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PHYS 191, Fall 2014, Dr. H. Merabet

Solutions to Practice Problems Chapter 6

Responses to Questions

Q6.1 No. Whether work is positive or negative does not depend on any choice of coordinates. Work done on an object by a force for a specified displacement of the object is positive if the force has a component in the direction of the displacement. The work is negative if the force has a component opposite to the direction of the displacement of the object.

Q6.8 In each case the only force that does work on the object is gravity. The work done by gravity is given by $W_{\text{grav}} = mgh$ and this is the same in all three cases. Since the object is released from rest, $W_{\text{grav}} = K_f$, where K_f is the kinetic energy the object has at the bottom. (i) In (c) the object has greater mass and hence less speed for the same kinetic energy. Therefore, cases (a) and (b) have the same speed at the bottom and greater speed than case (c). (ii) For all three cases the same amount of work is done.

Q6.15 (i) There is no vertical displacement of the briefcase so the vertical component of the force your hand exerts does no work. The kinetic energy of the briefcase doesn't change, so in the absence of air resistance there is no horizontal component of the force your hand exerts, and this force does no work. In the presence of air resistance, the force your hand exerts does a small amount of positive work, equal in magnitude to the negative work done by the air resistance force. (ii) There is an upward displacement of the briefcase so the upward force your hand exerts does positive work on the briefcase. The positive work done by your hand equals in magnitude the negative work done by gravity, if the initial and final speeds of the briefcase are the same.

Solutions to Problem

P6.1. **IDENTIFY** and **SET UP:** For parts (a) through (d), identify the appropriate value of ϕ and use the relation $W = F_{\text{P}}s = (F\cos\phi)s.$ In part (e), apply the relation $W_{\text{net}} = W_{\text{student}} + W_{\text{grav}} + W_n + W_f.$

EXECUTE: **(a)** Since you are applying a horizontal force, $\phi = 0°.$ Thus, $W_{\text{student}} = (2.40\text{ N})(\cos 0°)(1.50\text{ m}) = 3.60\text{ J}$

(b) The friction force acts in the horizontal direction, opposite to the motion, so $\phi = 180°.$ $W_f = (F_f \cos\phi)s = (0.600\text{ N})(\cos 180°)(1.50\text{ m}) = -0.900\text{ J}.$

(c) Since the normal force acts upward and perpendicular to the tabletop, $\phi = 90°.$ $W_n = (n\cos\phi)s = (ns)(\cos 90°) = 0.0\text{ J}$

(d) Since gravity acts downward and perpendicular to the tabletop, $\phi = 270°.$ $W_{\text{grav}} = (mg\cos\phi)s = (mgs)(\cos 270°) = 0.0\text{ J}.$

(e) $W_{\text{net}} = W_{\text{student}} + W_{\text{grav}} + W_n + W_f = 3.60\text{ J} + 0.0\text{ J} + 0.0\text{ J} - 0.900\text{ J} = 2.70\text{ J}.$

EVALUATE: Whenever a force acts perpendicular to the direction of motion, its contribution to the net work is zero.

P6.5. **IDENTIFY:** The gravity force is constant and the displacement is along a straight line, so $W = Fs\cos\phi.$

SET UP: The displacement is upward along the ladder and the gravity force is downward, so $\phi = 180.0° - 30.0° = 150.0°.$ $w = mg = 735\text{ N}.$

EXECUTE: **(a)** $W = (735\text{ N})(2.75\text{ m})\cos 150.0° = -1750\text{ J}.$

(b) No, the gravity force is independent of the motion of the painter.

EVALUATE: Gravity is downward and the vertical component of the displacement is upward, so the gravity force does negative work.

P6.13. **IDENTIFY:** Find the kinetic energy of the cheetah knowing its mass and speed.

SET UP: Use $K = \frac{1}{2}mv^2$ to relate *v* and *K*.

EXECUTE: **(a)** $K = \dfrac{1}{2}mv^2 = \dfrac{1}{2}(70\text{ kg})(32\text{ m/s})^2 = 3.6 \times 10^4\text{ J}.$

(b) *K* is proportional to $v^2,$ so *K* increases by a factor of 4 when *v* doubles.

EVALUATE: A running person, even with a mass of 70 kg, would have only 1/100 of the cheetah's kinetic energy since a person's top speed is only about 1/10 that of the cheetah.

P6.16. **IDENTIFY:** Use the equations for free-fall to find the speed of the weight when it reaches the ground and use the formula for kinetic energy.

SET UP: Kinetic energy is $K = \frac{1}{2}mv^2.$ The mass of an electron is $9.11\times10^{-31}\text{ kg}.$ In part (b) take $+y$ downward, so $a_y = +9.80\text{ m/s}^2$ and $v_y^2 = v_{0y}^2 + 2a_y(y - y_0).$

EXECUTE: **(a)** $K = \frac{1}{2}(9.11\times10^{-31}\text{ kg})(2.19\times10^6\text{ m/s})^2 = 2.18\times10^{-18}\text{ J}.$

(b) $v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$ gives $v_y = \sqrt{2(9.80\text{ m/s}^2)(1\cdot\text{m})} = 4.43\text{ m/s}.$ $K = \frac{1}{2}(1.0\text{ kg})(4.43\text{ m/s})^2 = 9.8\text{ J}.$

(c) Solving $K = \frac{1}{2}mv^2$ for *v* gives $v = \sqrt{\dfrac{2K}{m}} = \sqrt{\dfrac{2(100\text{ J})}{30\text{ kg}}} = 2.6\text{ m/s}.$ Yes, this is reasonable.

