CHAPTER 6 Motion in Two Dimensions

Practice Problems

6.1 Projectile Motion pages 147–152

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1. A stone is thrown horizontally at a speed of 5.0 m/s from the top of a cliff that is 78.4 m high.

a. How long does it take the stone to reach the bottom of the cliff?

Since $v_y = 0$, $y - v_y t = -\frac{1}{2}gt^2$

becomes $y = -\frac{1}{2}gt^2$

or $t = \sqrt{-\frac{2y}{g}}$

$= \sqrt{\frac{-(2)(-78.4\ \text{m})}{9.80\ \text{m/s}^2}}$

$= 4.00\ \text{s}$

b. How far from the base of the cliff does the stone hit the ground?

$x = v_x t$

$= (5.0\ \text{m/s})(4.00\ \text{s})$

$= 2.0\times10^1\ \text{m}$

c. What are the horizontal and vertical components of the stone's velocity just before it hits the ground?

$v_x = 5.0$ m/s. This is the same as the initial horizontal speed because the acceleration of gravity influences only the vertical motion. For the vertical component, use $v = v_i + gt$ with $v = v_y$ and v_i, the initial vertical component of velocity, zero.

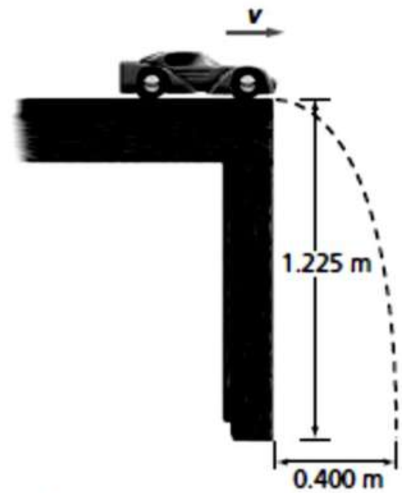
At $t = 4.00$ s

$v_y = gt$

$= (9.80\ \text{m/s}^2)(4.0\ \text{s})$

$= 39.2\ \text{m/s}$

52. The toy car in **Figure 6-12** runs off the edge of a table that is 1.225-m high. The car lands 0.400 m from the base of the table.



■ **Figure 6-12**

a. How long did it take the car to fall?

$y = v_{y0}t - \frac{1}{2}gt^2$

Since initial vertical velocity is zero,

$t = \sqrt{\frac{-2y}{g}} = \sqrt{\frac{(-2)(-1.225\ \text{m})}{9.80\ \text{m/s}^2}}$

$= 0.500\ \text{s}$

b. How fast was the car going on the table?

$v_x = \frac{x}{t} = \frac{0.400\ \text{m}}{0.500\ \text{s}} = 0.800\ \text{m/s}$

61. Car Racing A 615-kg racing car completes one lap in 14.3 s around a circular track with a radius of 50.0 m. The car moves at a constant speed.

a. What is the acceleration of the car?

$a_c = \frac{v^2}{r}$

$= \frac{4\pi^2 r}{T^2}$

$= \frac{4\pi^2(50.0\ \text{m})}{(14.3\ \text{s})^2}$

$= 9.59\ \text{m/s}^2$

b. What force must the track exert on the tires to produce this acceleration?

$F_c = ma_c = (615\ \text{kg})(9.59\ \text{m/s}^2)$

$= 5.90\times10^3\ \text{N}$

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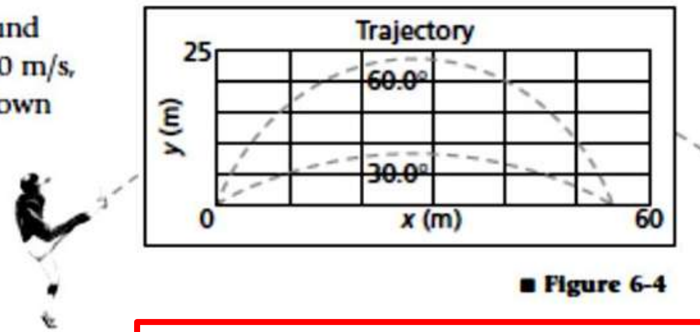
4. A player kicks a football from ground level with an initial velocity of 27.0 m/s, 30.0° above the horizontal, as shown in **Figure 6-4.** Find each of the following. Assume that air resistance is negligible.



■ **Figure 6-4**

a. the ball's hang time

$$v_y = v_i \sin \theta$$

When it lands, $y = v_y t - \frac{1}{2}gt^2 = 0$.

Therefore,

$$t^2 = \frac{2v_y t}{g}$$

$$t = \frac{2v_y}{g}$$

$$= \frac{2v_i \sin \theta}{g}$$

$$= \frac{(2)(27.0\ \text{m/s})(\sin 30.0°)}{9.80\ \text{m/s}^2}$$

$$= 2.76\ \text{s}$$

b. the ball's maximum height

Maximum height occurs at half the "hang time," or 1.38 s. Thus,

$$y = v_y t - \frac{1}{2}gt^2$$

$$= v_i \sin \theta\, t - \frac{1}{2}gt^2$$

$$= (27.0\ \text{m/s})(\sin 30.0°)(1.38\ \text{s}) - \frac{1}{2}(+9.80\ \text{m/s}^2)(1.38\ \text{s})^2$$

$$= 9.30\ \text{m}$$

c. the ball's range

Distance:

$$v_x = v_i \cos \theta$$

$$x = v_x t = (v_i \cos \theta)(t) = (27.0\ \text{m/s})(\cos 30.0°)(2.76\ \text{s}) = 64.5\ \text{m}$$

5. The player in problem 4 then kicks the ball with the same speed, but at 60.0° from the horizontal. What is the ball's hang time, range, and maximum height?

Following the method of Practice Problem 4,

Hangtime:

$$t = \frac{2v_i \sin \theta}{g}$$

$$= \frac{(2)(27.0\ \text{m/s})(\sin 60.0°)}{9.80\ \text{m/s}^2}$$

$$= 4.77\ \text{s}$$

Chapter 6 continued

Distance:

$$x = v_i \cos \theta\, t$$

$$= (27.0\ \text{m/s})(\cos 60.0°)(4.77\ \text{s})$$

$$= 64.4\ \text{m}$$

Maximum height:

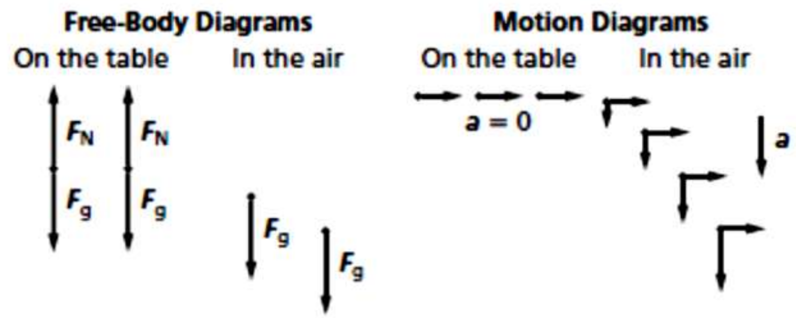
at $t = \frac{1}{2}(4.77\ \text{s}) = 2.38\ \text{s}$

$$y = v_i \sin \theta\, t - \frac{1}{2}gt^2$$

$$= (27.0\ \text{m/s})(\sin 60.0°)(2.38\ \text{s}) - \frac{1}{2}(+9.80\ \text{m/s}^2)(2.38\ \text{s})^2$$

$$= 27.9\ \text{m}$$

8. Free-Body Diagram An ice cube slides without friction across a table at a constant velocity. It slides off the table and lands on the floor. Draw free-body and motion diagrams of the ice cube at two points on the table and at two points in the air.



