Simulated Moment of Inertia Lab

In most of our experiments so far, we have dealt with spherical uniform objects without having to consider the shape or density when analyzing their motion. It turns out that the shape and density of an object play a large roll in the object’s motion. In lecture, you will learn about a quantity called the moment of inertia, which plays a similar roll as mass does in purely translational motion. The moment of inertia depends not only on the mass, but also on the shape and orientation of the object. The greater the object moment of inertia, the harder it is to get that object to rotate, just as the greater the mass of an object, the harder it is to linearly accelerate the object. In this lab, we will study how changing the size and mass distribution, and therefore the moment of inertia of an object affects its motion while rolling down a ramp.

Procedure

1. Start Virtual Physics and select Rotational Inertia from the list of assignments. The lab will open in the Mechanics laboratory.

2. The laboratory will be set up with a ball on a ramp with an angle of 30°. You will be observing the speed and acceleration of the ball down the ramp and comparing it with the motion of other types of balls. Click the red button in the Recording area to start recording data. Start the ball rolling down the ramp by clicking the Start button. When the ball hits the end of the ramp, a link will be generated in the Lab Book that contains the position, velocity and acceleration versus time data for the ball rolling down the ramp.

3. Click the Reset button to move the ball back to the top of the ramp. The diameter of the first ball was 2 meters. Set the diameter of the ball to 3 meters using the Objects section of the Parameters Palette. Repeat Step 2. Repeat the experiment one more time with a ball with a diameter of 0.5 meters. You should now have three data links in your lab book. Click to the right of the data links and a cursor will appear to allow you to label each

run with the corresponding ball diameter. Click on the icon to display the data and record the final velocity and acceleration for each ball in the data table below. Find the final velocity by looking for the velocity when r=0, when the ball reaches the end of the ramp. Also record the time when the ball reaches the end of the ramp.

4. Record the final angular velocities in the table, found in the Data Viewer under v_rot.

5. Reset the experiment. In the Parameters Palette change the Mass Distribution to Ring. Click the red Recording button and Start the experiment. When the ball reaches the end of the ramp, label the new data link to identify the ball, and compare the velocity and acceleration data to the solid ball data. Record the data in the Data Table on the previous page.

6. Repeat the experiment with hollow balls of the same diameters as the previously tested solid balls. Report the data in the Data Table. Remember to change the mass distribution to ring every time you reset. Also try adjusting the mass, without changing the radius, and with a change in radius.

Questions & Data Analysis

1. Fill out the table below with the data collected in procedure above

Ball Diameter (m)	Solid or Hollow	Final Velocity (m/s)	Linear Acceleration (m/s^2)	Time (s)	Final Rotational Velocity (rads/s)
2	Solid	18.7146	3.5024	5.344	18.7146
3	Solid	18.7146	3.5024	5.344	12.4764
0.5	Solid	18.7146	3.5024	5.344	74.8585
2	Hollow	17.1522	2.9420	5.831	17.1522
3	Hollow	17.1522	2.9420	5.831	11.4348
0.5	Hollow	17.1522	2.9420	5.831	68.6090

2. How did the accelerations of the first three balls compare?

Linear aceleration on all of the first three balls were the same.

3. As you have observed the motion of the three balls, you have probably noticed that there are similarities and differences between the rolling of the different balls. What is different about the rotations of the different balls?

We notice that translational properties of the motion remains the same when only the diameter changes but the rotational properties (angular velocity) does change.

4. You will now test balls with different properties to see how their motion compares. The balls you have been rolling up to this point have been solid balls, now you will be rolling hollow balls, with all of the mass in the outer shell of the ball. How do you think the motion will compare? Will the hollow ball or the solid ball roll down the ramp faster?

The hollow counterpart of the solid balls will roll slower because their moment of inertia is larger and therefor it requires a larger duration of time to achieve similar angular velocity.

5. What was different about the motion of the hollow ball?

The hollow balls were slower than solid ones and amongst hollow balls, only their angular velocity changed.

6. What trends do you see with the different variables you have tested?

Diameter is inversely proportional to final rotational velocity. Final velocity, and acceleration are independent of ball diameter.

7. Apply what you have studied in this lab to explain why you speed up when spinning on a chair, or on ice skates, when you pull your arms and legs in.

When the arms are streched the body has a larger moment of inertia much like the hollow ball, and spins slower. Once the arms and legs are pulled in the moment of inertia decrease and the speed of spinning increases.

Extra Credit: Why does shape, or mass distribution, affect the speed while size and total mass do not (Hint: A static frictional force supplies the torque) The following equations will be useful $\tau = RF sin\theta , \tau = I\alpha , a = R\alpha , I = C * m R^2$ where C is a constant.

$I\alpha = \tau = RF \cdot sin\theta = R(\mu mg cos\theta) \cdot sin\theta$

$(Cm R^2)(\frac{a}{R}) = R(\mu mg cos\theta) \cdot sin\theta$

$a = \mu \frac{cos\theta sin\theta}{C}$ (Independent of total mass and radius, but depends on mass distribution C)

$v \propto a$ (Therefore v is also independent of total mass and radius and depends on shape)