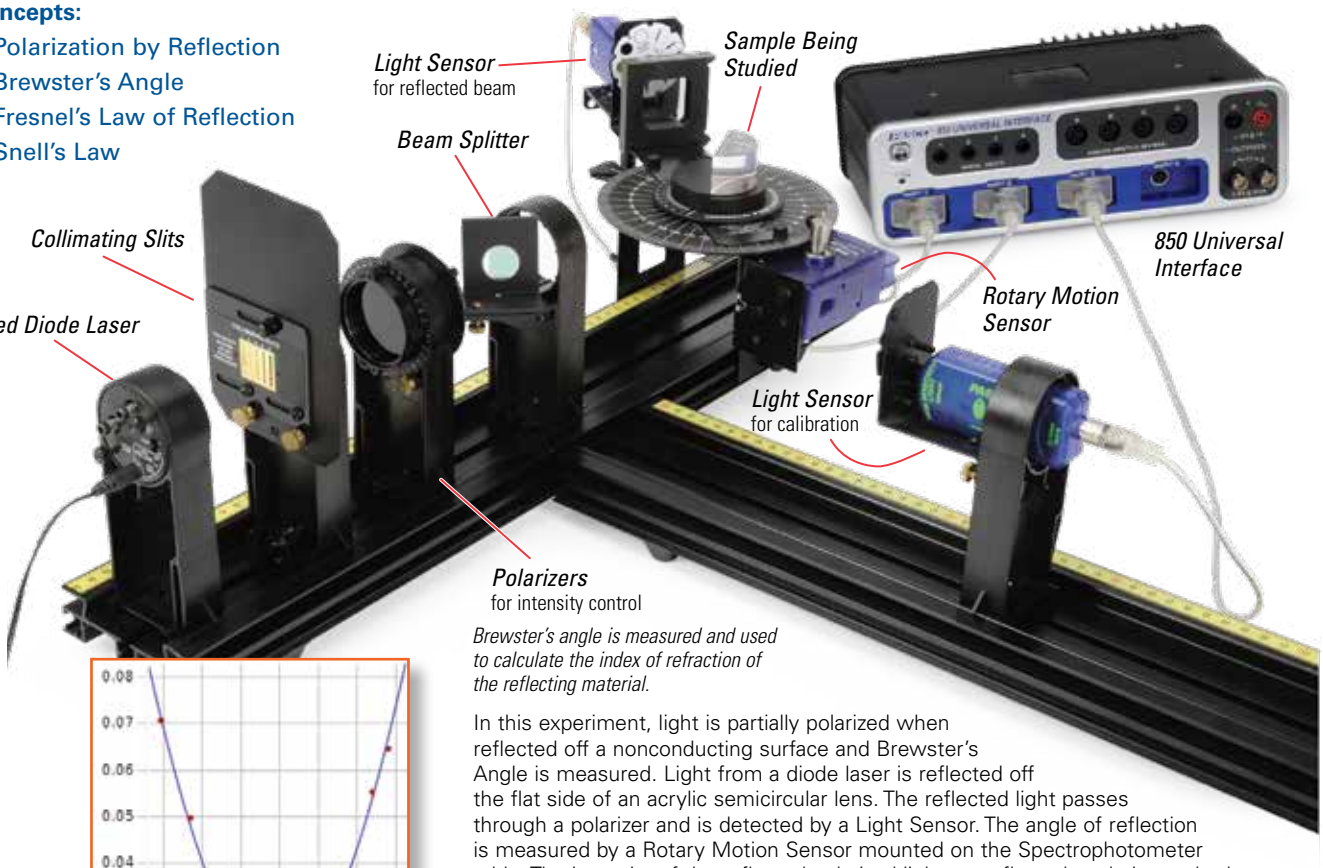
Designed for use with any of the following:

