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ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. The net work done on the wheelbarrow is

$$W_{\text{net}} = W_{\substack{\text{applied}\\\text{force}}} + W_{\text{friction}} = (F\cos 0°)\Delta x + (f\cos 180°)\Delta x$$
$$= (F - f)\Delta x = (50.0\text{ N} - 43\text{ N})(5.0\text{ m}) = +35\text{ J}$$

so choice (c) is the correct answer.

2. We assume the climber has negligible speed at both the beginning and the end of the climb. Then $KE_f = KE_i \approx 0$, and the work done by the muscles is

$$W_{nc} = 0 + \left(PE_f - PE_i\right) = mg\left(y_f - y_i\right) = (70.0\text{ kg})\left(9.80\text{ m/s}^2\right)(325\text{ m}) = 2.23\times10^5\text{ J}$$

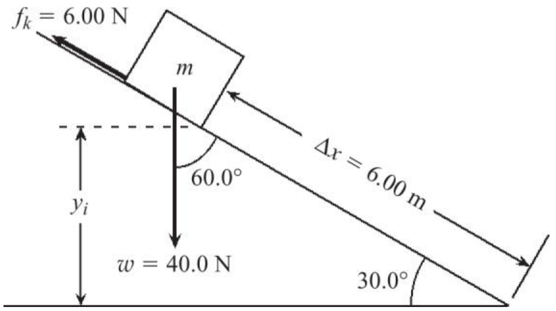
The average power delivered is $\overline{P} = \dfrac{W_{nc}}{\Delta t} = \dfrac{2.23\times10^5\text{ J}}{95.0\text{ min}\left(60\text{ s/1 min}\right)} = 39.1\text{ W}$ and the correct answer is choice (a).

3. The mass of the crate is

$$m = w/g = (40.0\text{ N})\big/\left(9.80\text{ m/s}^2\right) = 4.08\text{ kg}$$

and we may write the work-energy theorem as

$$W_{\text{net}} = W_{\text{friction}} + W_{\text{gravity}} = KE_f - KE_i$$



Since the crate starts from rest, $KE_i = \frac{1}{2}mv_i^2 = 0$ and we are left with

$$KE_f = W_{\text{friction}} + W_{\text{gravity}} = (f_k \cos 180°)\Delta x + (w \cos 60.0°)\Delta x$$

so

$$KE_f = (-6.00\text{ N})(6.00\text{ m}) + (40.0\text{ N})\cos 60.0°\ (6.00\text{ m}) = -36.0\text{ J} + 120\text{ J} = 84.0\text{ J}$$

and

$$v_f = \sqrt{\frac{2KE_f}{m}} = \sqrt{\frac{2(84.0\text{ J})}{4.08\text{ kg}}} = 6.42\ \text{m/s}$$

making choice (d) the correct response.

4. In the absence of any air resistance, the work done by nonconservative forces is zero. The work-energy theorem then states that $KE_f + PE_f = KE_i + PE_i$, which becomes

$$\frac{1}{2}\cancel{m}v_f^2 + \cancel{m}gy_f = \frac{1}{2}\cancel{m}v_i^2 + \cancel{m}gy_i \qquad \text{or} \qquad v_f = \sqrt{v_i^2 + 2g(y_i - y_f)}$$

Choosing the initial point to be where the skier leaves the end of the jump and the final point where he reaches maximum height, this yields

$$v_f = \sqrt{(15.0\ \text{m/s})^2 + 2\left(9.80\ \text{m/s}^2\right)(-4.50\ \text{m})} = 11.7\ \text{m/s}$$

making (a) the correct answer.

5. The net work needed to accelerate the object from $v = 0$ to v is

$$W_1 = KE_f - KE_i = \tfrac{1}{2}mv^2 - \tfrac{1}{2}m(0)^2 = \tfrac{1}{2}mv^2$$

The work required to accelerate the object from speed v to speed $2v$ is

$$W_2 = KE_f - KE_i = \tfrac{1}{2}m(2v)^2 - \tfrac{1}{2}mv^2 = \tfrac{1}{2}m\left(4v^2 - v^2\right) = 3\left(\tfrac{1}{2}mv^2\right) = 3W_1$$

Thus, the correct choice is (c).

6. Because the same slingshot is used in the same way for both the pebble and the bean, the work done on the projectile by the slingshot is the same in both cases. The work-energy theorem, $W_{\text{net}} = KE_f - KE_i = KE_f - 0$, then tells us that the projectile is given the same final kinetic energy in both cases. Thus,

$$\frac{1}{2}m_{\text{bean}}v_{\text{bean}}^2 = \frac{1}{2}m_{\text{pebble}}v_{\text{pebble}}^2 \qquad \text{or} \qquad \frac{m_{\text{bean}}}{m_{\text{pebble}}} = \frac{v_{\text{pebble}}^2}{v_{\text{bean}}^2} = \frac{(200\ \text{cm/s})^2}{(600\ \text{cm/s})^2} = \frac{1}{9}$$

and (a) is the correct choice.

