CHAPTER 6 | *WORK AND ENERGY*

CONCEPTUAL QUESTIONS

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.

CHAPTER 6 | *WORK AND ENERGY*

PROBLEMS

32. ***REASONING*** The only two forces that act on the gymnast are his weight and the force exerted on his hands by the high bar. The latter is the (non-conservative) reaction force to the force exerted on the bar by the gymnast, as predicted by Newton's third law. This force, however, does no work because it points perpendicular to the circular path of motion. Thus, $W_{nc} = 0$ J, and we can apply the principle of conservation of mechanical energy.

SOLUTION The conservation principle gives

$$\underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{E_f} = \underbrace{\tfrac{1}{2}mv_0^2 + mgh_0}_{E_0}$$

Since the gymnast's speed is momentarily zero at the top of the swing, $v_0 = 0$ m/s. If we take $h_f = 0$ m at the bottom of the swing, then $h_0 = 2r$, where *r* is the radius of the circular path followed by the gymnast's waist. Making these substitutions in the above expression and solving for v_f, we obtain

$$v_f = \sqrt{2gh_0} = \sqrt{2g(2r)} = \sqrt{2(9.80\ \text{m/s}^2)(2\times 1.1\ \text{m})} = \boxed{6.6\ \text{m/s}}$$

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33. ***REASONING*** Since air resistance is being neglected, the only force that acts on the falling water is the conservative gravitational force (its weight). Since the height of the falls and the speed of the water at the bottom are known, we may use the conservation of mechanical energy to find the speed of the water at the top of the falls.

SOLUTION The conservation of mechanical energy, as expressed by Equation 6.9b, states that

$$\underbrace{\tfrac{1}{2}mv_f^2 + mgh_f}_{E_f} = \underbrace{\tfrac{1}{2}mv_0^2 + mgh_0}_{E_f}$$

The mass *m* can be eliminated algebraically from this equation, since it appears as a factor in every term. Solving for v_0 gives

$$v_0 = \sqrt{v_f^2 + 2g\left(h_f - h_0\right)}$$

$$= \sqrt{(25.8\text{ m/s})^2 + 2\left(9.80\text{ m/s}^2\right)(0\text{ m} - 33.2\text{ m})} = \boxed{3.9\text{ m/s}}$$

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34. ***REASONING AND SOLUTION*** The conservation of energy gives

$$\tfrac{1}{2}mv_f^2 + mgh_f = \tfrac{1}{2}mv_0^2 + mgh_0$$

Rearranging gives

$$h_f - h_0 = \frac{(14.0\text{ m/s})^2 - (13.0\text{ m/s})^2}{2\left(9.80\text{ m/s}^2\right)} = \boxed{1.4\text{ m}}$$

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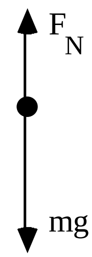
42. ***REASONING AND SOLUTION*** If air resistance is ignored, the only nonconservative force that acts on the skier is the normal force exerted on the skier by the snow. Since this force is always perpendicular to the direction of the displacement, the work done by the normal force is zero. We can conclude, therefore, that mechanical energy is conserved.

$$\frac{1}{2}mv_0^2 + mgh_0 = \frac{1}{2}mv_f^2 + mgh_f$$

Since the skier starts from rest $v_0 = 0$ m/s. Let h_f define the zero level for heights, then the final gravitational potential energy is zero. This gives

$$mgh_0 = \frac{1}{2}mv_f^2 \qquad (1)$$

At the crest of the second hill, the two forces that act on the skier are the normal force and the weight of the skier. The resultant of these two forces provides the necessary centripetal force to keep the skier moving along the circular arc of the hill. When the skier *just loses contact* with the snow, the normal force is zero and the weight of the skier must provide the necessary centripetal force.



$$mg = \frac{mv_f^2}{r} \qquad \text{so that} \qquad v_f^2 = gr \qquad (2)$$

Substituting this expression for v_f^2 into Equation (1) gives

$$mgh_0 = \frac{1}{2} mgr$$

Solving for h_0 gives

$$h_0 = \frac{r}{2} = \frac{36 \text{ m}}{2} = \boxed{18 \text{ m}}$$

CHAPTER 7 | *IMPULSE AND MOMENTUM*

CONCEPTUAL QUESTIONS

3. ***REASONING AND SOLUTION***

a. Yes. Momentum is a vector, and the two objects have the same momentum. This means that the direction of each object's momentum is the same. Momentum is mass times velocity, and the direction of the momentum is the same as the direction of the velocity. Thus, the velocity directions must be the same.

b. No. Momentum is mass times velocity. The fact that the objects have the same momentum means that the product of the mass and the magnitude of the velocity is the same for each. Thus, the magnitude of the velocity of one object can be smaller, for example, as long as the mass of that object is proportionally greater to keep the product of mass and velocity unchanged.

