energy decreases by an amount W. That is, a net force exerted on an object opposite to the object's direction of motion decreases its speed and its kinetic energy. An example is a moving hammer (Fig. 6–8) striking a nail. The net force on the hammer ($-\vec{\mathbf{F}}$ in Fig. 6–8, where $\vec{\mathbf{F}}$ is assumed constant for simplicity) acts toward the left, whereas the displacement $\vec{\mathbf{d}}$ of the hammer is toward the right. So the net work done on the hammer, $W_h = (F)(d)(\cos 180°) = -Fd$, is negative and the hammer's kinetic energy decreases (usually to zero).

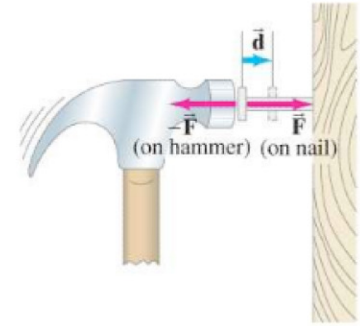


FIGURE 6–8 A moving hammer strikes a nail and comes to rest. The hammer exerts a force F on the nail; the nail exerts a force $-F$ on the hammer (Newton's third law). The work done on the nail by the hammer is positive $(W_n = Fd > 0)$. The work done on the hammer by the nail is negative $(W_h = -Fd)$.

Figure 6–8 also illustrates how energy can be considered the ability to do work. The hammer, as it slows down, does positive work on the nail: if the nail exerts a force $-\vec{\mathbf{F}}$ on the hammer to slow it down, the hammer exerts a force $+\vec{\mathbf{F}}$ on the nail (Newton's third law) through the distance d. Hence the work done on the nail by the hammer is $W_n = (+F)(+d) = Fd$ and is positive. We also see that $W_n = Fd = -W_h$: the work done on the nail W_n equals the negative of the work done on the hammer. That is, the decrease in kinetic energy of the hammer is equal to the work the hammer can do on another object—which is consistent with energy being the ability to do work.

Whereas the translational kinetic energy $\left(= \frac{1}{2}mv^2\right)$ is directly proportional to the mass of the object, it is proportional to the *square* of the speed. Thus, if the mass is doubled, the kinetic energy is doubled. But if the speed is doubled, the object has four times as much kinetic energy and is therefore capable of doing four times as much work.

If $W_{net} > 0$, KE increases
If $W_{net} < 0$, KE decreases

Let us summarize the relationship between work and kinetic energy (Eq. 6–4): if the net work W done on an object is positive, then the object's kinetic energy increases. If the net work W done on an object is negative, its kinetic energy decreases. If the net work done on the object is zero, its kinetic energy remains constant (which also means its speed is constant).

Energy units: the joule

Because of the direct connection between work and kinetic energy (Eq. 6–4), energy is measured in the same units as work: joules in SI units, ergs in the cgs, and foot-pounds in the British system. Like work, kinetic energy is a scalar quantity. The kinetic energy of a group of objects is the sum of the kinetic energies of the individual objects.

EXAMPLE 6–4 **KE and work done on a baseball.** A 145-g baseball is thrown so that it acquires a speed of 25 m/s. (*a*) What is its kinetic energy? (*b*) What was the net work done on the ball to make it reach this speed, if it started from rest?

APPROACH We use the definition of kinetic energy, Eq. 6–3, and then the work-energy principle, Eq. 6–4.

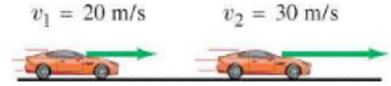
SOLUTION (*a*) The kinetic energy of the ball after the throw is

$$\text{KE} = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(0.145\,\text{kg})(25\,\text{m/s})^2 = 45\,\text{J}.$$

(*b*) Since the initial kinetic energy was zero, the net work done is just equal to the final kinetic energy, 45 J.

EXAMPLE 6–5 **Work on a car, to increase its KE.** How much net work is required to accelerate a 1000-kg car from 20 m/s to 30 m/s (Fig. 6–9)?

FIGURE 6–9 Example 6–5.



APPROACH To simplify a complex situation, let us treat the car as a particle or simple rigid object. We can then use the work-energy principle.

SOLUTION The net work needed is equal to the increase in kinetic energy:

$$\begin{aligned} W &= \text{KE}_2 - \text{KE}_1 = \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2 \\ &= \tfrac{1}{2}(1000\,\text{kg})(30\,\text{m/s})^2 - \tfrac{1}{2}(1000\,\text{kg})(20\,\text{m/s})^2 = 2.5 \times 10^5\,\text{J}. \end{aligned}$$

NOTE You might be tempted to work this Example by finding the force and using Eq. 6–1. That won't work, however, because we don't know how far or for how long the car was accelerated. In fact, a large force could be acting for a small distance, or a small force could be acting over a long distance; both could give the same net work.