- 850 Universal Interface
- Any PASPORT interface with 3 ports

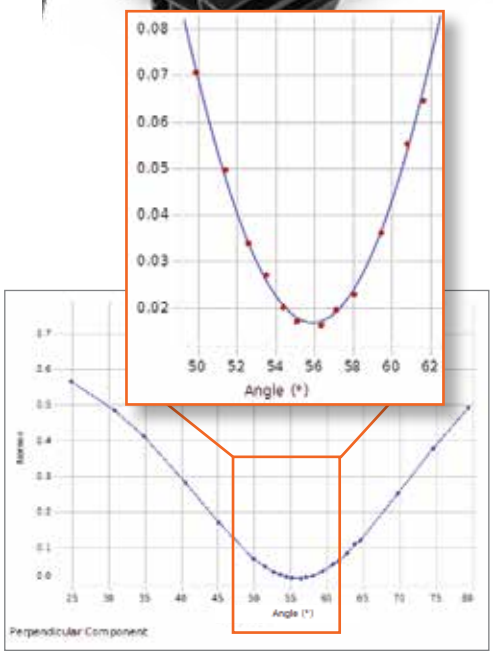
CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

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 vs. 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).

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

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Order Information

Brewster's Angle EX-5544A

Required:

850 Universal Interface* ..... p. 26

PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 850 Universal Interface or any PASPORT interface with three ports.*

Atomic Spectra

EX-5546B

Designed for use with any of the following:

- 850 Universal Interface
- 550 Universal Interface
- Any PASPORT interface with 2 ports

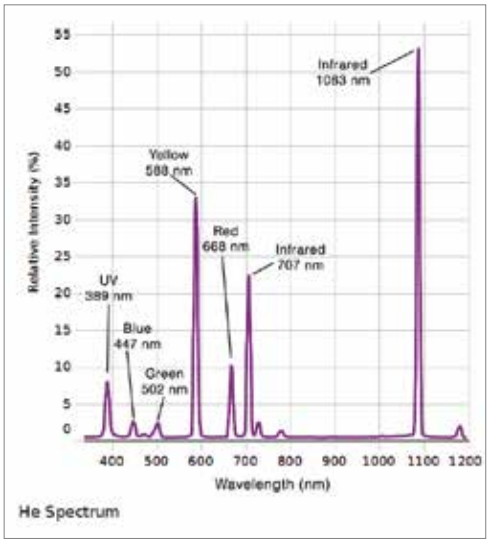
Concepts:

- Hydrogen balmer series
- Helium spectrum
- Mercury doublet

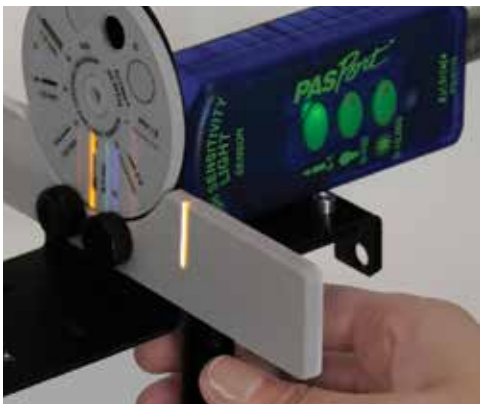
The wavelengths of the discrete lines of the atomic spectra of various gases are measured using a grating spectrophotometer.

