Experiment 2: Study a Physical pendulum and Torsional pendulum

Physical Pendulum: If you suspend any regular/irregular object from a fixed support, the object can oscillate about a horizontal axis passing through the fixed support. This arrangement constitutes a physical pendulum. The time period of this pendulum depends on the shape, size and mass of the object and also on the position of the point of suspension

Torsional Pendulum: If you suspend a small and heavy object from a wire and turn/twist the object, the suspension wire also gets twisted. The wire then tries to untwist itself and in the process the object executes torsional vibrations about the wire. This arrangement constitutes a torsional pendulum. The time period of this pendulum besides depending on the shape, size, and mass of the suspended object also depends on the rigidity constant of the wire from which it is suspended.

Make your pendulum:

Materials required: a cylindrical plastic box (having a lid) of length about 4-5 cm, sand (or flour), Cu wire of diameter 0.5mm or more, 15cm/30cm plastic scale

You have to fix a wire in the center of the lid of a cylindrical plastic box. You can make one or two holes in the lid and fix the wire tightly in the holes at the point B as shown in the figure 1. Ensure that there is no slipping between the wire and the lid. Fill the box completely with sand/grains/salt or any other powdery solid so that the arrangement acts as a solid of uniform mass distribution except the walls and lid of the box. Fix the other end of the wire at the point A. You will have to vary the length of the wire AB so leave some scope for it at the point A. But make sure that there is no slipping of wire at A.

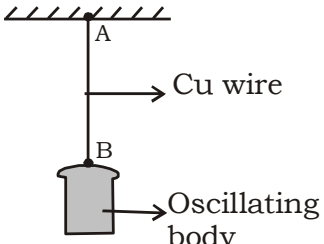

Figure 1

Making measurements:

You need to measure the radius and mass of the cylinder and also the radius of the wire from which it is suspended. You can measure the radius of the cylinder using your 15 cm/30 cm plastic scale in your geometry box. But you will have to device your own method to measure the radius of the wire with the plastic scale. For measuring the mass, you may take the help of the electronic balance available at most of the grocery shops or think of some other way to make the measurements.

Part A

Study the Physical pendulum:

- In this part, keep the length of the suspension wire of the pendulum small. Now pull the box to one side and start the oscillations (Figure 2). Find the time period of the oscillations.
- Find the moment of inertia I_p of the physical pendulum using the equation for the time period of physical pendulum,

  $$T = 2\pi\sqrt{(I_p/Mgd)} \quad \text{----------(i)}$$

  where d is the distance from the point of suspension to the centre of mass of the physical pendulum. You can measure d and use it in the above equation to find the moment of inertia.

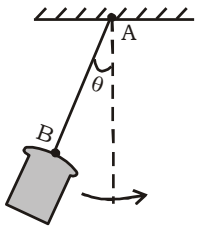

Figure 2

Question: Identify the axis about which the moment of inertia is obtained.

  - Also, find the moment of inertia of the cylinder about its centre of mass I_o using the equation given below

    $$I_p = I_o + Md^2$$

  Question: Identify the axis about which the moment of inertia I_o is obtained

- Let the length AB (Figure 2) of the wire be L. Vary the length L of the wire from say 5cm to 30cm and note the time period of the pendulum for the various lengths. Plot T vs L and T^2 vs L graphs. What conclusions can you draw from these graphs?

Part-B

Study the torsional pendulum:

In this part, keep the length of the suspension wire of the pendulum long. Now hold the box gently and rotate it by a small angle about the suspension wire (Figure 3). The box will start making rotational oscillations about the wire. Find the time period of these rotational oscillations.

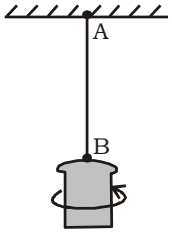

Figure 3

Question: Estimate the angle of twist given to the box by you

- Vary the length L of the wire from say 30 cm to 60 cm and note the time period of the pendulum for the various lengths. Plot T vs L and T^2 vs L graphs. What conclusions can you draw from these graphs?

Torsional constant C and rigidity modulus of wire η

The time period of a torsional pendulum is given by

$$T = 2\pi \sqrt{\frac{I_T}{C}} \quad \text{---------- (ii)}$$

where I_T is the moment of inertia of the box about the wire and C is the torsional constant of the wire

- You can find the ratio I_T/C from the above relation
- Find the moment of inertia of the cylindrical body using the relation

  $$I_T = MR^2/2$$

  where M is the mass of the solid cylinder and R is the radius of the solid cylinder. Identify the axis about which the moment of inertia is obtained.

Question: Find the ratio between this value of moment of inertia I_T and the value of I_o obtained in part A

Using the value of I_T, find the torsional constant C from the ratio I_T/C

- Also calculate the rigidity modulus η of the wire using the equation

  $$(\pi\eta r^4/2L) = C$$

  where η = rigidity modulus of the wire and r = radius of the wire

Extra exploration:

You can think of extending the experiment in various innovative ways for which you will be given extra credit. Some suggestions are

i) Measure the radius of the Cu wire and/or some other parameters in as many ways as you can

ii) Vary the mass/diameter/radius of the cylindrical box and see how it affects the results obtained.

Expectations:

1. A photograph of the complete experimental setup
2. Less than one-minute videos as you take the readings for measuring the
   i) Time period of oscillations of the physical pendulum
   ii) Time period of oscillations of the torsional pendulum
3. Neatly tabulated observations, graphs and calculations.
4. Error analysis of the data and the results obtained
5. Answer the questions asked at various places in the experimental writeup
6. A report describing your entire experiment, observations, graphs and inferences in a pdf format