9. Projectile Motion A softball is tossed into the air at an angle of 50.0° with the vertical at an initial velocity of 11.0 m/s. What is its maximum height?

$v_f^2 = v_{iy}^2 + 2a(d_f - d_i)$; $a = -g$, $d_i = 0$

At maximum height $v_f = 0$, so

$$d_f = \frac{v_{iy}^2}{2g}$$

$$= \frac{(v_i \cos \theta)^2}{2g}$$

$$= \frac{((11.0 \text{ m/s})(\cos 50.0°))^2}{(2)(9.80 \text{ m/s}^2)}$$

$$= 2.55 \text{ m}$$

10. Projectile Motion A tennis ball is thrown out a window 28 m above the ground at an initial velocity of 15.0 m/s and 20.0° below the horizontal. How far does the ball move horizontally before it hits the ground?

$x = v_{0x}t$, but need to find t

First, determine v_{yf}:

$$v_{yf}^2 = v_{yi}^2 + 2gy$$

$$v_{yf} = \sqrt{v_{yi}^2 + 2gy}$$

$$= \sqrt{(v_i \sin \theta)^2 + 2gy}$$

$$= \sqrt{((15.0 \text{ m/s})(\sin 20.0°))^2 + (2)(9.80 \text{ m/s}^2)(28 \text{ m})}$$

$$= 24.0 \text{ m/s}$$

Now use $v_{yf} = v_{yi} + gt$ to find t.

$$t = \frac{v_{yf} - v_{yi}}{g}$$

$$= \frac{v_{yf} - v_i \sin \theta}{g}$$

pter 6 continued

$$= \frac{2.40 \text{ m/s} - (15.0 \text{ m/s})(\sin 20.0°)}{9.80 \text{ m/s}^2}$$

$$= 1.92 \text{ s}$$

$$x = v_{xi}t$$

$$= (v_i \cos \theta)(t)$$

$$= (15.0 \text{ m/s})(\cos 20.0°)(1.92 \text{ s})$$

$$= 27.1 \text{ m}$$

Section Review

6.2 Circular Motion

18. Centripetal Force If a 40.0-g stone is whirled horizontally on the end of a 0.60-m string at a speed of 2.2 m/s, what is the tension in the string?

$$F_T = ma_c = \frac{mv^2}{r} = \frac{(0.0400\ \text{kg})(22\ \text{m/s})^2}{0.60\ \text{m}} = 0.32\ \text{N}$$

20. Centripetal Force A bowling ball has a mass of 7.3 kg. If you move it around a circle with a radius of 0.75 m at a speed of 2.5 m/s, what force would you have to exert on it?

$$F_{net} = ma_c = \frac{mv^2}{r} = \frac{(7.3\ \text{kg})(2.5\ \text{m/s})^2}{0.75\ \text{m}} = 61\ \text{N}$$

14. An airplane traveling at 201 m/s makes a turn. What is the smallest radius of the circular path (in km) that the pilot can make and keep the centripetal acceleration under 5.0 m/s^2?

$$a_c = \frac{v^2}{r},\ \text{so } r = \frac{v^2}{a_c} = \frac{(201\ \text{m/s})^2}{5.0\ \text{m/s}^2} = 8.1\ \text{km}$$

15. A 45-kg merry-go-round worker stands on the ride's platform 6.3 m from the center. If her speed as she goes around the circle is 4.1 m/s, what is the force of friction necessary to keep her from falling off the platform?

$$F_f = F_c = \frac{mv^2}{r} = \frac{(45\ \text{kg})(4.1\ \text{m/s})^2}{6.3\ \text{m}} = 120\ \text{N}$$

Practice Problems

6.3 Relative Velocity

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22. You are riding in a bus moving slowly through heavy traffic at 2.0 m/s. You hurry to the front of the bus at 4.0 m/s relative to the bus. What is your speed relative to the street?

$$v_{y/g} = v_{b/g} + v_{y/b} = 2.0\ \text{m/s} + 4.0\ \text{m/s} = 6.0\ \text{m/s relative to street}$$

24. A boat is rowed directly upriver at a speed of 2.5 m/s relative to the water. Viewers on the shore see that the boat is moving at only 0.5 m/s relative to the shore. What is the speed of the river? Is it moving with or against the boat?

$v_{b/g} = v_{b/w} + v_{w/g}$;

so, $v_{w/g} = v_{b/g} - v_{b/w}$

$= 0.5\ \text{m/s} - 2.5\ \text{m/s}$

$= 2.0$ m/s; against the boat

25. An airplane flies due north at 150 km/h relative to the air. There is a wind blowing at 75 km/h to the east relative to the ground. What is the plane's speed relative to the ground?

$$v = \sqrt{v_p^2 + v_w^2} = \sqrt{(150\ \text{km/h})^2 + (75\ \text{km/h})^2} = 1.7\times10^2\ \text{km/h}$$

CHAPTER 7

Gravitation

Practice Problems

7.1 Planetary Motion and Gravitation pages 171–178

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1. If Ganymede, one of Jupiter's moons, has a period of 32 days, how many units are there in its orbital radius? Use the information given in Example Problem 1.

$$\left(\frac{T_G}{T_I}\right)^2 = \left(\frac{r_G}{r_I}\right)^3$$

$$r_G = \sqrt[3]{(4.2 \text{ units})^3\left(\frac{32 \text{ days}}{1.8 \text{ days}}\right)^2}$$

$$= \sqrt[3]{23.4\times10^3 \text{ units}^3}$$

$$= 29 \text{ units}$$

2. An asteroid revolves around the Sun with a mean orbital radius twice that of Earth's. Predict the period of the asteroid in Earth years.

$$\left(\frac{T_a}{T_E}\right)^2 = \left(\frac{r_a}{r_E}\right)^3 \text{ with } r_a = 2r_E$$

$$T_a = \sqrt{\left(\frac{r_a}{r_E}\right)^3 T_E^2}$$

$$= \sqrt{\left(\frac{2r_E}{r_E}\right)^3 (1.0 \text{ y})^2}$$

$$= 2.8 \text{ y}$$

13. Use Newton's thought experiment on the motion of satellites to solve the following.

a. Calculate the speed that a satellite shot from a cannon must have to orbit Earth 150 km above its surface.

$$v = \sqrt{\frac{Gm_E}{r}} = \sqrt{\frac{(6.67\times10^{-11} \text{ N·m}^2/\text{kg}^2)(5.97\times10^{24} \text{ kg})}{(6.38\times10^6 \text{ m} + 1.5\times10^5 \text{ m})}}$$

$$= 7.8\times10^3 \text{ m/s}$$

b. How long, in seconds and minutes, would it take for the satellite to complete one orbit and return to the cannon?

