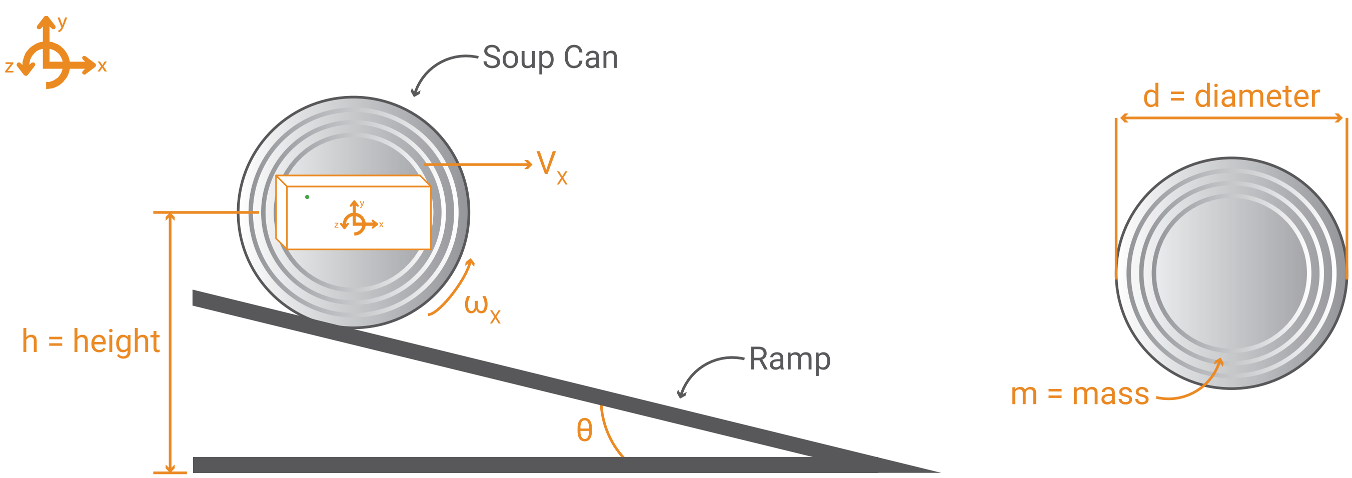
Angular Velocity of Rolling Object at Different Inclines

Exploration

The moment of inertia (MOI) is the rotational inertia of an object as it rotates about a specific axis. Moment of inertia determines the torque required for a specific angular rotation about an axis. The moment of inertia depends upon the distribution of mass of the rotating object in relation to the axis the object is rotating about.



Materials

- PocketLab (use two if available)
- Inclined ramp (stiff piece of cardboard, sheet of wood, or sheet of plastic)
- Can of soup
- **Optional:** Protractor
- **Optional:** Digital scale or triple beam balance

Objective:

In this experiment, students will:

1. Explore how changing the incline angle of a ramp will affect the angular velocity of a can of soup as it rolls down the ramp.
2. Compare the angular velocity to the average speed at which the can rolls down the ramp.

Method

1. Set up the ramp. Start with a low angle. Use the protractor to measure the angle of the incline. You can also calculate the angle of the ramp using the 3-axis accelerometer and geometry as in the lesson Measure The Angle of a Incline Plane. Record the angle.
   Note: Using a class set of textbooks to support the incline is helpful because you can add height in even increments.
2. Measure and record the diameter of the soup can.
3. Tape PocketLab to the end of the soup can or cylinder.
4. Release the soup can or cylinder so it rolls down the ramp.
5. Monitor and record the angular velocity with the PocketLab. If PocketLab is oriented like the diagram, the rotation of interest will be about the z-axis.
6. By observing the PocketLab angular velocity data, measure how much time it takes for the soup can to reach the bottom of the ramp. You should be able to determine the time point when the soup can starts rolling and then see a sudden change in angular velocity when the soup can reaches the bottom of the ramp.
7. Measure how much time elapses until the soup can stops rolling.
8. Measure the length of the distance traveled with a tape measure.
9. Increase the angle of incline using the protractor and repeat steps 4–6. Continue to increase the angle of incline until you have tested at least 4 different angles.

Predictions

- As the incline angle of the ramp increases, predict how the angular velocity and linear velocity will be affected. Explain your answer.

Data Analysis and Observations

- How can you calculate the soup can's linear velocity using the angular velocity data and the dimensions of the soup can? Try using the formula below, where V is velocity, z is angular velocity about the zaxis, and d is the diameter of the soup can:

$$V=\omega_z * (\pi d)$$

- Judging by your own qualitative observations, did the angular velocity and/or speed of the can of soup/cylinder seem to change as the angle of incline increased?
- Looking at the recorded data, how did the angle of incline affect the angular velocity and linear velocity of the can of soup/cylinder?

Conclusions

- Explain how the angular velocity of a rotating object can affect the linear velocity of that object? Use data to support your ideas. Relate your answer to a different real world example (example: a bicycle wheel).
- Explain the relationship between the incline angle and the angular velocity and speed of the can of soup/cylinder. Note: There are many scientific principles to consider here: coefficient of friction, moment of inertia, gravitational potential energy, and kinetic and rotational energy.

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TEACHER GUIDE

To change the angle of incline easily, use textbooks of the same height to change the angle. Measure the change in angle when one textbook is added, then add the appropriate textbooks to change the incline to the desired angle. To increase the mathematical rigor of the lab, students should mass the can of soup. They will then be able to calculate the potential energy of the can at different angles $(PE = mgh)$, the moment of inertia of the can $(I = \frac{1}{2} mr^2)$, the can's rotational kinetic energy $(\frac{1}{2} Iw^2)$, where $w = angular\ velocity$, and the translational kinetic energy of the can $(\frac{1}{2} mv^2)$.These equations can all be used together to highlight the energy balance for the system $mgh = \frac{1}{2} Iw^2 + \frac{1}{2} mv^2$.

If the math is too rigorous however, the relationships in the lab can still be identified, especially with some basic knowledge of gravitational potential energy. Students should observe both an increase in angular velocity and average speed as the angle of the ramp increases. Students may notice that as the ramp angle increases, the height of the top of the ramp will also increase, resulting in greater gravitational potential energy. The moment of inertia of the can is its resistance to change in rotation around a specific axis. It is related to the distribution of mass relative to the axis of rotation. Because the can stays constant, the moment of inertia stays constant. As the incline increases, the can gains more potential energy making it harder and harder for the can to resist rotation. The result is a faster rotation and therefore a faster linear velocity to the bottom of the ramp. Push students to compare the can of soup to a bike or another real world example. By pedaling faster the angular velocity of the wheels increase, pushing off the ground at a faster rate. The result is a greater linear velocity.