Rotational Dynamics

The appendix feature "Angular Kinematics" developed the kinematic equations for rotational motion. Similarly, the appendix feature "Rotation and Inertia" applied the concept of inertia to rotational motion. In this feature, you will see how torque relates to rotational equilibrium and angular acceleration. You will also learn how momentum and kinetic energy are described in rotational motion.

Figure 1
The two forces exerted on this table are equal and opposite, yet the table moves. How is this possible?

Rotational equilibrium

If you and a friend push on opposite sides of a table, as shown in **Figure 1,** the two forces acting on the table are equal in magnitude and opposite in direction. You might think that the table won't move because the two forces balance each other. But it does; it rotates in place.

The piece of furniture can move even though the net force acting on it is zero because the net torque acting on it is not zero. If the net force on an object is zero, the object is in *translational equilibrium.* If the net torque on an object is zero, the object is in *rotational equilibrium.* For an object to be completely in equilibrium, both rotational and translational, there must be both zero net force and zero net torque. The dependence of equilibrium on the absence of net torque is called the *second condition for equilibrium.*

Newton's second law for rotation

Just as net force is related to translational acceleration according to Newton's second law, there is a relationship between the net torque on an object and the angular acceleration given to the object. Specifically, the net torque on an object is equal to the moment of inertia times the angular acceleration. This relationship is parallel to Newton's second law of motion and is known as Newton's second law for rotating objects. This law is expressed mathematically as follows:

NEWTON'S SECOND LAW FOR ROTATING OBJECTS

$$\tau_{net} = I\alpha$$

net torque = moment of inertia × angular acceleration

This equation shows that a net positive torque corresponds to a positive angular acceleration, and a net negative torque corresponds to a negative angular acceleration. Thus, it is important to keep track of the signs of the torques acting on the object when using this equation to calculate an object's angular acceleration.