$$T = 2\pi\sqrt{\frac{r^3}{Gm_E}} = 2\pi\sqrt{\frac{(6.38\times10^6 \text{ m} + 1.5\times10^5 \text{ m})^3}{(6.67\times10^{-11} \text{ N·m}^2/\text{kg}^2)(5.97\times10^{24} \text{ kg})}}$$

$$= 5.3\times10^3 \text{ s} \approx 88 \text{ min}$$

6. Neptune's Orbital Period Neptune orbits the Sun with an orbital radius of 4.495×10^{12} m, which allows gases, such as methane, to condense and form an atmosphere, as shown in **Figure 7-8.** If the mass of the Sun is 1.99×10^{30} kg, calculate the period of Neptune's orbit.

$$T = 2\pi\sqrt{\frac{r^3}{Gm_S}}$$

$$= 2\pi\sqrt{\frac{(4.495\times10^{12} \text{ m})^3}{(6.67\times10^{-11} \text{ N·m}^2/\text{kg}^2)(1.99\times10^{30} \text{ kg})}}$$

$$= 5.20\times10^9 \text{ s} = 6.02\times10^5 \text{ days}$$

16. Gravitational Field The mass of the Moon is 7.3×10^{22} kg and its radius is 1785 km. What is the strength of the gravitational field on the surface of the Moon?

$$g = \frac{GM}{r^2} = \frac{(6.67\times10^{-11} \text{ N·m}^2/\text{kg}^2)(7.3\times10^{22} \text{ kg})}{(1.785\times10^3 \text{ m})^2}$$

$$= 1.5 \text{ N/kg, about one-sixth that on Earth}$$

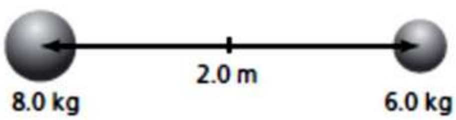
55. Tom has a mass of 70.0 kg and Sally has a mass of 50.0 kg. Tom and Sally are standing 20.0 m apart on the dance floor. Sally looks up and sees Tom. She feels an attraction. If the attraction is gravitational, find its size. Assume that both Tom and Sally can be replaced by spherical masses.

$$F = G\frac{m_T m_S}{r^2}$$

$$= (6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)\frac{(70.0\ \text{kg})(50.0\ \text{kg})}{(20.0\ \text{m})^2}$$

$$= 5.84\times10^{-10}\ \text{N}$$

56. Two balls have their centers 2.0 m apart, as shown in **Figure 7-23.** One ball has a mass of 8.0 kg. The other has a mass of 6.0 kg. What is the gravitational force between them?



■ **Figure 7-23**

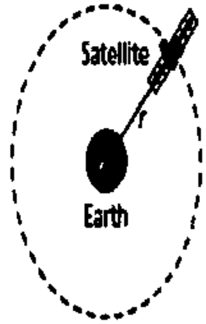
$$F = G\frac{m_1 m_2}{r^2}$$

$$= (6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)\frac{(8.0\ \text{kg})(6.0\ \text{kg})}{(2.0\ \text{m})^2}$$

$$= 8.0\times10^{-10}\ \text{N}$$

Level 1

71. Satellite A geosynchronous satellite is one that appears to remain over one spot on Earth, as shown in **Figure 7-24.** Assume that a geosynchronous satellite has an orbital radius of 4.23×10^{7} m.



■ **Figure 7-24** (Not to scale)

a. Calculate its speed in orbit.

$$v = \sqrt{\frac{Gm_E}{r}}$$

$$= \sqrt{\frac{(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.97\times10^{24}\ \text{kg})}{4.23\times10^{7}\ \text{m}}}$$

$$= 3.07\times10^{3}\ \text{m/s or } 3.07\ \text{km/s}$$

b. Calculate its period.

$$T = 2\pi\sqrt{\frac{r^3}{Gm_E}}$$

$$= 2\pi\sqrt{\frac{(4.23\times10^{7}\ \text{m})^3}{(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.97\times10^{24}\ \text{kg})}}$$

$$= 2\pi\sqrt{1.90\times10^{8}\ \text{s}^2}$$

$$= 8.66\times10^{4}\ \text{s or } 24.1\ \text{h}$$

72. Asteroid The asteroid Ceres has a mass of 7×10^{20} kg and a radius of 500 km.

a. What is g on the surface of Ceres?

$$g = \frac{Gm}{r^2}$$

$$= \frac{(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(7\times10^{20}\ \text{kg})}{(500\times10^{3}\ \text{m})^2}$$

$$= 0.2\ \text{m/s}^2$$

b. How much would a 90-kg astronaut weigh on Ceres?

$$F_g = mg = (90\ \text{kg})(0.2\ \text{m/s}^2) = 20\ \text{N}$$

CHAPTER 10

Energy, Work, and Simple Machines

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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?

$y = (10.0\text{ m})(\sin 11.0°)$

$= 1.91\text{ m}$

$W = Fd = mgd \sin\theta$

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

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

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?

$W = Fd = mgd$

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

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

Level 1

52. The third floor of a house is 8 m above street level. How much work is needed to move a 150-kg refrigerator to the third floor?

$W = Fd = mgd$

$= (150\text{ kg})(9.80\text{ m/s}^2)(8\text{ m})$

$= 1\times10^4\text{ J}$

53. Haloke does 176 J of work lifting himself 0.300 m. What is Haloke's mass?

$W = Fd = mgd$; therefore,

$m = \frac{W}{gd} = \frac{176\text{ J}}{(9.80\text{ m/s}^2)(0.300\text{ m})}$

$= 59.9\text{ kg}$

54. Football After scoring a touchdown, an 84.0-kg wide receiver celebrates by leaping 1.20 m off the ground. How much work was done by the wide receiver in the celebration?

$W = Fd = mgd$

$= (84.0\text{ kg})(9.80\text{ m/s}^2)(1.20\text{ m})$

$= 988\text{ J}$

59. A force of 300.0 N is used to push a 145-kg mass 30.0 m horizontally in 3.00 s.

a. Calculate the work done on the mass.

$W = Fd = (300.0\text{ N})(30.0\text{ m})$

$= 9.00\times10^3\text{ J}$

$= 9.00\text{ kJ}$

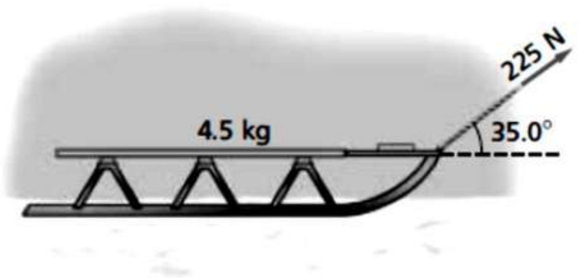
b. Calculate the power developed.

$P = \frac{W}{t} = \frac{9.00\times10^3\text{ J}}{3.00\text{ s}}$

$= 3.00\times10^3\text{ W}$

$= 3.00\text{ kW}$

66. Sled Diego pulls a 4.5-kg sled across level snow with a force of 225 N on a rope that is 35.0° above the horizontal, as shown in **Figure 10-18.** If the sled moves a distance of 65.3 m, how much work does Diego do?