EVALUATE: A running speed of 6 m/s corresponds to running a 100-m dash in about 17 s, so 2.6 m/s is reasonable for a running child.

P6.20. **IDENTIFY:** From the work-energy relation, $W = W_{\text{grav}} = \Delta K_{\text{rock}}.$

SET UP: As the rock rises, the gravitational force, $F = mg,$ does work on the rock. Since this force acts in the direction opposite to the motion and displacement, *s*, the work is negative. Let *h* be the vertical distance the rock travels.

EXECUTE: **(a)** Applying $W_{\text{grav}} = K_2 - K_1$ we obtain $-mgh = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$. Dividing by m and solving for v_1, $v_1 = \sqrt{v_2^2 + 2gh}$. Substituting $h = 15.0\text{ m}$ and $v_2 = 25.0\text{ m/s}$,

$$v_1 = \sqrt{(25.0\text{ m/s})^2 + 2(9.80\text{ m/s}^2)(15.0\text{ m})} = 30.3\text{ m/s}$$

(b) Solve the same work-energy relation for h. At the maximum height $v_2 = 0$.

$$-mgh = \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2 \text{ and } h = \frac{v_1^2 - v_2^2}{2g} = \frac{(30.3\text{ m/s})^2 - (0.0\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = 46.8\text{ m}.$$

EVALUATE: Note that the weight of 20 N was never used in the calculations because both gravitational potential and kinetic energy are proportional to mass, m. Thus any object, that attains 25.0 m/s at a height of 15.0 m, must have an initial velocity of 30.3 m/s. As the rock moves upward gravity does negative work and this reduces the kinetic energy of the rock.

P6.29. IDENTIFY: $W_{\text{tot}} = K_2 - K_1$. Only friction does work.

SET UP: $W_{\text{tot}} = W_{f_\text{k}} = -\mu_\text{k} mgs$. $K_2 = 0$ (car stops). $K_1 = \frac{1}{2}mv_0^2$.

EXECUTE: **(a)** $W_{\text{tot}} = K_2 - K_1$ gives $-\mu_\text{k} mgs = -\frac{1}{2}mv_0^2$. $s = \dfrac{v_0^2}{2\mu_\text{k} g}$.

(b) (i) $\mu_{\text{k}b} = 2\mu_{\text{k}a}$. $s\mu_\text{k} = \dfrac{v_0^2}{2g} = \text{constant}$ so $s_a\mu_{\text{k}a} = s_b\mu_{\text{k}b}$. $s_b = \left(\dfrac{\mu_{\text{k}a}}{\mu_{\text{k}b}}\right)s_a = s_a/2$. The minimum stopping distance would be halved. (ii) $v_{0b} = 2v_{0a}$. $\dfrac{s}{v_0^2} = \dfrac{1}{2\mu_\text{k} g} = \text{constant}$, so $\dfrac{s_a}{v_{0a}^2} = \dfrac{s_b}{v_{0b}^2}$. $s_b = s_a\left(\dfrac{v_{0b}}{v_{0a}}\right)^2 = 4s_a$. The stopping distance would become 4 times as great. (iii) $v_{0b} = 2v_{0a}$, $\mu_{\text{k}b} = 2\mu_{\text{k}a}$. $\dfrac{s\mu_\text{k}}{v_0^2} = \dfrac{1}{2g} = \text{constant}$, so $\dfrac{s_a\mu_{\text{k}a}}{v_{0a}^2} = \dfrac{s_b\mu_{\text{k}b}}{v_{0b}^2}$. $s_b = s_a\left(\dfrac{\mu_{\text{k}a}}{\mu_{\text{k}b}}\right)\left(\dfrac{v_{0b}}{v_{0a}}\right)^2 = s_a\left(\dfrac{1}{2}\right)(2)^2 = 2s_a$. The stopping distance would double.

EVALUATE: The stopping distance is directly proportional to the square of the initial speed and indirectly proportional to the coefficient of kinetic friction.

P6.34. IDENTIFY: The magnitude of the work can be found by finding the area under the graph.

SET UP: The area under each triangle is $1/2\text{ base} \times \text{height}$. $F_x > 0$, so the work done is positive when x increases during the displacement.

EXECUTE: **(a)** $1/2\ (8\text{ m})(10\text{ N}) = 40\text{ J}$.

(b) $1/2\ (4\text{ m})(10\text{ N}) = 20\text{ J}$.

(c) $1/2\ (12\text{ m})(10\text{ N}) = 60\text{ J}$.

EVALUATE: The sum of the answers to parts (a) and (b) equals the answer to part (c).

P6.37. **IDENTIFY:** Apply Eq. (6.6) to the box.