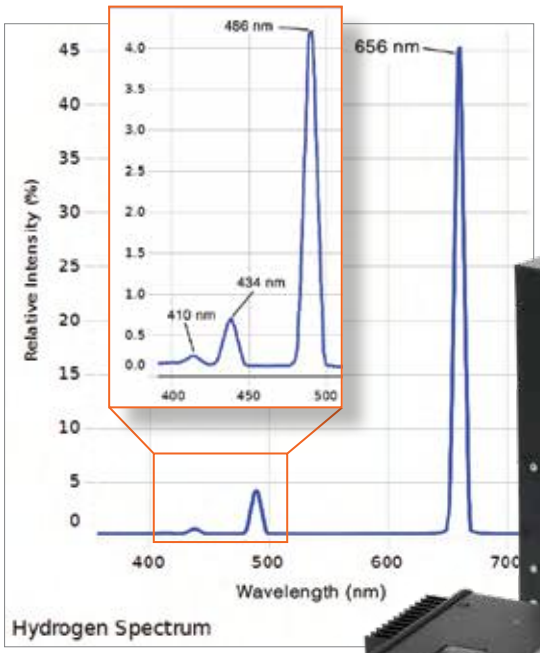
The atomic spectra of hydrogen, helium, and mercury are scanned by hand using a grating spectrophotometer, which measures relative light intensity as a function of angle. From the resulting graph, the wavelengths of the spectral lines are determined by measuring the angle from the central maximum to each line. First and second order lines are examined.

The 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 vs. 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
• Round Base with Rod (2)	ME-8270
• Spectral Tube Power Supply and Mount	SE-9460
• Hydrogen Spectral Tube	SE-9461
• Helium Spectral Tube	SE-9462
• Mercury Spectral Tube	SE-9466

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Order Information

Atomic Spectra EX-5546B

Required:

550 or 850 Universal Interface* ..... p. 26

PASCO Capstone Software ..... pp. 70-73

** This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.*

Photoelectric Effect

EX-5549A

Designed for use with either of the following:

- 850 Universal Interface
- 550 Universal Interface

Concepts:

- 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 vs. 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.

Use the 850 Universal Interface and PASCO Capstone to collect and analyze 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 vs. frequency.

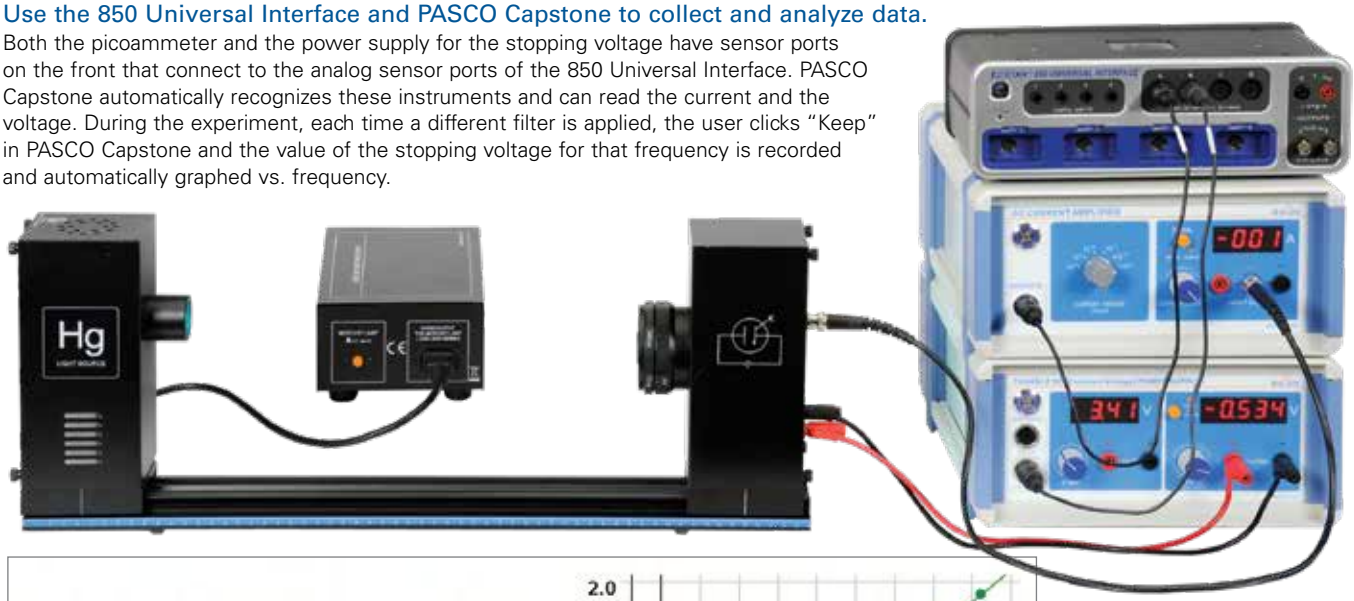
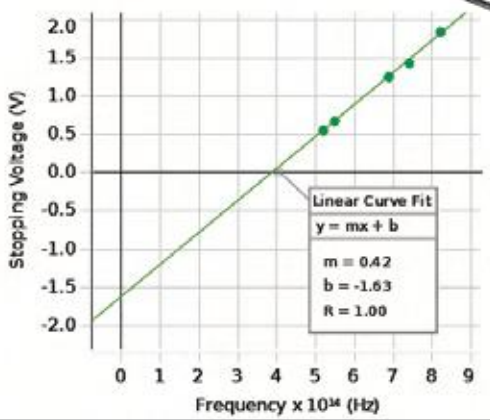