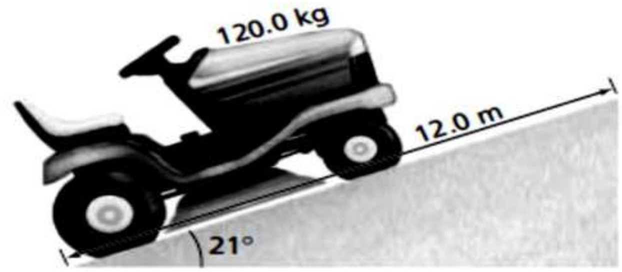
■ **Figure 10-18**

$W = Fd\cos\theta$

$= (225\text{ N})(65.3\text{ m})(\cos 35.0°)$

$= 1.20\times10^4\text{ J}$

63. Lawn Tractor A 120-kg lawn tractor, shown in **Figure 10-17,** goes up a 21° incline that is 12.0 m long in 2.5 s. Calculate the power that is developed by the tractor.



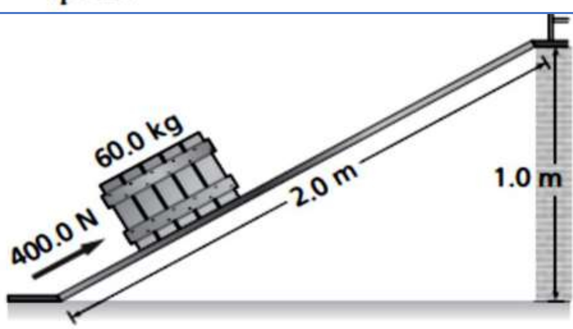
■ **Figure 10-17**

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

$$= \frac{(120\text{ kg})(9.80\text{ m/s}^2)(12.0\text{ m})(\sin 21°)}{2.5\text{ s}}$$

$$= 2.0\times10^3\text{ W} = 2.0\text{ kW}$$

70. Maricruz slides a 60.0-kg crate up an inclined ramp that is 2.0-m long and attached to a platform 1.0 m above floor level, as shown in **Figure 10-19.** A 400.0-N force, parallel to the ramp, is needed to slide the crate up the ramp at a constant speed.



■ **Figure 10-19**

a. How much work does Maricruz do in sliding the crate up the ramp?

$W = Fd = (400.0\text{ N})(2.0\text{ m}) = 8.0\times10^2\text{ J}$

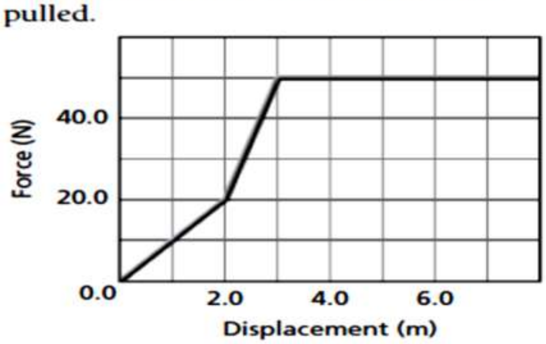
b. How much work would be done if Maricruz simply lifted the crate straight up from the floor to the platform?

$W = Fd = mgd$

$= (60.0\text{ kg})(9.80\text{ m/s}^2)(1.0\text{ m})$

$= 5.9\times10^2\text{ J}$

78. The graph in **Figure 10-22** shows the force and displacement of an object being pulled.



■ **Figure 10-22**

a. Calculate the work done to pull the object 7.0 m.

Find the area under the curve (see graph):

0.0 to 2.0 m:

$\frac{1}{2}(20.0\text{ N})(2.0\text{ m}) = 2.0\times10^1\text{ J}$

2.0 m to 3.0 m:

$\frac{1}{2}(30.0\text{ N})(1.0\text{ m}) + (20\text{ N})(1.0\text{ m}) = 35\text{ J}$

3.0 m to 7.0 m:

$(50.0\text{ N})(4.0\text{ m}) = 2.0\times10^2\text{ J}$

Total work:

$2.0\times10^1\text{ J} + 35\text{ J} + 2.0\times10^2\text{ J}$

$= 2.6\times10^2\text{ J}$

b. Calculate the power that would be developed if the work was done in 2.0 s.

$$P = \frac{W}{t} = \frac{2.6\times10^2\text{ J}}{2.0\text{ s}} = 1.3\times10^2\text{ W}$$

81. A pulley system lifts a 1345-N weight a distance of 0.975 m. Paul pulls the rope a distance of 3.90 m, exerting a force of 375 N.

a. What is the ideal mechanical advantage of the system?

$$IMA = \frac{d_e}{d_r} = \frac{3.90\text{ m}}{0.975\text{ m}} = 4.00$$

b. What is the mechanical advantage?

$$MA = \frac{F_r}{F_e} = \frac{1345\text{ N}}{375\text{ N}} = 3.59$$

c. How efficient is the system?

$$\text{efficiency} = \frac{MA}{IMA} \times 100$$

$$= \frac{3.59}{4.00} \times 100$$

$$= 89.8\%$$

82. A force of 1.4 N is exerted through a distance of 40.0 cm on a rope in a pulley system to lift a 0.50-kg mass 10.0 cm. Calculate the following.

a. the *MA*

$$MA = \frac{F_r}{F_e} = \frac{mg}{F_e}$$

$$= \frac{(0.50\text{ kg})(9.80\text{ m/s}^2)}{1.4\text{ N}}$$

$$= 3.5$$

b. the *IMA*

$$IMA = \frac{d_e}{d_r} = \frac{40.0\text{ cm}}{10.0\text{ cm}} = 4.00$$

c. the efficiency

$$\text{efficiency} = \frac{MA}{IMA} \times 100$$

$$= \frac{3.5}{4.00} \times 100 = 88\%$$

83. A student exerts a force of 250 N on a lever, through a distance of 1.6 m, as he lifts a 150-kg crate. If the efficiency of the lever is 90.0 percent, how far is the crate lifted?

$$e = 90 = \frac{MA}{IMA} \times 100 = \frac{\frac{F_r}{F_e}}{\frac{d_e}{d_r}} \times 100$$

$$= \frac{F_r d_r}{F_e d_e} \times 100$$

Chapter 10 continued

$$\text{so, } d_r = \frac{eF_e d_e}{100F_r} = \frac{eF_e d_e}{100mg}$$

$$= \frac{(90.0)(250\text{ N})(1.6\text{ m})}{(100)(150\text{ kg})(9.80\text{ m/s}^2)}$$

$$= 0.24\text{ m}$$

Level 2

84. What work is required to lift a 215-kg mass a distance of 5.65 m, using a machine that is 72.5 percent efficient?

$$e = \frac{W_o}{W_i} \times 100$$

$$= \frac{F_r d_r}{W_i} \times 100$$

$$= \frac{mgd_r}{W_i} \times 100$$

$$W_i = \frac{mgd_r}{e} \times 100$$

$$= \frac{(215\text{ kg})(9.80\text{ m/s}^2)(5.65\text{ m})(100)}{72.5}$$

$$= 1.64\times10^4\text{ J}$$

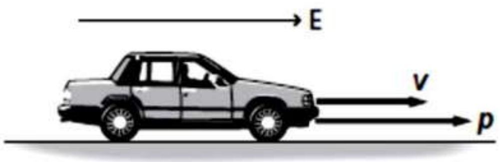
CHAPTER 9 Momentum and Its Conservation

9.1 Impulse and Momentum pages 229–235

page 233

1. A compact car, with mass 725 kg, is moving at 115 km/h toward the east. Sketch the moving car.

a. Find the magnitude and direction of its momentum. Draw an arrow on your sketch showing the momentum.



$$p = mv$$
$$= (725\text{ kg})(115\text{ km/h})\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right)$$
$$= 2.32\times10^{4}\text{ kg·m/s eastward}$$

b. A second car, with a mass of 2175 kg, has the same momentum. What is its velocity?

