Research Experiences for Teachers (RET) – 2011
LESSON PLAN TEMPLATE

MODULE TOPIC: Torsional Pendulum

RATIONALE: 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 students to study and analyze torsional motion using a torsional pendulum.

STANDARD(S) & INDICATOR(S):

5.1.12.B.3. Revise predictions and explanations using evidence, and connect explanations/arguments to established scientific knowledge, models, and theories.

5.2.8.E.2. Compare the motion of an object acted on by balanced forces with the motion of an object acted on by unbalanced forces in a given specific scenario.

OBJECTIVE(S):

Students will be able to:

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

Student will compare the period of the torsional pendulum to the theoretical values that they will calculate and they will analyze the error.

MATERIALS:

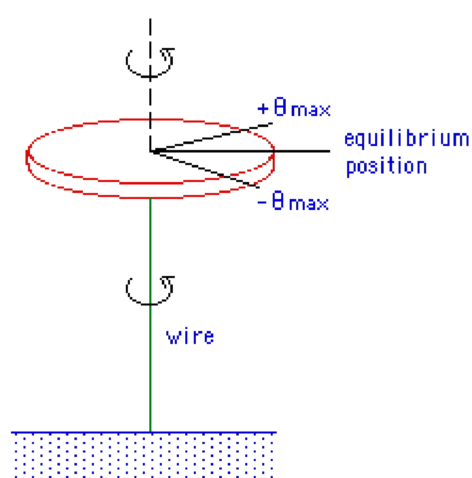
		ScienceWorkshop
1	Torsion Pendulum Accessory	ME-6694
1	Large Rod Stand	ME-8735
1	45 cm Long Steel Rod	ME-8736
1	Mini-Rotational Accessory	CI-6691
1	Rotary Motion Sensor	CI-6538
1 1	Force Sensor Pliers for bending wire	CI-6746
1	Mass Balance	SE-8757
1	Computer Interface	CI-6400

LIST OF HANDOUTS (attach original copies of each handout - teacher & student edition)

Lab: Torsional Pendulum, Formal Lab Report Guidelines

BACKGROUND INFORMATION:

A torsional pendulum can consist of a wire fixed on both ends. If the wire is twisted, a restoring torque will return it to its equilibrium (initial) position. For small angles, the restoring torque, □□□ is proportional to the angular displacement, □□ of the wire: □=□□□□□□The torsional spring constant,□□, is a proportionality constant and it depends on the properties of the wire.



When a disk is attached to the top of the wire and the wire is twisted and released, the disk undergoes simple harmonic motion with a period $T = 2\pi\sqrt{\frac{I}{\kappa}}$. The period depends on the torsional spring constant and on the moment of inertia. The moment of inertia, I, of a disk is given by $I = \frac{1}{2}MR^2$ where M is the mass of the disk and R is the radius of the disk.

CLASSROOM ACTIVITY DESCRIPTION (LABORATORY/EXERCISES/PROBLEMS) including detailed procedures:

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

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

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

The following detailed procedure is from PASCO:

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.

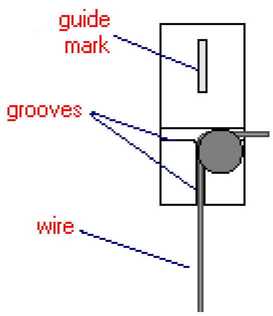


Figure 1: Upper Clamp

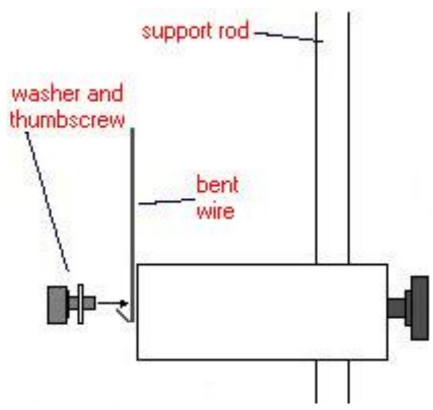


Figure 2: Lower Clamp

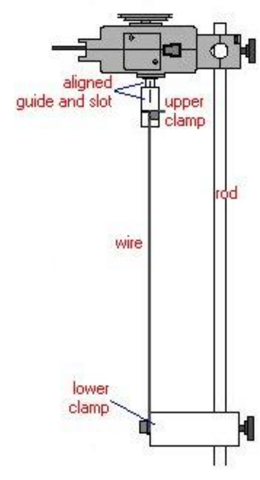
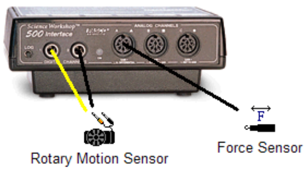


Figure 3: Setup

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 τ=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.

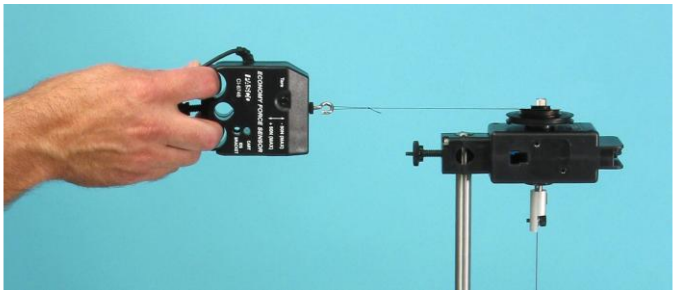


Figure 4: Measuring the Torque

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.

SAMPLE QUESTIONS TO ELICIT CLASS DISCUSSION:

1. Compare how the period of oscillation varies as the torsional pendulum constant increases?
2. Compare the measured and calculated values of the period using percent difference.

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

3. What are possible sources of error?

HOMEWORK ACTIVITY/EXERCISES/PROBLEMS:

Students will write a lab report according to the formal lab report guidelines.

PARAMETERS TO EVALUATE STUDENT WORK PRODUCTS:

A written report that discusses the effect of the torsional constant on the period of a torsional pendulum using three different torsional wires, including analyses of data and graphs.

REFERENCES:

-Serway and Jewett, Physics for Scientists and Engineers
-PASCO

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