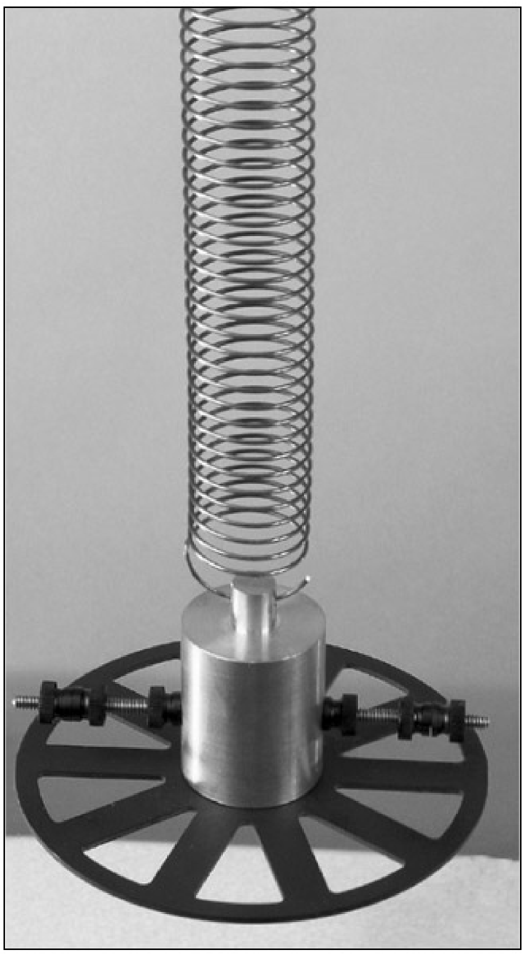
Instruction Manual

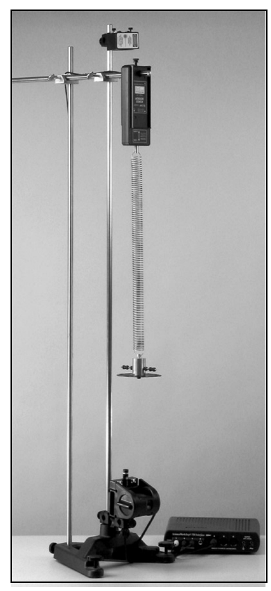
Manual No. 012-08397A

Wilberforce Pendulum

Model No. ME-8091



Items Included



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Wilberforce Pendulum

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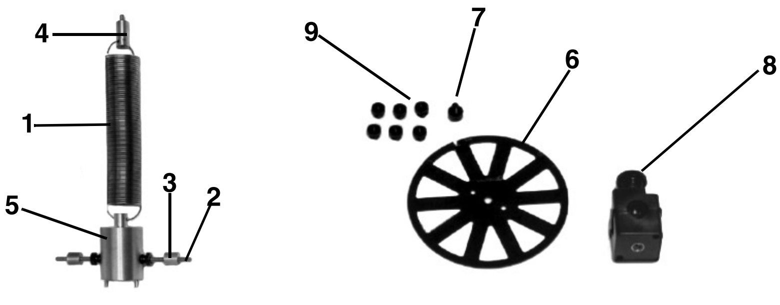
Equipment List



Included Equipment	Replacement Model Number*
1. Spring (1)	632-056
2. Threaded rod (1)	648-08341
3. Brass Cylinder Mass, 0.9 cm diameter, 5.5 g (2)	615-231
4. Brass Cylinder Mount Holder, 0.9 cm diameter, 11 g (1)	648-08325
5. Brass Cylinder Bob, 3.0 cm diameter, 234 g (1)	648-08324
6. Photogate Wheel (1)	648-08323
7. Thumbscrew for Photogate Wheel (1)	616-141
8. Rod Clamp (1)	003-05134
9. Plastic masses (with thumbscrews), 0.5 g	614-029

*Use Replacement Model Numbers to expedite replacement orders.