7. Since the rollers on the ramp used by David were frictionless, he did not do any work overcoming nonconservative forces as he slid the block up the ramp. Neglecting any change in kinetic energy of the block (either because the speed was constant in the case of sliding the block, or, in the case of lifting the block, the speed at the ground and at the truck bed were both zero), the work done by either Mark or David equals the increase in the gravitational potential energy of the block as it is lifted from the ground to the truck bed. Because they lift identical blocks through the same vertical distance, they do equal amounts of work and the correct choice is (b).

8. The kinetic energy is proportional to the square of the speed of the particle. Thus, doubling the speed will increase the kinetic energy by a factor of 4. This is seen from

$$KE_f = \frac{1}{2}mv_f^2 = \frac{1}{2}m(2v_i)^2 = 4\left(\frac{1}{2}mv_i^2\right) = 4KE_i$$

and (a) is the correct response here.

9. $KE_{\text{car}} = \frac{1}{2}m_{\text{car}}v^2 = \frac{1}{2}\left(\frac{1}{2}m_{\text{truck}}\right)v^2 = \frac{1}{2}\left(\frac{1}{2}m_{\text{truck}}v^2\right) = \frac{1}{2}KE_{\text{truck}}$, so (b) is the correct answer.

10. Once the athlete leaves the surface of the trampoline, only a conservative force (her weight) acts on her. Therefore, her total mechanical energy is constant during her flight, or $KE_f + PE_f = KE_i + PE_i$. Taking the $y = 0$ at the surface of the trampoline, $PE_i = mgy_i = 0$. Also, her speed when she reaches maximum height is zero, or $KE_f = 0$. This leaves us with $PE_f = KE_i$, or $\cancel{m}gy_{\max} = \frac{1}{2}\cancel{m}v_i^2$, which gives the maximum height as

$$y_{\max} = \frac{v_i^2}{2g} = \frac{(8.5\ \text{m/s})^2}{2(9.80\ \text{m/s}^2)} = 3.7\ \text{m}$$

making (c) the correct choice.

11. The work-energy theorem states that $W_{net} = KE_f - KE_i$. Thus, if $W_{net} = 0$, then $KE_f = KE_i$ or $\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2$, which leads to the conclusion that the speed is unchanged $(v_f = v_i)$. The velocity of the particle involves both magnitude (speed) and direction. The work-energy theorem shows that the magnitude or speed is unchanged when $W_{net} = 0$, but makes no statement about the direction of the velocity. Therefore, choice (d) is correct but choice (c) is not necessarily true.

12. As the block falls freely, only the conservative gravitational force acts on it. Therefore, mechanical energy is conserved, or $KE_f + PE_f = KE_i + PE_i$. Assuming that the block is released from rest $(KE_i = 0)$, and taking $y = 0$ at ground level $(PE_f = 0)$, we have

$$KE_f = PE_i \qquad \text{or} \qquad \frac{1}{2}mv_f^2 = mgy_i \qquad \text{and} \qquad y_i = \frac{v_f^2}{2g}$$

Thus, to double the final speed, it is necessary to increase the initial height by a factor of four, and the correct choice for this question is (e).

13. If the car is to have uniform acceleration, a constant net force F must act on it. Since the instantaneous power delivered to the car is $P = Fv$, we see that maximum power is required just as the car reaches its maximum speed. The correct answer is (b).

ANSWERS TO EVEN NUMBERED CONCEPTUAL QUESTIONS

4. (a) Kinetic energy is always positive. Mass and speed squared are both positive.

(b) Gravitational potential energy can be negative when the object is lower than the chosen reference level.

PROBLEM SOLUTIONS

5.1 If the weights are to move at constant velocity, the net force on them must be zero. Thus, the force exerted on the weights is upward, parallel to the displacement, with magnitude 350 N. The work done by this force is

$$W = (F\cos\theta)s = [(350\text{ N})\cos 0°](2.00\text{ m}) = \boxed{700\text{ J}}$$

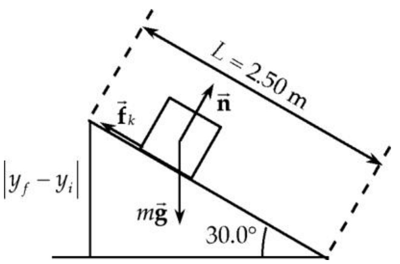
5.5 (a) The gravitational force acting on the object is

$$w = mg = (5.00\text{ kg})(9.80\text{ m/s}^2) = 49.0\text{ N}$$

and the work done by this force is

$$W_g = -\Delta PE_g = -mg(y_f - y_i) = +w(y_i - y_f)$$

or $$W_g = w(L\sin 30.0°) = (49.0\text{ N})(2.50\text{ m})\sin 30.0° = \boxed{61.3\text{ J}}$$



