Variable Inertia Set

96-1060

INSTRUCTIONAL GUIDE

Contents

Variable Inertia Set:

- 2 disks consisting of two halves each
- 8 chrome-plated steel ball bearings

Recommended for Activities:

- **Inclined Plane (P3-3541)**

Background

This is a unique activity that is simple to set up and *qualitatively* illustrates an abstract concept in an easy-to-understand manner. It consists of two plastic discs in two halves (4 halves total) with the same mass and diameter. The discs are hollow inside with compartments allowing arrangement of the ball bearings into a variety of configurations. You can place the steel balls (19mm ball size) along the rim of the discs, in the center, or in a straight line across, as illustrated. This effectively varies the distribution of mass around the center, around the edge, or a variety of combinations

Introduction

In rotating systems, the rotational inertia is analogous to the mass in linear systems. Rotational inertia depends on the mass and how the mass is distributed around the point of rotation: the farther away, the higher the rotational inertia. Rotational inertia, like mass, resists acceleration. The higher the rotational inertia, the more torque it takes to cause rotational acceleration.

When a body rotates or spins about an axis, the angle made by its rotating mass, with the axis, in the plane of rotation is changing with time; that is, there is an angular velocity. This is zero when the body is not spinning. On the other hand, if angular velocity increases (or decreases), there is angular acceleration. When you change the rotational motion of a body, you change its angular velocity or give it an angular acceleration/deceleration.

Just as a linear force causes the change in linear motion, Torque (τ), causes the change in rotational motion. This relationship is expressed with the equation:

$$\tau = I\alpha$$

where I is the moment of inertia of the body and α is its angular acceleration. The greater the moment of inertial of a body, the greater the torque that would be needed to give it an angular acceleration.

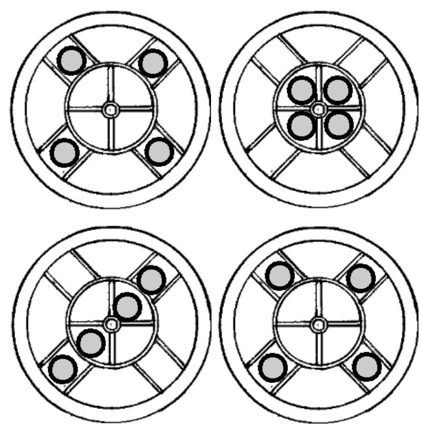
But what makes the moment of inertia of a body greater (or smaller)? One factor is its mass. Heavier objects have greater inertia. However, objects with the same mass react differently to rotating forces depending on where their masses are concentrated about the axis of rotation.

Set-Up

Set up an **inclined plane** at least a meter long for the best results. A backstop or catcher also helps to keep the disks prom running away. Make sure the halves of each disk are aligned with each other so there is no edge between them. This will ensure they roll straight down the plane without swerving to one side or the other.

Activity

1. First, remove the ball bearings from each disk. Place and hold the two discs (on their edges) side by side at the top of the incline and let them go simultaneously. Note their relative speeds by watching them from the side. This should result in the disks reaching the bottom at the same time since their inertia is identical.



2. Use the ball bearings to change where the mass is distributed in the two shells. Load one of the discs with 4 ball bearings in the outer rim, and load ball bearings into the inner circle compartments. Roll them down the incline as before.

3. Try the experiment with one disk loaded with four ball bearings in a line and the other with 4 ball bearings loaded in the outside compartments. Roll them down your incline. Compare their speeds.

4. So far you have kept the mass of the two discs equal, loaded or unloaded. Now experiment with the two discs loaded so their weights become different. Use four balls on one disc, for example, and none on the other. Compare their rolling speeds again.

Discussion

A body's moment of inertia depends on two factors—its mass and the square of its distance from the axis of rotation. The equation for the moment of inertia depends on the shape of the body. Below are the equations for 3 shapes:

$I = {}^{1}/_{2}\, mr^2$	$I = mr^2$	$I = {}^{1}/_{12}\, mL^2$
Disk	*Hoop*	*Stick*

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In Activity 1, the bodies are identical and are best represented as disks since their masses are distributed evenly about the axis of rotation. Since they have the same mass and same torque being applied to them (from friction between the ramp and edge of the disk), they will have the same angular acceleration and thus the same moment of inertia. If released at the exact same time, they should reach the bottom of the ramp at the same time as well.

The bodies in Activity 2 can be most accurately described as hoops since their mass is concentrated around a radius and not evenly distributed as in a disk. They still have identical mass, but their moment of inertia is different. The hoop with the larger radius (thus the larger moment of inertia) will reach the bottom last.

Activity 3 compares the moment of inertia of two dissimilar shapes—a hoop and a stick. The equations above can be used to determine the difference in moment of inertia between the bodies and predict which one will reach the bottom first. Since $L = 2r$ in the equations above, the stick will always reach the bottom first.

Related Products

Rotational Inertia Demonstrator (P3-3545) A Beautiful and engaging investigation of angular motion! Observe the angular acceleration of the apparatus, and investigate the effects of changes in torque and inertia.

Ring and Disk Apparatus (P3-3540) Two objects of equal mass and equal radius - one a solid disk and the other a ring - roll down an incline. Which reaches the end first?

Rotating Platform (P3-3510) The Rotating Platform can be used with hand weights to study rotational inertia, conservation of angular momentum, and action-reaction. Diameter 40cm