CHAPTER 6 | *WORK AND ENERGY*

CONCEPTUAL QUESTIONS

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1. ***REASONING AND SOLUTION*** The work done by $\mathbf{F}_1$ in moving the box through a displacement $\mathbf{s}$ is $W_1 = (F_1 \cos 0°)s = F_1 s$. The work done by $\mathbf{F}_2$ is $W_2 = (F_2 \cos \boldsymbol{q})s$. From the drawing, we see that $F_1 > F_2 \cos \boldsymbol{q}$; therefore, the force $\mathbf{F}_1$ does more work.

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2. ***REASONING AND SOLUTION*** The force $\mathbf{P}$ acts along the displacement; therefore, it does positive work. Both the normal force $\mathbf{F}_N$ and the weight $m\mathbf{g}$ are perpendicular to the displacement; therefore, they do zero work. The kinetic frictional force $\mathbf{f}_k$ acts opposite to the direction of the displacement; therefore, it does negative work.

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3. ***REASONING AND SOLUTION*** Work can be positive or negative. Work is positive when the force has a component in the same direction as the direction of the displacement, or equivalently, when the angle $\boldsymbol{q}$ between the force $\mathbf{F}$ and the displacement $\mathbf{s}$ is less than 90°. The work is negative when the force has a component in the direction *opposite* to the displacement; that is, when $\boldsymbol{q}$ is greater than 90°.

Since the force does positive work on a particle that has a displacement pointing in the $+x$ direction, the force must have an x component that points in the $+x$ direction. Furthermore, since the same force does negative work on a particle that has a displacement pointing in the $+y$ direction, the force has a y component that points in the *negative y* direction.

When the x and y components of this force are sketched head to tail, as in the figure at the right, we see that the force must point in the fourth quadrant.

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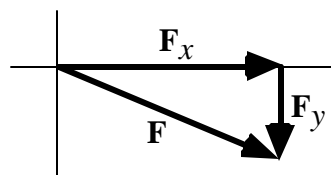
4. ***REASONING AND SOLUTION*** The sailboat moves at constant velocity, and, therefore, has zero acceleration. From Newton's second law, we know that the net external force on the sailboat must be zero.

a. There is no work done on the sailboat by a zero net external force.

b. Work is done by the individual forces that act on the boat; namely the wind that propels the boat forward and the water that resists the motion of the boat.   Since the wind propels the boat forward, it does positive work on the boat. Since the force of the water is a resistive force, it acts opposite to the displacement of the boat, and, therefore, it does negative work. Since the total work done on the boat is zero, each force must do an equal amount of work with one quantity being positive, and the other being negative.

Note: The answer to part (a) could have been deduced from the work-energy theorem as well. Since the velocity of the boat is constant, the kinetic energy of the boat does not change and the total work done on the boat is zero.

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5.   ***REASONING AND SOLUTION***   The speed of the ball decreases; therefore, the ball is subjected to an external resistive force. A resistive force always points opposite to the direction of the displacement of the ball. Therefore, the external force does negative work.

Using the work-energy theorem, we see that the change in the kinetic energy of the ball is negative; therefore, the total work done on the ball is negative. We can conclude, therefore, that the net force did negative work on the ball.

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6.   ***REASONING AND SOLUTION***   The kinetic energy of an object of mass m moving with speed v is given by $\mathrm{KE} = \frac{1}{2}mv^2$. The kinetic energy depends on both the mass and the speed of the object.   The mass of an automobile is significantly greater than the mass of a motorcycle. Therefore, even if an automobile is moving slowly, it is possible that the product $\frac{1}{2}mv^2$ is greater for the car than it is for the faster-moving motorcycle.

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7.   ***REASONING AND SOLUTION***   A net external force acts on a particle. This net force is not zero. From Newton's second law, we can conclude that the net external force causes the particle to accelerate. Since the particle experiences an acceleration, its velocity must change. The change in velocity, however, may occur as a change in magnitude only, a change in direction only, or a change in both magnitude and direction.

a. This is sufficient information to conclude that the velocity of the particle changes; however, there is not sufficient information to determine exactly how the velocity changes.

b. There is not sufficient information to determine if the kinetic energy of the particle changes. In terms of the work-energy theorem, the kinetic energy will change if the net external force does work on the particle. But without knowing the direction of the net external force with respect to the particle's displacement, we cannot know if work is done.

c. There is not sufficient information to determine if the speed of the particle changes. Kinetic energy is $\frac{1}{2}mv^2$, so the speed v will change if the kinetic energy changes. But, as explained in part (b), there is insufficient information to determine whether the kinetic energy changes.

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8. ***REASONING AND SOLUTION***   The speed of a particle doubles and then doubles again, because a net external force acts on it. Let m and v_0 represent the mass and initial speed of the particle, respectively. During the first doubling, the change in the kinetic energy of the particle is

$$\mathrm{KE}_f - \mathrm{KE}_0 = \frac{1}{2}m\left(2v_0\right)^2 - \frac{1}{2}mv_0^2 = \frac{3}{2}mv_0^2$$

During the second doubling, the change in the kinetic energy of the particle is

$$\mathrm{KE}_f - \mathrm{KE}_0 = \frac{1}{2}m\left(4v_0\right)^2 - \frac{1}{2}m\left(2v_0\right)^2 = 6mv_0^2$$

From the work-energy theorem, we know that a change in kinetic energy is equal to the work done by the net external force. Therefore, more work is done by the net force during the second doubling.