SET UP: Let point 1 be just before the box reaches the end of the spring and let point 2 be where the spring has maximum compression and the box has momentarily come to rest.

EXECUTE: $W_{\text{tot}} = K_2 - K_1$

$K_1 = \frac{1}{2}mv_0^2, \quad K_2 = 0$

Work is done by the spring force. $W_{\text{tot}} = -\frac{1}{2}kx_2^2$, where x_2 is the amount the spring is compressed.

$-\frac{1}{2}kx_2^2 = -\frac{1}{2}mv_0^2$ and $x_2 = v_0\sqrt{m/k} = (3.0 \text{ m/s})\sqrt{(6.0 \text{ kg})/(7500 \text{ N/m})} = 8.5 \text{ cm}$

EVALUATE: The compression of the spring increases when either v_0 or *m* increases and decreases when *k* increases (stiffer spring).

P6.50. **IDENTIFY:** Knowing the rate at which energy is consumed, we want to find out the total energy used.

SET UP: Find the elapsed time Δt in each case by dividing the distance by the speed, $\Delta t = d/v$. Then calculate the energy as $W = P\Delta t$.

EXECUTE: *Running:* $\Delta t = (5.0 \text{ km})/(10 \text{ km/h}) = 0.50 \text{ h} = 1.8 \times 10^3 \text{ s}$. The energy used is $W = (700 \text{ W})(1.8 \times 10^3 \text{ s}) = 1.3 \times 10^6 \text{ J}$.

Walking: $\Delta t = \dfrac{5.0 \text{ km}}{3.0 \text{ km/h}}\left(\dfrac{3600 \text{ s}}{\text{h}}\right) = 6.0 \times 10^3 \text{ s}$. The energy used is $W = (290 \text{ W})(6.0 \times 10^3 \text{ s}) = 1.7 \times 10^6 \text{ J}$.

EVALUATE: The less intense exercise lasts longer and therefore burns up more energy than the intense exercise.

P6.63. **IDENTIFY** and **SET UP:** Since the forces are constant, Eq. (6.2) can be used to calculate the work done by each force. The forces on the suitcase are shown in Figure 6.63a.

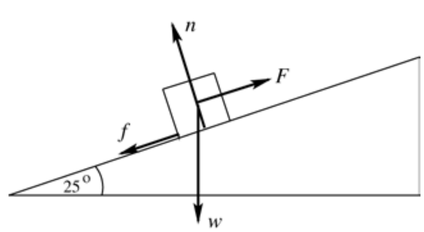


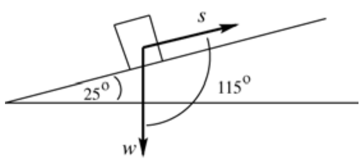
Figure 6.63a

In part (f), Eq. (6.6) is used to relate the total work to the initial and final kinetic energy.

EXECUTE: **(a)** $W_F = (F\cos\phi)s$

Both $\vec{F}$ and $\vec{s}$ are parallel to the incline and in the same direction, so $\phi = 90°$ and $W_F = Fs = (140 \text{ N})(3.80 \text{ m}) = 532 \text{ J}$.

(b) The directions of the displacement and of the gravity force are shown in Figure 6.63b.



$$W_w = (w\cos\phi)s$$
$$\phi = 115°, \text{ so}$$
$$W_w = (196 \text{ N})(\cos 115°)(3.80 \text{ m})$$
$$W_w = -315 \text{ J}$$

Figure 6.63b

Alternatively, the component of w parallel to the incline is $w\sin 25°$. This component is down the incline so its angle with $\vec{s}$ is $\phi = 180°$. $W_{w\sin 25°} = (196 \text{ N}\sin 25°)(\cos 180°)(3.80 \text{ m}) = -315 \text{ J}$. The other component of w, $w\cos 25°$, is perpendicular to $\vec{s}$ and hence does no work. Thus $W_w = W_{w\sin 25°} = -315 \text{ J}$, which agrees with the above.

(c) The normal force is perpendicular to the displacement $(\phi = 90°)$, so $W_n = 0$.

(d) $n = w\cos 25°$ so $f_\text{k} = \mu_\text{k} n = \mu_\text{k} w\cos 25° = (0.30)(196 \text{ N})\cos 25° = 53.3 \text{ N}$

$W_f = (f_\text{k}\cos\phi)x = (53.3 \text{ N})(\cos 180°)(3.80 \text{ m}) = -202 \text{ J}$

(e) $W_\text{tot} = W_F + W_w + W_n + W_f = +532 \text{ J} - 315 \text{ J} + 0 - 202 \text{ J} = 15 \text{ J}$

(f) $W_\text{tot} = K_2 - K_1$, $K_1 = 0$, so $K_2 = W_\text{tot}$

$\frac{1}{2}mv_2^2 = W_\text{tot}$ so $v_2 = \sqrt{\dfrac{2W_\text{tot}}{m}} = \sqrt{\dfrac{2(15 \text{ J})}{20.0 \text{ kg}}} = 1.2 \text{ m/s}$

EVALUATE: The total work done is positive and the kinetic energy of the suitcase increases as it moves up the incline.