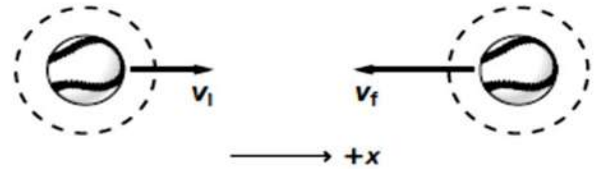
$$v = \frac{p}{m}$$
$$= \frac{(2.32\times10^{4}\text{ kg·m/s})\left(\frac{3600\text{ s}}{1\text{ h}}\right)\left(\frac{1\text{ km}}{1000\text{ m}}\right)}{2175\text{ kg}}$$
$$= 38.4\text{ km/h eastward}$$

56. Golf Rocío strikes a 0.058-kg golf ball with a force of 272 N and gives it a velocity of 62.0 m/s. How long was Rocío's club in contact with the ball?

$$\Delta t = \frac{m\Delta v}{F} = \frac{(0.058\text{ kg})(62.0\text{ m/s})}{272\text{ N}}$$
$$= 0.013\text{ s}$$

9. Impulse and Momentum A 0.174-kg softball is pitched horizontally at 26.0 m/s. The ball moves in the opposite direction at 38.0 m/s after it is hit by the bat.

a. Draw arrows showing the ball's momentum before and after the bat hits it.



b. What is the change in momentum of the ball?

$$\Delta p = m(v_f - v_i)$$
$$= (0.174\text{ kg})(38.0\text{ m/s} - (-26.0\text{ m/s}))$$
$$= 11.1\text{ kg·m/s}$$

c. What is the impulse delivered by the bat?

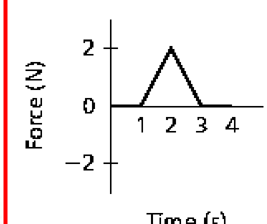
$$F\Delta t = p_f - p_i$$
$$= \Delta p$$
$$= 11.1\text{ kg·m/s}$$
$$= 11.1\text{ N·s}$$

d. If the bat and softball are in contact for 0.80 ms, what is the average force that the bat exerts on the ball?

$$F\Delta t = m(v_f - v_i)$$
$$F = \frac{m(v_f - v_i)}{\Delta t}$$
$$= \frac{(0.174\text{ kg})(38.0\text{ m/s} - (-26.0\text{ m/s}))}{(0.80\text{ ms})\left(\frac{1\text{ s}}{1000\text{ ms}}\right)}$$
$$= 1.4\times10^{4}\text{ N}$$

66. A 0.150-kg ball, moving in the positive direction at 12 m/s, is acted on by the impulse shown in the graph in **Figure 9-16.** What is the ball's speed at 4.0 s?

$$F\Delta t = m\Delta v$$
$$\text{Area of graph} = m\Delta v$$
$$\frac{1}{2}(2.0\text{ N})(2.0\text{ s}) = m(v_f - v_i)$$
$$2.0\text{ N·s} = (0.150\text{ kg})(v_f - 12\text{ m/s})$$
$$v_f = \frac{2.0\text{ kg·m/s}}{0.150\text{ kg}} + 12\text{ m/s}$$
$$= 25\text{ m/s}$$



■ Figure 9-16

23. A 1383-kg car moving south at 11.2 m/s is struck by a 1732-kg car moving east at 31.3 m/s. The cars are stuck together. How fast and in what direction do they move immediately after the collision?

Before:

$$p_{i,x} = p_{1,x} + p_{2,x}$$
$$= 0 + m_2 v_{2i}$$
$$p_{i,y} = p_{1,y} + p_{2,y}$$
$$= m_1 v_{1i} + 0$$
$$p_f = p_i$$
$$= \sqrt{p_{1,x}{}^2 + p_{i,y}{}^2}$$
$$= \sqrt{(m_2 v_{2i})^2 + (m_1 v_{1i})^2}$$
$$v_f = \frac{p_f}{m_1 + m_2}$$
$$= \frac{\sqrt{(m_2 v_{2i})^2 + (m_1 v_{1i})^2}}{m_1 + m_2}$$
$$= \frac{\sqrt{((1732\text{ kg})(31.3\text{ m/s}))^2 + ((1383\text{ kg})(-11.2\text{ m/s}))^2}}{1383\text{ kg} + 1782\text{ kg}}$$
$$= 18.1\text{ m/s}$$
$$\theta = \tan^{-1}\left(\frac{p_{i,y}}{p_{i,x}}\right) = \tan^{-1}\left(\frac{m_1 v_{1i}}{m_2 v_{2i}}\right) = \tan^{-1}\left(\frac{(1383\text{ kg})(-11.2\text{ m/s})}{(1732\text{ kg})(31.3\text{ m/s})}\right) = 15.9°$$

south of east

68. Hockey A hockey puck has a mass of 0.115 kg and strikes the pole of the net at 37 m/s. It bounces off in the opposite direction at 25 m/s, as shown in **Figure 9-17.**

a. What is the impulse on the puck?

$$F\Delta t = m(v_f - v_i)$$
$$= (0.115\text{ kg})(-25\text{ m/s} - 37\text{ m/s})$$
$$= -7.1\text{ kg·m/s}$$

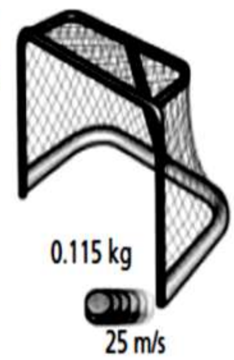


Figure 9-17

57. A 0.145-kg baseball is pitched at 42 m/s. The batter hits it horizontally to the pitcher at 58 m/s.

a. Find the change in momentum of the ball.

