

**Rotationsbewegungen - Versuch**

Best.- Nr. 1041474



Nachfolgend finden Sie die englischen Bedienungsanleitungen zu den Komponenten des Versuches (in Klammern finden Sie die Conatex-Bestell-Nummern).  
Durch Klicken auf die Bestellnummer gelangen sie direkt auf die entsprechende Beschreibung der Komponente.

1. Drehbewegungs-Sensor ([1041011](#))
2. Dreh-Zubehör ([1041012](#), [1041559](#))
3. Torsionspendel-Zubehör ([1041478](#))
4. Angetriebene Harmonie und Chaos Zubehör ([1041013](#))
5. Mechanischer Oszillator / Treiber ([1041519](#))
6. Variables „g-Pendel“ -Zubehör ([1041517](#), [1041577](#))
7. Stativfuß-V-förm ([1041513](#)) und 90 cm Stativstab



## Rotary Motion Sensor

PS-2120



### Sensor Specifications

<b>Resolution:</b>	0.02 mm (linear) and 0.09 degrees (angular)
<b>Accuracy</b>	+/- 0.09 degrees
<b>Maximum speed</b>	30 revolutions/sec
<b>Default sample rate:</b>	10 samples/sec
<b>Maximum sample rate:</b>	1000 samples/sec

## Rotary Motion Quick Start

The PS-2120 Rotary Motion Sensor measures both linear and angular position, velocity, and acceleration.

### Additional Equipment Needed

- USB Link (PS-2100) with USB-compatible computer or PS-2000 Xplorer
- EZscreen or DataStudio™ software (version 1.6.1 or later)

### Equipment Setup

1. Connect the sensor to a USB Link or to an Xplorer.
2. Connect the USB Link or Xplorer cable to a USB port on your computer or a USB hub.
3. The software launches when it detects a PASPORT sensor. Select **EZscreen** or **DataStudio**.



# Using the Rotary Motion Sensor

The PASPORT™ Rotary Motion Sensor will zero automatically when you click the **Start** button in DataStudio. This will reset all measurements of the Rotary Motion Sensor to zero upon beginning data collection. If you would like the sensor to “remember” its position between data runs, deselect the “Zero Automatically on Start” box, which is located in the Setup window (only available in DataStudio 1.6.2 or later). This “position memory” will be lost when you disconnect the sensor, or you reopen or quit DataStudio.

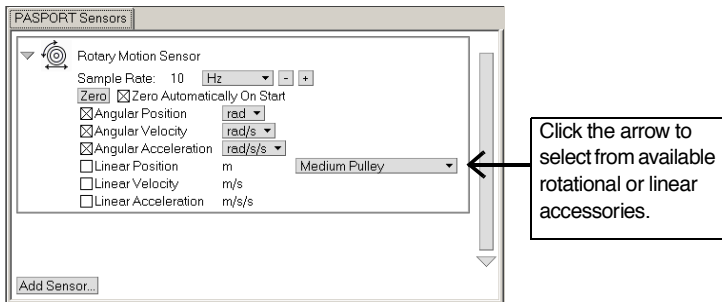


Figure 1: PASPORT setup window

In addition, the **Zero** button in the Setup window can be used to *manually zero* the sensor. Deselect the “Zero Automatically on Start” box, place the sensor in the desired orientation, and click the Zero button.

When measuring either linear or rotational motion quantities, you must select the appropriate accessory from the pull-down menu in the setup window. The large pulley groove is the default, but you can select other configurations from the menu in the setup window (see Figure 1).

## Rotary Motion Activities

### EZScreen Activity

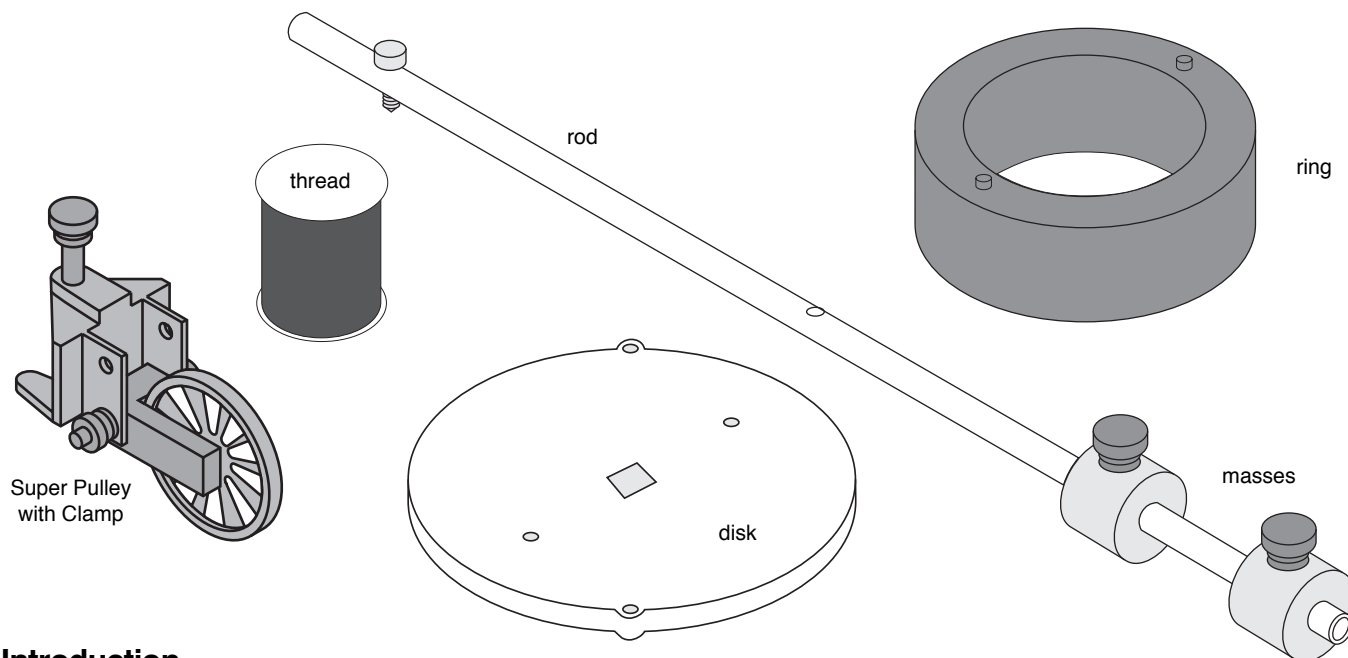
1. To take rotational measurements in your classroom, click **EZscreen** in the PASPORTAL window.
2. In the lower right corner of the EZscreen, click the Rotary Motion Sensor icon to cycle through measurement types. (Linear measurements are based on the large pulley groove.)
3. Click the **Start** button once to collect data and again to stop.

### DataStudio Activity - Angular Acceleration

1. Plug the PS-2120 Rotary Motion Sensor into a USB link or Xplorer.
2. Use the included clamp to attach the sensor horizontally to a ring stand.
3. Place a 30 cm section of string over the large pulley.
4. Choose two masses with a difference of 2 grams. Tie one mass on each end of the string.
5. Hold the masses (the lesser mass as low as possible) and click the **Start** button.
6. Release the masses, but catch them before hitting the pulley. Click the **Stop** button.
7. What does the angular position vs. time graph suggest about the motion of the masses after they were released?
8. Repeat the experiment for masses with a difference of 4 grams.
9. How does the angular position vs. time graph change? Explain.

**Instruction Sheet  
for the PASCO  
Model CI-6691**

# MINI-ROTATIONAL ACCESSORY



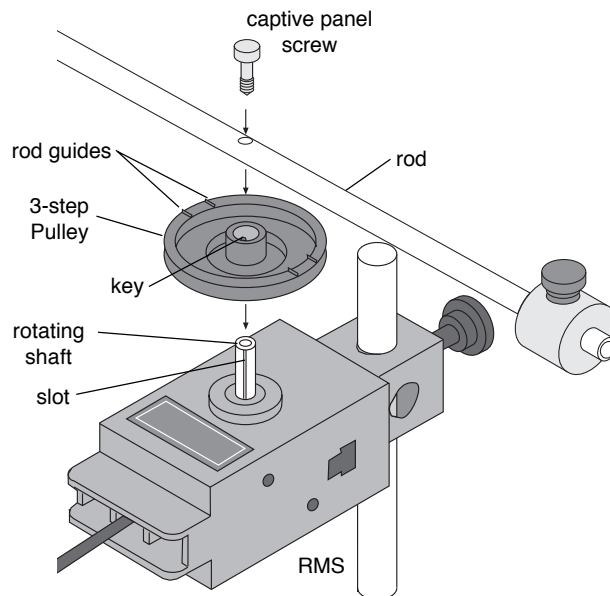
## Introduction

The PASCO CI-6691 Mini-Rotational Accessory is designed for use with the PASCO CI-6538 Rotary Motion Sensor (RMS) or the PASCO CI-6625 Rotary Motion Sensor for ULI to perform rotational inertia, conservation of angular momentum, and pendulum experiments. Included are an aluminum disk, a steel ring, a long thin rod and two brass masses which can be attached at any point on the thin rod to act as point masses.

Please refer to the instruction manual supplied with the Rotary Motion Sensor for a detailed description of experiments using the Mini-Rotational Accessory.

## Attaching the Rod

To attach the rod to the RMS, it is necessary to turn the 3-step Pulley so the rod guides on the underside of the pulley face up. The 3-step Pulley and the rotating shaft on the RMS are keyed to assemble only in one position. Assemble the apparatus as illustrated.



**Attaching the Rod to the Rotary Motion Sensor**

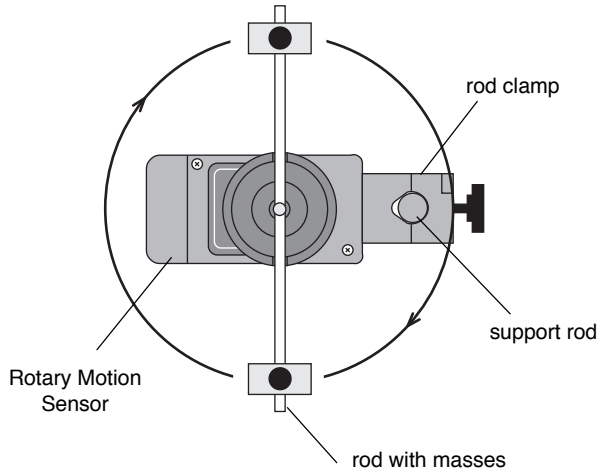
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This instruction sheet written by: Jon Hanks

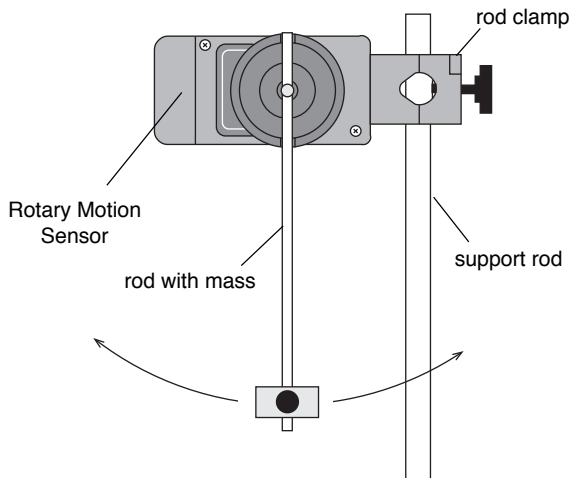
### Using the Rod

The rod can be used for two purposes:

- The center of the rod can be attached to the shaft of the Rotary Motion Sensor and used with the point masses to find the rotational inertia of point masses.