Additional Equipment Required (for setups with or without an interface)	Model Number*
Large Rod Base (1)	ME-8735
Stainless Steel Rods (120 cm) (2)	ME-8741
Stainless Steel Rod (45 cm or 90 cm) (1)	ME-8736 or ME-8738
Multi-Clamps (2)	SE-9442

(Equipment Continued from Page 3)

Equipment Recommended (for setups with interfaces)	Model Number*
A computer	NA
Any PASCO data acquisition device (*ScienceWorkshop*® interface, PASPORT™ interface, etc.)	Various
DataStudio Software	CI-6870C
Force Sensor (1)	CI-6637 or PS-2104
Motion Sensor (1)	CI-6688 or PS-2103
Laser Switch (1)	ME-9259A
X-Y Adjustable Diode Laser (1)	OS-8526
Adjustable Angle Clamp (1)	ME-8744

NA = not available for sale from PASCO scientific

Introduction

The Wilberforce Pendulum allows students to investigate the relationship between translational and torsional motion in an oscillating pendulum. With force and motion sensors, a laser, laser switch, and DataStudio software, students can collect real-time data of the period, velocity, and acceleration of the pendulum's oscillations. Using the pendulum with the included Photogate Wheel, students can observe the effect of rotational inertia on the oscillations. Brass masses slide onto the crossbar of the pendulum bob, allowing students to discover the affect of mass position on the period of oscillation. The angular velocity, position, and acceleration during rotation can also be plotted in a Graph display in DataStudio, enabling students to see a visual display of the oscillatory periods and to isolate the point at which the vertical and angular periods become equal.

***WARNING**: Before setting up your equipment, please inform your students of the hazards of lasers and enforce appropriate safety precautions in your classroom. For more information, see Appendix B: Laser Safety in this manual.*

Setup Options

The Wilberforce Pendulum can be used with or without an interface [either *ScienceWorkshop interfaces* or PASPORT interfaces (USB Links etc),] and with various attachment pieces. With the spring and attachments included, you can attach a Photogate Wheel for rotary inertia experiments or use the brass mass to study the effect of mass on the oscillatory period (Figures 1a and 1b).

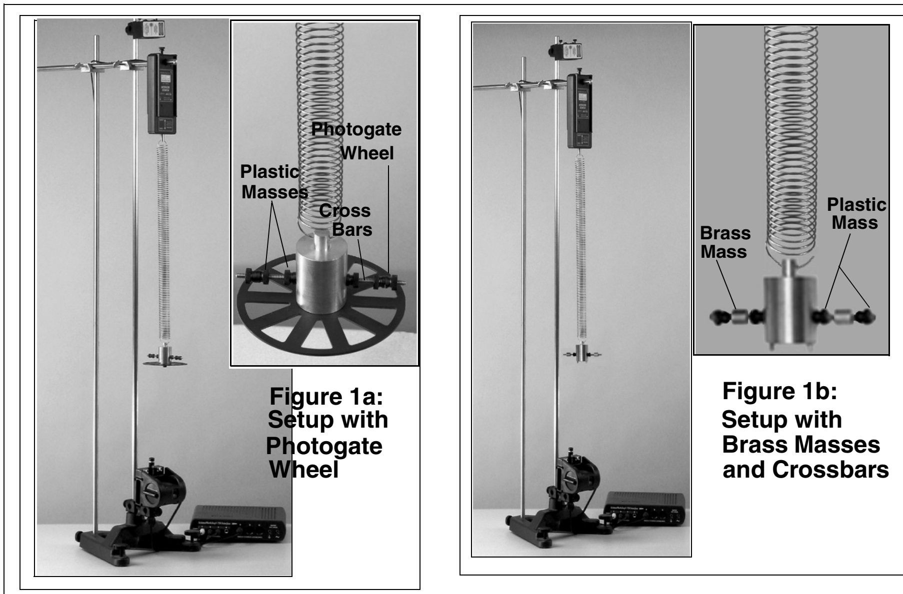


Figure 1a: Setup with Photogate Wheel

Figure 1b: Setup with Brass Masses and Crossbars

Figure 1: Setup with *ScienceWorkshop* Interface and Sensors

Equipment Setup

Equipment Setup (without an Interface or Sensors)

To mount the pendulum, perform steps 1-4 below. You will need a stopwatch to record the period of the oscillations. Figure 2 below shows the setup without an interface.

