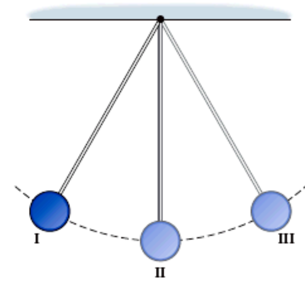
Discussion Examples
Chapter 7: Work and Kinetic Energy

2. A pendulum bob swings from point I to point II along the circular arc indicated in **Figure 7–14**. **(a)** Is the work done on the bob by gravity **A**, positive; **B**, negative; or **C**, zero? **(b)** Is the work done on the bob by the string **A**, positive; **B**, negative; or **C**, zero?

Picture the Problem: A pendulum bob swings from point I to point II along the circular arc indicated in the figure at right.



Strategy: Apply equation 7-3, which says that the work done on an object is positive if the force and the displacement are along the same direction, but zero if the force is perpendicular to the displacement.

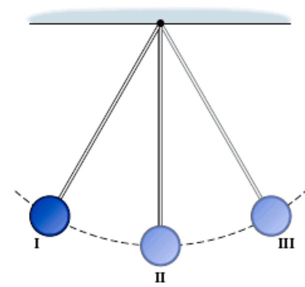
Solution: 1. (a) As the pendulum bob swings from point I to point II, the force of gravity points downward and a component of the displacement is downward. Therefore, the work done on the bob by gravity is $\boxed{\text{positive}}$.

2. (b) As the pendulum bob swings, the force exerted by the string is radial (toward the pivot point) but the displacement is tangential, perpendicular to the force. We conclude that the work done on the bob by the string is $\boxed{\text{zero}}$.

Insight: The work done by the Earth is negative if the bob swings from point II to point III because a component of the displacement is upward but the force is downward.

3. A pendulum bob swings from point II to point III along the circular arc indicated in Figure 7–14. **(a)** Is the work done on the bob by gravity **A**, positive; **B**, negative; or **C**, zero? **(b)** Is the work done on the bob by the string **A**, positive; **B**, negative; or **C**, zero?

Picture the Problem: A pendulum bob swings from point II to point III along the circular arc indicated in the figure at right.



Strategy: Apply equation 7-3, which says that the work done on an object is positive if the force and the displacement are along the same direction, but zero if the force is perpendicular to the displacement.

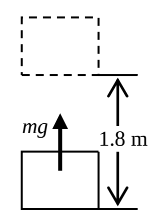
Solution: 1. (a) As the pendulum bob swings from point II to point III, the force of gravity points downward and a component of the displacement is upward. Therefore, the work done on the bob by gravity is $\boxed{\text{negative}}$.

2. (b) As the pendulum bob swings, the force exerted by the string is radial (toward the pivot point) but the displacement is tangential, perpendicular to the force. We conclude that the work done on the bob by the string is $\boxed{\text{zero}}$.

Insight: The work done by the Earth is positive if the bob swings from point I to point II because a component of the displacement is downward and the force is downward.

8. You pick up a 3.4-kg can of paint from the ground and lift it to a height of 1.8 m. **(a)** How much work do you do on the can of paint? **(b)** You hold the can stationary for half a minute, waiting for a friend on a ladder to take it. How much work do you do during this time? **(c)** Your friend decides against the paint, so you lower it back to the ground. How much work do you do on the can as you lower it?

Picture the Problem: The paint can is lifted vertically.



Strategy: Multiply the force by the distance because the two vectors point in the same direction in part (a). In part (b) the distance traveled is zero, and in part (c) the force and distance are antiparallel.

Solution: 1. (a) Apply equation 7-1: $W = Fd = mgd$

$$W = (3.4 \text{ kg})(9.81 \text{ m/s}^2)(1.8 \text{ m}) = \boxed{60 \text{ J}}$$

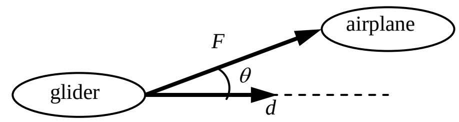
2. (b) Now the force and distance are perpendicular: $W = \boxed{0}$

3. (c) Now the force and distance are antiparallel: $W = -mgd = \boxed{-60 \text{ J}} = -0.060 \text{ kJ}$

Insight: The applied force equals the weight as long as the paint can does not accelerate. The can gains potential energy as it is lifted and loses potential energy as it is lowered. (We will discuss potential energy in Chapter 8.)

14. A small plane tows a glider at constant speed and altitude. If the plane does 2.00×10^5 J of work to tow the glider 145 m and the tension in the tow rope is 2560 N, what is the angle between the tow rope and the horizontal?

Picture the Problem: The plane and glider must be at different altitudes. Since the altitudes are constant, both are moving horizontally.



Strategy: Use equation 7-3, solving for the angle between the force and the direction of motion.

