Lab: **Torsional Pendulum**

BACKGROUND

Torsional vibrations can be observed in our world both in the macroscopic level and in the microscopic. Examples of torsional vibrations in the macroscopic level are the vibrations of suspension bridges. These can be detected with vibration sensors. In the microscopic level, molecules in solids vibrate with a variety of motions one of which is torsional vibrations. Raman spectroscopy allows for the detection of these vibrations. This lesson will allow you to study and analyze the torsional vibrations of a torsional pendulum using a rotary motion sensor.

RESEARCH QUESTION

What is the effect of the torsional constant on the period of a torsional pendulum?

OBJECTIVE

Evaluate the effect of the torsional constant on the period of the torsional pendulum using three torsional wires of different thickness.

Compare the period of the torsional pendulum to the theoretical values that you will calculate and analyze the error.

EXPERIMENTAL PLAN

In the first part of the experiment you will apply a torque onto the torsional pendulum. This torque will rotate the pendulum and create an angular displacement. You will experimentally determine the torsional spring constant from the slope of the torque vs angular displacement graph.

In the second part of the experiment you will attach a disk on the top of the torsional pendulum and set it into small torsional vibrations. You will experimentally determine the period of the torsional pendulum by observing the oscillations in the graph of angular displacement vs time.

You will repeat the procedure for each of the three different wires. This will allow you to have three different torsional constants and the resulting three periods of oscillation. You will use these to evaluate the effect of the torsional constant on the period of the torsional pendulum.

ASSESSMENT

Write a formal lab report (see guidelines). The answers to the research question and objective should appear in your conclusion.

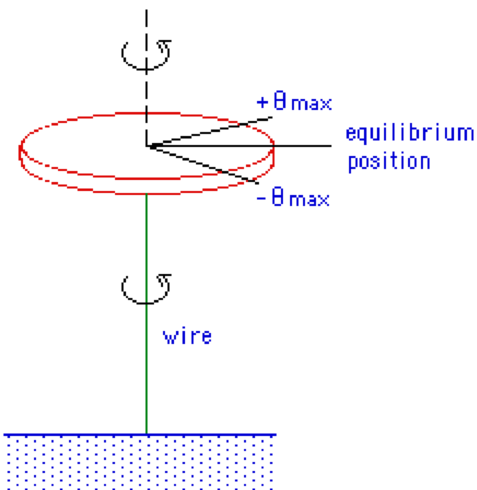
NOTE: The Equipment, Theory, Set-Up and Procedure sections that follow were adapted from PASCO.

EQUIPMENT

		ScienceWorkshop
1	Torsion Pendulum Accessory	ME-6694
1	Large Rod Stand	ME-8735
1	45 cm Long Steel Rod	ME-8736
1	Mini-Rotational Accessory	CI-6691
1	Rotary Motion Sensor	CI-6538
1 1	Force Sensor Pliers for bending wire	CI-6746
1	Mass Balance	SE-8757
1	Computer Interface	CI-6400

THEORY

Consider a wire securely fixed on both ends. If the wire is twisted, it will exert a restoring torque when trying to return to its original untwisted position. For small twists, the restoring torque is proportional to the angular displacement of the wire.



$\tau = \kappa\Theta$

The proportionality constant, κ, depends on the properties of the wire and is called the torsional spring constant.

When the object attached to the wire is twisted and released, the objects executes simple harmonic motion with a period, T, given by

$$T = 2\pi\sqrt{\frac{I}{\kappa}} \qquad (2)$$

where I is the rotational inertia of the object about the axis of rotation.

The rotational inertia of a disk is given by

$$I = \frac{1}{2}MR^2 \qquad (3)$$

where M is the mass of the disk and R is the radius of the disk.

SET UP for ScienceWorkshop Sensors

1. Start with the 0.032" diameter wire. Use pliers to bend each end of the wire into an "L" shape.

2. Fit the bent ends of the wire under the screws and washers of the upper and lower clamps, as illustrated in Figures 1 and 2. Make sure the screws are firmly tightened.