Equipment Setup (with an Interface and Sensors)

You will need a Rod Stand (ME-8735), three Stainless Steel Rods (ME-8736 or 8738), two Multi-Clamps (SE-9442), one Adjustable Angle Clamp (ME-8744), a Laser, and Laser Switch. (See the Equipment lists on pages 3-4.)

1. Insert two 120 cm rods into the base of a rod stand. Keep the rods upright in a vertical position.

2. Attach a Multi-Clamp to the upper end of each rod (See Figure 2). Slide a 45 (or 90 cm) steel rod through the hole in the Multi-Clamps. Adjust the Multi-Clamps to hold the rod horizontally in place.

3. Loop one end of a spring hook through the hole on the top of the brass cylinder bob. Loop the hook on the other end of the spring through the cylindrical, brass mount holder.

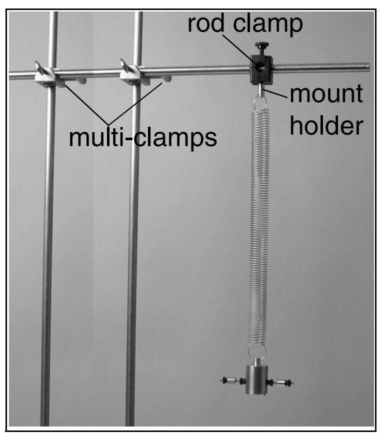


Figure 2: Standalone Setup (without sensors)

(If using the pendulum without an interface, mount a rod clamp to the horizontal rod, screw the brass mount holder (medium-sized cylindrical brass mass) into the bottom hole of the rod clamp, and hook the spring through the hole in the mount holder. See Figure 2.)

4. a) For setup with Photogate Wheel: Use a thumbscrew provided to attach the wheel to the bottom of the large brass mass. Screw two plastic masses onto each side of the brass cylinder bob (Figure 3). Add another plastic mass to each side, allowing a gap between the second mass and the first mass. Finally, add a third plastic mass to each side; the third mass is to hold the second mass in place. (**Note:** When using the Photogate Wheel, *do not* put the *brass* masses on the crossbar.)

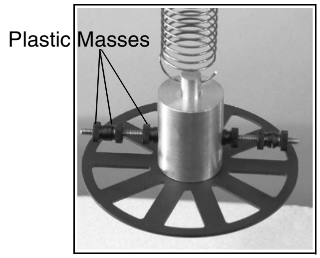


Figure 3: Setup with Photogate Wheel

OR

4b) For setup without the Photogate Wheel: Screw a small, plastic mass over each side on the horizontal cross bar jutting from the large brass mass. Screw on a brass mass on each side of the crossbar. Use a measuring tape to ensure each brass mass is equidistant from the bob in the center. Use two more plastic masses to hold the brass masses in place (Figures 4a and 4b).

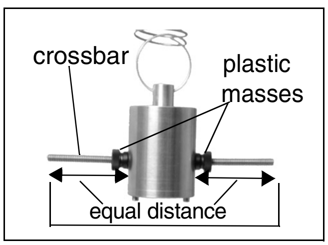


Figure 4a: Crossbar with plastic masses

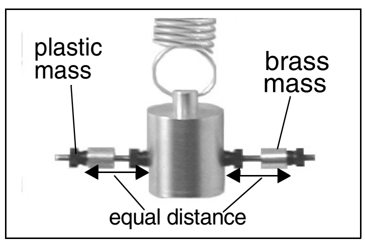


Figure 4b: Brass masses on crossbar

If using an interface, proceed with steps 5-12 that follow.