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9. ***REASONING AND SOLUTION***   A shopping bag hangs straight down from the hand of a person who walks across a horizontal floor at constant velocity.

a. The force exerted on the shopping bag by the hand is perpendicular to the direction of motion; hence, the work done by the hand is zero.

b. If the person then rides up an escalator at constant velocity, a component of the force exerted by the hand will point in the direction of the displacement and do a positive amount of work.

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10. ***REASONING AND SOLUTION***   The change in the gravitational potential energy of the astronaut is given by $\Delta \mathrm{PE} = mgH$, where H is the height of the ladder. The value of g is greater on earth than it is on the moon; therefore, the gravitational potential energy of the astronaut changes by a greater amount on earth.

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11. ***REASONING AND SOLUTION***   A net external nonconservative force does positive work on a particle, and both its kinetic and potential energies change.

a. The change in the total mechanical energy of the particle is given by $\Delta E = \Delta KE + \Delta PE$. From Equation 6.7b, $W_{nc} = \Delta KE + \Delta PE$; in other words, the work done on the particle by the net external nonconservative force is equal to the change in the particle's total mechanical energy. Since the force does positive work on the particle, we can conclude from Equation 6.7b that the particle's total mechanical energy must increase.

b. We do not have sufficient information to reach any conclusions on the individual changes in the kinetic and potential energies. Either ΔKE or ΔPE could be positive or negative, while the sum $\Delta KE + \Delta PE$ is positive. If either the change in the kinetic energy or the change in the potential energy is negative, the only conclusion that can be reached is that the magnitude of the negative quantity must be smaller than the magnitude of the positive quantity.

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12. ***REASONING AND SOLUTION***   If the total mechanical energy of an object is conserved, then the sum of the kinetic energy and the potential energy must be constant.

a. If the kinetic energy decreases, the gravitational potential energy must increase by the same amount that the kinetic energy decreases.

b. If the potential energy decreases, the kinetic energy must increase by the same amount that the potential energy decreases.

c. If the kinetic energy does not change, the potential energy cannot change either.

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13. ***REASONING AND SOLUTION***   Yes, the speed of the Magnum XL-200 would be 0 m/s at the top of the second hill. As the roller coaster descends the first hill, its total mechanical energy remains constant at all times. Its gravitational potential energy at the top of the hill is converted entirely into kinetic energy at the bottom. When the roller coaster ascends the second hill, its total mechanical energy also remains constant, and is equal to what it had during the descent of the first hill. As the roller coaster moves up the hill, kinetic energy is converted into gravitational potential energy. By the time it reaches the top of the second hill, all of its kinetic energy has been converted into gravitational potential energy, and so its speed is 0 m/s at the top.

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14. ***REASONING AND SOLUTION***   As the person moves downward from the top of the Ferris wheel, his displacement points downward. Since the person's weight also points downward, the work done by gravity is positive. As the person moves upward from the bottom, his displacement points upward. Since the weight still points downward, the work done by gravity is negative. The

magnitude of the work done in each half cycle is the same; therefore, the net work done in one revolution is zero.

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15. ***REASONING AND SOLUTION***   Car A turns off its engine and coasts up the hill. Car B keeps its engine running and drives up the hill at constant speed.   If air resistance and friction are negligible, then only the motion of car A is an example of the principle of conservation of mechanical energy. During the motion of car A, there are no nonconservative forces present. As car A coasts up the hill it loses kinetic energy and gains an equal amount of gravitational potential energy.   The motion of car B is not described by the principle of conservation of mechanical energy, because the driving force that propels car B up the hill is a nonconservative force.

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16. ***REASONING AND SOLUTION***   A trapeze artist, starting from rest, swings downward on the bar, lets go at the bottom of the swing, and falls freely to the net. An assistant, standing on the same platform as the trapeze artist, jumps from rest straight downward.

a. The work done by gravity, on either person, is $W = mgh$, where m is the mass of the person, and h is the magnitude of the vertical component of the person's displacement. The value of h is the same for both the trapeze artist and the assistant; however, the value of m is, in general, different for the trapeze artist and the assistant. Therefore, gravity does the most work on the more massive person.

b. Both the trapeze artist and the assistant strike the net with *the same speed.* Here's why. They both start out at rest on the platform above the net. As the trapeze artist swings downward, before letting go of the bar, she moves along the arc of a circle. The work done by the tension in the trapeze cords is zero because it points perpendicular to the circular path of motion. Thus, if air resistance is ignored, the work done by the nonconservative forces is zero, $W_{nc} = 0$ J. The total mechanical energy of each person is conserved, regardless of the path taken to the net. Since both the trapeze artist and the assistant had the same initial total mechanical energy (all potential), they must have the same total mechanical energy (all kinetic) when they reach the net. That is, for either person, $mgh = (1/2)mv^2$. Solving for v gives $v = \sqrt{2gh}$, independent of the mass of the person. The value of h is the same for both the trapeze artist and the assistant; therefore, they strike the net with the same speed.

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17. ***REASONING AND SOLUTION***   Since each plane has the same speed, the kinetic energy of each fuel tank will be the same at the instant of release. Since each plane is at the same height above the ground, each fuel tank must fall through the same vertical displacement. Therefore, the work done by gravity on each fuel tank is the same. From the work-energy theorem, each fuel tank will gain the same amount of kinetic energy during the fall.   Therefore, each fuel tank will hit the ground with the same speed.

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18. ***REASONING AND SOLUTION***   Average power $\overline{P}$ is the average rate at which work W is done: $\overline{P} = W/t$. It is not correct to conclude that one engine is doing twice the work of another just because it is generating twice the power. If one engine generates twice the power as the other, it may be generating the same amount of work in one half of the time.

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