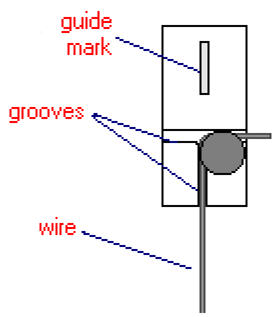


Figure 1: Upper Clamp

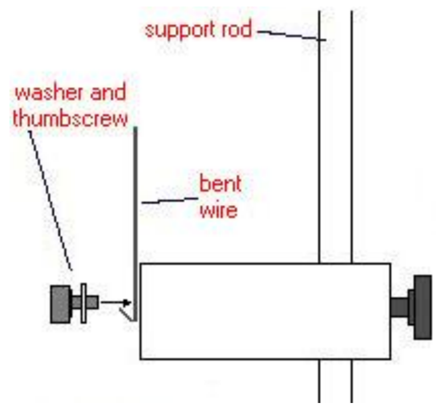


Figure 2: Lower Clamp

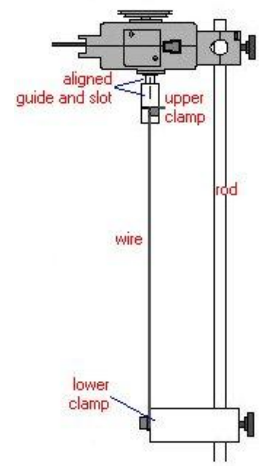
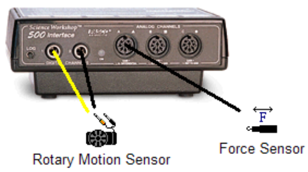


Figure 3: Setup

3. Adjust the Rotary Motion Sensor on the support rod such that the guide on the upper clamp is aligned with the slot on the shaft of the Rotary Motion Sensor. See Figure 3.

4. Adjust the height of the set up so that the upper clamp is approximately half way up the shaft of the Rotary Motion Sensor (see Figure 3). NOTE: When switching to a new diameter wire, try to keep the length of the wires, from clamp to clamp, relatively constant.

5. Plug the Rotary Motion Sensor into Channels 1 and 2 on the ScienceWorkshop interface. Reversing the yellow and black plugs will just change the direction of positive rotation. Plug the Force Sensor into Channel A.



6. Open the DataStudio file called "Torsional Pendulum".

PROCEDURE

A. Determining the Torsional Spring Constant

1. Measure the radius of the medium pulley of the Rotary Motion Sensor in meters. Enter this radius (not diameter!) into the DataStudio calculator window where it asks for the experimental constants. The torque is calculated using $\tau=rF$, where F is the force measured using the Force Sensor.
2. Attach about 20 cm of string to the Rotary Motion Sensor by tying it around the small pulley. Then thread the string through the notch in the medium pulley and wrap the string around the medium pulley 3 times. Attach the Force Sensor to the end of the string.
3. Hold the force sensor parallel to the table at the height of the large pulley and prepare to pull it straight out as shown in Figure 4.

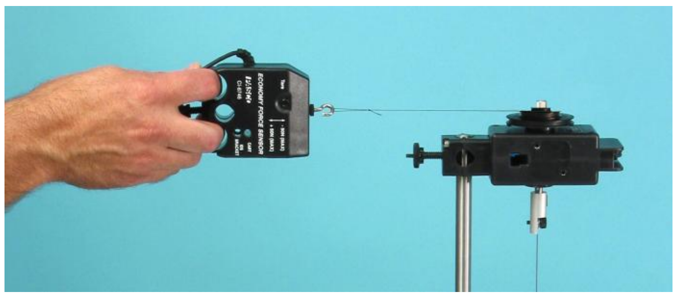


Figure 4: Measuring the Torque

4. Let the string go slack and press the tare button on the Force Sensor. Click the START button in DataStudio and pull the Force Sensor horizontally until the pulley turns about one revolution. Click on STOP.
5. Use the Fit Tool to determine the slope of the graph of Torque vs. Angle. This slope is equal to the torsional spring constant for the wire (see Equation 1).

B. Determining the Rotational Inertia

1. Measure the mass and radius of the disk.
2. Calculate the rotational inertia of the disk using Equation (3).

C. Calculating the Theoretical Period of Oscillation

Using the rotational inertia of the disk and the torsional spring constant for the wire, calculate the theoretical period using Equation (2).

D. Measuring the Period of Oscillation

1. Remove the Force Sensor. The string can still be attached in this part of the experiment as long as it does not impede the oscillation. Twist the disk 1/4 of a turn.
2. Click on the Angle vs. Time graph to bring it forward. Then click on the START button and release the disk.
3. After several oscillations have been completed, click on STOP.
4. Use the Smart Tool to find the period of oscillation.
5. Compare the measured and calculated values of the period using a percent difference.

$$\%difference = \left|\frac{measured - calculated}{calculated}\right| x100$$

Formal Lab Report Guidelines
Mrs. Coyle

1 Heading: Cover page to include lab title, date, names of partners.

2 Research Question: State the research question of the experiment.

2 Objective: State the objective of the experiment.

5 Theoretical Background: Write a few paragraphs that explain the physics principles studied in this lab. Include mathematical equations if needed.

3 Procedure: A brief listing of the steps followed.

4 Diagrams: Labeled diagrams of the experimental set-up. Each diagram should have a title and a number.

6 Data: Data tables with units. They should have a title and number (example: Table 1: Velocity Data). **Note:** If graphs are the data include them here.

7 Calculations: Detailed calculations with formulas, substitution and units. One sample calculation for each data point.

8 Conclusion: One paragraph that includes the answer to the research question and objective. Here you should include error analysis and possible sources of error.

-Reports should be typed double spaced, font 12.