

will be zero. If the object is not rotating initially ( $\omega = 0$ ), it will not start rotating. Equations 9-1 and 9-2 are the only requirements for an object to be in equilibrium.

We will mainly consider cases in which the forces all act in a plane (we call it the  $xy$  plane). In such cases the torque is calculated about an axis that is perpendicular to the  $xy$  plane. *The choice of this axis is arbitrary.* If the object is at rest, then  $\Sigma\tau = 0$  about any axis whatever. Therefore we can choose any axis that makes our calculation easier. Once the axis is chosen, all torques must be calculated about that axis.

### CAUTION

*Axis choice for  $\Sigma\tau = 0$  is arbitrary. All torques must be calculated about the same axis.*

### CONCEPTUAL EXAMPLE 9-3

**A lever.** The bar in Fig. 9-6 is being used as a lever to pry up a large rock. The small rock acts as a fulcrum (pivot point). The force  $F_P$  required at the long end of the bar can be quite a bit smaller than the rock's weight  $mg$ , since it is the *torques* that balance in the rotation about the fulcrum. If, however, the leverage isn't sufficient, and the large rock isn't budged, what are two ways to increase the leverage?

**RESPONSE** One way is to increase the lever arm of the force  $F_P$  by slipping a pipe over the end of the bar and thereby pushing with a longer lever arm. A second way is to move the fulcrum closer to the large rock. This may change the long lever arm  $R$  only a little, but it changes the short lever arm  $r$  by a substantial fraction and therefore changes the ratio of  $R/r$  dramatically. In order to pry the rock, the torque due to  $F_P$  must at least balance the torque due to  $mg$ , so  $mgr = F_P R$  and

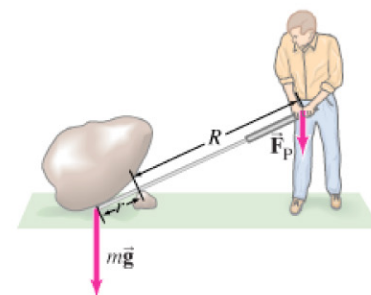
$$\frac{r}{R} = \frac{F_P}{mg}.$$

With  $r$  smaller, the weight  $mg$  can be balanced with less force  $F_P$ . The ratio  $R/r$  is the **mechanical advantage** of the system. A lever is a "simple machine." We discussed another simple machine, the pulley, in Chapter 4, Example 4-14.



### PHYSICS APPLIED

*The lever*



**FIGURE 9-6** Example 9-3. A lever can "multiply" your force.

**EXERCISE B** For simplicity, we wrote the equation in Example 9-3 as if the lever were perpendicular to the forces. Would the equation be valid even for a lever at an angle as shown in Fig. 9-6?

## 9-2 Solving Statics Problems

This subject of statics is important because it allows us to calculate certain forces on (or within) a structure when some of the forces on it are already known. We will mainly consider situations in which all the forces act in a plane, so we can have two force equations ( $x$  and  $y$  components) and one torque equation, for a total of three equations. Of course, you do not have to use all three equations if they are not needed. When using a torque equation, a torque that tends to rotate the object counterclockwise is usually considered positive, whereas a torque that tends to rotate it clockwise is considered negative. (But the opposite convention would not be wrong.)

One of the forces that acts on objects is the force of gravity. Our analysis in this Chapter is greatly simplified if we use the concept of center of gravity (CG) or center of mass (CM), which for practical purposes are the same point. As we discussed in Section 7-8, we can consider the force of gravity on the object as acting at its CG. For uniform symmetrically shaped objects, the CG is at the geometric center. For more complicated objects, the CG can be determined as discussed in Section 7-8.

There is no single technique for attacking statics problems, but the following procedure may be helpful.

### PROBLEM SOLVING

$\tau > 0$  counterclockwise  
 $\tau < 0$  clockwise