Rotational Inertia

Learning Outcomes Objectives

- Determine the rotational inertia of an object.
- Compare predicted values with experimental results.

Principles

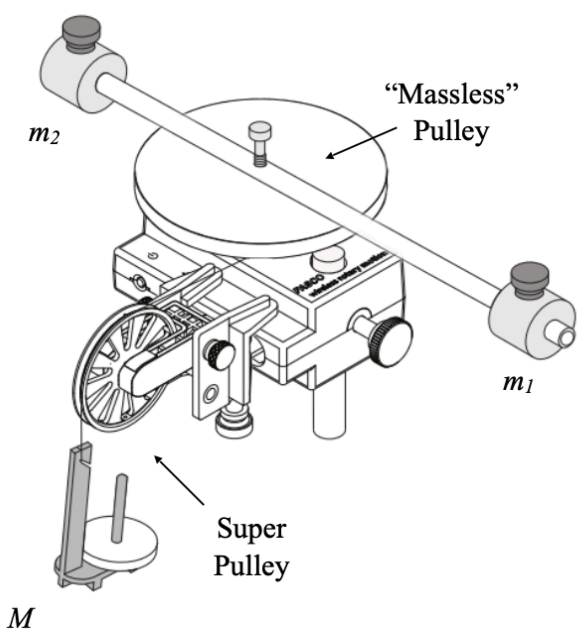
The rotational inertia of a body depends on the body's mass and the way its mass is distributed about an axis of rotation. In general, the more compact an object, the less rotational inertia it has.

Newton's 2nd Law for torques can be used to determine experimentally the rotational inertia of various bodies:

$$\tau_{net} = \sum_{i=1}^{n} \tau_i = I_{total}\alpha$$

Warm Up

A hollow, cylindrical rod of radius r_{rod}, length L, and mass m_{rod} is free to rotate about an axis through its central diameter. Two discrete particles of masses m_1 and m_2 are placed at distances of r_1 and r_2 from the rotation axis, respectively. The rod is attached to a "massless" pulley of radius R through the rod's axis of rotation.



This pulley is connected by a very light string to a mass M that hangs over a frictionless super pulley. M, via the string, exerts a perpendicular torque on the pulley when it is allowed to fall from rest which causes it to have an angular acceleration.

You will determine rotational inertia using two different methods, then compare those methods:

Method 1

1. **Determine the total rotational inertia of the system using $I_{total} = \Sigma I_i$** (see table of inertia values in the textbook).

Method 2

1. **If the angular acceleration is measured to be α, determine the total rotational inertia of the system using Newton's 2nd Law for torques, $\Sigma\tau_i = I\alpha$.** Note: You are not plugging into to I, but rather, you are solving for I in terms of α and things that can be experimentally measured by using Newton's 2nd Law for torques.

Apparatus

1. bar and "point" masses
2. super pulley
3. wireless rotary motion sensor
4. Calipers
5. Balance
6. support rod and base
7. mass hanger
8. ~ 1.5m string

Experiment

Method 1

1. **Measure the length L and mass m_{rod} of the rod**.

2. **Measure the masses of m_1 and m_2**.

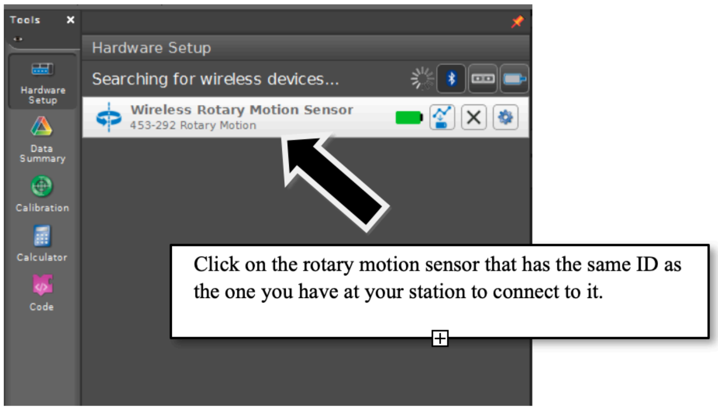
3. **Choose and record r_1 and r_2 radial distances on the rod to position masses m_1 and m_2.**

4. **Use your derivation for the rotational inertia of the system (in the warm up) to predict the rotational inertia of the rod and masses.**

Method 2

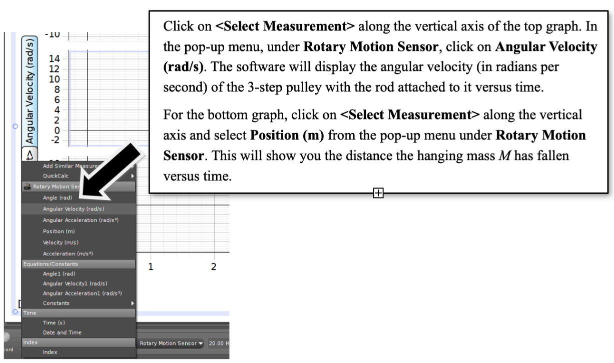
1. Measure the diameter of the large groove on the step pulley of the rotary motion sensor. From this, **calculate the radius of the step pulley.**

2. Press the power button on the wireless rotary motion sensor to turn it on. After opening the Capstone software, click on **Hardware Setup**, located on the left side of the screen. This will open a window displaying nearby wireless devices.



3. Click on the gear icon to open the **Properties** window for the rotary motion sensor. Make sure that for the **Linear Accessory** option, the correct size pulley is selected. For example, if you wind the string around the large groove on the step pulley, make sure that **Large Pulley (Groove)** is selected from the drop-down menu. Click **OK** and close the **Hardware Setup** window.

4. Double-click on the **Graph** icon to open a new graph. Click next to  in the menu bar above the graph to create a new y-axis on the display. There should be two graphs shown that share the same horizontal axis.



5. Wind the string around one of the grooves on the step pulley of the rotary motion sensor by rotating the pulley until M (70g including the hanger) is raised almost to the height of the super pulley. Hold M in place. Start recording data and then release M. Stop recording data *just before* M reaches the floor.
6. **Determine the angular acceleration of the system based on the angular velocity vs. time graph**. **Explain how you do this.**

7. **Use your data from the position vs. time graph to determine the linear distance *h* that *M* had fallen during the experiment.**

8. **From your answer to the previous question, what is the linear acceleration of M?**

9. **From your answer to the previous question, what is the net force on M?**

10. **From your answer to the previous question, what is the tension in the string?**

11. **From your answer to the previous question, what is the torque applied by the string on the massless pulley?**

12. **Using your measurements and derivations, calculate the rod's rotational inertia.**

Reflection

1. **How do the two values for rotational inertia compare? Calculate the percent difference or percent error as appropriate to compare.**

2. **Which method do you think is more accurate, Method 1, using $I = \Sigma I_i$; or Method 2, using $\Sigma\tau_i = I\alpha$? Why? *Defend* your choice!**