CHAPTER 10 Energy, Work, and Simple Machines

Practice Problems

10.1 Energy and Work pages 257–265

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1. Refer to Example Problem 1 to solve the following problem.

   a. If the hockey player exerted twice as much force, 9.00 N, on the puck, how would the puck's change in kinetic energy be affected?

   Because $W = Fd$ and $\Delta KE = W$, doubling the force would double the work, which would double the change in kinetic energy to 1.35 J.

   b. If the player exerted a 9.00–N force, but the stick was in contact with the puck for only half the distance, 0.075 m, what would be the change in kinetic energy?

   Because $W = Fd$, halving the distance would cut the work in half, which also would cut the change in kinetic energy in half, to 0.68 J.

2. Together, two students exert a force of 825 N in pushing a car a distance of 35 m.

   a. How much work do the students do on the car?

   $W = Fd = (825\ \text{N})(35\ \text{m})$

   $= 2.9\times10^4\ \text{J}$

   b. If the force was doubled, how much work would they do pushing the car the same distance?

   $W = Fd$

   $= (2)(825\ \text{N})(35\ \text{m})$

   $= 5.8\times10^4\ \text{J}$ **which is twice as much work**

3. A rock climber wears a 7.5-kg backpack while scaling a cliff. After 30.0 min, the climber is 8.2 m above the starting point.

   a. How much work does the climber do on the backpack?

   $W = Fd$

   $= mgd$

   $= (7.5\ \text{kg})(9.80\ \text{m/s}^2)(8.2\ \text{m})$

   $= 6.0\times10^2\ \text{J}$

   b. If the climber weighs 645 N, how much work does she do lifting herself and the backpack?

   $W = Fd + 6.0\times10^2\ \text{J}$

   $= (645\ \text{N})(8.2\ \text{m}) + 6.0\times10^2\ \text{J}$

   $= 5.9\times10^3\ \text{J}$

   c. What is the change in the climber's energy?

   $W = \Delta KE$

   $\Delta KE = 5.9\times10^3\ \text{J}$

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4. If the sailor in Example Problem 2 pulled with the same force, and along the same distance, but at an angle of 50.0°, how much work would he do?

   $W = Fd \cos \theta$

   $= (255\ \text{N})(30.0\ \text{m})(\cos 50.0°)$

   $= 4.92\times10^3\ \text{J}$

5. Two people lift a heavy box a distance of 15 m. They use ropes, each of which makes an angle of 15° with the vertical. Each person exerts a force of 225 N. How much work do they do?

   $W = Fd \cos \theta$

   $= (2)(225\ \text{N})(15\ \text{m})(\cos 15°)$

   $= 6.5\times10^3\ \text{J}$

6. An airplane passenger carries a 215-N suitcase up the stairs, a displacement of 4.20 m vertically, and 4.60 m horizontally.

   a. How much work does the passenger do?

   Since gravity acts vertically, only the vertical displacement needs to be considered.

   $W = Fd = (215\ \text{N})(4.20\ \text{m}) = 903\ \text{J}$

   b. The same passenger carries the same suitcase back down the same set of stairs. How much work does the passenger do now?

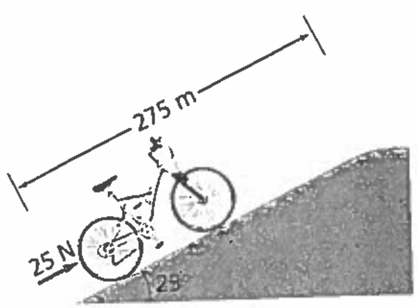
   Force is upward, but vertical displacement is downward, so

   $W = Fd\cos\theta$
   $= (215\ \text{N})(4.20\ \text{m})(\cos 180.0^\circ)$
   $= -903\ \text{J}$

7. A rope is used to pull a metal box a distance of 15.0 m across the floor. The rope is held at an angle of 46.0° with the floor, and a force of 628 N is applied to the rope. How much work does the force on the rope do?

   $W = Fd\cos\theta$
   $= (628\ \text{N})(15.0\ \text{m})(\cos 46.0^\circ)$
   $= 6.54\times10^3\ \text{J}$

8. A bicycle rider pushes a bicycle that has a mass of 13 kg up a steep hill. The incline is 25° and the road is 275 m long, as shown in **Figure 10-4.** The rider pushes the bike parallel to the road with a force of 25 N.



■ **Figure 10-4** (Not to scale)

   a. How much work does the rider do on the bike?

   Force and displacement are in the same direction.