Table I: Photoelectric Effect with 4 mm Aperture

	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 vs. 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	SE-6614
• DC Current Amplifier	SE-6621
• Tunable DC Power Supply	SE-6615
• Cables for 850 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.....p. 26

PASCO Capstone Software.....pp. 70-73

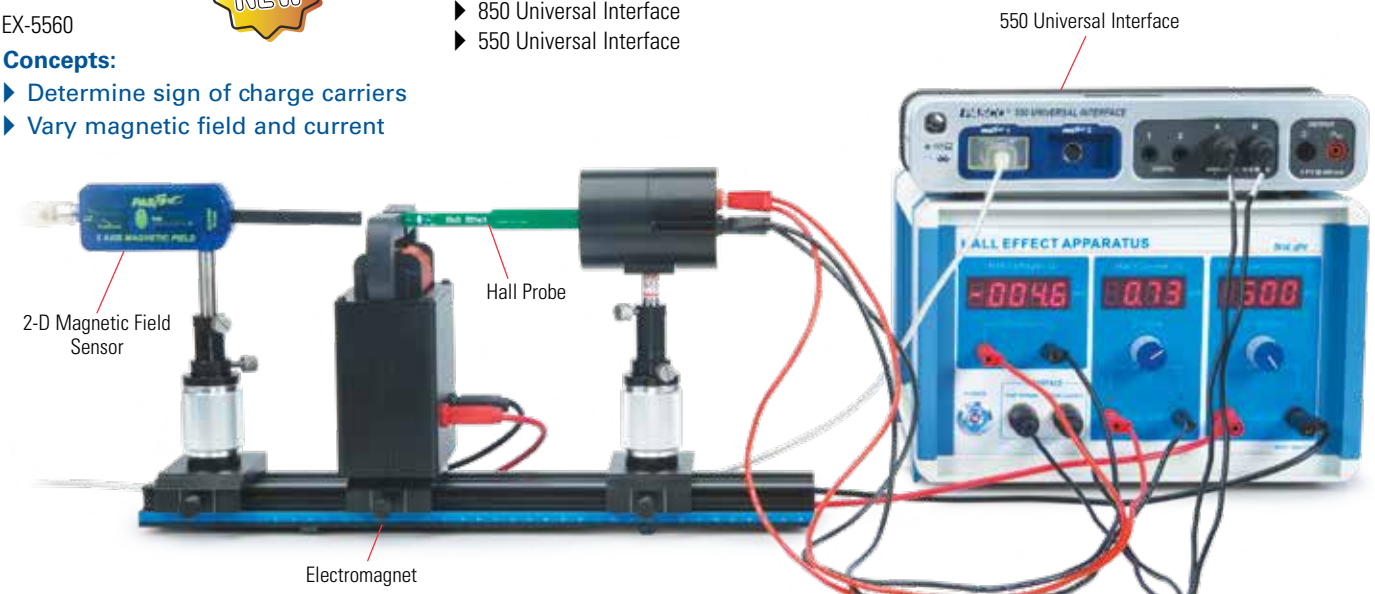
Hall Effect

EX-5560

NEW

Designed for use with either of the following:
- 850 Universal Interface
- 550 Universal Interface