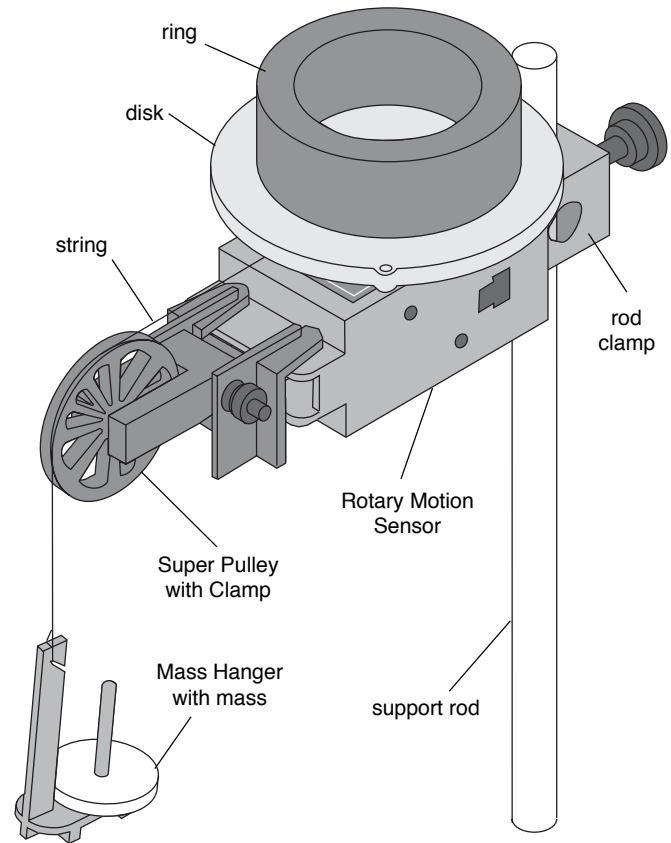
- The end of the rod can be attached to the Rotary Motion Sensor shaft to use it as a pendulum.



### Using the Disk and Ring

For rotational inertia experiments, wrap a string attached to a mass around the 3-step Pulley included with the Rotary Motion Sensor. Hang the mass over the Super Pulley to accelerate the apparatus.

Perform a conservation of angular momentum experiment by dropping the ring onto the rotating disk.



### Limited Warranty

PASCO scientific warrants this 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. This 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.

### To Reach PASCO

For Technical Support call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

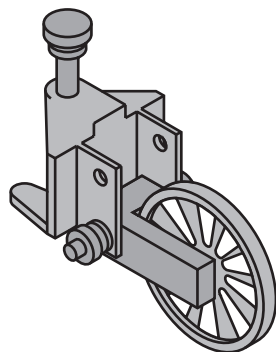
email: techsupp@PASCO.com

Tech support fax: (916) 786-3292

Web: <http://www.pasco.com>

**Instruction Sheet  
for the PASCO  
Model ME-9448**

# Super Pulley with Clamp



## Introduction

The PASCO Model, ME-9448 Super Pulley with Clamp is designed to be used wherever an integral clamp that features the low friction characteristics of our Super Pulley is needed.

## Specifications

Fully adjustable pulley height.

Fits tables up to  $\frac{3}{4}$ " thick.

Pulley:

Diameter = 5.1cm (2")

Outside circumference = 16cm (6.3")

Groove circumference = 15cm (5.9")

Mass = 5g

Moment of inertia approx.  $18.6 \times 10^{-7} \text{kgm}^2$

## Helpful Hints

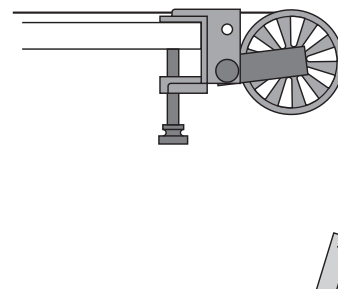


Figure 1

When using the Super Pulley with Clamp on a force table keep strings as close and parallel to the surface of the table as possible. See Figure 1.

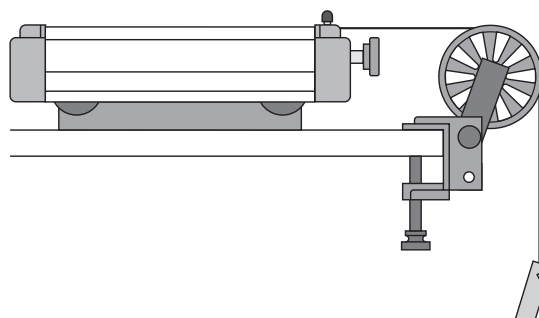


Figure 2

Strings should also remain parallel when using the Super Pulley with Clamp on incline planes or any table that might be used for demonstration. See Figure 2.

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Includes  
Teacher's Notes  
and  
Typical  
Experiment Results

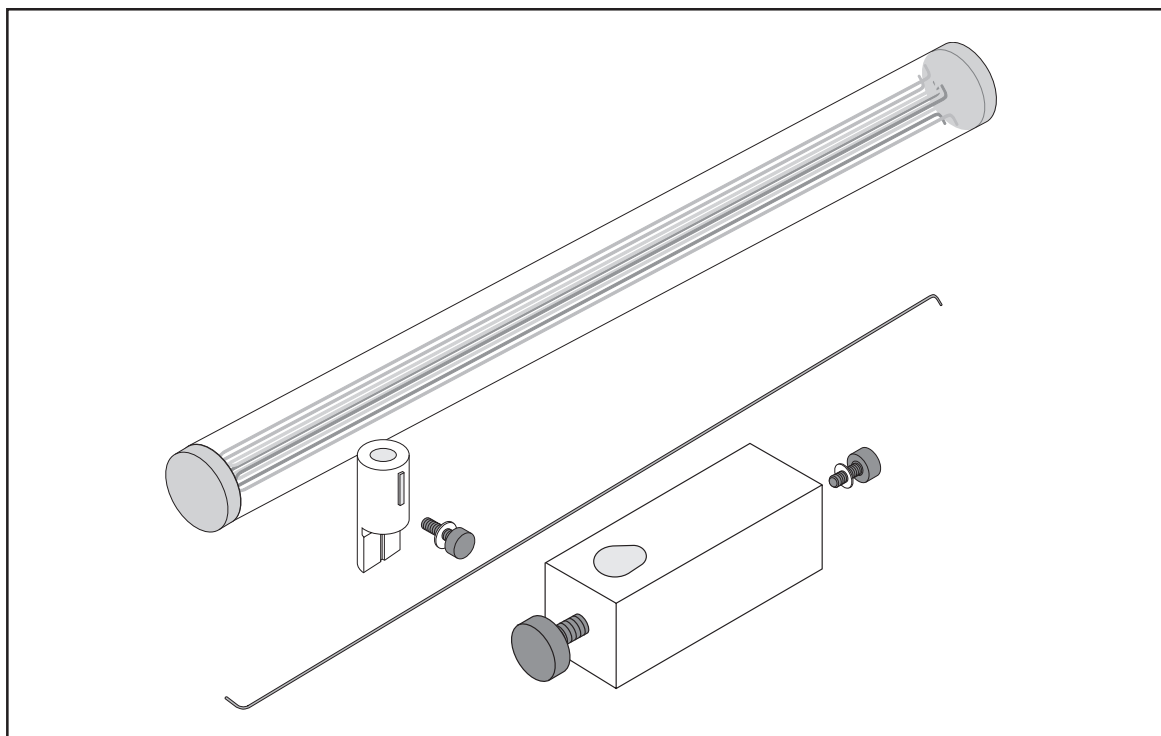


**Instruction Manual and  
Experiment Guide for the  
PASCO scientific  
Model ME-6694**

012-06339A

7/97

# **TORSION PENDULUM**



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\$7.50

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# Copyright, Warranty, and Equipment Return

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## Credits

Author: Sunny Bishop

## Equipment Return

Should the product have to be returned to PASCO scientific for any reason, notify PASCO scientific by letter, phone, or fax BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

► **NOTE:** NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION FROM PASCO.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

- ① The packing carton must be strong enough for the item shipped.
- ② Make certain there are at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
- ③ Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument come in contact with the packing carton.

Address: PASCO scientific  
10101 Foothills Blvd.  
P.O. Box 619011  
Roseville, CA 95678-9011

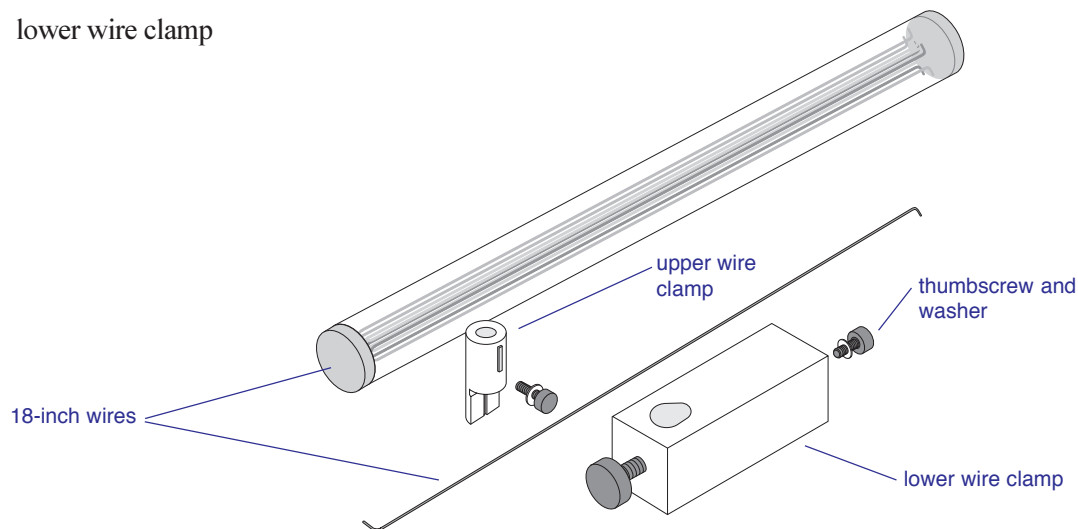
Phone: (916) 786-3800  
FAX: (916) 786-3292  
email: techsupp@pasco.com  
web: www.pasco.com

## Introduction

The PASCO ME-6694 Torsion Pendulum, an accessory for the PASCO CI-6538 Rotary Motion Sensor (RMS), facilitates the study of torque and the moment of inertia in a rotating body. The apparatus uses the data acquisition capabilities of the RMS with *Science Workshop*<sup>™</sup> through the PASCO 500 or 700 computer interfaces. Using the Torsion Pendulum, students can collect experimental data on rotational acceleration, rotational position, and rotational velocity for a variety of experiments with the PASCO CI-6691 Mini-Rotational Accessory. Three wires with different diameters supplied with the Torsion Pendulum provide three different and repeatable torque magnitudes.