Take the direction of the pitch to be positive.

$$\Delta p = mv_f - mv_i = m(v_f - v_i)$$
$$= (0.145\text{ kg})(-58\text{ m/s} - (+42\text{ m/s}))$$
$$= -14\text{ kg·m/s}$$

b. If the ball and bat are in contact for 4.6×10^{-4} s, what is the average force during contact?

$$F\Delta t = \Delta p$$
$$F = \frac{\Delta p}{\Delta t}$$
$$= \frac{m(v_f - v_i)}{\Delta t}$$
$$= \frac{(0.145\text{ kg})(-58\text{ m/s} - (+42\text{ m/s}))}{4.6\times10^{-4}\text{ s}}$$
$$= -3.2\times10^{4}\text{ N}$$

58. Bowling A force of 186 N acts on a 7.3-kg bowling ball for 0.40 s. What is the bowling ball's change in momentum? What is its change in velocity?

$$\Delta p = F\Delta t$$
$$= (186\text{ N})(0.40\text{ s})$$
$$= 74\text{ N·s}$$
$$= 74\text{ kg·m/s}$$
$$\Delta v = \frac{\Delta p}{m}$$
$$= \frac{F\Delta t}{m}$$
$$= \frac{(186\text{ N})(0.40\text{ s})}{7.3\text{ kg}}$$
$$= 1.0\times10^{1}\text{ m/s}$$

75. Two lab carts are pushed together with a spring mechanism compressed between them. Upon release, the 5.0-kg cart repels one way with a velocity of 0.12 m/s, while the 2.0-kg cart goes in the opposite direction. What is the velocity of the 2.0-kg cart?

$$m_1v_i = -m_2v_f$$

$$v_f = \frac{m_1v_i}{-m_2}$$

$$= \frac{(5.0\text{ kg})(0.12\text{ m/s})}{-(2.0\text{ kg})}$$

$$= -0.30\text{ m/s}$$

80. A 2575-kg van runs into the back of an 825-kg compact car at rest. They move off together at 8.5 m/s. Assuming that the friction with the road is negligible, calculate the initial speed of the van.

$$p_{Ci} + p_{Di} = p_{Cf} + p_{Df}$$

$$m_Cv_{Ci} = (m_C + m_D)v_f$$

$$\text{so, } v_{Ci} = \frac{m_C + m_D}{m_C}$$

$$v_f = \frac{(2575\text{ kg} + 825\text{ kg})(8.5\text{ m/s})}{2575\text{ kg}}$$

$$= 11\text{ m/s}$$

82. A 0.200-kg plastic ball moves with a velocity of 0.30 m/s. It collides with a second plastic ball of mass 0.100 kg, which is moving along the same line at a speed of 0.10 m/s. After the collision, both balls continue moving in the same, original direction. The speed of the 0.100-kg ball is 0.26 m/s. What is the new velocity of the 0.200-kg ball?

$$m_Cv_{Ci} + m_Dv_{Di} = m_Cv_{Cf} + m_Dv_{Df}$$

$$\text{so, } v_{Cf} = \frac{m_Cv_{Ci} + m_Dv_{Di} - m_Dv_{Df}}{m_C}$$

$$= \frac{(0.200\text{ kg})(0.30\text{ m/s}) + (0.100\text{ kg})(0.10\text{ m/s}) - (0.100\text{ kg})(0.26\text{ m/s})}{0.200\text{ kg}}$$

= 0.22 m/s in the original direction

83. A constant force of 6.00 N acts on a 3.00-kg object for 10.0 s. What are the changes in the object's momentum and velocity?

The change in momentum is

$$\Delta p = F\Delta t$$

$$= (6.00\text{ N})(10.0\text{ s})$$

$$= 60.0\text{ N·s} = 60.0\text{ kg·m/s}$$

The change in velocity is found from the impulse.

$$F\Delta t = m\Delta v$$

$$\Delta v = \frac{F\Delta t}{m}$$

$$= \frac{(6.00\text{ N})(10.0\text{ s})}{3.00\text{ kg}}$$

$$= 20.0\text{ m/s}$$

84. The velocity of a 625-kg car is changed from 10.0 m/s to 44.0 m/s in 68.0 s by an external, constant force.

a. What is the resulting change in momentum of the car?

$$\Delta p = m\Delta v = m(v_f - v_i)$$

$$= (625\text{ kg})(44.0\text{ m/s} - 10.0\text{ m/s})$$

$$= 2.12\times10^4\text{ kg·m/s}$$

b. What is the magnitude of the force?

$$F\Delta t = m\Delta v$$

$$\text{so, } F = \frac{m\Delta v}{\Delta t}$$

$$= \frac{m(v_f - v_i)}{\Delta t}$$

$$= \frac{(625\text{ kg})(44.0\text{ m/s} - 10.0\text{ m/s})}{68.0\text{ s}}$$

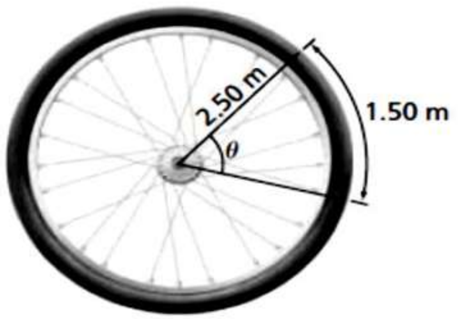
$$= 313\text{ N}$$

CHAPTER 8

Rotational Motion

Level 1

72. A wheel is rotated so that a point on the edge moves through 1.50 m. The radius of the wheel is 2.50 m, as shown in **Figure 8-21.** Through what angle (in radians) is the wheel rotated?



■ **Figure 8-21**

$d = r\theta$

so $\theta = \frac{d}{r}$

$= \frac{1.50 \text{ m}}{2.50 \text{ m}}$

$= 0.600 \text{ rad}$

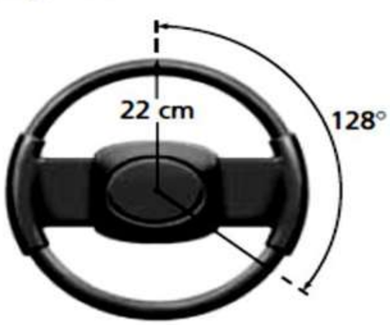
73. The outer edge of a truck tire that has a radius of 45 cm has a velocity of 23 m/s. What is the angular velocity of the tire in rad/s?

$v = r\omega,$

$\omega = \frac{v}{r}$

$= \frac{23 \text{ m/s}}{0.45 \text{ m}} = 51 \text{ rad/s}$

74. A steering wheel is rotated through 128°, as shown in **Figure 8-22.** Its radius is 22 cm. How far would a point on the steering wheel's edge move?



■ **Figure 8-22**

$d = r\theta$

$= (0.22 \text{ m})(128°)\left(\frac{2\pi \text{ rad}}{360°}\right) = 0.49 \text{ m}$

75. Propeller A propeller spins at 1880 rev/min.

a. What is its angular velocity in rad/s?

$\omega = \left(1880 \frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi \text{ rad}}{\text{rev}}\right)\left(\frac{\text{min}}{60 \text{ s}}\right)$

$= 197 \text{ rad/s}$

b. What is the angular displacement of the propeller in 2.50 s?

$\theta = \omega t$

$= (197 \text{ rad/s})(2.50 \text{ s})$

$= 492 \text{ rad}$

76. The propeller in the previous problem slows from 475 rev/min to 187 rev/min in 4.00 s. What is its angular acceleration?

$\alpha = \frac{\Delta\omega}{\Delta t}$

$= \frac{\omega_f - \omega_i}{\Delta t}$

$= \frac{(187 \text{ rev/min} - 475 \text{ rev/min})}{4.00 \text{ s}}\left(\frac{2\pi \text{ rad}}{\text{rev}}\right)$

$\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$

$= -7.54 \text{ rad/s}^2$

77. An automobile wheel with a 9.00 cm radius, as shown in **Figure 8-23,** rotates at 2.50 rad/s. How fast does a point 7.00 cm from the center travel?