Concepts:
- Determine sign of charge carriers
- Vary magnetic field and current



The Hall Effect experiment (conducted by Edwin Hall in 1879) determines the sign of the charge carriers in current flow. A current can be thought of as a negative charge moving in one direction (Figure 1) or as a positive charge moving in the opposite direction (Figure 2). To determine which it actually is, the semiconductor is immersed in the magnetic field transverse to the direction of flow of current. The moving charge experiences a $q\vec{v}$ x $\vec{B}$ force, causing a charge buildup on one side of the semiconductor (creating an electric field), which in turn leads to a $q\vec{E}$ force. The direction of the electric field will depend on the sign of the charge carriers, and the polarity of the Hall voltage across the semiconductor reveals this sign.

The magnitude of the Hall voltage is dependent on the current, the charge carrier density, and the magnitude of the magnetic field. In modern day electronics, the Hall Effect is used to measure the magnitude and direction of magnetic fields.

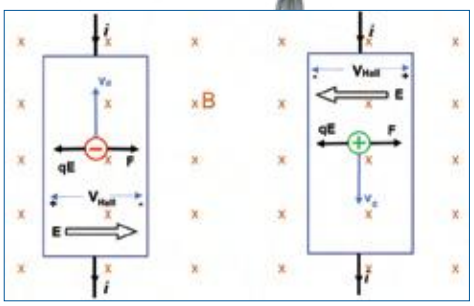
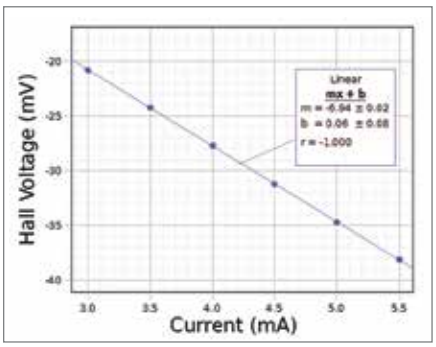


Figure 1 Figure 2



Using the 550 Universal Interface to record data, this plot of the Hall Voltage vs. the Current was made in PASCO Capstone software. In this case, the magnetic field was held constant and the current through the semiconductor was varied.

PASCO Advantage

The open design of this Hall Effect apparatus makes it possible for students to see the direction of the current and the magnetic field, enabling them to use the sign of the Hall voltage to deduce the sign of the charge carriers.



The directions of the current and the voltage probe are clearly marked on the probe that holds the semiconductor.

Includes

- Hall Probe Unit, n-Semiconductor (GaAs)
- Hall Effect Power Supply
- U-Core Electromagnetic Coil
- Track, Length 40 cm
- Optical Carrier (2)
- 2-D Magnetic Field Sensor (PS-2162)
- Adjustable Post Holder with 9 cm Post (2)
- Banana Cords (6)
- Connecting Cables for 550/850 Interface (2)

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

Hall Effect.....EX-5560
Required:
550 or 850 Universal Interface.....pp. 26-28
PASCO Capstone Software.....pp. 70-73

Franck-Hertz

EX-5561

Designed for use with either of the following:

