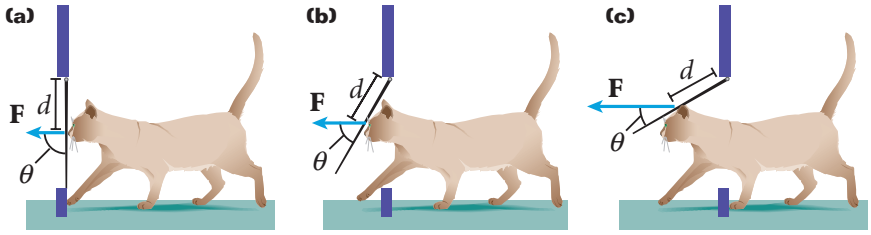

Figure 17
In each example, the cat is pushing on the door at the same distance from the axis. To produce the same torque, the cat must apply greater force for smaller angles.

The lever arm depends on the angle

Forces do not have to be perpendicular to an object to cause the object to rotate. Imagine the cat-flap door again. In **Figure 17(a),** the force exerted by the cat is perpendicular. When the angle is less than 90°, as in **(b)** and **(c),** the door will still rotate, but not as easily. The symbol for torque is the Greek letter *tau* (τ), and the magnitude of the torque is given by the following equation:

TORQUE

$$\tau = Fd \sin \theta$$

torque = force × lever arm

The SI unit of torque is the N•m. Notice that the inclusion of the factor sin θ in this equation takes into account the changes in torque shown in **Figure 17.**

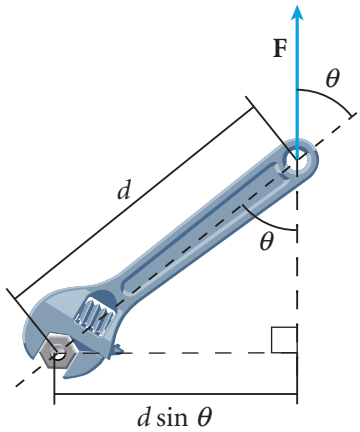

Figure 18
The direction of the lever arm is always perpendicular to the direction of the applied force.

Figure 18 shows a wrench pivoted around a bolt. In this case, the applied force acts at an angle to the wrench. The quantity d is the distance from the axis of rotation to the point where force is applied. The quantity $d \sin \theta$, however, is the *perpendicular* distance from the axis of rotation to a line drawn along the direction of the force. *Thus, $d \sin \theta$ is the lever arm.* Note that the perpendicular distance between the door hinge and the point of application of force **F** in **Figure 17** decreases as the cat goes further through the door.

THE SIGN OF A TORQUE

Torque, like displacement and force, is a vector quantity. In this textbook, we will assign each torque a positive or negative sign, depending on the direction the force tends to rotate an object. We will use the convention that the sign of the torque resulting from a force is positive if the rotation is counterclockwise and negative if the rotation is clockwise. In calculations, remember to assign positive and negative values to forces and displacements according to the sign convention established in the chapter "Motion in One Dimension."

TIP

To determine the sign of a torque, imagine that the torque is the only one acting on the object and that the object is free to rotate. Visualize the direction that the object would rotate. If more than one force is acting, treat each force separately. Be careful to associate the correct sign with each torque.