## Equipment

- 18-inch wires, 3 each: diameters (inches): 0.032, 0.047, 0.063
- upper wire clamp
- lower wire clamp



### Additional Equipment Required:

- *Science Workshop*<sup>™</sup> version 2.1 or higher
- PASCO Computer Interface (500 or 700)
- computer
- Rotary Motion Sensor (CI-6538)
- Mini-Rotational Accessory (CI-6691)
- Force Sensor (CI-6537)

### Additional Equipment Suggested

- Table Clamp (ME-9376B) or Large Rod Stand (ME-8735)
- Support Rod (90 cm) (ME-8738)

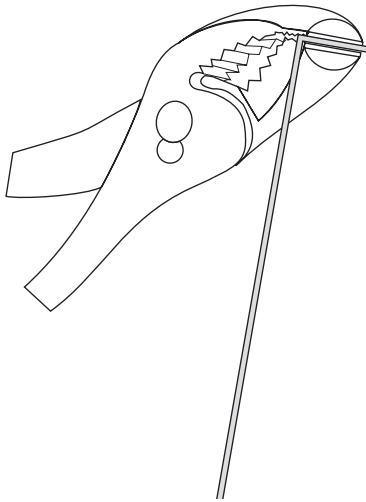
### ► Safety Note:

**Always wear safety glasses when experimenting with the Torsion Pendulum.**

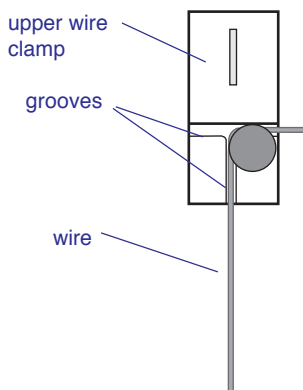
### Replacement Wires

To order a set of wires, call PASCO (800-772-8700) and order part number 003-06354.

► **Note:** You will need bend the wires as illustrated in Figure 1. (The direction of the bend is not critical.)



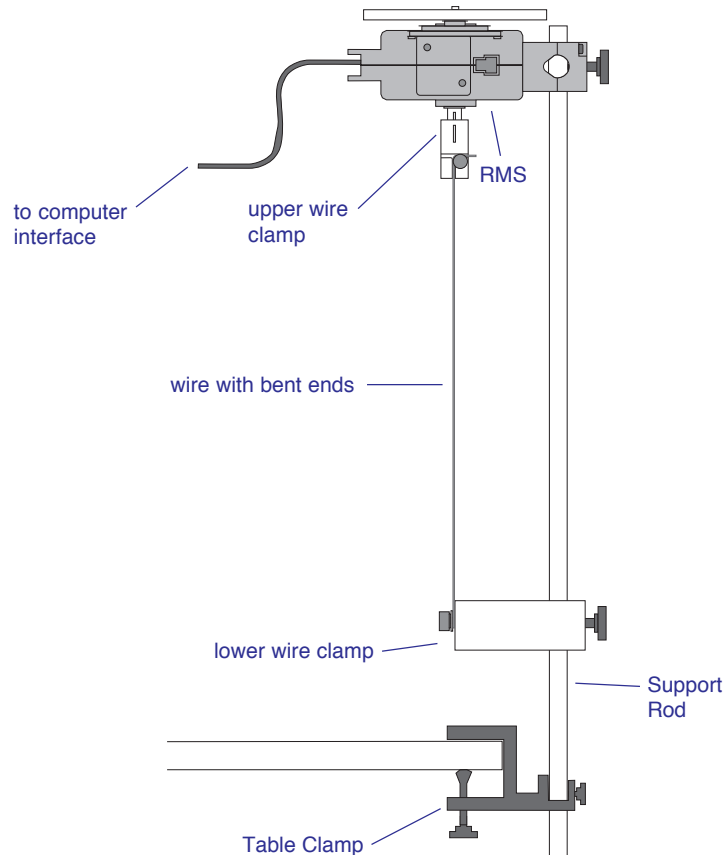
**Figure 1**  
Bend the ends of the wires to 90° angles.



**Figure 3**  
Securing the wire to the upper wire clamp

## Assembly with the Rotary Motion Sensor (RMS)

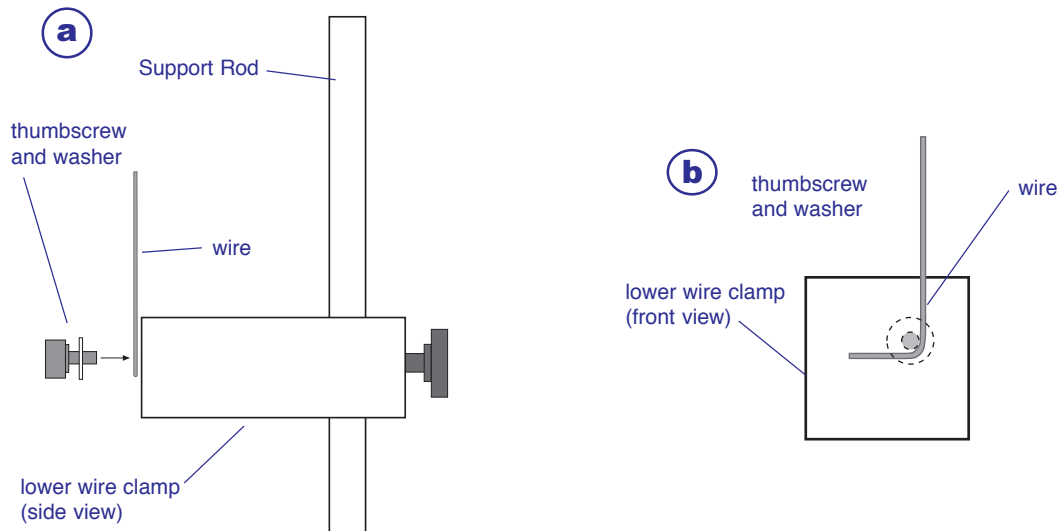
1. Use the Table Clamp to secure the Support Rod to a table in close proximity to your computer interface (Figure 2).



**Figure 2**  
Assembly of the Torsion Pendulum and the Rotary Motion Sensor

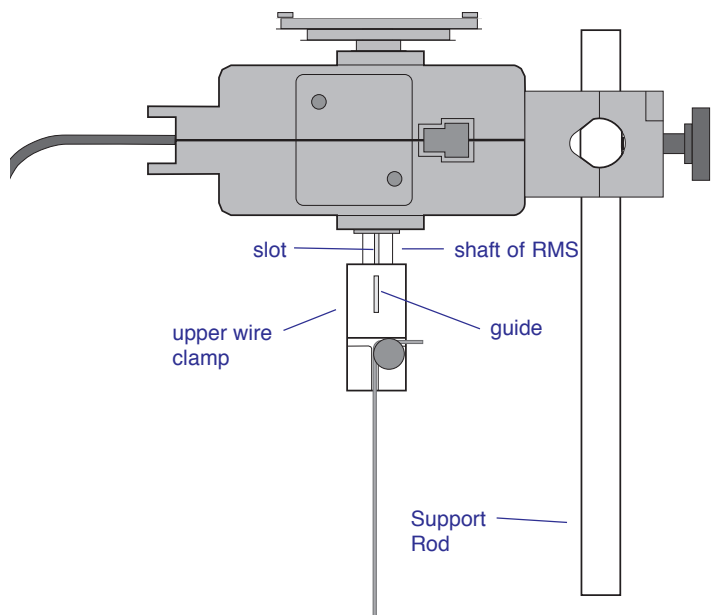
2. Slip the lower wire clamp onto the Support Rod.
3. Clamp the RMS at the top of the Support Rod.
4. Clamp one end of the wire under the washer of the upper wire clamp by firmly tightening the thumbscrew, being sure to seat the wire in the grooves (Figure 3).

- Clamp the other end of the wire under the washer of the lower wire clamp by tightening the thumbscrew firmly. Be sure that the elbow of the bend in the wire fits snugly against the axle of the thumbscrew (Figures 4a and 4b).



**Figure 4**  
Lateral (a) and front (b) views of attaching the bent wire to the lower clamp.

- Adjust the height of the lower wire clamp to about 18 inches below the shaft of the RMS.
- Align the guide of the upper wire clamp with the slot of the shaft of the RMS. Slide the upper wire clamp onto the shaft (Figure 4).
- Adjust height of the lower wire clamp as necessary to position to top of the upper wire clamp approximately half-way up the shaft (Figure 5).
- If necessary, adjust the lower wire clamp so the wire is perpendicular to the table.
- Recheck all screws on the clamps to be sure each part is firmly secured.



**Figure 5**  
Sliding the upper wire clamp onto the shaft of the Rotary Motion Sensor

► *Note: The manual has been written with the assumption that the user has a basic familiarity with Science Workshop and has access to the “User’s Guide” for Science Workshop. Users can gain basic skills with Science Workshop by viewing the training video and by doing the tutorial within Science Workshop. Another useful resource is the “Quick Reference Card” for Science Workshop.*

## Suggested Experiment

The following experiment will help students build skills in using the Torsion Pendulum using *Science Workshop* for data acquisition. Students may want to experiment further with varying lengths, thickness, or composition of wire, or with effects of variations of temperature on the torsional spring constant,  $\kappa$ .

## Experiment 1. Determining the Magnitude of the Moment of Inertia ( $I$ ) Using Two Methods

### Purpose

The purpose of the experiment is compare the magnitude of the moment of inertia ( $I$ ) of a disk and cylinder calculated by (1) using a torsional spring constant ( $\kappa$ ) and the period of oscillation of the Torsion Pendulum ( $T$ ) and (2) with  $I$  calculated using mass and radius measurements.

### Materials and Equipment Required

- Torsion Pendulum (ME-6694)
- Rotary Motion Sensor (CI-6538)
- Mini-Rotational Accessory (CI-6691)
- *Science Workshop* 2.1 or higher
- PASCO computer interface (500 or 700)
- computer
- Force Sensor (CI-6537)
- Table Clamp (ME-9376B)
- Support Rod (90 cm) (ME-8738)
- mass balance
- metric ruler
- sturdy, non-stretching string— 18 inches
- pages 2 and 3 of the manual

### Theory

The magnitude of the moment of inertia ( $I$ ) of a disk can be determined with the Torsion Pendulum using the following relationship:

$$I = \left( \frac{T}{2\pi} \right)^2 \kappa$$

where  $T$  = the time (s) for a period of oscillation of the Torsion Pendulum and  $\kappa$  = the torsional spring constant of the wire.

The magnitude of the moment of inertia of a disk can also be determined by measuring the mass ( $m$ ) and radius ( $R$ ) of the disk and using the relationship:

$$I = \frac{1}{2} m R^2$$

Therefore, in the case of a uniform disk rotating about its cylinder axis, the following relationship can be shown:

$$\frac{1}{2} m R^2 = \left( \frac{T}{2\pi} \right)^2 \kappa$$

In the case of a disk plus a cylinder (Part C of the experiment), the following relationship can be demonstrated:

$$\left( \frac{T}{2\pi} \right)^2 \kappa = \frac{1}{2} m R^2 + \frac{1}{2} m (R_1^2 + R_2^2)$$

where  $R_1$  = the inner radius of the cylinder and  $R_2$  = the outer radius of the cylinder.



## Part A: Determining the Torsional Spring Constants of the Wires ( $\kappa$ )


### Set Up the Equipment

1. Assemble the Torsion Pendulum and the RMS as directed on pages 2 and 3 of the manual, using the 0.032 inch (diameter) wire.
2. Securely tie the Force Sensor to the large pulley of the 3-step pulley on the RMS with a piece of sturdy string 0.5 m in length.