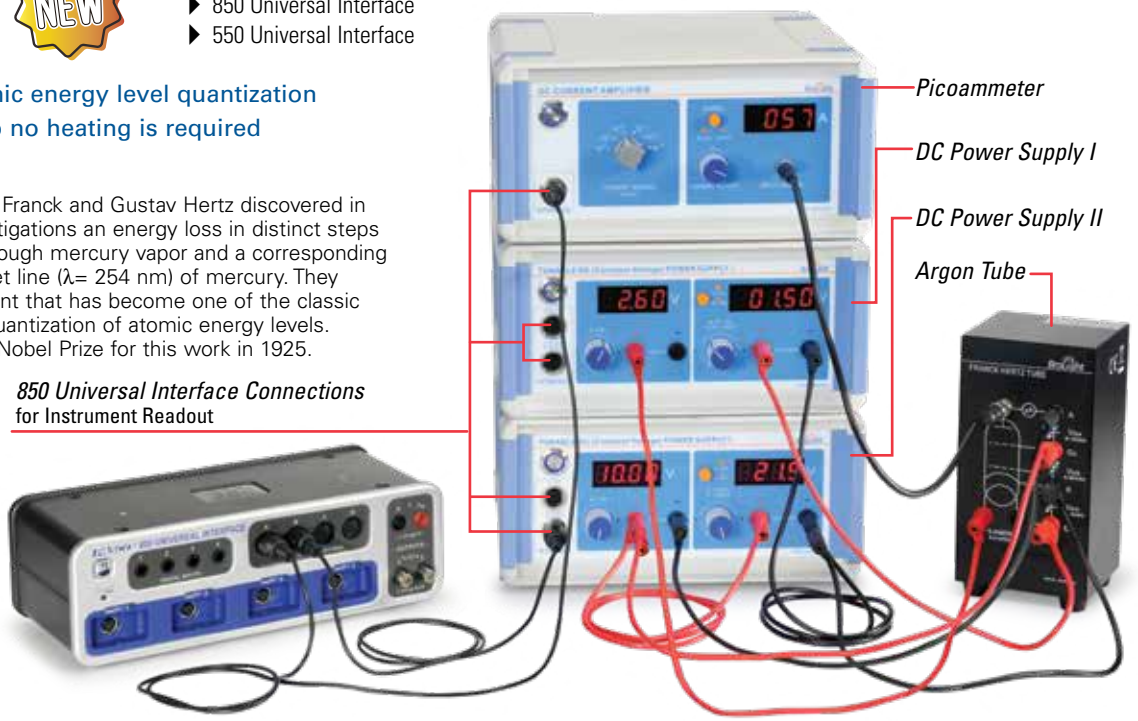
- 850 Universal Interface
- 550 Universal Interface

Concepts:

- Demonstrate atomic energy level quantization
- Uses argon gas so no heating is required

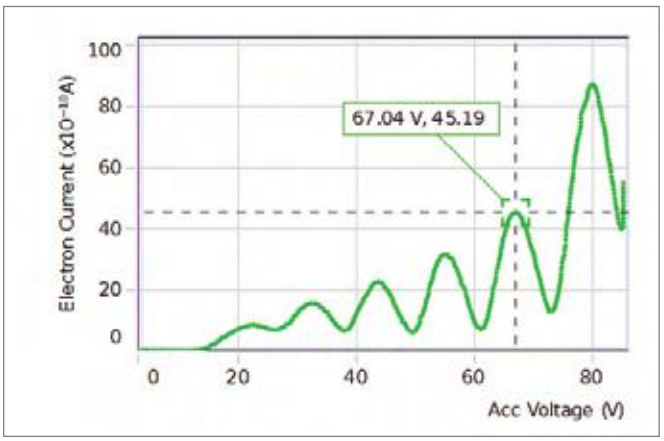
Introduction

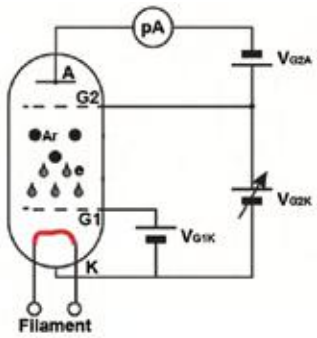
As early as 1914, James Franck and Gustav Hertz discovered in the course of their investigations an energy loss in distinct steps for electrons passing through mercury vapor and a corresponding emission at the ultraviolet line (λ= 254 nm) of mercury. They performed this experiment that has become one of the classic demonstrations of the quantization of atomic energy levels. They were awarded the Nobel Prize for this work in 1925.



