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Variable Inertia Set
VBINR-2

Warning:

- **Not a toy; use only in a laboratory or educational setting.**
- **Choking Hazard- small parts**
- **California Proposition 65**
  Warning: This product can expose you to chemicals including lead and nickel which is known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Introduction

This kit is used to show how mass and distribution of objects affect the way objects resist to rotary motion. Inertia is the property by which mass resists change in motion. The greater the rotational inertia of an object, the harder it is to rotate it from a stationary position and the harder it is to stop if it is already rotating. With this set, you can study how moments of inertia in objects change with the ways in which their mass is distributed about the axis of rotation. You do this by changing the mass distribution and observing what happens.

This set includes two transparent plastic discs that are halved with the same mass and diameter. The discs are hollow inside with compartments for placing steel balls in a variety of configurations to demonstrate the distribution of mass. The transparency makes it easier for the student to see and understand how distribution affects inertia. Placing the steel balls along the rim of the discs would cause the discs to become rim heavy. Placing the steels balls in the center circle would cause the discs to become center heavy.

Experiments

For this experiment you will need an inclined plane and optionally, a stopwatch. To create an inclined plane, you can take a flat surface such as a book or wooden board and prop the edge up on a block (or similar).

Exercise 1:

Place and hold the two discs (on their edges) side by side at the top of the incline and let them go simultaneously, rolling down the incline. Note their relative speeds by watching them from a side. Optionally you can have another person time the motion. Do they come down together? Do they reach the bottom at the same time?

Exercise 2:

Use the steel balls to distribute weight differently from each other. Load one of the discs inserting 2 or 4 balls in the outer rim while you insert the same number of balls into the inner circle of the other disc. Roll them down the incline as before. What do you observe regarding their relative speeds of rotation? Which of them comes down faster? Why?

Exercise 3:

Load both of the discs however you want but make sure they are loaded with the same number of balls and have the same configuration. Roll them down the incline. Compare their speeds.

Exercise 4:

So far, the mass of the two discs have been kept the same. Now experiment with the two discs loaded where their weights are different. For example, use four balls on the same disc and none on the other. Compare their rolling speeds again.

Discussion

The moment of inertia (I) of an object depends on two factors- its mass and the square distance from the axis of rotation. In the case of a disc (a slice of a solid cylinder), it equals: $1/2\ m\ r^2$ where m is mass and r is radial distance of the mass from the axis of rotation. Note: For differently shaped objects, the moment of inertia is calculated differently.

In Exercise 1, the two discs take the same time to reach the bottom of the incline, which is easily explained by their having equal masses and equal radii. However, in Exercise 2, the disc with the outer most compartments come down slower than the other disc with the balls placed in the center circle, even though, like in Exercise 1, the masses are the same. The rim heavy disc resists the rotation more than the center heavy disc. This is because of the difference in distances (radius) at which the major mass concentration lies with reference to the load at a greater radius than the other disc. The moment of inertia is proportional to r^2 and mass being the same in both cases, the rim heavy disc has more inertia and rolls slower.

This reasoning also applies to Exercise 3, which explains why the rolling speeds are the same for each disc. In Exercise 4, it is easy to see why the two discs should roll at different speeds. The moment of inertia also depends on the total mass, which was different for each disc.

The dependence of the moment of inertia of an object on the mass distribution about the axis of rotation has many applications in everyday life. Bicycle wheels, for example, should have more weight at their hubs than at their rims. The moment of inertia for a ring, equal to mr^2 is greatly influenced by the squared distance factor in the equation. Note: If the major mass were at the rim and if the wheel diameter were doubled, its moment of inertia would increase by a factor of 4. The moments of inertia of objects also depend on the axis on which they are rotated.