   $W = Fd$
   $= (25\ \text{N})(275\ \text{m})$
   $= 6.9\times10^3\ \text{J}$

   b. How much work is done by the force of gravity on the bike?

   The force is downward (−90°), and the displacement is 25° above the horizontal or 115° from the force.

   $W = Fd\cos\theta$
   $= mgd\cos\theta$
   $= (13\ \text{kg})(9.80\ \text{m/s}^2)(275\ \text{m})(\cos 115^\circ)$
   $= -1.5\times10^4\ \text{J}$

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9. A box that weighs 575 N is lifted a distance of 20.0 m straight up by a cable attached to a motor. The job is done in 10.0 s. What power is developed by the motor in W and kW?

   $P = \frac{W}{t} = \frac{Fd}{t} = \frac{(575\ \text{N})(20.0\ \text{m})}{10.0\ \text{s}}$
   $= 1.15\times10^3\ \text{W} = 1.15\ \text{kW}$

10. You push a wheelbarrow a distance of 60.0 m at a constant speed for 25.0 s, by exerting a 145-N force horizontally.

   a. What power do you develop?

   $P = \frac{W}{t} = \frac{Fd}{t} = \frac{(145\ \text{N})(60.0\ \text{m})}{25.0\ \text{s}} = 348\ \text{W}$

   b. If you move the wheelbarrow twice as fast, how much power is developed?

   t is halved, so P is doubled to 696 W.

11. What power does a pump develop to lift 35 L of water per minute from a depth of 110 m? (1 L of water has a mass of 1.00 kg.)

   $P = \frac{W}{t} = \frac{mgd}{t} = \left(\frac{m}{t}\right)gd$

   where $\frac{m}{t} = (35\ \text{L/min})(1.00\ \text{kg/L})$

   Thus,

   $P = \left(\frac{m}{t}\right)gd$
   $= (35\ \text{L/min})(1.00\ \text{kg/L})(9.80\ \text{m/s}^2)(110\ \text{m})(1\ \text{min}/60\text{s})$
   $= 0.63\ \text{kW}$

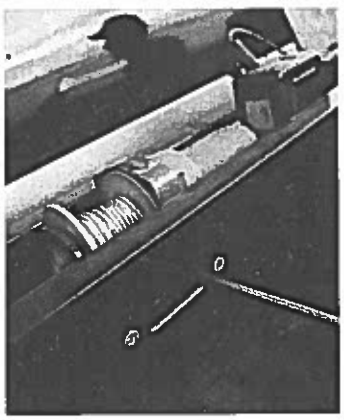
12. An electric motor develops 65 kW of power as it lifts a loaded elevator 17.5 m in 35 s. How much force does the motor exert?

$$P = \frac{W}{t} = \frac{Fd}{t}$$

$$F = \frac{Pt}{d} = \frac{(65\times10^3\ \text{W})(35\ \text{s})}{17.5\ \text{m}}$$

$$= 1.3\times10^5\ \text{N}$$

13. A winch designed to be mounted on a truck, as shown in **Figure 10-7**, is advertised as being able to exert a 6.8×10^3-N force and to develop a power of 0.30 kW. How long would it take the truck and the winch to pull an object 15 m?



■ **Figure 10-7**

$$P = \frac{W}{t} = \frac{Fd}{t}$$

$$t = \frac{Fd}{P}$$

$$= \frac{(6.8\times10^3\ \text{N})(15\ \text{m})}{(0.30\times10^3\ \text{W})} = 340\ \text{s}$$

$$= 5.7\ \text{min}$$

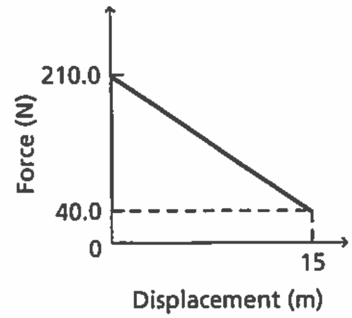
14. Your car has stalled and you need to push it. You notice as the car gets going that you need less and less force to keep it going. Suppose that for the first 15 m, your force decreased at a constant rate from 210.0 N to 40.0 N. How much work did you do on the car? Draw a force-displacement graph to represent the work done during this period.

The work done is the area of the trapezoid under the solid line:

$$W = \frac{1}{2}d(F_1 + F_2)$$

$$= \frac{1}{2}(15\ \text{m})(210.0\ \text{N} + 40.0\ \text{N})$$

$$= 1.9\times10^3\ \text{J}$$



Section Review

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15. **Work** Murimi pushes a 20-kg mass 10 m across a floor with a horizontal force of 80 N. Calculate the amount of work done by Murimi.

$$W = Fd = (80\ \text{N})(10\ \text{m}) = 8\times10^2\ \text{J}$$

The mass is not important to this problem.