### Set Up Science Workshop

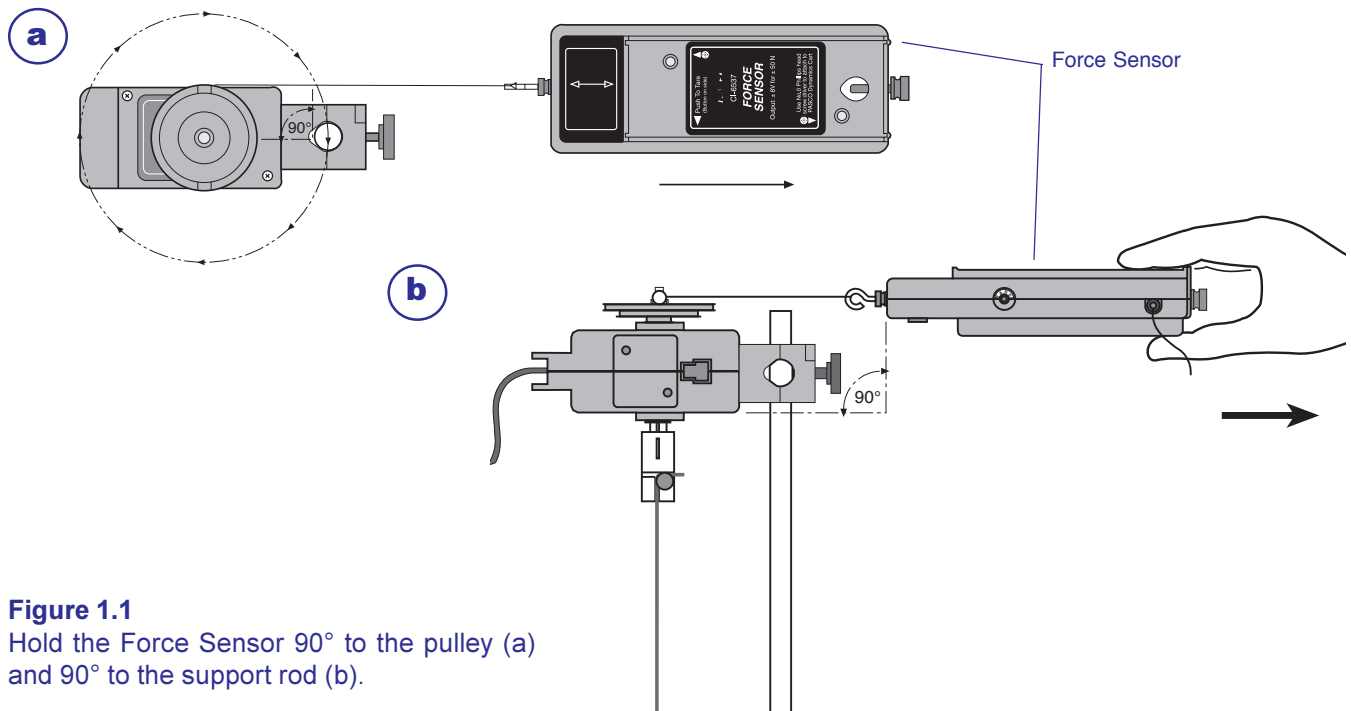
1. Plug the digital plugs of the RMS into digital channels 1 & 2 on the computer interface box.
2. Plug the DIN connector of the Force Sensor into analog channel 1 of the computer interface box.
3. Turn on the interface box and start *Science Workshop*.
4. In the Setup Window, set up the RMS on digital channels 1 & 2 and the Force Sensor on analog channel 1.

► **Note:** Refer to the RMS and Force Sensor manuals for more detailed instructions on setting them up in Science Workshop.

5. Double-click the Force Sensor icon and set the sensitivity to Med (10X).
6. Click the Sampling Options button and set the sampling rate to 50/s.
7. Click and drag a Graph icon to the Force Sensor icon. Click the Statistics button and select **Curve Fit > Linear Fit** from the pop-up menu. Size and move the Graph display as is convenient.
8. Double-click the RMS icon and set Divisions/Rotation to 1440.
9. Click the x-axis input button (  ) on the Graph display and select **Digital 1> Angular Position (angPos)** (This will set the input for the x-axis).

## Collect the Data

1. *Put your safety glasses on.*
2. Wind the string around the large pulley in a clockwise direction.



**Figure 1.1**  
Hold the Force Sensor 90° to the pulley (a)  
and 90° to the support rod (b).

3. Hold the Force Sensor parallel to the table at the height of large pulley and prepare to pull it straight out (Figure 1.1).
4. Start recording data and pull the Force Sensor straight out until about 5 N of force is exerted.
5. Stop recording data (This will be Run 1).
6. Change the wire to the 0.47 inch diameter wire.
7. Repeat steps 2-5 (Run 2).
8. Change the wire to the 0.62 inch diameter wire.
9. Repeat steps 2-5 (Run 3). Save the file.

## Analyze the Data

1. Use the following formula to calculate the torsional spring constant ( $\kappa$ ) for each wire and record in Table 1.1:

$$\kappa = \left( \frac{F}{\theta} \right) \ell$$

where  $\ell$  = the length of the lever arm in meters (the distance from the axis of the pulley to the groove of the pulley) and  $F$  = force in expressed in newtons, and  $\theta$  in the angular displacement at a force  $F$ .

**Table 1.1**

Calculation of torsional spring constants of the wires ( $\kappa$ )

Run	wire diameter (inches)	slope of F vs. angPos	$\ell$ (m)	$\kappa$ (N·m)
1	0.032			
2	0.047			
3	0.062			

► **Note:** Click the Autoscale button on each Graph display if necessary.

## Part B: Determining the Moment of Inertia ( $I$ ) of a Disk Using Two Methods

### Set Up Science Workshop

1. Use the setup detailed in Part A. Save As a different file name, and delete all data sets (Runs 1 - 3) and the Graph display.

(Note: The Force Sensor will not be used in Parts B and C.)

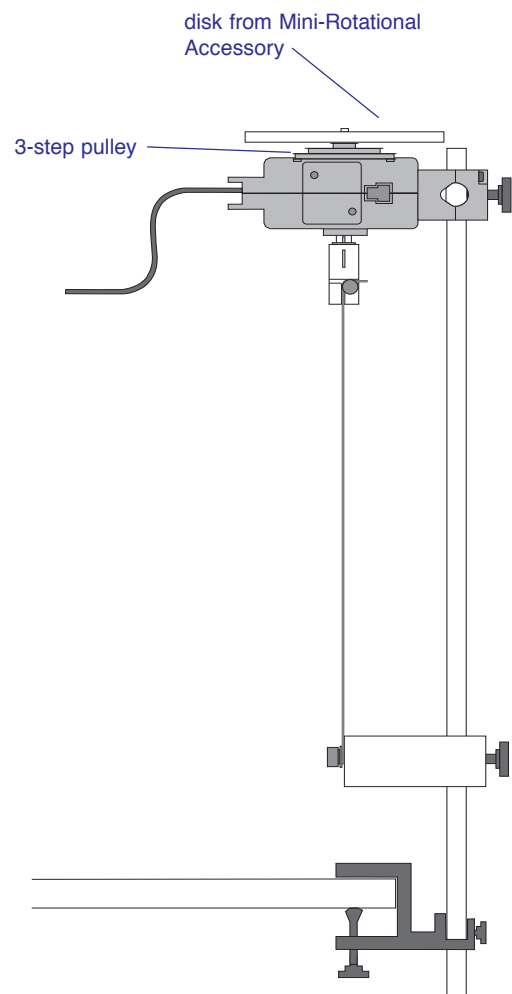
2. Click the Sampling Options button and set the sampling rate to 200 Hz.
3. Click and drag a Graph display to the RMS icon and choose **Angular Position (ang Pos)** from the pop-up menu. (This will set input for the y-axis.)

### Set Up the Equipment

1. Attach the disk from the Mini-Rotational Accessory to the 3-step pulley with the thumbscrew (Figure 1.2).
2. Check the thumbscrews holding the wire to be sure they are tight.

### Collect the Data

1. **Put your safety glasses on.**
2. Twist the disk 1/4 turn clockwise.
3. Begin recording data, release the disk, and record for about 3 –5 seconds.
4. Stop recording data.
5. Click on the Autoscale button to resize the graph, if necessary.
6. Use the Smart Cursor to determine the time for each period of oscillation ( $T$ ) of the pendulum (measure the time between adjacent maxima of the angular position vs. time graph). Record in Table 1.2.
7. Change the wire to the 0.047 inch diameter wire and repeat steps 2–6.



**Figure 1.2**  
Experimental setup

8. Change the wire to the 0.062 inch diameter wire and repeat steps 2–6.
9. Determine the mass and radius of the disk and record below.

mass of disk (kg) \_\_\_\_\_

radius of disk (m) \_\_\_\_\_

**Table 1.2**

Calculation of  $I$  from torsional spring constants of wires ( $\kappa$ )

Run	wire diameter (inches)	$\kappa$ (N·m) (from pt.A)	T (s)	$I$ (kg/m <sup>2</sup> )
1	0.032			
2	0.047			
3	0.062			

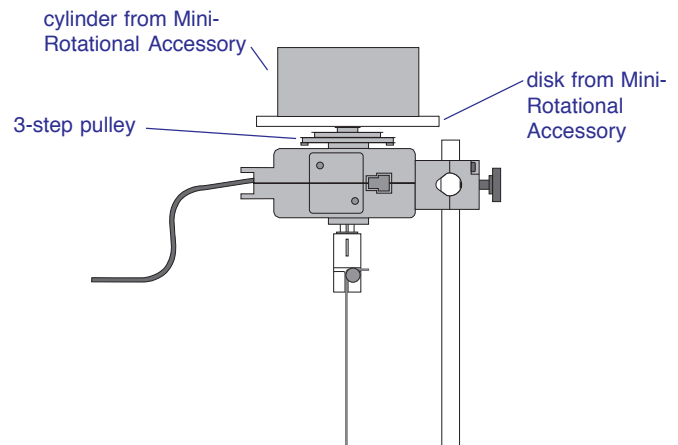
$I$  (using mass and radius measurements) \_\_\_\_\_

### Compare the values of calculated $I$

1. Calculate  $I$  using both formulas:  $I = \left(\frac{T}{2\pi}\right)^2 \kappa$  and  $I = \frac{1}{2} mR^2$  and record above.

### Part C: Determining the Moment of Inertia ( $I$ ) of a Disk and Cylinder Using Two Methods

1. Place the ring of the Mini-Rotational Accessory on the disk (Figure 1.3).
2. Repeat steps 2–6 of Part B. Record your data in Table 1.3.
3. Change the wire to the 0.047 inch diameter wire and repeat steps 2–6.
4. Change the wire to the 0.032 inch diameter wire and repeat steps 2–6.
5. Measure the mass and  $R_1$  and  $R_2$  of the cylinder and record below.



