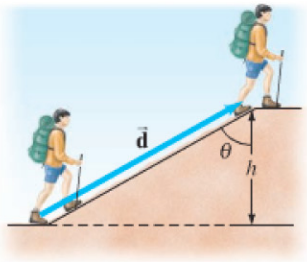
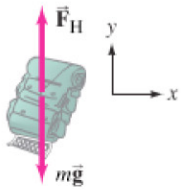
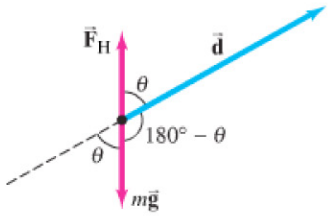


(a)



(b)



(c)

FIGURE 6–4 Example 6–2.

EXAMPLE 6–2 **Work on a backpack.** (*a*) Determine the work a hiker must do on a 15.0-kg backpack to carry it up a hill of height $h = 10.0\,\text{m}$, as shown in Fig. 6–4a. Determine also (*b*) the work done by gravity on the backpack, and (*c*) the net work done on the backpack. For simplicity, assume the motion is smooth and at constant velocity (i.e., acceleration is negligible).

APPROACH We explicitly follow the Problem Solving Box step by step.

SOLUTION

1. **Draw a free-body diagram.** The forces on the backpack are shown in Fig. 6–4b: the force of gravity, $m\vec{\mathbf{g}}$, acting downward; and $\vec{\mathbf{F}}_\text{H}$, the force the hiker must exert upward to support the backpack. Since we assume there is negligible acceleration, horizontal forces on the backpack are negligible.
2. **Choose a coordinate system.** We are interested in the vertical motion of the backpack, so we choose the y coordinate as positive vertically upward.
3. **Apply Newton's laws.** Newton's second law applied in the vertical direction to the backpack gives

$$\Sigma F_y = ma_y$$
$$F_\text{H} - mg = 0.$$

Hence,

$$F_\text{H} = mg = (15.0\,\text{kg})(9.80\,\text{m/s}^2) = 147\,\text{N}.$$

4. **Find the work done by a specific force.** (*a*) To calculate the work done by the hiker on the backpack, we write Eq. 6–1 as

$$W_\text{H} = F_\text{H}(d\cos\theta),$$

and we note from Fig. 6–4a that $d\cos\theta = h$. So the work done by the hiker is

$$W_\text{H} = F_\text{H}(d\cos\theta) = F_\text{H}h = mgh$$
$$= (147\,\text{N})(10.0\,\text{m}) = 1470\,\text{J}.$$

Note that the work done depends only on the change in elevation and not on the angle of the hill, θ. The hiker would do the same work to lift the pack vertically the same height h.

(*b*) The work done by gravity on the backpack is (from Eq. 6–1 and Fig. 6–4c)

$$W_\text{G} = F_\text{G}\,d\cos(180^\circ - \theta).$$

Since $\cos(180^\circ - \theta) = -\cos\theta$, we have

$$W_\text{G} = F_\text{G}\,d(-\cos\theta) = mg(-d\cos\theta)$$
$$= -mgh$$
$$= -(15.0\,\text{kg})(9.80\,\text{m/s}^2)(10.0\,\text{m}) = -1470\,\text{J}.$$

PROBLEM SOLVING
Work done by gravity depends on the height of the hill and not on the angle of incline

NOTE The work done by gravity (which is negative here) doesn't depend on the angle of the incline, only on the vertical height h of the hill. This is because gravity acts vertically, so only the vertical component of displacement contributes to work done.

5. **Find the net work done.** (*a*) The *net* work done on the backpack is $W_\text{net} = 0$, since the net force on the backpack is zero (it is assumed not to accelerate significantly). We can also determine the net work done by adding the work done by each force:

$$W_\text{net} = W_\text{G} + W_\text{H} = -1470\,\text{J} + 1470\,\text{J} = 0.$$

NOTE Even though the *net* work done by all the forces on the backpack is zero, the hiker does do work on the backpack equal to 1470 J.