(b) The normal force exerted on the block by the incline is $n = mg\cos 30.0°$, so the friction force is

$$f_k = \mu_k n = (0.436)(49.0\text{ N})\cos 30.0° = 18.5\text{ N}$$

This force is directed opposite to the displacement (that is q = 180°), and the work it does is

$$W_f = (f_k \cos\theta)L = [(18.5\text{ N})\cos 180°](2.50\text{ m}) = \boxed{-46.3\text{ J}}$$

(c) Since the normal force is perpendicular to the displacement, so the work done by the normal force is $W_n = (n\cos 90.0°)L = \boxed{0}$.

(d) If a shorter ramp is used to increase the angle of inclination while maintaining the same vertical displacement $|y_f - y_i|$, the $\boxed{\text{work done by gravity will not change}}$, the $\boxed{\text{work done by the friction force will decrease}}$ (because the normal force, and hence the friction force, will decrease and also because the ramp length L decreases), and the $\boxed{\text{work done by the normal force remains zero}}$ (because the normal force remains perpendicular to the displacement).

5.9 (a) The work-energy theorem, $W_{\text{net}} = KE_f - KE_i$, gives

$$5\,000\text{ J} = \frac{1}{2}(2.50\times 10^3\text{ kg})v^2 - 0,\text{ or}\quad v = \boxed{2.00\text{ m/s}}$$

(b) $W = (F\cos\theta)s = (F\cos 0°)(25.0\text{ m}) = 5\,000\text{ J}$, so $F = \boxed{200\text{ N}}$

5.13 (a) We use the work-energy theorem to find the work.

$$W = \Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = 0 - \frac{1}{2}(70\ \text{kg})(4.0\ \text{m/s})^2 = \boxed{-5.6\times10^2\ \text{J}}$$

(b) $W = (F\cos\theta)s = (f_k\cos180^\circ)s = (-\mu_k n)s = (-\mu_k\, mg)s$,

so $$s = -\frac{W}{\mu_k\, mg} = -\frac{(-5.6\times10^2\ \text{J})}{(0.70)(70\ \text{kg})(9.80\ \text{m/s}^2)} = \boxed{1.2\ \text{m}}$$

5.15 (a) As the bullet penetrates the tree trunk, the only force doing work on it is the force of resistance exerted by the trunk. This force is directed opposite to the displacement, so the work done is $W_{\text{net}} = (f_{\text{av}}\cos180^\circ)\Delta x = KE_f - KE_i$, and the magnitude of the average resistance force is

$$f_{\text{av}} = \frac{KE_f - KE_i}{(\Delta x)\cos180^\circ} = \frac{0 - \frac{1}{2}(7.80\times10^{-3}\ \text{kg})(575\ \text{m/s})^2}{-(5.50\times10^{-2}\ \text{m})} = \boxed{2.34\times10^4\ \text{N}}$$

(b) If the friction force is constant, the bullet will have a constant acceleration and its average velocity while stopping is $\bar{v} = (v_f + v_i)/2$. The time required to stop is then

$$\Delta t = \frac{\Delta x}{\bar{v}} = \frac{2(\Delta x)}{v_f + v_i} = \frac{2(5.50\times10^{-2}\ \text{m})}{0 + 575\ \text{m/s}} = \boxed{1.91\times10^{-4}\ \text{s}}$$

5.19 (a) $PE_i = mgy_i = (0.20\ \text{kg})(9.80\ \text{m/s}^2)(1.3\ \text{m}) = \boxed{2.5\ \text{J}}$

(b) $PE_f = mgy_f = (0.20\text{ kg})(9.80\text{ m/s}^2)(-5.0\text{ m}) = \boxed{-9.8\text{ J}}$

(c) $\Delta PE = PE_f - PE_i = -9.8\text{ J} - 2.5\text{ J} = \boxed{-12\text{ J}}$

5.33 Since no nonconservative forces do work, we use conservation of mechanical energy, with the zero of potential energy selected at the level of the base of the hill. Then,

$\frac{1}{2}mv_f^2 + mgy_f = \frac{1}{2}mv_i^2 + mgy_i$ with $y_f = 0$ yields

$$y_i = \frac{v_f^2 - v_i^2}{2g} = \frac{(3.00\text{ m/s})^2 - 0}{2(9.80\text{ m/s}^2)} = \boxed{0.459\text{ m}}$$

Note that this result is independent of the mass of the child and sled.

$$\Delta KE_A = \frac{1}{2}m_A v_f^2 - 0 = \frac{1}{2}(50\text{ kg})(157\text{ m}^2/\text{s}^2) = 3.9\times10^3\text{ J} = \boxed{3.9\text{ kJ}}$$