Solution: 1. Solve equation 7-3 for the angle: $W = Fd\cos\theta$ or $\cos\theta = \dfrac{W}{Fd}$

2. Calculate the angle: $\theta = \cos^{-1}\left(\dfrac{W}{Fd}\right) = \cos^{-1}\left[\dfrac{2.00\times10^5\text{ J}}{(2560\text{ N})(145\text{ m})}\right] = \boxed{57.4^\circ}$

Insight: Only the component of the force along the direction of the motion does any work. The vertical component of the force helps to lift the glider a little.

27. After hitting a long fly ball that goes over the right fielder's head and lands in the outfield, the batter decides to keep going past second base and try for third base. The 62.0-kg player begins sliding 3.40 m from the base with a speed of 4.35 m/s. If the player comes to rest at third base, **(a)** how much work was done on the player by friction? **(b)** What was the coefficient of kinetic friction between the player and the ground?

Picture the Problem: The runner slides horizontally on level ground over a distance of 3.40 m and comes to rest.

Strategy: The work done by friction equals the negative of the kinetic energy the runner had just before the slide. It also equals the force exerted by friction times the distance of the slide.

Solution: 1. (a) Calculate $W = \Delta K$:

$$W = \Delta K = K_f - K_i = 0 - \tfrac{1}{2}mv_i^2$$

$$W = -\tfrac{1}{2}(62.0\text{ kg})(4.35\text{ m/s})^2 = \boxed{-587\text{ J}}$$

2. (b) The work done by friction equals the average force of friction times the distance the player slid:

$$W = -Fd = -(\mu_k mg)d \quad \text{so that} \quad \mu_k = -\frac{W}{mgd}$$

$$\mu_k = -\frac{(-587\text{ J})}{(62.0\text{ kg})(9.81\text{ m/s}^2)(3.40\text{ m})} = \boxed{0.284}$$

Insight: Kinetic friction always does negative work because the force is always opposite to the direction of motion.

48. In order to keep a leaking ship from sinking, it is necessary to pump 12.0 lb of water each second from below deck up a height of 2.00 m and over the side. What is the minimum horsepower motor that can be used to save the ship?

Picture the Problem: The water is pumped vertically upward.

Strategy: The power required is the work required to change the elevation divided by the time. As in Conceptual Checkpoint 7-1 and Example 7-2 the work required to change the elevation of an object is $W = mgh$.

Solution: Divide the work required by the time:

$$P = \frac{W}{t} = \frac{mgh}{t} = \frac{(12.0\text{ lb} \times 4.448\text{ N/lb})(2.00\text{ m})}{(1.00\text{ s})}$$

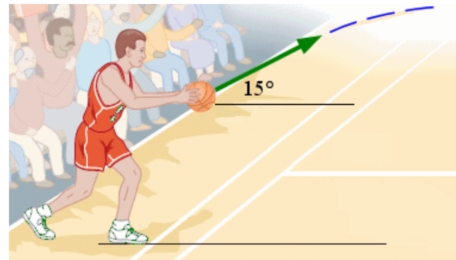
$$P = 107\text{ W} \times 1\text{ hp}/746\text{ W} = \boxed{0.143\text{ hp}}$$

Insight: A ¼-hp motor would do the trick. Pumping faster than this would require more power.

Chapter 8: Potential Energy and Conservation of Energy

26. **IP** A player passes a 0.600-kg basketball downcourt for a fast break. The ball leaves the player's hands with a speed of 8.30 m/s and slows down to 7.10 m/s at its highest point. **(a)** Ignoring air resistance, how high above the release point is the ball when it is at its maximum height? **(b)** How would doubling the ball's mass affect the result in part (a)? Explain.

Picture the Problem: As the ball flies through the air and gains altitude some of its initial kinetic energy is converted into gravitational potential energy.



Strategy: Set the mechanical energy at the start of the throw equal to the mechanical energy at its highest point. Let the height be $y_i = 0$ at the start of the throw, and find y_f at the highest point.

Solution: 1. (a) Set $E_i = E_f$ and solve for y_f:

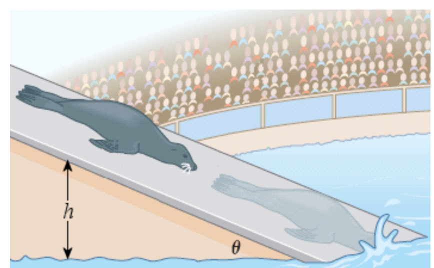
$$E_i = E_f$$
$$K_i + U_i = K_f + U_f$$
$$\tfrac{1}{2}mv_i^2 + 0 = \tfrac{1}{2}mv_f^2 + mgy_f$$
$$y_f = \frac{1}{2g}\left(v_i^2 - v_f^2\right) = \frac{(8.30\text{ m/s})^2 - (7.10\text{ m/s})^2}{2(9.81\text{ m/s}^2)} = \boxed{0.942\text{ m}}$$

2. (b) The height change is independent of the mass, so doubling the ball's mass would cause no change to (a).

Insight: A more massive ball would have more kinetic energy at the start, but would require more energy to change its height by 0.942 m, so the mass cancels out.