8. ***REASONING AND SOLUTION*** The impulse-momentum theorem, Equation 7.4, states that $\overline{\mathbf{F}}\Delta t = m\mathbf{v}_f - m\mathbf{v}_0$. Assuming that the golf ball is at rest when it is struck with the club, $\overline{\mathbf{F}}\Delta t = m\mathbf{v}_f$.

During a good "follow-through" when driving a golf ball, the club is in contact with the ball for the longest possible time. From the impulse-momentum theorem, it is clear that when the contact time Δt is a maximum, the final linear momentum $m\boldsymbol{v}_f$ of the ball is a maximum. In other words, during a good "follow through" the maximum amount of momentum is transferred to the ball. Therefore, the ball will travel through a larger horizontal distance.

CHAPTER 7 | *IMPULSE AND MOMENTUM*

PROBLEMS

6. ***REASONING AND SOLUTION***

a. According to Equation 7.4, the impulse-momentum theorem, $\overline{\mathbf{F}}\Delta t = m\mathbf{v}_f - m\mathbf{v}_0$. Since the goalie catches the puck, $v_f = 0$. Solving for the average force exerted on the puck, we have

$$\overline{F} = \frac{m(v_f - v_o)}{\Delta t} = \frac{0.17 kg[0 - 65 m/s]}{5.0 \times 10^{-3} s} = -2.2 \times 10^3 N$$

By Newton's third law, the force exerted on the goalie by the puck is equal in magnitude, but opposite in direction, to the force exerted on the puck by the goalie. Thus, the average force exerted on the goalie is $\boxed{+2.2 \times 10^3 \text{ N}}$.

b. If, instead of catching the puck, the goalie slaps it with his stick and returns the puck straight back to the player with a velocity of –65 m/s, then the average force exerted on the puck by the goalie is

$$\overline{F} = \frac{m(v_f - v_o)}{\Delta t} = \frac{0.17 kg[(-65 m/s) - (+65 m/s)]}{5.0 \times 10^{-3} s} = -4.2 \times 10^3 N$$

The average force exerted on the goalie by the puck is thus $\boxed{+4.4 \times 10^3 \text{ N}}$.

The answer in part (b) is twice that in part (a). This is consistent with the conclusion of Conceptual Example 3. The change in the momentum of the puck is greater when the puck rebounds from the stick. Thus, the puck exerts a greater impulse, and hence a greater force, on the goalie.

12. ***REASONING*** This is a problem in vector addition, and we will use the component method for vector addition. Using this method, we will add the components of the individual momenta in the direction due north to obtain the component of the vector sum in the direction due north. We will obtain the component of the vector sum in the direction due east in a similar fashion from the individual components in that direction. For each jogger the momentum is the mass times the velocity.

SOLUTION Assuming that the directions north and east are positive, the components of the joggers' momenta are as shown in the following table:

	Direction due east	Direction due north
85 kg jogger	$85 kg \times 2.0 m/s = 170 kg \cdot m/s$	0 kg•m/s
55 kg jogger	$55 kg \times (3.0 m/s \cdot \cos 32^o)$ $= 140 kg \cdot m/s$	$55 kg \times (3.0 m/s \cdot \sin 32^o)$ $= 87 kg \cdot m/s$
Total	310 kg•m/s	87 kg•m/s

Using the Pythagorean theorem, we find that the magnitude of the total momentum is

$$\sqrt{(310 kg \cdot m/s)^2 + (87 kg \cdot m/s)^2} = 322 kg \cdot m/s$$

The total momentum vector points north of east by an angle *q*, which is given by

$$q = \tan^{-1}\left[\frac{87 kg \cdot m/s}{310 kg \cdot m/s}\right] = 16^o$$

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16. ***REASONING AND SOLUTION*** The momentum of the spaceship is transferred to the rocket, so $(m_s + m_r)v_s = m_r v_r$, and the rocket's velocity is

$$v_r = \frac{(m_s + m_r)v_s}{m_r} = \frac{(4.0 \times 10^6 \text{ kg} + 1300 \text{ kg})(230 \text{ m/s})}{1300 \text{ kg}} = \boxed{7.1 \times 10^5 \text{ m/s}}$$
