611-1220 (40-330) Variable Inertia

Warranty and Parts:

We replace all defective parts free of charge. Additional replacement parts may be ordered by referring to part numbers above. We accept Master Card and Visa, School P.O. All products warranted to be free from defect for **90 days.** Does not apply to accident, misuse, or normal wear and tear.

Description:

This is a unique lab that is simple to set up and 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 injection molded compartments into which balls are inserted in 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 to become either "center heavy" or "rim heavy."

Introduction:

Use this kit is 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.

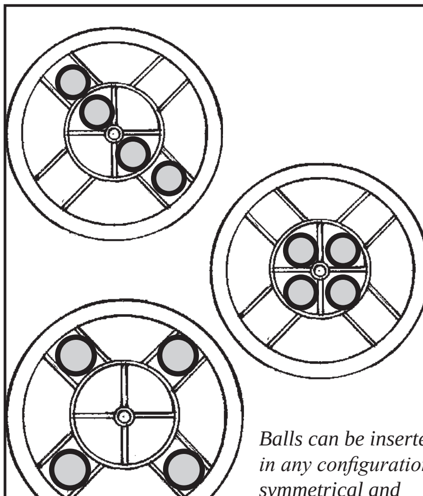
Just as linear inertia resists linear motion, rotational inertia of a body makes it resists any change in rotational motion.

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:

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



Balls can be inserted in any configuration, symmetrical and asymmetrical.

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 angular velocity increases (or decreases), there is **angular accel eration** (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** α , where **I** is the **moment of inertia** of the body and 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.

Perform the following experiments and verify this yourself.

Experiments:

Place a flat surface (wide book, 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) 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?

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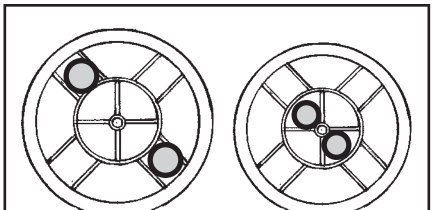


Case 2

Case 3:

Try the experiment loading both discs wherever you want but make sure they are identically loaded. You can use either one, two, three or four balls per disc so long as both discs are the same. Roll them down your incline. Compare their speeds.

Case 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 the same disc, for example, and none on the other. Compare their rolling speeds again.

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 (a slice of a solid cylinder), it equals:

$1/2\ m\ r^2$

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

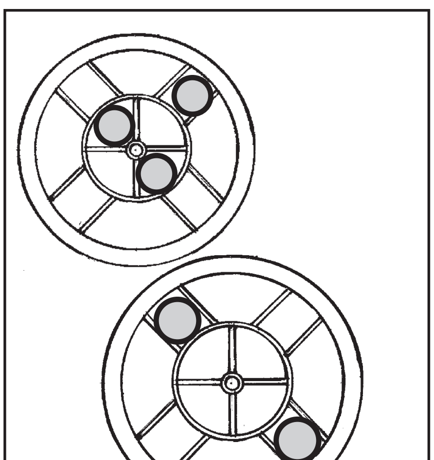
(Note for differently shaped bodies, the moment of inertia is calculated differently.)

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 I α, such that, the greater the I, the smaller the acceleration for a given torque.

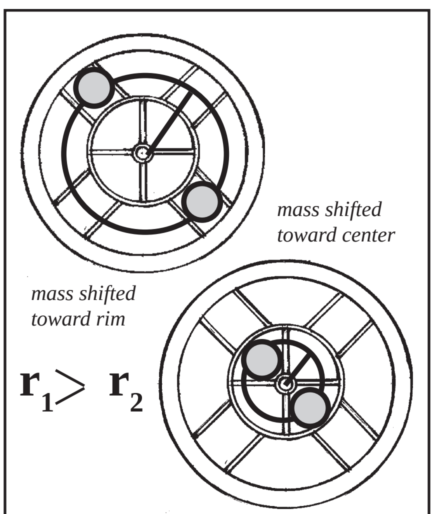
By the above reasoning you should be able to explain why the rolling speeds would **not** be different for the two discs in **Case 3.** Here, in addition to the total mass remaining the same, it would also be distributed in the same way in both the discs since you loaded them in identical positions using 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 $\mathbf{mr^2}$ 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.



Case 4



Related Products:

• 611-0035 Inclined Plane
All-aluminum with protractor and prop, folds for storage, instructions.

• 611-1215 Ring and Disc
Simple materials - wood disc and PVC ring - with same diameter and mass show mass is distributed in rolling bodies.

How To Teach with Variable Inertia:

Concepts Taught: Inertia - linear vs rotational. Moment of inertia of rotating bodies, relation to mass, distance from axis of rotation and to mass distribution. Center of mass; center of gravity. Torque. Translational & rotational equilibrium. Angular displacement. Angular velocity, angular acceleration & momentum.

Curriculum Fit: PS/Motion and Force. *Causes of Motion and Equilibrium* **Grades 6 - 8.**

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