PASCO Advantage

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.





This diagram shows the internal structure of the Franck-Hertz tube and the wiring diagram.

Includes:

- Franck-Hertz Tube Enclosure with Argon Tube (SE-9650)
- Tunable DC (Constant Voltage) Power Supply I (SE-6615)
- Tunable DC (Constant Voltage) Power Supply II (SE-9644)
- DC Current Amplifier (SE-6621)
- Red and Black Patch Cords
- Interface Cables (2)

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. Within a very short time, the excited argon electron will 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.

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

Franck-Hertz EX-5561

Required:

550 or 850 Universal Interface ..... pp. 26-28

PASCO Capstone Software ..... pp. 70-73

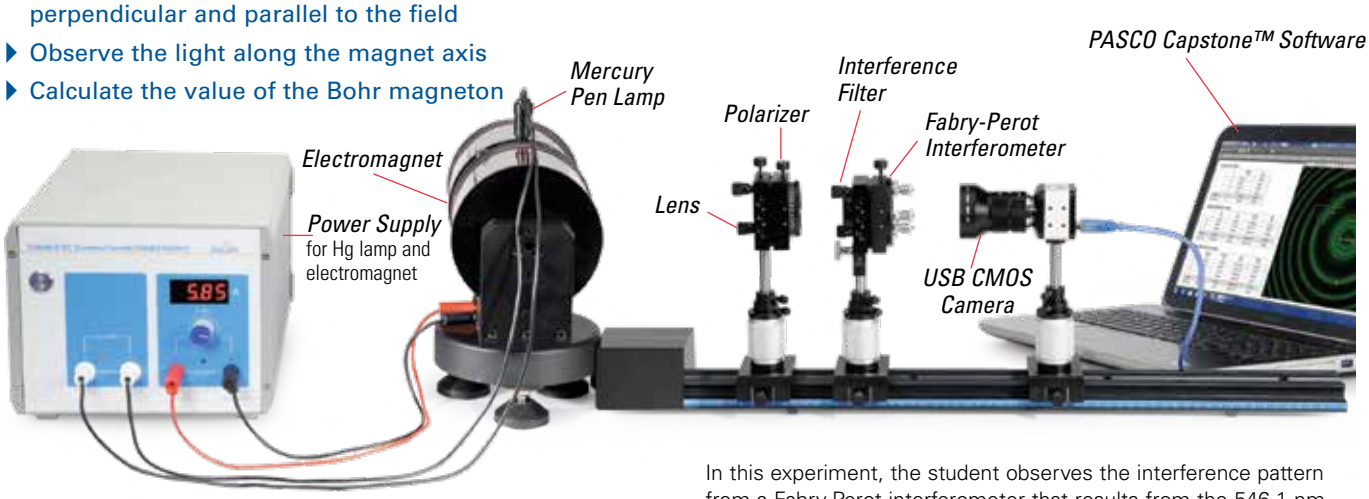
Zeeman Effect

No interface required

EX-5562

Concepts:

