Moment of inertia

You may have noticed that it is easier to rotate a baseball bat around some axes than others. The resistance of an object to changes in rotational motion is measured by a quantity called the **moment of inertia.**

The moment of inertia, which is abbreviated as *I,* is similar to mass because they are both forms of inertia. However, there is an important difference between them. Mass is an intrinsic property of an object, and the moment of inertia is not. The moment of inertia depends on the object's mass and the distribution of that mass around the axis of rotation. The farther the mass of an object is, on average, from the axis of rotation, the greater is the object's moment of inertia and the more difficult it is to rotate the object.

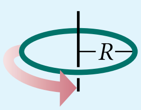
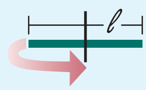
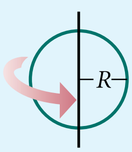
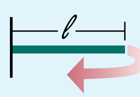
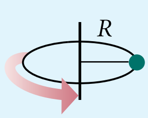
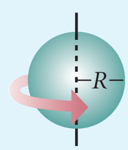
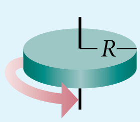
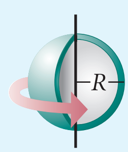
According to Newton's second law, when a net force acts on an object, the resulting acceleration of the object depends on the object's mass. Similarly, when a net torque acts on an object, the resulting change in the rotational motion of the object depends on the object's moment of inertia. (This law is covered in more detail in the appendix feature "Rotational Dynamics.")

Some simple formulas for calculating the moment of inertia of common shapes are shown in **Table 1.** The units for moment of inertia are $kg \bullet m^2$. To get an idea of the size of this unit, note that bowling balls typically have moments of inertia about an axis through their centers ranging from about $0.7\ kg \bullet m^2$ to $1.8\ kg \bullet m^2$, depending on the mass and size of the ball.

Did you know?

A baseball bat can be modeled as a rotating thin rod. When a bat is held at its end, its length is greatest with respect to the rotation axis, so its moment of inertia is greatest. Thus, the bat is easier to swing if you hold the bat closer to the center. Baseball players sometimes do this either because a bat is too heavy (large M) or too long (large ℓ).

Table 1 The Moment of Inertia for Various Rigid Objects of Mass *M*

Shape	Moment of inertia	Shape	Moment of inertia
 thin hoop about symmetry axis	MR^2	 thin rod about perpendicular axis through center	$\frac{1}{12}M\ell^2$
 thin hoop about diameter	$\frac{1}{2}MR^2$	 thin rod about perpendicular axis through end	$\frac{1}{3}M\ell^2$
 point mass about axis	MR^2	 solid sphere about diameter	$\frac{2}{5}MR^2$
 disk or cylinder about symmetry axis	$\frac{1}{2}MR^2$	 thin spherical shell about diameter	$\frac{2}{3}MR^2$