6.3. **IDENTIFY:** Each force can be used in the relation $W = F_{\parallel}s = (F\cos\phi)s$ for parts (b) through (d). For part (e), apply the net work relation as $W_{\text{net}} = W_{\text{worker}} + W_{\text{grav}} + W_n + W_f$.

SET UP: In order to move the crate at constant velocity, the worker must apply a force that equals the force of friction, $F_{\text{worker}} = f_{\text{k}} = \mu_{\text{k}}n.$

EXECUTE: **(a)** The magnitude of the force the worker must apply is:

$$F_{\text{worker}} = f_{\text{k}} = \mu_{\text{k}}n = \mu_{\text{k}}mg = (0.25)(30.0\text{ kg})(9.80\text{ m/s}^2) = 74\text{ N}$$

(b) Since the force applied by the worker is horizontal and in the direction of the displacement, $\phi = 0°$ and the work is:

$$W_{\text{worker}} = (F_{\text{worker}}\cos\phi)s = [(74\text{ N})(\cos 0°)](4.5\text{ m}) = +333\text{ J}$$

(c) Friction acts in the direction opposite of motion, thus $\phi = 180°$ and the work of friction is:

$$W_f = (f_{\text{k}}\cos\phi)s = [(74\text{ N})(\cos 180°)](4.5\text{ m}) = -333\text{ J}$$

(d) Both gravity and the normal force act perpendicular to the direction of displacement. Thus, neither force does any work on the crate and $W_{\text{grav}} = W_n = 0.0$ J.

(e) Substituting into the net work relation, the net work done on the crate is:

$$W_{\text{net}} = W_{\text{worker}} + W_{\text{grav}} + W_n + W_f = +333\text{ J} + 0.0\text{ J} + 0.0\text{ J} - 333\text{ J} = 0.0\text{ J}$$

EVALUATE: The net work done on the crate is zero because the two contributing forces, F_{worker} and F_f, are equal in magnitude and opposite in direction.

6.6. **IDENTIFY** and **SET UP:** $W_F = (F\cos\phi)s,$ since the forces are constant. We can calculate the total work by summing the work done by each force. The forces are sketched in Figure 6.6.

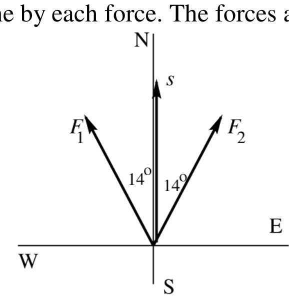

Figure 6.6

EXECUTE: $W_1 = F_1 s\cos\phi_1$

$W_1 = (1.80\times10^6\text{ N})(0.75\times10^3\text{ m})\cos 14°$

$W_1 = 1.31\times10^9\text{ J}$

$W_2 = F_2 s\cos\phi_2 = W_1$

$W_{\text{tot}} = W_1 + W_2 = 2(1.31\times10^9\text{ J}) = 2.62\times10^9\text{ J}$

EVALUATE: Only the component $F\cos\phi$ of force in the direction of the displacement does work. These components are in the direction of $\vec{s}$ so the forces do positive work.

6.8. **IDENTIFY:** Apply Eq.(6.5).

SET UP: $\hat{\boldsymbol{i}}\cdot\hat{\boldsymbol{i}} = \hat{\boldsymbol{j}}\cdot\hat{\boldsymbol{j}} = 1$ and $\hat{\boldsymbol{i}}\cdot\hat{\boldsymbol{j}} = \hat{\boldsymbol{j}}\cdot\hat{\boldsymbol{i}} = 0$

EXECUTE: The work you do is $\vec{\boldsymbol{F}}\cdot\vec{\boldsymbol{s}} = ((30\text{ N})\hat{\boldsymbol{i}} - (40\text{ N})\hat{\boldsymbol{j}})\cdot((-9.0\text{ m})\hat{\boldsymbol{i}} - (3.0\text{ m})\hat{\boldsymbol{j}})$

$\vec{\boldsymbol{F}}\cdot\vec{\boldsymbol{s}} = (30\text{ N})(-9.0\text{ m}) + (-40\text{ N})(-3.0\text{ m}) = -270\text{ N}\cdot\text{m} + 120\text{ N}\cdot\text{m} = -150\text{ J}$.