5. Use the center hole in the Force Sensor to slide the Force Sensor over the horizontal rod (Figure 5).

6. Insert the screw from the cylindrical mount holder into the bottom hole of the Force Sensor and rotate to tighten.

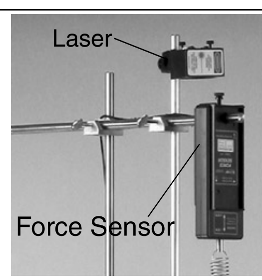


Figure 5: Force Sensor and Laser Mounted on Rods

7. Mount an Adjustable Angle Clamp to the lower end of the base rod. Insert the Laser Switch through the hole in the rod clamp such that the Laser Switch remains in a vertical position and the opening faces up (See Figure 6). Slide the Motion Sensor over the Laser Switch. Turn the Adjustable Angle Clamp until the laser switch holds vertically in place. Do not allow the Laser Switch room to move, slip, or fall out of place.

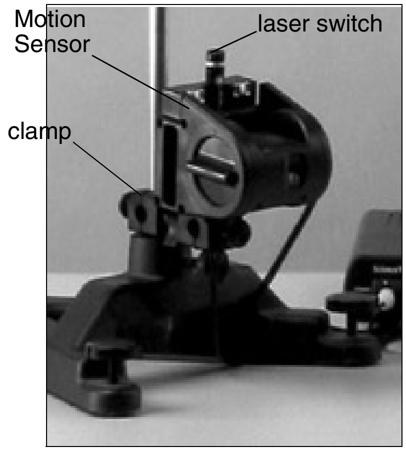


Figure 6: Mounting the Motion Sensor with Laser

8. Plug the Motion Sensor into digital channels 1 and 2 on the *ScienceWorkshop* interface.

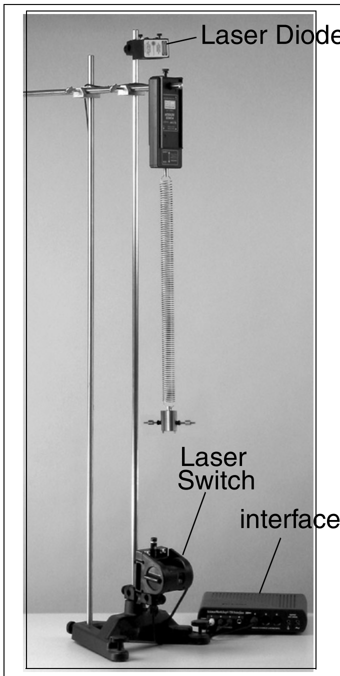


Figure 7: Setup

WARNING: Never look directly at the laser light source (from the Laser Diode) or reflected light from the laser, such as from a mirror. Although the lasers used in this experiment are of low power, looking directly into the laser light source or its reflected light from a mirror could cause severe eye injuries or burns. To avoid eye injury, do not look directly into the beam of the laser and wear laser protective eyewear. To align the Laser Diode with the Laser Switch, use an alignment marker (i.e ruler, piece of tape, etc.) to check the alignment *before* turning on the lasers. For more information about laser safety, see Appendix B of this manual.

9. Align the Laser Diode vertical over the opening on the laser switch. Use the adjustment knobs on the Laser Diode to move the laser horizontally.

10. Plug from the Laser Switch to digital channel 3 on the *ScienceWorkshop* interface. For a picture of the complete setup, see Figure 7.

11. Follow the DataStudio setup instructions in Appendices C (*ScienceWorkshop* interfaces) and D (PASPORT interfaces.)

12. When you are ready to collect data, plug the Laser Diode into a wall outlet. (**Note:** As a safety precaution, unplug the Laser Diode and Laser Switch until just before you are ready to begin data collection.)

Suggested Experiment: Investigating Translational and Torsional Motion in a Pendulum

This experiment has two parts: In Part I, you will investigate the relationship between translational and torsional oscillatory motion in a pendulum with a brass mass hanging from a spring. In Part II, you will examine the effect of the inertia from a Photogate Wheel on a pendulum.

