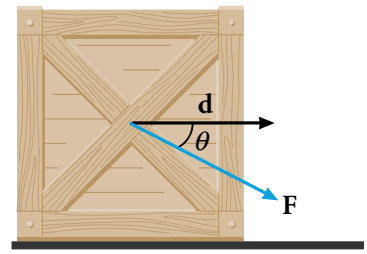
For example, imagine pushing a crate along the ground. If the force you exert is horizontal, all of your effort moves the crate. If your force is at an angle, only the horizontal component of your applied force causes a displacement and contributes to the work. If the angle between the force and the direction of the displacement is θ, as in **Figure 2,** work can be expressed as follows:

$$W = Fd\cos\theta$$

If $\theta = 0°$, then $\cos 0° = 1$ and $W = Fd$, which is the definition of work given earlier. If $\theta = 90°$, however, then $\cos 90° = 0$ and $W = 0$. So, no work is done on a bucket of water being carried by a student walking horizontally. The upward force exerted by the student to support the bucket is perpendicular to the displacement of the bucket, which results in no work done on the bucket.

Finally, if many constant forces are acting on an object, you can find the *net* work done on the object by first finding the net force on the object.



$W = Fd\cos\theta$

Figure 2
The work done on this crate is equal to the force times the displacement times the cosine of the angle between them.

NET WORK DONE BY A CONSTANT NET FORCE

$$W_{net} = F_{net}d\cos\theta$$

net work = net force × displacement × cosine of the angle between them

Work has dimensions of force times length. In the SI system, work has a unit of newtons times meters (N•m), or joules (J). To give you an idea of how large a joule is, consider that the work done in lifting an apple from your waist to the top of your head is about 1 J.

Did you know?

The joule is named for the British physicist James Prescott Joule (1818–1889). Joule made major contributions to the understanding of energy, heat, and electricity.

SAMPLE PROBLEM A

Work

PROBLEM

How much work is done on a vacuum cleaner pulled 3.0 m by a force of 50.0 N at an angle of 30.0° above the horizontal?

SOLUTION

Given: $F = 50.0$ N $\quad \theta = 30.0°$ $\quad d = 3.0$ m

Unknown: $W = ?$

Use the equation for net work done by a constant force:

$$W = Fd\cos\theta$$

Only the horizontal component of the applied force is doing work on the vacuum cleaner.

$$W = (50.0\text{ N})(3.0\text{ m})(\cos 30.0°)$$

$$\boxed{W = 130\text{ J}}$$