**Figure 1.3**  
Experimental setup for Part C

mass of cylinder (kg) \_\_\_\_\_

$R_1$  (m) \_\_\_\_\_

$R_2$  (m) \_\_\_\_\_

**Table 1.3**

Calculation of  $I_{\text{disk and cylinder}}$  from the torsional spring constants of wires ( $\kappa$ )

wire diameter (inches)	$\kappa$ (N·m) (from part A)	T (s)	$I_{\text{disk and cylinder}}$ (kg/m <sup>2</sup> )
0.032			
0.047			
0.062			

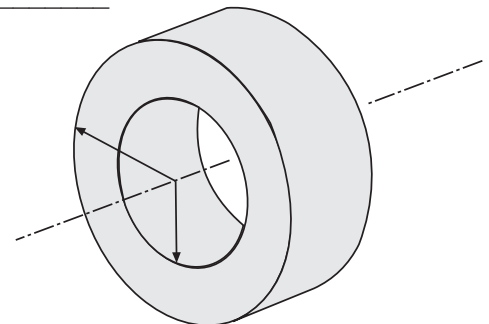
$I_{\text{disk and cylinder}}$  (using mass and radius measurements) \_\_\_\_\_

#### Compare the values of calculated $I$

1. Calculate  $I$  using both formulas:

$$I = \left( \frac{T}{2\pi} \right)^2 \kappa \quad \text{and} \quad I = \frac{1}{2}mR^2 + \frac{1}{2}m(R_1^2 + R_2^2)$$

and record above.



$$I = \frac{1}{2}m(R_1^2 + R_2^2)$$

## Questions

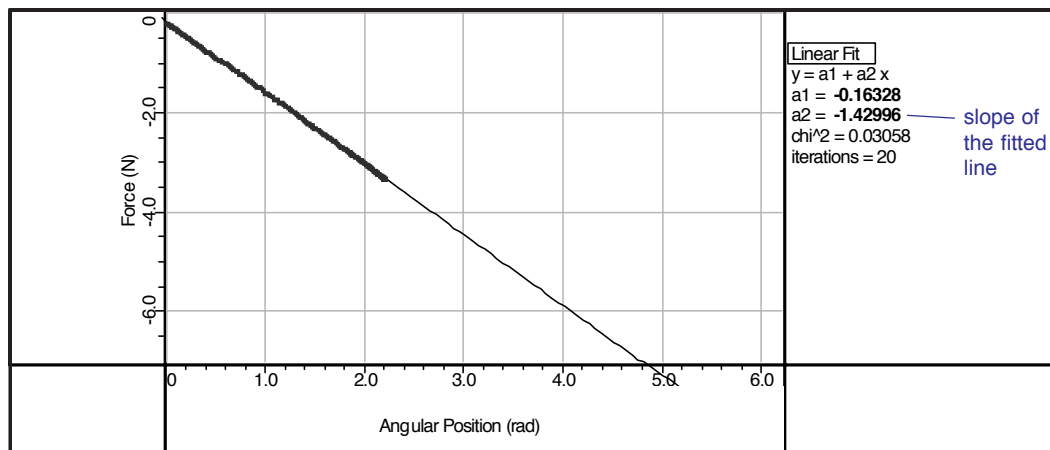
1. How closely did the calculations of  $I$  match?
2. What are some possible sources of experimental error?

## Teacher's Notes:

### General

► **Safety Note:** Use safety glasses when operating the Torsion Pendulum

Experimental data will vary somewhat from the typical data included here due to the differences in wire lengths and other variables, but the overall data patterns will be the same.



**Figure TN1.1**

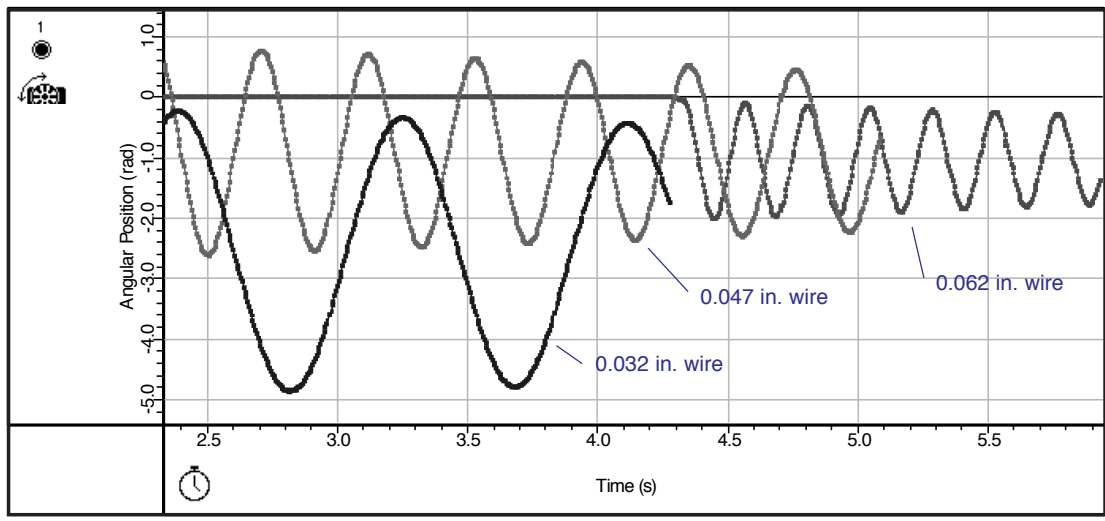
Typical data for determining the torsional spring constant ( $\kappa$ ) (0.047 inch diameter wire)

**Table TN1.1**

Calculation of torsional spring constants of the wires ( $\kappa$ ), typical data

Run	wire diameter (inches)	slope of F vs. angPos	$l$ (m)	$\kappa$ (N·m)
1	0.032	-0.3162	0.0254	0.008
2	0.047	-1.4300	0.0254	0.036
3	0.062	-4.4465	0.0254	0.113



**Part B****Figure TN1.2**

Typical data for determining the period of rotation ( $T$ ) for the three wire diameters (disk accessory)

**Table TN1.2**

Calculation of  $I$  from torsional spring constants ( $\kappa$ ) of wires

Run	wire diameter (inches)	$\kappa^*$ (N·m)	$T$ (s)	$I$ (kg/m <sup>2</sup> )
1	0.032	0.008	0.861	$1.5 \times 10^{-4}$
2	0.047	0.036	0.408	$1.5 \times 10^{-4}$
3	0.062	0.113	0.239	$1.6 \times 10^{-4}$

mass of disk 0.126 kg\*

radius of disk 0.047 m\*

\*may vary somewhat

\*from part A

$I$  (using mass and radius measurements)  $1.4 \times 10^{-4}$

## Part C

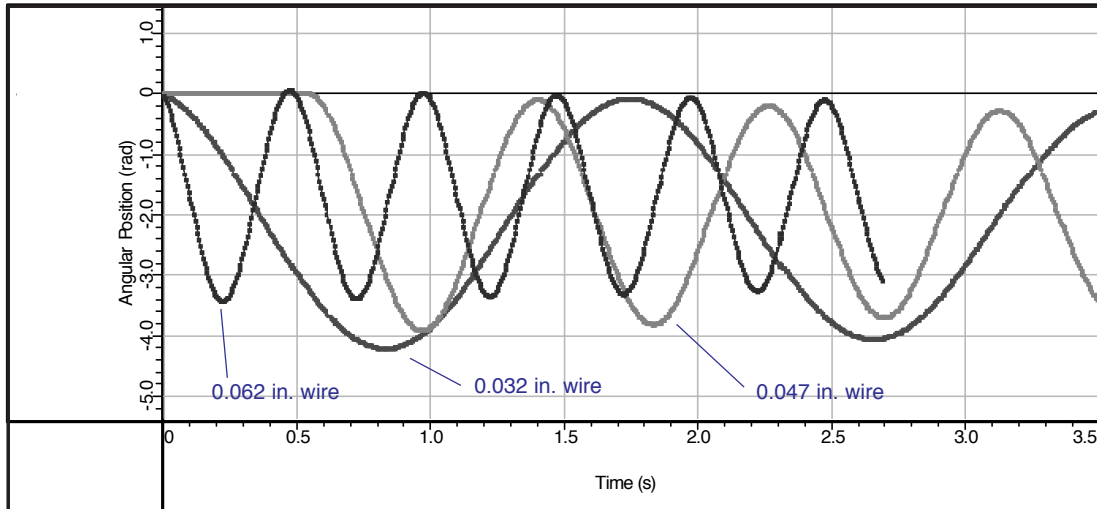


Figure TN1.3

Typical data for determining the period of rotation ( $T$ ) for the three wire diameters (disk plus cylinder)

Table TN1.3

Calculation of  $I_{\text{disk plus cylinder}}$  from torsional spring constants ( $\kappa$ ) of wires

Run	wire diameter (inches)	$\kappa^*$ (N·m)	$T$ (s)	$I$ (kg/m <sup>2</sup> )
1	0.032	0.008	1.826	$6.8 \times 10^{-4}$
2	0.047	0.036	0.861	$6.8 \times 10^{-4}$
3	0.062	0.113	0.500	$7.2 \times 10^{-4}$

$$\text{mass of cylinder } \underline{0.468 \text{ kg}^*}$$

$$R_1 \text{ of cylinder } \underline{0.027 \text{ m}^*}$$

$$R_2 \text{ of cylinder } \underline{0.039 \text{ m}^*}$$

\*may vary somewhat

\*from part A

$$I_{\text{disk plus cylinder}} \text{ (using mass and radius measurements) } \underline{6.7 \times 10^{-4} \text{ kg/m}^2}$$

$$I = 1.4 \times 10^{-4} \text{ kg/m}^2 \text{ (disk)**} + 5.3 \times 10^{-4} \text{ kg/m}^2 \text{ (cylinder)}$$

$$I = 6.7 \times 10^{-4} \text{ kg/m}^2$$

\*\*from Part B

## Questions

1. The experiment demonstrated that the magnitude of the moment of inertia of a disk can be determined two ways: using the torsional spring constant of a wire ( $\kappa$ ) and the period of oscillation of the Torsion Pendulum ( $T$ ), applying the relationship  $I = \left(\frac{T}{2\pi}\right)^2 \kappa$  and by measuring the mass and diameter of the disk and applying the relationship  $I = \frac{1}{2}mR^2$ .
2. The calculated magnitude of  $I$  is approximately the same using either method. However, some experimental error is to be expected, particularly since some portions contributing to  $I$  (the pulley, axle, etc.) were not included in the calculation of  $I$  from using mass and radius measurements, but were included in the calculation of  $I$  using the torsional spring constant of the wire and period of oscillation of the Torsion Pendulum.

The same comments apply to Part C.

## Technical Support

### Feedback

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

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### Contacting Technical Support

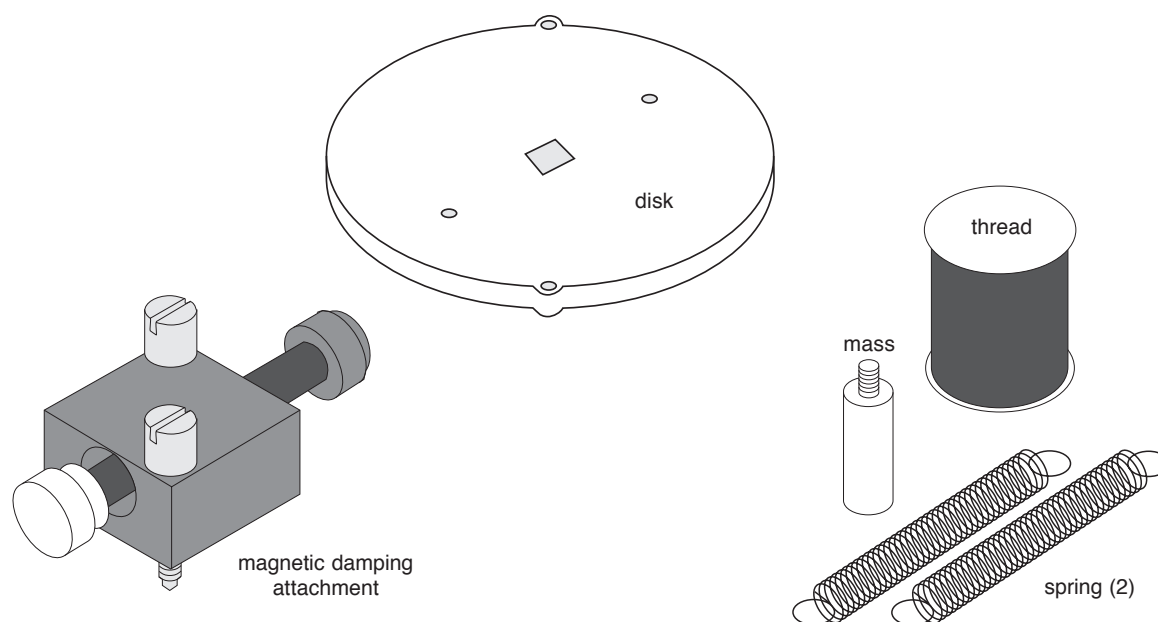
Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

- ▶ If your problem is with the PASCO apparatus, note:
  - Title and model number (usually listed on the label);
  - Approximate age of apparatus;
  - A detailed description of the problem/sequence of events (in case you can't call PASCO right away, you won't lose valuable data);
  - If possible, have the apparatus within reach when calling to facilitate description of individual parts.
- ▶ If your problem relates to the instruction manual, note:
  - Part number and revision (listed by month and year on the front cover);
  - Have the manual at hand to discuss your questions.