EVALUATE: The x-component of $\vec{\boldsymbol{F}}$ does negative work and the y-component of $\vec{\boldsymbol{F}}$ does positive work. The total work done by $\vec{\boldsymbol{F}}$ is the sum of the work done by each of its components.

6.11. **IDENTIFY:** $K = \frac{1}{2}mv^2$. Since the meteor comes to rest the energy it delivers to the ground equals its original kinetic energy.

SET UP: $v = 12\text{ km/s} = 1.2\times10^4\text{ m/s}$. A 1.0 megaton bomb releases 4.184×10^{15} J of energy.

EXECUTE: **(a)** $K = \frac{1}{2}(1.4\times10^8\text{ kg})(1.2\times10^4\text{ m/s})^2 = 1.0\times10^{16}\text{ J}$.

(b) $\dfrac{1.0\times10^{16}\text{ J}}{4.184\times10^{15}\text{ J}} = 2.4$. The energy is equivalent to 2.4 one-megaton bombs.

EVALUATE: Part of the energy transferred to the ground lifts soil and rocks into the air and creates a large crater.

6.21. **IDENTIFY:** Apply $W = Fs\cos\phi$ and $W_{\text{tot}} = \Delta K$.

SET UP: $\phi = 0°$

EXECUTE: From Equations (6.1), (6.5) and (6.6), and solving for F,

$$F = \frac{\Delta K}{s} = \frac{\frac{1}{2}m(v_2^2 - v_1^2)}{s} = \frac{\frac{1}{2}(8.00\text{ kg})((6.00\text{ m/s})^2 - (4.00\text{ m/s})^2)}{(2.50\text{ m})} = 32.0\text{ N}.$$

EVALUATE: The force is in the direction of the displacement, so the force does positive work and the kinetic energy of the object increases.

6.100. **IDENTIFY:** Apply $W_{\text{tot}} = K_2 - K_1$ to relate the initial speed v_0 to the distance x along the plank that the box moves before coming to rest.

SET UP: The component of weight down the incline is $mg\sin\alpha$, the normal force is $mg\cos\alpha$ and the friction force is $f = \mu mg\cos\alpha$.

EXECUTE: $\Delta K = 0 - \frac{1}{2}mv_0^2$ and $W = \int_0^x(-mg\sin\alpha - \mu mg\cos\alpha)dx.$ Then,

$$W = -mg\int_0^x(\sin\alpha + Ax\cos\alpha)dx,\ W = -mg\left[\sin\alpha x + \frac{Ax^2}{2}\cos\alpha\right].$$

Set $W = \Delta K$: $-\frac{1}{2}mv_0^2 = -mg\left[\sin\alpha x + \frac{Ax^2}{2}\cos\alpha\right]$. To eliminate x, note that the box comes to a rest when the force of static friction balances the component of the weight directed down the plane. So, $mg\sin\alpha = Ax\,mg\cos\alpha$. Solve this for x and substitute into the previous equation: $x = \frac{\sin\alpha}{A\cos\alpha}$. Then, $\frac{1}{2}v_0^2 = +g\left[\sin\alpha\frac{\sin\alpha}{A\cos\alpha} + \frac{1}{2}A\left(\frac{\sin\alpha}{A\cos\alpha}\right)^2\cos\alpha\right]$, and upon canceling factors and collecting terms, $v_0^2 = \frac{3g\sin^2\alpha}{A\cos\alpha}$. The box will remain stationary whenever $v_0^2 \ge \frac{3g\sin^2\alpha}{A\cos\alpha}$.

EVALUATE: If v_0 is too small the box stops at a point where the friction force is too small to hold the box in place. $\sin\alpha$ increases and $\cos\alpha$ decreases as α increases, so the v_0 required increases as α increases.