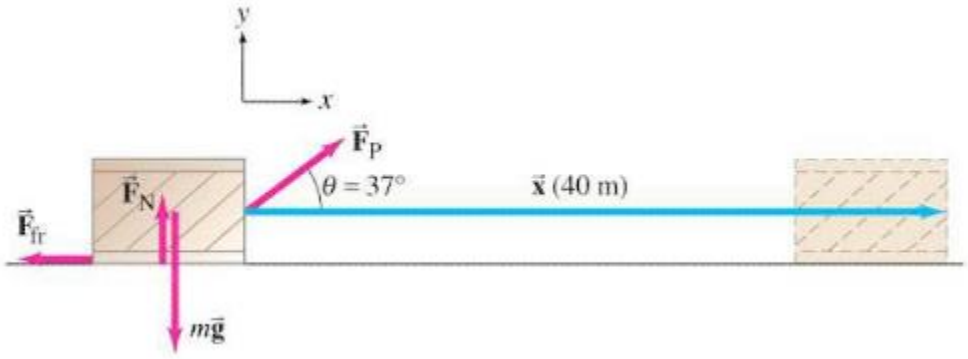
EXAMPLE 6–1 **Work done on a crate.** A person pulls a 50-kg crate 40 m along a horizontal floor by a constant force $F_P = 100\,N$, which acts at a 37° angle as shown in Fig. 6–3. The floor is rough and exerts a friction force $F_{fr} = 50\,N$. Determine (*a*) the work done by each force acting on the crate, and (*b*) the net work done on the crate.



SOLUTION (*a*) The work done by the gravitational and normal forces is zero, since they are perpendicular to the displacement $\vec{x}$ ($\theta = 90°$ in Eq. 6–1):

$$W_G = mgx\cos 90° = 0$$
$$W_N = F_N x\cos 90° = 0.$$

The work done by $\vec{F}_P$ is

$$W_P = F_P x\cos\theta = (100\,N)(40\,m)\cos 37° = 3200\,J.$$

The work done by the friction force is

$$W_{fr} = F_{fr} x\cos 180° = (50\,N)(40\,m)(-1) = -2000\,J.$$

The angle between the displacement $\vec{x}$ and the force $\vec{F}_{fr}$ is 180° because they point in opposite directions. Since the force of friction is opposing the motion (and $\cos 180° = -1$), the work done by friction on the crate is *negative*.

(*b*) The net work can be calculated in two equivalent ways:
(1) The net work done on an object is the algebraic sum of the work done by each force, since work is a scalar:

$$\begin{aligned} W_{\text{net}} &= W_{\text{G}} + W_{\text{N}} + W_{\text{P}} + W_{\text{fr}} \\ &= 0 + 0 + 3200\,\text{J} - 2000\,\text{J} \\ &= 1200\,\text{J}. \end{aligned}$$

(2) The net work can also be calculated by first determining the net force on the object and then taking its component along the displacement: $(F_{\text{net}})_x = F_{\text{P}} \cos\theta - F_{\text{fr}}$. Then the net work is

$$\begin{aligned} W_{\text{net}} = (F_{\text{net}})_x\, x &= (F_{\text{P}} \cos\theta - F_{\text{fr}})x \\ &= (100\,\text{N} \cos 37^\circ - 50\,\text{N})(40\,\text{m}) \\ &= 1200\,\text{J}. \end{aligned}$$

In the vertical (y) direction, there is no displacement and no work done.