Note: When using the Photogate Wheel, use the plastic masses instead of the brass masses on the crossbar. If you attach the disk, you must use the plastic, black masses on the crossbar because the brass masses have too much rotational inertia. To change the period of the pendulum's oscillations, change the distance of the masses from the center.

Part I: Effect of Mass on Oscillatory Periods in a Pendulum

1. Follow the equipment setup procedure described on pages 5-6 of this manual.

2. Move the position of the masses on the crossbar until they are equidistant from the centermost point on the pendulum bob.

3. Record the weight of the brass masses in Table 1. (Note: If a mass balance is not available, see the Specifications section in Appendix A.)

4. With a metric measuring tape, measure the distance of each mass from the center point on the bob. Record your measurement in Table 1.

5. Pull on the bob to begin moving the pendulum in a vertical direction. The crossbar will rotate as the pendulum bobs up and down.

6. In DataStudio, click the **Start** button to begin collecting data. Observe the data in real-time as the pendulum oscillates. (If using the pendulum without a computer and interface, use a stopwatch to time both the vertical and rotational periods of the oscillations and the time when the periods become equal.)

7. Move the masses on the crossbar to a new position and repeat steps 4 through 6. (Encourage students to move the masses on the crossbar to various positions to see the affect that mass position has on the period and angular velocity. Have students adjust the masses until the periods of the vertical and rotational oscillations are the same.)

Tip: If the masses on the crossbar are not equidistant from the center, the crossbar will not spin smoothly.

Note: The periods of the vertical and rotational oscillations must be exactly the same (quantitatively equal) for the oscillations to switch completely between the vertical and rotational modes. If the periods are not equal, adjust the masses on the crossbar and pull the pendulum again. This may take a few runs of trial and error.)

Table 1: Oscillatory Periods with Varying Mass on a Pendulum Bob

Run No.	Distance of Mass from Pendulum Bob (cm)	Oscillatory Period (seconds)*	Maximum Angular Velocity (rad/s)	Maximum Force (N/m)
1		vertical: rotational:		
2		vertical: rotational:		
3		vertical: rotational:		
4		vertical: rotational:		
5		vertical: rotational:		

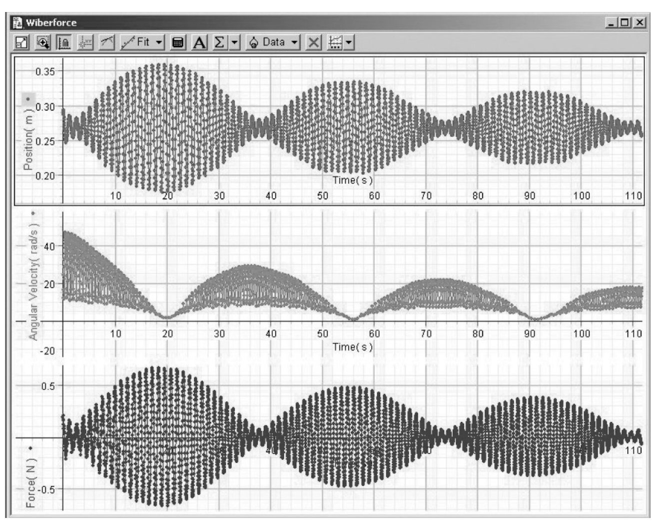
*To measure the period in DataStudio, use the **Smart Tool** to measure the difference between wave crests or troughs.