■ **Figure 8-23**

$v = r\omega$

$= (7.00 \text{ cm})(2.50 \text{ rad/s})$

$= 17.5 \text{ cm/s}$

81. Wrench A bolt is to be tightened with a torque of 8.0 N·m. If you have a wrench that is 0.35 m long, what is the least amount of force you must exert?

$\tau = Fr \sin \theta$

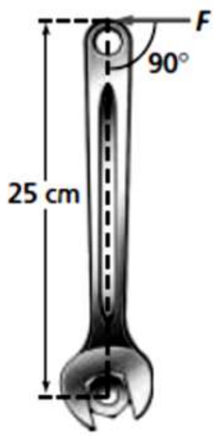
so $F = \dfrac{\tau}{r \sin \theta}$

For the least possible force, the angle is 90.0°, then

$$F = \frac{8.0 \text{ N·m}}{(0.35 \text{ m})(\sin 90.0°)}$$

$= 23$ N

82. What is the torque on a bolt produced by a 15-N force exerted perpendicular to a wrench that is 25 cm long, as shown in **Figure 8-24**?



■ **Figure 8-24**

$\tau = Fr \sin \theta$

$= (15 \text{ N})(0.25 \text{ m})(\sin 90.0°)$

$= 3.8$ N·m

Level 2

84. A bicycle wheel with a radius of 38 cm is given an angular acceleration of 2.67 rad/s^2 by applying a force of 0.35 N on the edge of the wheel. What is the wheel's moment of inertia?

$\alpha = \dfrac{\tau}{I}$

$I = \dfrac{\tau}{\alpha}$

$= \dfrac{Fr \sin \theta}{\alpha}$

$$= \frac{(0.35 \text{ N})(0.38 \text{ m})(\sin 90.0°)}{2.67 \text{ rad/s}^2}$$

$= 0.050$ kg·m^2

34. Newton's Second Law for Rotational Motion A rope is wrapped around a pulley and pulled with a force of 13.0 N. The pulley's radius is 0.150 m. The pulley's rotational speed goes from 0.0 to 14.0 rev/min in 4.50 s. What is the moment of inertia of the pulley?

$I = \dfrac{\tau}{\alpha}$

$= \dfrac{Fr}{\dfrac{\Delta\omega}{\Delta t}}$

$= \dfrac{Fr\Delta t}{\omega_f - \omega_i}$

$$= \frac{(13.0 \text{ N})(0.150 \text{ m})(4.50 \text{ s})}{\left(14.0 \frac{\text{rev}}{\text{min}} - 0.0 \frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi \text{ rad}}{\text{rev}}\right)\left(\frac{\text{min}}{60 \text{ s}}\right)}$$

$= 5.99$ kg·m^2

18. Two baskets of fruit hang from strings going around pulleys of different diameters, as shown in **Figure 8-6.** What is the mass of basket A?

$\tau_1 = \tau_2$

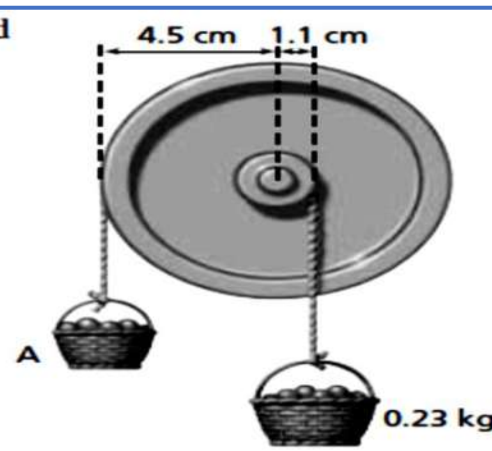
$F_1r_1 = F_2r_2$

$m_1gr_1 = m_2gr_2$

$m_1 = \dfrac{m_2r_2}{r_1}$

$$= \frac{(0.23 \text{ kg})(1.1 \text{ cm})}{4.5 \text{ cm}}$$

$= 0.056$ kg



CHAPTER 11

Energy and Its Conservation

11.1 The Many Forms of Energy

pages 307–308

Level 1

54. A 1600-kg car travels at a speed of 12.5 m/s. What is its kinetic energy?

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(1600\text{ kg})(12.5\text{ m/s})^2$$
$$= 1.3\times10^5\text{ J}$$

55. A racing car has a mass of 1525 kg. What is its kinetic energy if it has a speed of 108 km/h?

$$KE = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(1525\text{ kg})\left(\frac{(108\text{ km/h})(1000\text{ m/km})}{3600\text{ s/h}}\right)^2$$
$$= 6.86\times10^5\text{ J}$$

56. Shawn and his bike have a combined mass of 45.0 kg. Shawn rides his bike 1.80 km in 10.0 min at a constant velocity. What is Shawn's kinetic energy?

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{d}{t}\right)^2$$
$$= \frac{1}{2}(45\text{ kg})\left(\frac{(1.80\text{ km})(1000\text{ m/km})}{(10.0\text{ min})(60\text{ s/min})}\right)^2$$
$$= 203\text{ J}$$

57. Tony has a mass of 45 kg and is moving with a speed of 10.0 m/s.

a. Find Tony's kinetic energy.

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(45\text{ kg})(10.0\text{ m/s})^2$$
$$= 2.3\times10^3\text{ J}$$

b. Tony's speed changes to 5.0 m/s. Now what is his kinetic energy?

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(45\text{ kg})(5.0\text{ m/s})^2$$
$$= 5.6\times10^2\text{ J}$$

61. A 15.0-kg cart is moving with a velocity of 7.50 m/s down a level hallway. A constant force of 10.0 N acts on the cart, and its velocity becomes 3.20 m/s.

a. What is the change in kinetic energy of the cart?

$$\Delta KE = KE_f - KE_i = \frac{1}{2}m(v_f^2 - v_i^2)$$
$$= \frac{1}{2}(15.0\text{ kg})((3.20\text{ m/s})^2 - (7.50\text{ m/s})^2)$$
$$= -345\text{ J}$$

b. How much work was done on the cart?

$$W = \Delta KE = -345\text{ J}$$

c. How far did the cart move while the force acted?

$$W = Fd$$
$$\text{so } d = \frac{W}{F} = \frac{-345\text{ J}}{-10.0\text{ N}} = 34.5\text{ m}$$

62. How much potential energy does DeAnna with a mass of 60.0 kg, gain when she climbs a gymnasium rope a distance of 3.5 m?

$$PE = mgh$$
$$= (60.0\text{ kg})(9.80\text{ m/s}^2)(3.5\text{ m})$$
$$= 2.1\times10^3\text{ J}$$

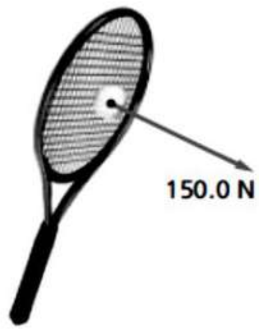
63. Bowling A 6.4-kg bowling ball is lifted 2.1 m into a storage rack. Calculate the increase in the ball's potential energy.

$$PE = mgh$$
$$= (6.4\text{ kg})(9.80\text{ m/s}^2)(2.1\text{ m})$$
$$= 1.3\times10^2\text{ J}$$

64. Mary weighs 505 N. She walks down a flight of stairs to a level 5.50 m below her starting point. What is the change in Mary's potential energy?

$$PE = mg\Delta h = F_g\Delta h$$
$$= (505\text{ N})(-5.50\text{ m})$$
$$= -2.78\times10^3\text{ J}$$

69. Tennis It is not uncommon during the serve of a professional tennis player for the racket to exert an average force of 150.0 N on the ball. If the ball has a mass of 0.060 kg and is in contact with the strings of the racket, as shown in **Figure 11-18,** for 0.030 s, what is the kinetic energy of the ball as it leaves the racket? Assume that the ball starts from rest.