**Instruction Sheet  
for the PASCO  
Model CI-6689A**

# CHAOS ACCESSORY



## Introduction

The PASCO CI-6689A Chaos Accessory is designed for use with the PASCO CI-6538 Rotary Motion Sensor (RMS) or the PASCO CI-6625 Rotary Motion Sensor for ULI. It consists of an aluminum disk (identical to the one provided with the PASCO CI-6691 Mini-Rotational Accessory), a mass which attaches to the edge of the disk to form a physical pendulum, two springs for putting tension in the thread, and an adjustable-gap magnet which attaches to the side of the RMS to provide variable magnetic damping.

Please refer to the instruction manual supplied with the Rotary Motion Sensor for a detailed description of experiments using the Chaos Accessory.

## Chaos Experiment

The purpose is to examine the different modes of oscillation of a damped driven physical pendulum caused by varying the driving amplitude, driving frequency, magnetic damping, and initial conditions.

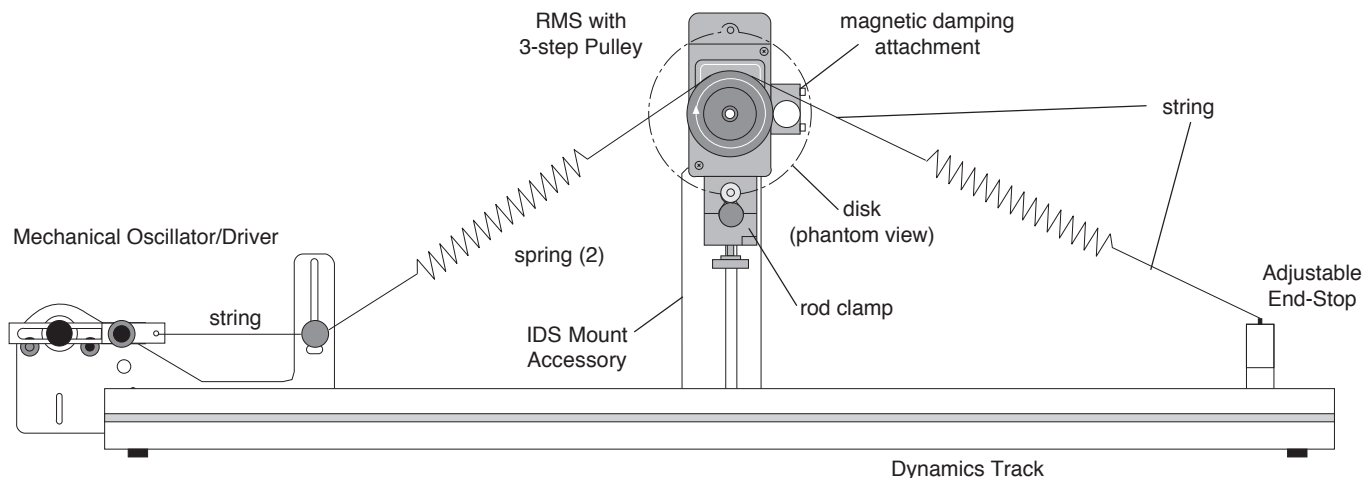
## Additional Equipment Required

- IDS Mount Accessory (CI-6692)

A mounting bracket for mounting the RMS to the PASCO Introductory Dynamics System tracks (1.2 meter ME-9435A or 2.2 meter ME-9458).

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This instruction sheet written by: Jon Hanks



**Chaos Experiment Setup**

**Damped Pendulum Experiment**

The purpose is to show the motion of a magnetically damped physical pendulum.

**Limited Warranty**

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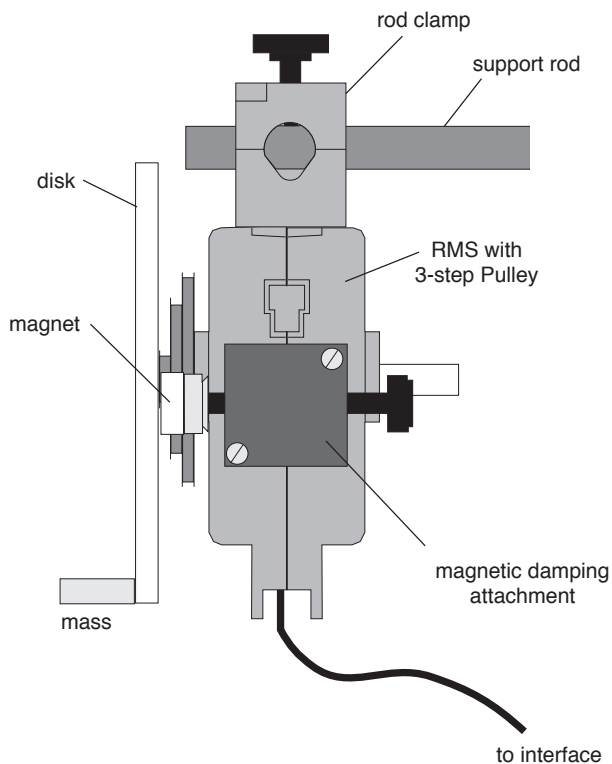
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Web: <http://www.pasco.com>

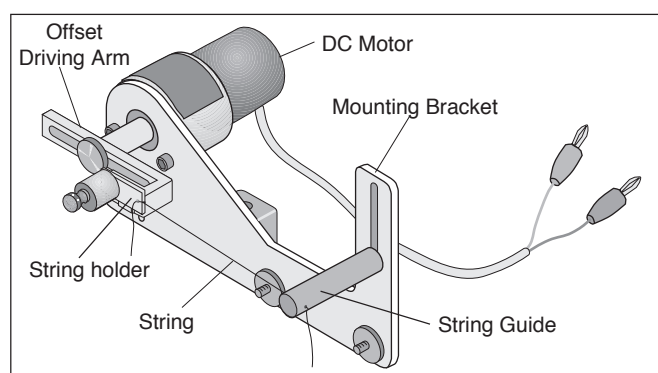


**Damped Pendulum Experiment Setup**

**Instruction Sheet  
for the PASCO  
Model ME-8750**

# HARMONIC OSCILLATOR/DRIVER

## Introduction



## Equipment

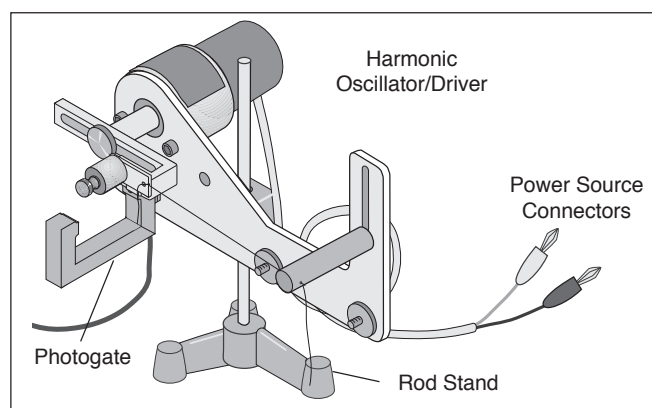
The PASCO ME-8750 Harmonic Oscillator/Driver is designed to drive apparatus requiring a low frequency (0.3 to 3 Hz), high torque, sinusoidal oscillation. It consists of a DC motor with an offset driving arm and a mounting bracket. A string can be attached between the driving arm and the apparatus which is to be driven. The Oscillator/Driver will provide a sinusoidal pull on the string. If one desires to both push and pull on an apparatus, the PASCO Push/Pull Accessory (ME-8751) may be added to the Oscillator/Driver.

## Features

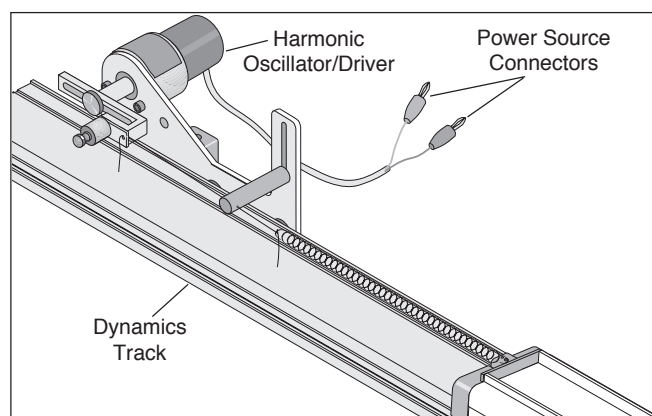
- 12 VDC motor (frequency: 0.3-3 Hz, current: 0-0.3 A)
- Adjustable Amplitude: adjustable up to 12 cm.
- Photogate Attachment: A photogate can be attached to measure the frequency of the oscillator.
- Driver mounts on Dynamics Track or Rod Stand
- Rubber washers on mounting bracket provide quieter operation on the dynamics track.
- Optional Push/Pull Accessory (ME-8751): Mounts to oscillator, replacing the string and allowing the apparatus to be pushed as well as pulled.

## Operation of the Oscillator/Driver

- ① **Mounting:** The Oscillator/Driver can be mounted to a dynamics track to drive dynamics carts or it can be mounted on a rod stand for driving other apparatus. See Figures 1 and 2. Tie one end of a string to the white plastic piece on the driving arm and thread the other end of the string through the hole in the guide. The level of the guide can be adjusted by about 5.5 cm to match the height of the object to be driven.



**Figure 1: Oscillator/Driver Mounted on a Rod Stand**



**Figure 2: Oscillator/Driver Mounted on Dynamics Track**

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This instruction sheet written/edited by: Ann & Jon Hanks



- ② Amplitude Adjustment: To vary the amplitude, loosen the thumb screw that holds the arm to the motor shaft and slide the arm to a new position. Retighten the thumb screw to hold the arm in place. The amplitude is zero when the arm is positioned such that the screw which holds the string holder is aligned over the motor shaft.
- ③ Power Supply: Plug the leads from the Oscillator/Driver into a 12 V (0-0.3 A) variable DC power supply.

► **NOTE:** Do not exceed 12 V.

- ④ Frequency Adjustment: To adjust the frequency, change the voltage of the power supply. An increase in the voltage corresponds to an increase in the frequency.
- ⑤ Measuring the Frequency: Mount a photogate onto the Oscillator/Driver using the slot located below the motor. Each period, the arm will block the photogate. See Figure 1.

### Suggested Uses for the Oscillator/Driver

- ① Attach a spring to each end of a dynamics cart. Connect the free end of one spring to the adjustable end stop at one end of the dynamics track. Connect the free end of the second spring to a string tied to the Oscillator/Driver and threaded through the string guide. Drive the spring and cart system at various frequencies to find the resonant frequency of the system.

► **NOTE:** It generally takes the system a little time to respond to a change in frequency of the driving force so some patience is needed to see the resulting change in amplitude.