16. **Work** A mover loads a 185-kg refrigerator into a moving van by pushing it up a 10.0-m, friction-free ramp at an angle of inclination of 11.0°. How much work is done by the mover?

$$y = (10.0\ \text{m})(\sin 11.0°)$$

$$= 1.91\ \text{m}$$

$$W = Fd = mgd \sin \theta$$

$$= (185\ \text{kg})(9.80\ \text{m/s}^2)(10.0\ \text{m})(\sin 11.0°)$$

$$= 3.46\times10^3\ \text{J}$$

17. **Work and Power** Does the work required to lift a book to a high shelf depend on how fast you raise it? Does the power required to lift the book depend on how fast you raise it? Explain.

No, work is not a function of time. However, power is a function of time, so the power required to lift the book does depend on how fast you raise it.

18. **Power** An elevator lifts a total mass of 1.1×10^3 kg a distance of 40.0 m in 12.5 s. How much power does the elevator generate?

$$P = \frac{W}{t} = \frac{Fd}{t} = \frac{mgd}{t}$$

$$= \frac{(1.1\times10^3\ \text{kg})(9.80\ \text{m/s}^2)(40.0\ \text{m})}{12.5\ \text{s}}$$

$$= 3.4\times10^4\ \text{W}$$

19. **Work** A 0.180-kg ball falls 2.5 m. How much work does the force of gravity do on the ball?

$$W = F_g d = mgd$$

$$= (0.180\ \text{kg})(9.80\ \text{m/s}^2)(2.5\ \text{m})$$

$$= 4.4\ \text{J}$$

20. **Mass** A forklift raises a box 1.2 m and does 7.0 kJ of work on it. What is the mass of the box?

$$W = Fd = mgd$$

$$\text{so } m = \frac{W}{gd} = \frac{7.0\times10^3\ \text{J}}{(9.80\ \text{m/s}^2)(1.2\ \text{m})}$$

$$= 6.0\times10^2\ \text{kg}$$

21. **Work** You and a friend each carry identical boxes from the first floor of a building to a room located on the second floor, farther down the hall. You choose to carry the box first up the stairs, and then down the hall to the room. Your friend carries it down the hall on the first floor, then up a different stairwell to the second floor. Who does more work?

Both do the same amount of work. Only the height lifted and the vertical force exerted count.

22. **Work and Kinetic Energy** If the work done on an object doubles its kinetic energy, does it double its velocity? If not, by what ratio does it change the velocity?

Kinetic energy is proportional to the square of the velocity, so doubling the energy doubles the square of the velocity. The velocity increases by a factor of the square root of 2, or 1.4.

23. **Critical Thinking** Explain how to find the change in energy of a system if three agents exert forces on the system at once.

Since work is the change in kinetic energy, calculate the work done by each force. The work can be positive, negative, or zero, depending on the relative angles of the force and displacement of the object. The sum of the three works is the change in energy of the system.

Practice Problems

10.2 Machines pages 266–273

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24. If the gear radius in the bicycle in Example Problem 4 is doubled, while the force exerted on the chain and the distance the wheel rim moves remain the same, what quantities change, and by how much?

$$IMA = \frac{r_e}{r_r} = \frac{8.00\ \text{cm}}{35.6\ \text{cm}} = 0.225\ \text{(doubled)}$$

$$MA = \left(\frac{e}{100}\right)IMA = \frac{95.0}{100}(0.225)$$

$$= 0.214\ \text{(doubled)}$$

$$MA = \frac{F_r}{F_e} \text{ so } F_r = (MA)(F_e)$$

$$= (0.214)(155\ \text{N})$$

$$= 33.2\ \text{N}$$

$$IMA = \frac{d_e}{d_r}$$

$$\text{so } d_e = (IMA)(d_r)$$

$$= (0.225)(14.0\ \text{cm})$$

$$= 3.15\ \text{cm}$$

25. A sledgehammer is used to drive a wedge into a log to split it. When the wedge is driven 0.20 m into the log, the log is separated a distance of 5.0 cm. A force of 1.7×10^4 N is needed to split the log, and the sledgehammer exerts a force of 1.1×10^4 N.

a. What is the *IMA* of the wedge?

$$IMA = \frac{d_e}{d_r} = \frac{(0.20\ \text{m})}{(0.050\ \text{m})} = 4.0$$