**Moment of Inertia**

There are countless mechanisms in our lives that rely on rotations. Consider a vehicle, such as a truck, a passenger car, or a school bus. The wheels themselves are the most obvious mechanism that involves rotation, but rotation is involved in almost every function of the vehicle—from the drive shaft to the windshield wipers to the doors.

Similar to translational motion, rotational motion is governed by Newton’s second law of motion

α = τ /*I*

*Equation 1: Newton’s second law of motion for rotation*

where α is the angular acceleration, τ is the torque, and *I* is the moment of inertia.

Torque is the driver. Torque is force applied to an object to cause it to spin. The moment of inertia is related to the mass and the distribution of mass relative to the axis of rotation. You can see from Equation 1 that the acceleration is proportional to torque and inversely proportional to the moment of inertia.

In this activity, you will investigate the nature of the moment of inertia by exploring the effect of rotating different objects.

**MATERIALS**

computer, Chromebook, or mobile device running Graphical Analysis 4 app

Go Direct Centripetal Force Apparatus

Go Direct Force and Acceleration

Centripetal Force Apparatus Moment of Inertia Kit

hanging mass (50 g mass recommended)

string (approximately 1 m in length)

meter stick

**PRELIMINARY QUESTIONS**

1. Attach a small mass to the end of a long stick. A 50 g mass taped close to the end of a meter stick works well. Hold the end closest to the mass and rotate the stick like a windshield wiper. Consider the torque you apply to the stick and how fast you can cause it to rotate back and forth.
2. Now grasp the stick from the other end and repeat the same motion. Be careful not to hit a classmate! What do you observe?
3. Determine the units for the moment of inertia using the units of angular acceleration and torque.

*I* = τ / α

Moment of inertia units of measure: \_\_\_\_\_\_\_\_\_

1. In this investigation you will collect angular acceleration data for the following objects:

* beam
* disk (horizontal orientation)
* 2 disks
* disk and hoop
* disk (vertical orientation)
* hoop (vertical orientation)

With your lab partners, consider the units for the moment of inertia and predict the order of the objects according to their angular acceleration. Document your prediction in Table 1.

|  |  |  |  |
| --- | --- | --- | --- |
| Table 1 | | | |
| Object | Predicted acceleration ranking  (1 least, 6 most) | Angular acceleration  (rad/s2) | Actual acceleration ranking  (1 least, 6 most) |
| Beam |  |  |  |
| Disk (horizontal orientation) |  |  |  |
| 2 disks |  |  |  |
| Disk and hoop |  |  |  |
| Disk (vertical orientation) |  |  |  |
| Hoop (vertical orientation) |  |  |  |

**PROCEDURE**

1. Attach the Go Direct Force and Acceleration Sensor to the bearing shaft of the Go Direct Centripetal Force Apparatus. Make sure that the sensor rests on the clip mid-way down the shaft, and use the plastic thumb screw to gently secure it to the shaft. **Note**: If the Centripetal Force Apparatus had been previously set up with the beam, remove the beam before attaching the Force and Acceleration Sensor.
2. Attach the pulley bracket and pulley from the Moment of Inertia Kit to the base of the Centripetal Force Apparatus. Align the pulley with the middle step of the three-step pulley. Have a light string, approximately 1 m in length, and a 50 g mass available.
3. Set up the sensor and data-collection app.
4. Turn on the Force and Acceleration Sensor.
5. Launch Graphical Analysis 4 and connect to the sensor.
6. Click or tap Sensor Channels. Deselect the Force channel and select the Z-axis gyro channel.
7. Click or tap Done.
8. Collect and analyze data.
9. Collect data for the first object using the 50 g mass to drive the experiment. In order to capture the beginning of the fall, click or tap Collect to start data collection, and then release the falling mass.
10. To determine the angular acceleration, select the first section of angular velocity data and click or tap, Graph Tools,button.ga._graph-tools.01.png. **Note**: The entire data collection trial may not be linear. For best results, select only the data from the first portion of the trial.
11. Select Apply Curve Fit, select Linear, and then click or tap Apply. The angular acceleration is equal to the slope of the linear fit. Enter the acceleration value in Table 1.
12. Repeat this step to collect and analyze data for the remaining objects.

**ANALYSIS**

1. With your lab group, discuss the results of your investigation. Did your predictions match your actual results? If so, provide rationale as to why your predictions matched the data. If not, discuss what misconceptions you might have had initially, and what the results indicate. Document the results of your discussions.

2. Explain in your own words how the mass distribution of an object affects its rotational acceleration.

3. Calculate the moments of inertia for the objects tested based on the data you collected. You will need the radius of the 2nd step of the three-step pulley (0.0145 m) and the mass of the falling mass (use the actual mass). Record these values in Table 2. **Note**: Because you will conduct the same calculation six times, you may find it easiest to use a spreadsheet.

4. Look up moments of inertia for objects similar to those tested, such as a beam, disk, and hoop. Estimate the theoretical moment of inertia for each of your experimental objects and record the estimated values in Table 2. Determine the percent difference between the observed (experimental) moment of inertia and the theoretical value.

|  |  |  |  |
| --- | --- | --- | --- |
| Table 2 | | | |
| Object | Moment of inertia–experimental  (kg•m2) | Moment of inertia– theoretical  (kg•m2) | Percent difference (%) |
| Beam |  |  |  |
| Disk (horizontal orientation) |  |  |  |
| 2 disks |  |  |  |
| Disk and hoop |  |  |  |
| Disk (vertical orientation) |  |  |  |
| Hoop (vertical orientation) |  |  |  |