- 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





End view through the axis of the magnet

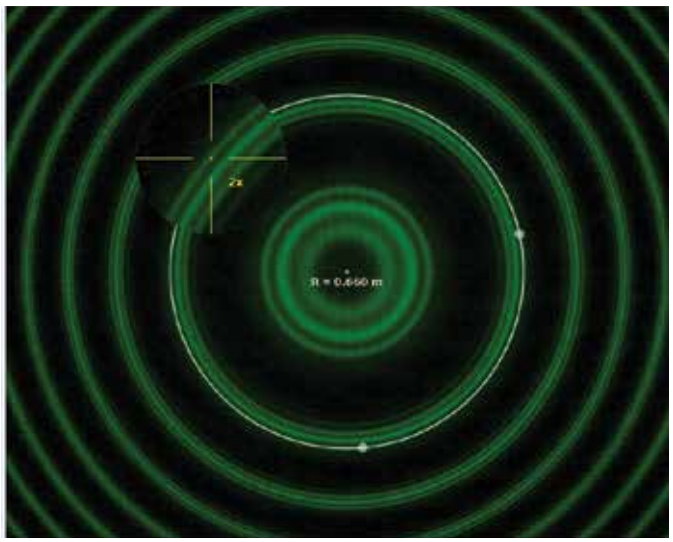


Electromagnet produces about one Tesla.

In this experiment, the student observes the interference pattern from a Fabry-Perot interferometer that 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.



PASCO Advantage

In PASCO Capstone software, students can use the video magnifier tool to enlarge the region to see the details of the line splitting. Also, the radius tool needs only three points to define the circle, so even rings that are partially out of view can be measured.

Includes

- Electromagnet
- Power Supply
- Optics
- Tesla Meter
- PASCO Capstone Single User License

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

Zeeman Effect EX-5562
Required:
PASCO Capstone Software ..... pp. 70-73

Educators Trust PASCO Professional Development






PASCO's Professional Development provides teachers with the training, guidance, and innovative solutions they need to lead sensor-based science lessons. Our trainers are curriculum experts who model how to confidently guide students through inquiry-based science lessons.

Sessions are relevant for teachers at all grade levels. Trainings include classroom-ready activities aligned to STEM-based standards and national and state correlations for:

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- *High school and higher education Biology, Chemistry, Earth Science, Environmental Science, Physical Science, and Physics*
- *Advanced, AP®, and IB® courses in Biology, Chemistry, Environmental Science, and Physics**

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With ongoing teacher support and a free follow-up webinar, PASCO PD isn't just a one-time workshop. Our trainers provide their ongoing support and expertise, whenever and wherever you need it.

"When educators learn, students learn more."

Hayes Mizell, in "Why Professional Development Matters."
Written for Learning Forward.
http://www.learningforward.org/docs/pdf/why_pd_matters_web.pdf



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What a PASCO Professional Development plan provides for you, your school, and your district

1 Student-centered, classroom-ready lab activities for all sciences, all devices

Our labs range from structured-inquiry to open-inquiry. They can be used on multiple platforms including iOS, Android™, Chromebook™, Mac®, and Windows®.

With them, teachers can:

- Integrate technology into the classroom, while showing students better ways to collect data.
- Engage students and make data meaningful for them while they *do* science.

2 Customizable delivery options and training formats that fit your needs

We custom-design the training to suit your individual requirements. Training programs include:

- Training onsite at your school
- Support in the classroom while you teach
- Webinar-based training
- Train-the-trainer
- Summer institutes

3 Skills development

Our approach is to help you create a solid foundation for success, as students develop these fundamental skills underlying content standards:

- Critical thinking skills
- Procedural expertise
- Proficiency in design and construction of lab experiments
- Analytical skills
- Inquiry-based learning leading to science literacy

4 Technical skills necessary to integrate probeware with your Science Standards

PASCO's trainers will show you how to use probeware to effectively engage students in scientific and engineering practices, while addressing disciplinary core ideas and crosscutting concepts.



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This rugged datalogger can be used with PASPORT and Wireless sensors. **(page 20)**

NEW! Demonstration Motor/Generator

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NEW! Wireless Rotary Motion Sensor

Combined with the new Rotational Inertia Accessory **(page 176)**, the Wireless Rotary Motion Sensor **(page 9)** makes a complete rotation laboratory.



SMART Fan Accessory

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