47. A 42.0-kg seal at an amusement park slides from rest down a ramp into the pool below. The top of the ramp is 1.75 m higher than the surface of the water and the ramp is inclined at an angle of 35.0° above the horizontal. If the seal reaches the water with a speed of 4.40 m/s, what is **(a)** the work done by kinetic friction and **(b)** the coefficient of kinetic friction between the seal and the ramp?

Picture the Problem: The seal slides down the ramp, changing altitude and speed, and loses mechanical energy along the way due to friction.



Strategy: The nonconservative work done by friction changes the mechanical energy of the seal. Use equation 8-9 and the given information to find the nonconservative work. Then use Newton's Second Law to find the normal force on the seal, and use the normal force to find the force of kinetic friction. Solve the resulting expression for μ_k. Let $y = 0$ at the water's surface.

Solution: 1. (a) Use equations 8-9, 7-6, and 8-3 to find W_{nc}:

$$W_{nc} = \Delta E = E_f - E_i$$
$$= \left(\tfrac{1}{2}mv_f^2 + mgy_f\right) - \left(\tfrac{1}{2}mv_i^2 + mgy_i\right)$$
$$= \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) + mg\left(y_f - y_i\right)$$
$$= (42.0\text{ kg})\left\{\tfrac{1}{2}\left[(4.40\text{ m/s})^2 - 0^2\right] + (9.81\text{ m/s}^2)(0 - 1.75\text{ m})\right\}$$
$$W_{nc} = \boxed{-314\text{ J}}$$

2. Use Newton's Second Law to find the normal force:

$$\sum F_y = N - mg\cos\theta = 0 \quad\Rightarrow\quad N = mg\cos\theta$$

3. Use the right triangle formed by the ramp to find the distance the seal slides:

$$\sin\theta = \frac{h}{d} \quad\Rightarrow\quad d = \frac{h}{\sin\theta}$$

4. (b) Set W_{nc} equal to the work done by friction and solve for μ_k:

$$W_{nc} = -f_k d = -\mu_k N d = -\mu_k\left(mg\cos\theta\right)\left(h/\sin\theta\right)$$
$$\mu_k = -\frac{W_{nc}\sin\theta}{(mg\cos\theta)h} = -\frac{(-314\text{ J})\tan 35.0°}{(42.0\text{ kg})(9.81\text{ m/s}^2)(1.75\text{ m})} = \boxed{0.305}$$

Insight: Verify for yourself that if the slide were frictionless the seal would enter the water at 5.86 m/s.

50. **IP** An 81.0-kg in-line skater does $+3420\text{ J}$ of nonconservative work by pushing against the ground with his skates. In addition, friction does -715 J of nonconservative work on the skater. The skater's initial and final speeds are 2.50 m/s and 1.22 m/s, respectively. **(a)** Has the skater gone uphill, downhill, or remained at the same level? Explain. **(b)** Calculate the change in height of the skater.

Picture the Problem: The skater travels up a hill (we know this for reasons given below), changing his kinetic and gravitational potential energies, while both his muscles and friction do nonconservative work on him.

Strategy: The total nonconservative work done on the skater changes his mechanical energy according to equation 8-9. This nonconservative work includes the positive work W_{nc1} done by his muscles and the negative work W_{nc2} done by the friction. Use this relationship and the known change in potential energy to find Δy.

Solution: 1. (a) The skater has gone $\boxed{\text{uphill}}$ because the work done by the skater is larger than that done by friction, so the skater has gained mechanical energy. However, the final speed of the skater is less than the initial speed, so he has lost kinetic energy. Therefore he must have gained potential energy, and has gone uphill.

2. (b) Set the nonconservative work equal to the change in mechanical energy and solve for Δy:

$$W_{\text{nc}} = W_{\text{nc1}} + W_{\text{nc2}} = \Delta E = E_{\text{f}} - E_{\text{i}}$$

$$W_{\text{nc1}} + W_{\text{nc2}} = \left(K_{\text{f}} + U_{\text{f}}\right) - \left(K_{\text{i}} + U_{\text{i}}\right) = \tfrac{1}{2}m\left(v_{\text{f}}^2 - v_{\text{i}}^2\right) + mg\Delta y$$

$$\Delta y = \left[W_{\text{nc1}} + W_{\text{nc2}} - \tfrac{1}{2}m\left(v_{\text{f}}^2 - v_{\text{i}}^2\right)\right]\Big/ mg$$

$$= \frac{\left\{(3420\text{ J}) + (-715\text{ J}) - \tfrac{1}{2}(81.0\text{ kg})\left[(1.22\text{ m/s})^2 - (2.50\text{ m/s})^2\right]\right\}}{(81.0\text{ kg})(9.81\text{ m/s}^2)} = \boxed{3.65\text{ m}}$$

Insight: Verify for yourself that if the skates had been frictionless but the skater's muscles did the same amount of work, the skater's final speed would have been 4.37 m/s. He would have sped up if it weren't for friction!