- ② Use two carts and three springs to find the resonant frequencies of the two different modes of oscillation. See Figure 3.

### Other Suggested Uses Requiring Additional Push/Pull Accessory

- ③ Mount the Oscillator/Driver on a rod stand and hang a Longitudinal Wave Spring (WA-9401) from the hook on the Push/Pull accessory. Create a transverse wave in the spring to demonstrate that the wavelength varies down the length of the hanging spring.
- ④ Drive a set of hanging balls (see Figure 4) at various frequencies to show different modes of oscillation and chaotic motion.

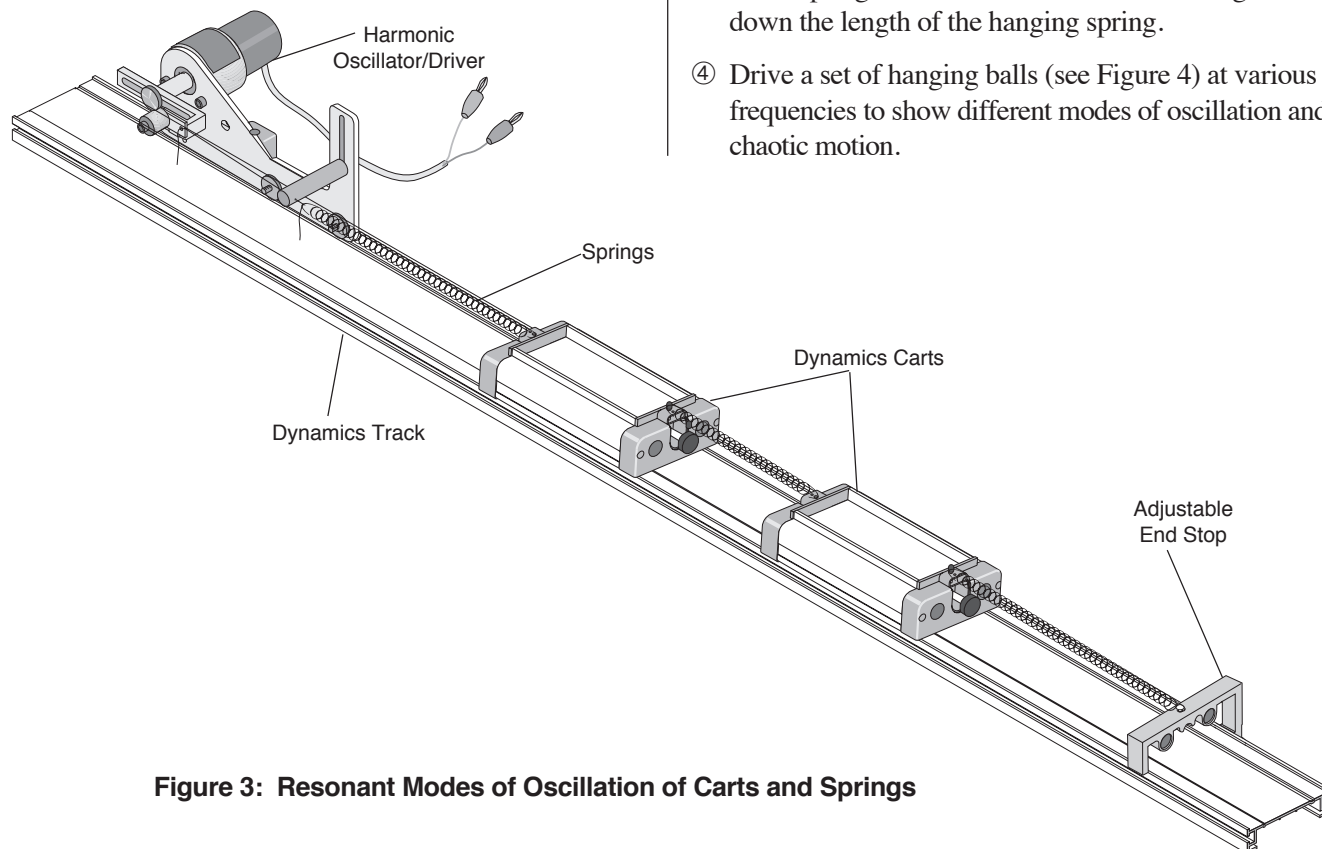
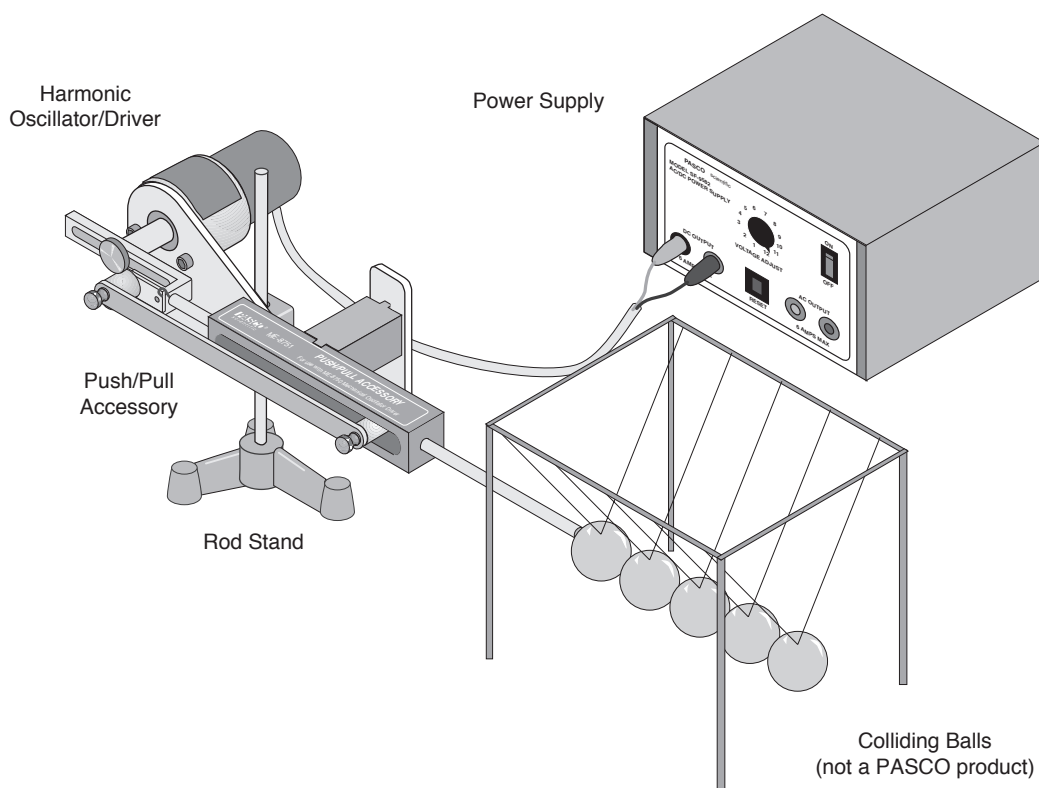


Figure 3: Resonant Modes of Oscillation of Carts and Springs

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**Figure 4: Resonant Modes of Oscillation and Chaotic Motion**

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## **Feed-Back**

If you have any comments about this product or this manual please let us know. If you have any suggestions on alternate experiments or find a problem in the manual please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

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Tech Support Fax: (916)786-3292

## **Contacting Technical Support**

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- If your problem is computer/software related, note:

Title and Revision Date of software.

Type of Computer (Make, Model, Speed).

Type of external Cables/Peripherals.

- If your problem is with the PASCO apparatus, note:

Title and Model number (usually listed on the label).

Approximate age of apparatus.

A detailed description of the problem/sequence of events. (In case you can't call PASCO right away, you won't lose valuable data.)

If possible, have the apparatus within reach when calling. This makes descriptions of individual parts much easier.

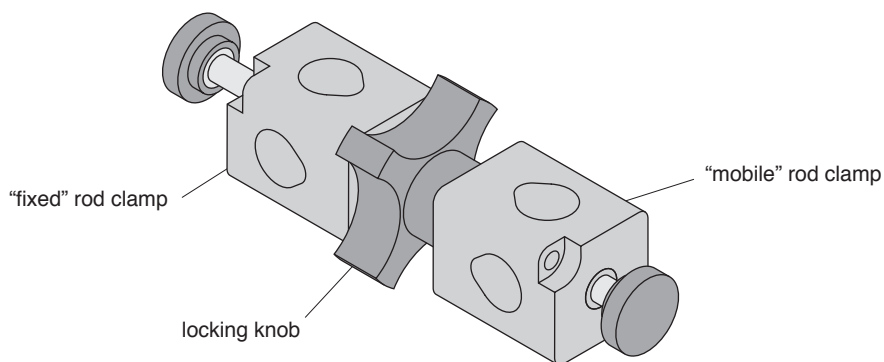
- If your problem relates to the instruction manual, note:

Part number and Revision (listed by month and year on the front cover).

Have the manual at hand to discuss your questions.

**Instruction Sheet  
for the PASCO  
Model ME-8744**

# ADJUSTABLE ANGLE ROD CLAMP



## Introduction

The Adjustable Angle Rod Clamp is designed to allow users flexibility in their lab set up.

## Equipment

– Adjustable Angle Rod Clamp assembly.

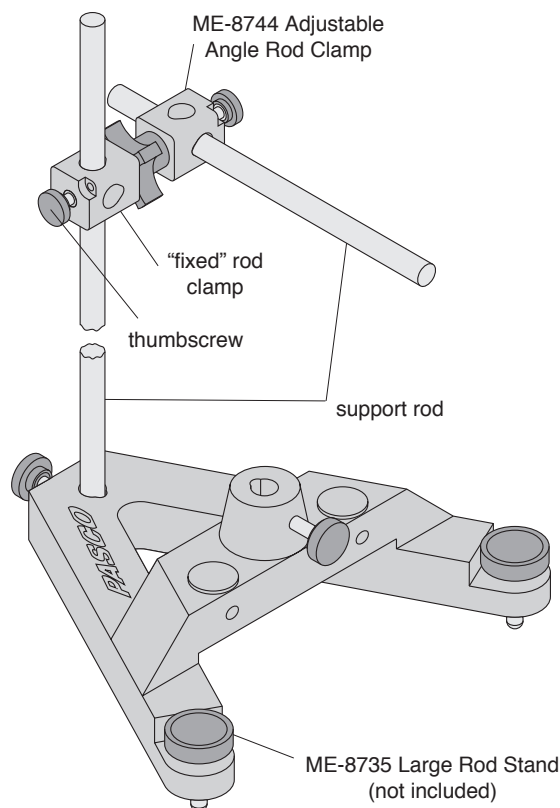
### Additional equipment recommended:

- PASCO ME-8735 Large Rod Stand
- PASCO ME-8738 90 cm Support Rod

## Assembly

### To use the Adjustable Angle Rod Clamp:

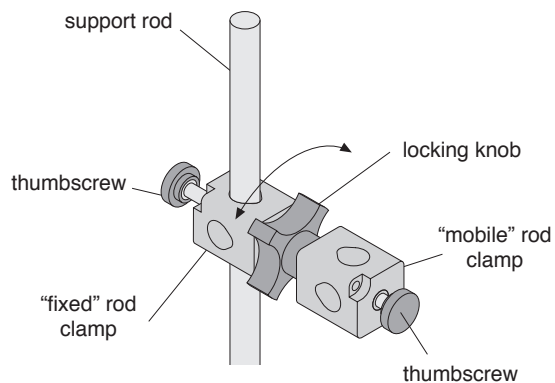
- ① Attach the “fixed” rod clamp, with the locking knob permanently affixed, to a base rod up to 1/2” (12.5 mm) in diameter. See Figure 1.
- ② Secure the rod clamp in place with the thumbscrew.
- ③ Loosen the locking knob and rotate the “mobile” rod clamp into the desired position. See Figure 2.
- ④ Tighten the locking knob against the mobile rod clamp until secure.
- ⑤ Place additional rod or equipment in the mobile rod clamp and secure with the thumbscrew.