Part II: The Effect of Rotational Inertia on Oscillatory Periods from a Pendulum Swing

Table 2: The Effect of Rotational Inertia on a Pendulum's Oscillation

Run No.	Disk Radius (cm)	Rotational Inertia (kg/m^2)	Oscillation Period (seconds)	Maximum Angular Velocity (rad/s)	Maximum Force (N/m)
1			vertical: rotational:		
2			vertical: rotational:		
3			vertical: rotational:		
4			vertical: rotational:		
5			vertical: rotational:		

Sample Data/Results



Troubleshooting

Problem(s)	Possible Reason(s)	Possible Solution(s)
No position reading appears in DataStudio.	Motion Sensor is not plugged into the interface.	Plug the digital channels of the Motion Sensor into the interface.
The period for the torsional and vertical motions are not the same.	Masses are unequal distances from the center of the crossbar.	Move the masses on the cross bar. Moving the masses out increases the period. Keep adjusting the distance of the masses until the periods are the same.
Force reading is negative.	Improper calibration or direction of force measurement is not defined in DataStudio.	Calibrate the Force Sensor both at zero and with a known mass. Follow the calibration instructions in the Force Sensor Manual or the DataStudio online help. If using a PASPORT Force Sensor, open the Setup window, scroll to the Force Sensor, and select the “Pull Positive” option.
Rotational data does not appear in software during data collection.	a) The Laser Switch is not plugged into an interface. b) Laser Diode is not turned on. c) Laser Switch and Diode are not vertically aligned. d) Smart Pulley option was not selected in the DataStudio Setup window (applies to *ScienceWorkshop* interfaces). e) Timing sequence for the laser switch is not defined in DataStudio (applies to PASPORT interfaces).	a) Plug the Laser Switch into a digital channel on the interface. b) Plug the Laser Diode into a power outlet. c) Adjust the beam position on the Laser Diode until it aligns with the Laser Switch. d) In the Sensors list of the Experiment Setup window, select the Smart Pulley option. e) In DataStudio, define a timing sequence for the laser switch. (See the table of contents in the online help for defining timing sequences with photogates and other timers.)

Appendix A: Specifications

Wilberforce Pendulum Components	
Springs	10.2 cm length, 48.5 g
Brass Cylinder Bob	234.0 g, 3.0 cm (diameter) x 1.0 cm length
Brass Cylinder Mount	11.0 g, 0.9 cm (diameter) x 1.9 cm (length)
Brass Cylindrical Masses	5.5 g, 0.9 cm (diameter) x 3.7 cm (length)
Photogate Wheel	10 cm diameter, 7.5 g, 31.4 cm circumference
Plastic Masses	0.5 g
Crossbar	6.0 g, 10 cm length

Appendix B: Laser Safety Information

The OS-8528 Diode is a low power, Class I laser. When Class I lasers are used in accordance with Occupational Health and Safety Administration (OSHA) standards, Class I lasers are not harmful.

PASCO cannot be held liable for negligent use in the classroom. As a courtesy, we are providing you with the following laser safety instructions. These reminders are not a comprehensive list of all possible safety measures or hazards. For more information, see the OSHA web site (http://www.osha.gov). Also see http://www.safetymanual.com or www.laserinstitute.org

Safety Reminders:

• Never look directly into the laser.

Figure 5a: Harmful ways to look at a laser beam

• Do not point a laser at your own eye or at the eyes of other individuals.

- Never remove any of the covering or components of the AP-8586 Diode Laser. If the laser is defective, return the defective laser immediately to PASCO scientific.
- Although laser protective eyewear is not typically required for class I lasers, if you are uncomfortable or unsure about working around lasers, wear protective laser goggles or spectacles.

About Laser Protective Eyewear

The eyewear must be designed for use with lasers and meet OSHA standards specific to the type and class of laser you are using. You can tell if the type of goggle or spectacle you are using meets laser standards by looking at the insignia on the side of the frame. Any type of plastic chemical protective goggle will not suffice. Also, you need to select protective eyewear with the correct filter for the wavelength range of the laser (For the Laser Diode, you need a 660-680 nm filter.)

Example: Laser goggles designed to protect for Class I lasers do not provide maximum protection when using Class II lasers. For more information, see the OSHA web site (www.osha.gov).

