40-330 Variable Inertia

Instructions & Applications

Parts List
- Plastic disc half, 4: 36-4330
- 10-32 screw, 2: 20-1408
- 3/4" diameter balls, 8: 94-0061
- wing nut, 2: 20-2414
- Instructions: 24-4330

Warranty & Replacement Parts
We replace all defective parts free of charge. Additional replacement parts may be ordered toll-free at 1-800-875-3214 by referring to part numbers above. We accept Master Card and Visa, minimum replacement part order $5.00 (School P.O. $20.00). All products warranted to be free from defect for one year. Does not apply to accident, misuse, or normal wear and tear. Made in U.S.A.

Introduction
Use this kit to verify how mass of bodies and distribution of bodies affect the way bodies resist rotary motion. Inertia is the property by which bodies resist change in motion. Just as linear inertia resists linear motion, rotational inertia of a body makes it resists any change in rotational motion. The greater the rotational inertia of a body, the harder it is to rotate it from a stationary position, and the harder to stop it if it is already rotating. With this kit, you can study how moments of inertia of bodies 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.

Additional Materials Needed:
- An inclined plane of some sort (book, board supported on a block; desk top)
- (Optional) stopwatch

How To Teach With Variable Inertia:

Theory
Inertia is the property by which a stationary object resists moving and a moving object resists stopping. When the change in motion is in a straight line, it is referred to as linear motion. Rotational inertia, also called Moment of Inertia, is the body’s resistance to a change in its rotational motion. 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 the angular velocity increases (or decreases), there is an angular acceleration (or deceleration.) 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 $F$ equal to $m a$ (where $m$ is the mass and $a$ is the linear acceleration) causes the change in linear motion, in the case of rotational motion, a Torque $(T)$ causes the change. This torque is equal to $I \alpha$, where $I$ is the moment of inertia of the body and $\alpha$ is its angular acceleration. The greater the moment of inertia 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 of the factors is its mass. Heavier objects have greater inertia. Interestingly, however, objects with the same mass react differently to rotating forces depending on where their masses are concentrated about the axis of rotation.

Perform the following experiments and verify this yourself.

Experiments
Place a flat surface (like a wide book, a wooden board or 40-250 Inclined Plane from Science First®) on the table top and support one of its edges on a block (or similar solid object) to create an inclined plane.

Case 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. (If necessary, you can time their motion with the help of another person.)
Do they come down together? Do they reach the bottom at the same time?

**Case 2**
Use the metal balls to "weight" the two discs differently from each other. Load one of the discs inserting 2 or 4 balls in the outer rim (see sketch) while you insert 2 or 4 balls into two of the inner circle compartments. Roll them down the incline as before.

What do you observe regarding their relative speeds of rotation? Which of them comes down faster, and why?

**Discussion**
The moment of inertia (I) of a body depends on two factors - its mass and the square of its distance from the axis of rotation. In the case of a disc (which is a slice of a solid cylinder), it equals 1/2 m r^2

where m is the mass and r the radial distance of the mass from the axis of rotation.

(Note: for differently shaped bodies, the moment of inertia is calculated differently.)

In Case 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 Case 2, the disc with the outermost compartments plugged comes down slower than the other disc with plugs closer to the center, although, like in Case 1, the total masses of the two discs are the same. In other words, the rim-heavy disc resists the rotation more than the other (center-heavy) disc. This is because of the difference in the distances (r's) at which the major mass concentration lies with reference to the load at greater r than the other disc with reference to the axis about which it is forced to roll. Moment of inertia being proportional to squared r and mass being the same in both cases, the rim-heavy disc has more inertia; and it rolls slower. Recall that the torque is equal to 1 ω, such that, the greater the I, the smaller the acceleration for a given torque.

By the above reasoning you should be able to explain why the rolling speeds would not be different for the two discs in Case 3. Here, in addition to the total mass remaining the same, it would also be distributed in the same way in both the discs since you loaded them in identical positions using identical balls.

Lastly, in Case 4, it is easy to see why the two discs should roll at different speeds. Moment of Inertia also depends on the total mass, and you have made it different for the two discs.

The dependence of the moment of inertia of a body 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 that 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.

Moments of Inertia of bodies also depend on the axis on which they are rotated.

**Related Products**
The following products may be ordered from your distributor or, if unavailable, directly from manufacturer Science First®.

40-250 Inclined Plane

All-aluminum construction with attached protractor and prop, folds for storage, instructions. Can be used with 40-330 Variable Inertia or in a variety of other demonstrations involving friction, acceleration, the relation between work and energy.

40-320 Ring & Disc:

Simple materials - wood disc and PVC ring - both 3 1/2 inches in diameter with same mass, demonstrate how mass is distributed in rolling bodies. Roll them together down incline, study the difference in acceleration.