**Figure 1: Setting Up the ME-8744  
Adjustable Angle Rod Clamp**

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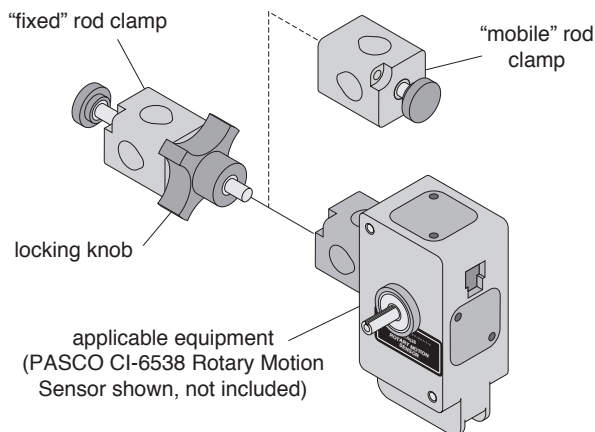
This instruction sheet written/edited by: Robert Morrison



**Figure 2: Adjustable Angle Rod Clamp Adjustment**

**Alternate use:**

- ① Follow steps one and two above.
- ② Loosen the locking knob, and remove the mobile rod clamp.
- ③ Replace the mobile rod clamp with a piece of equipment that has a 1/4 - 20 thread. See Figure 3.
- ④ Rotate the equipment to the correct orientation then secure it with the locking knob.



**Figure 3: Alternate Use for the Adjustable Angle Rod Clamp**

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**Equipment Return**

Should this product have to be returned to PASCO scientific, for whatever reason, notify PASCO scientific by letter or phone BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

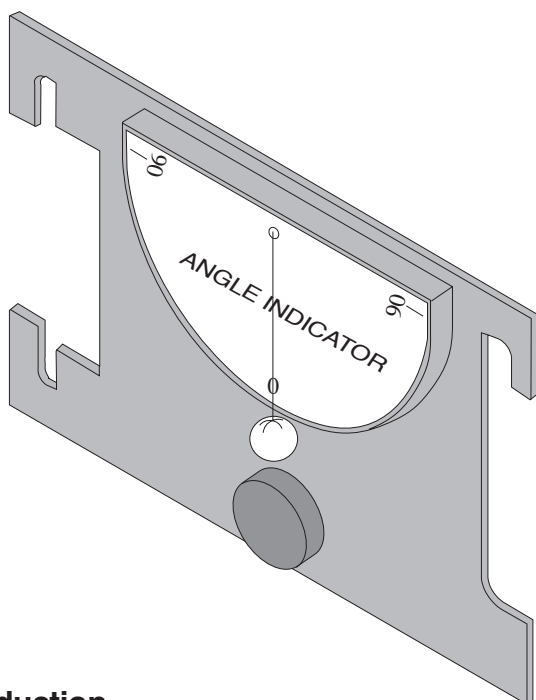
**► NOTE:**  
NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

- ① The carton must be strong enough for the item shipped.
- ② Make certain there is at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
- ③ Make certain that the packing material cannot shift in the box, or become compressed, thus letting the instrument come in contact with the edge of the box.

**Instruction Sheet  
for the PASCO  
Model ME-9495**

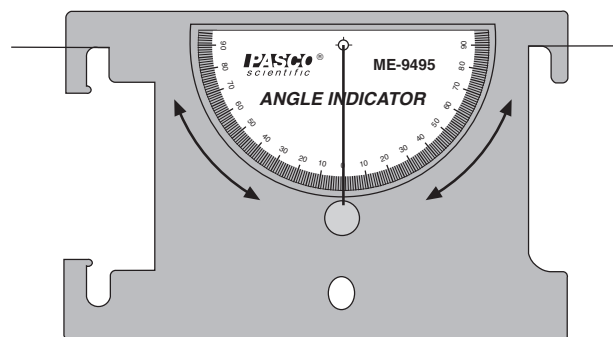
# ANGLE INDICATOR



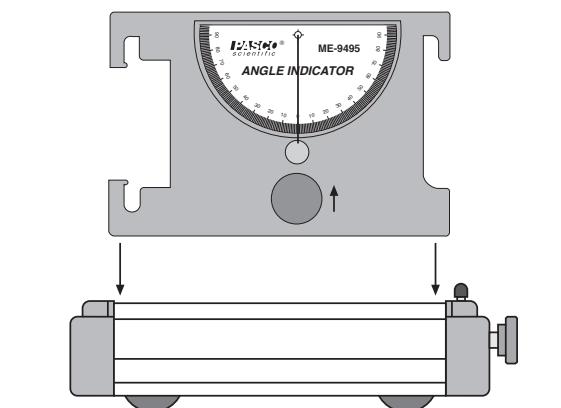
## Introduction

The PASCO ME-9495 Angle Indicator is an accessory used for measuring angles from  $0^\circ$  to  $90^\circ$  in two directions. There are four different methods of using the Angle Indicator:

- hand-held, by tying a string to each side of the device.

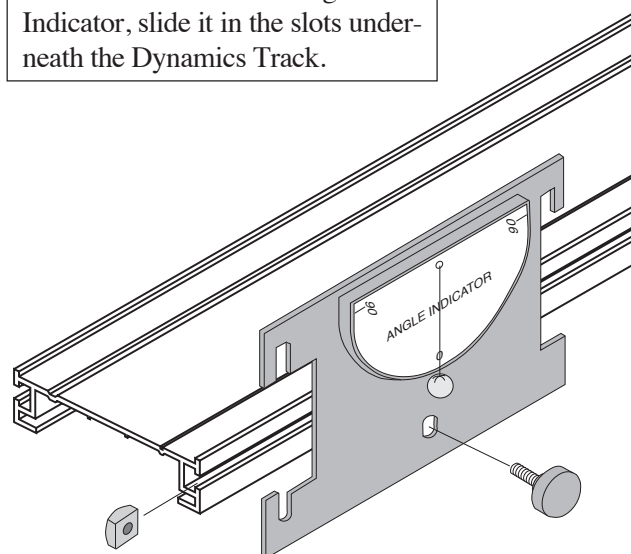


- attached to a PASCO Dynamics Cart, by sliding the device into the slots on the top of the cart. It is necessary to adjust the thumbscrew and square nut as far up as possible on the Angle Indicator.



- attached to the side of a PASCO Dynamics Track.

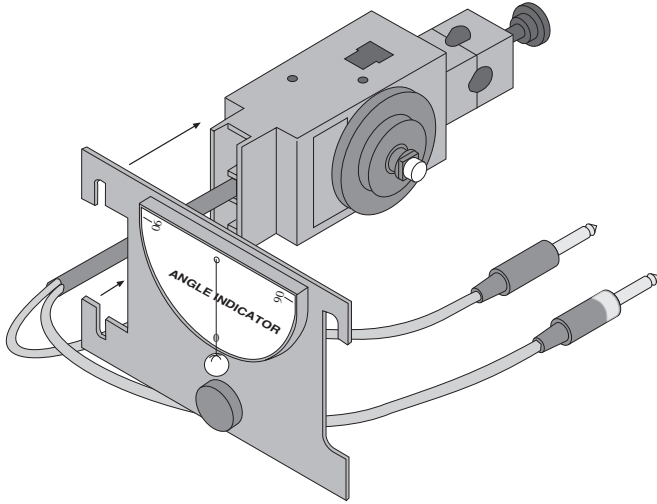
► **NOTE:** To store the Angle Indicator, slide it in the slots underneath the Dynamics Track.



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This instruction sheet written/edited by:

- slipped over the platform on the PASCO CI-6538 Rotary Motion Sensor.

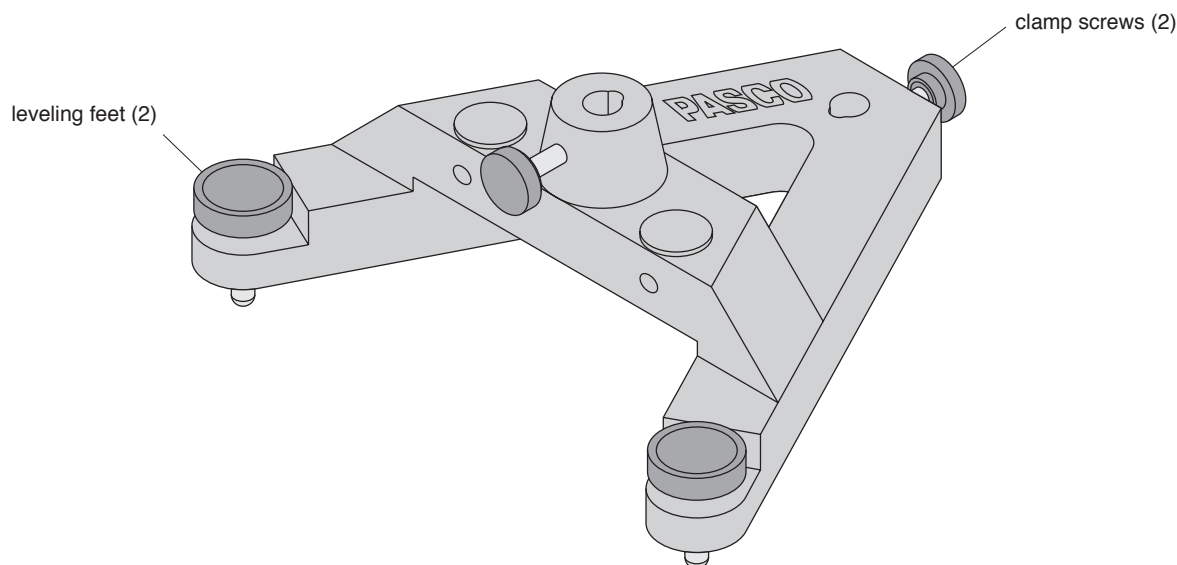


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**Instruction Sheet  
for the PASCO  
Model ME-8735**

## Large Rod Stand



### Introduction

The PASCO Model ME-8735 Large Rod Stand can be used whenever a sturdy base for your vertical support rod is needed.

Rods with an outside diameter of 1/4" to 1/2" (6.5mm to 13mm) may be placed in either the central mounting hole and/or the alternate mounting hole at the peak of the stand. They can be secured to the stand with either of the two clamp screws provided.

The Large Rod Stand can be leveled by turning the knobs on the leveling feet.

### When using the Large Rod Stand keep the following in mind:

- ① The mass of the Large Rod Stand is approximately 9 lbs. (4 kg). If dropped, the Large Rod Stand may be damaged, cause damage to other equipment or cause injury. To prevent personal injury and damage, always carry the Large Rod Stand with a firm grip and try to setup the Large Rod Stand away from the edge of any table or work bench whenever possible.
- ② To prevent the Large Rod Stand from tipping or toppling over during experiments, be reasonable as you setup experiments. Always be sure the Large Rod Stand is able to rest firmly when any possible motion of your experiments occur.

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This instruction sheet written/edited by: Eric Ayars



## Equipment Included

One ME-8735 Large Rod Stand complete with two leveling feet and two clamp screws.

## Limited Warranty

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## Equipment Return

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- ③ Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument come in contact with the packing carton.

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