Appendix C: DataStudio Setup Instructions for Wilberforce Pendulum Experiments with *ScienceWorkshop* Interfaces

1. Connect the sensors to the *ScienceWorkshop* interface, as follows:

a) Plug the stereo plugs on the Motion Sensor to digital channels 1 and 2 on the interface. b) Plug the DIN connector on the Force Sensor to any analog channel on the interface. c) Plug the stereo plug of the Laser Switch into digital channel 3 on the *ScienceWorkshop* interface.

2. Open DataStudio and select "Create Experiment."

3. Click the **Setup** button to open the Experiment Setup window.

4. In the Sensors list, drag the Motion Sensor icon to the first two digital channels on the picture of the interface. Drag the Force Sensor to the same channel you have the sensor plugged into on the picture of the interface.

Note: *If you do not see the Sensor list, click the* ***Setup*** *button on the main toolbar. In the Experiment Setup window, click the* ***Change*** *button. In the "Please Choose Data Source" window, select the appropriate interface and click the* ***OK*** *button.*

5. Select the Smart Pulley from the Sensors list and drag it to the third digital channel on the interface. [For the Laser Switch, you will use the Smart Pulley icon (instead of the Laser Switch icon) in the Setup window. If you use the Laser Switch icon, you need to set up a timing scheme in DataStudio.]

6. Double click on the Smart Pulley icon to open the Sensor Properties dialog. In the Measurement tab, click to check the Angular Position (rad), Angular Velocity (rad/s), and Angular Acceleration (rad/s/s) options.

7. Your experiment is setup in DataStudio. On the main toolbar, click the **Start** button to begin recording data. You will obtain six graphs: position vs. time, velocity vs. time, force vs. time, angular position vs. time, angular velocity vs. time, and angular acceleration vs. time.

Note: *Calibration of the Force Sensor is optional. However, if you wish to calibrate, click on the Calibration tab and follow the "General Procedure for Calibrating Sensors" in the DataStudio online help. You will need a set of known masses for calibrating the Force Sensor.*

Appendix D: DataStudio Setup Instructions for Wilberforce Pendulum Experiments with PASPORT Interfaces

1. Connect two USB links (or other PASPORT interfaces) to a USB port (or USB hub) on your computer.
2. Plug the Motion Sensor and Force Sensor each to a USB Link or other PASPORT interface.
3. Plug the Laser Switch into either port on a PASPORT Photogate Port (PS-2123).
4. Click the **Setup** button to open the Experiment Setup window.
5. In the Experiment Setup window, scroll to the Force Sensor options and select "Force, pull positive." Scroll to the Motion Sensor and click (to check) the boxes next to "Velocity."
6. In the PASPORT Setup window, click the **Add Timer** button, select Recordable Timer from the **Choose Timer** window, and click OK. You will use a custom timing sequence to record each time the rotation disk passes the beam of the laser.
7. In the Setup window, scroll to and doubleclick the Recordable Timer option. When you are ready to begin collecting data, click the **Record Sequence** button. Blocked and unblocked events will appear in the open display.
8. You will obtain six graphs: position vs. time, velocity vs. time, and force vs. time, angular position vs. time, angular velocity vs. time, and angular acceleration vs. time.

***Note:** If you do not see the Sensor list, click the **Setup** button on the main toolbar. To view the entire list of sensors, click the Maximize button in the upper right-hand corner of the screen.*

***Note:** Calibration of the Force Sensor is optional. However, if you wish to calibrate, "General Procedure for Calibrating Sensors" in the DataStudio online help. You will need a set of known masses for calibrating the Force Sensor.*

Appendix E: Technical Support

For assistance with the ME-8091 Wilberforce Pendulum or any other PASCO products, contact PASCO as follows:

Address: PASCO scientific

10101 Foothills Blvd.

Roseville, CA 95747-7100

Phone: (916) 786-3800

FAX: (916) 786-3292

Web: www.pasco.com

Email: techsupp@pasco.com

Appendix F: Copyright and Warranty Information

Copyright Notice

Limited Warranty

PASCO scientific warrants the product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. The warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of a manufacturing defect or improper use by the customer shall be made solely by PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment after repair will be paid by PASCO scientific.