■ **Figure 11-18**

$Ft = m\Delta v = mv_f - mv_i$ and $v_i = 0$

so $v_f = \frac{Ft}{m} = \frac{(150.0\text{ N})(3.0\times10^{-2}\text{ s})}{6.0\times10^{-2}\text{ kg}}$

$= 75\text{ m/s}$

$KE = \frac{1}{2}mv^2$

$= \frac{1}{2}(6.0\times10^{-2}\text{ kg})(75\text{ m/s})^2$

$= 1.7\times10^2\text{ J}$

70. Pam, wearing a rocket pack, stands on frictionless ice. She has a mass of 45 kg. The rocket supplies a constant force for 22.0 m, and Pam acquires a speed of 62.0 m/s.

a. What is the magnitude of the force?

$\Delta KE_f = \frac{1}{2}mv_f^2$

$= \frac{1}{2}(45\text{ kg})(62.0\text{ m/s})^2$

$= 8.6\times10^4\text{ J}$

b. What is Pam's final kinetic energy?

Work done on Pam equals her change in kinetic energy.

$W = Fd = \Delta KE = KE_f - KE_i$

$KE_i = 0\text{ J}$

So, $F = \frac{KE_f}{d} = \frac{8.6\times10^4\text{ J}}{22.0\text{ m}}$

$= 3.9\times10^3\text{ N}$

65. Weightlifting A weightlifter raises a 180-kg barbell to a height of 1.95 m. What is the increase in the potential energy of the barbell?

$PE = mgh$

$= (180\text{ kg})(9.80\text{ m/s}^2)(1.95\text{ m})$

$= 3.4\times10^3\text{ J}$

66. A 10.0-kg test rocket is fired vertically from Cape Canaveral. Its fuel gives it a kinetic energy of 1960 J by the time the rocket engine burns all of the fuel. What additional height will the rocket rise?

$PE = mgh = KE$

$h = \frac{KE}{mg} = \frac{1960}{(10.0\text{ kg})(9.80\text{ m/s}^2)}$

$= 20.0\text{ m}$

67. Antwan raised a 12.0-N physics book from a table 75 cm above the floor to a shelf 2.15 m above the floor. What was the change in the potential energy of the system?

$PE = mg\Delta h = F_g\Delta h = F_g(h_f - h_i)$

$= (12.0\text{ N})(2.15\text{ m} - 0.75\text{ m})$

$= 17\text{ J}$

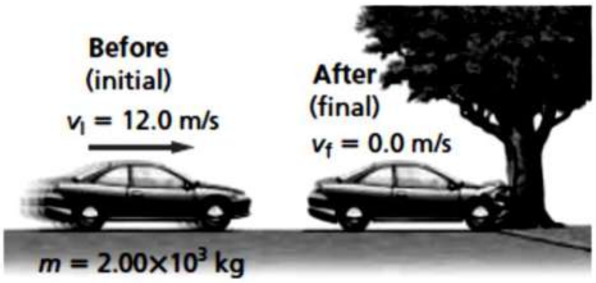
68. A hallway display of energy is constructed in which several people pull on a rope that lifts a block 1.00 m. The display indicates that 1.00 J of work is done. What is the mass of the block?

$W = PE = mgh$

$m = \frac{W}{gh} = \frac{1.00\text{ J}}{(9.80\text{ m/s}^2)(1.00\text{ m})}$

$= 0.102\text{ kg}$

71. Collision A 2.00×10^3-kg car has a speed of 12.0 m/s. The car then hits a tree. The tree doesn't move, and the car comes to rest, as shown in **Figure 11-19.**



■ **Figure 11-19**

a. Find the change in kinetic energy of the car.

$$\Delta KE = KE_f - KE_i = \frac{1}{2}m(v_f^2 - v_i^2)$$
$$= \frac{1}{2}(2.00\times10^3\ \text{kg})((0.0\ \text{m/s})^2 - (12.0\ \text{m/s})^2)$$
$$= -1.44\times10^5\ \text{J}$$

b. Find the amount of work done as the front of the car crashes into the tree.

$$W = \Delta KE = -1.44\times10^5\ \text{J}$$

c. Find the size of the force that pushed in the front of the car by 50.0 cm.

$$W = Fd$$
$$\text{so } F = \frac{W}{d}$$
$$= \frac{-1.44\times10^5\ \text{J}}{0.500\ \text{m}}$$
$$= -2.88\times10^5\ \text{N}$$

82. Slide Lorena's mass is 28 kg. She climbs the 4.8-m ladder of a slide and reaches a velocity of 3.2 m/s at the bottom of the slide. How much work was done by friction on Lorena?

The work done by friction on Lorena equals the change in her mechanical energy.

$$W = \Delta PE + \Delta KE$$
$$= mg(h_f - h_i) + \frac{1}{2}m(v_f^2 - v_i^2)$$
$$= (28\ \text{kg})(9.80\ \text{m/s}^2)(0.0\ \text{m} - 4.8\ \text{m}) + \frac{1}{2}(28\ \text{kg})((3.2\ \text{m/s})^2 - (0.0\ \text{m/s})^2)$$
$$= -1.2\times10^3\ \text{J}$$

Level 1

73. A 98.0-N sack of grain is hoisted to a storage room 50.0 m above the ground floor of a grain elevator.

a. How much work was done?

$$W = \Delta PE = mg\Delta h = F_g\Delta h$$
$$= (98.0\ \text{N})(50.0\ \text{m})$$
$$= 4.90\times10^3\ \text{J}$$

b. What is the increase in potential energy of the sack of grain at this height?

$$\Delta PE = W = 4.90\times10^3\ \text{J}$$

c. The rope being used to lift the sack of grain breaks just as the sack reaches the storage room. What kinetic energy does the sack have just before it strikes the ground floor?

$$KE = \Delta PE = 4.90\times10^3\ \text{J}$$

39. You throw a clay ball at a hockey puck on ice. The smashed clay ball and the hockey puck stick together and move slowly. (11.2)

a. Is momentum conserved in the collision? Explain.

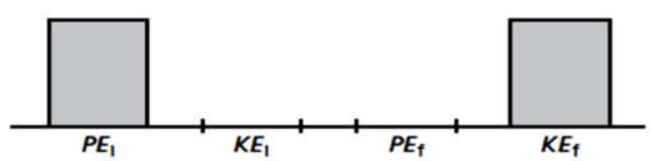
The total momentum of the ball and the puck together is conserved in the collision because there are no unbalanced forces on this system.

b. Is kinetic energy conserved? Explain.

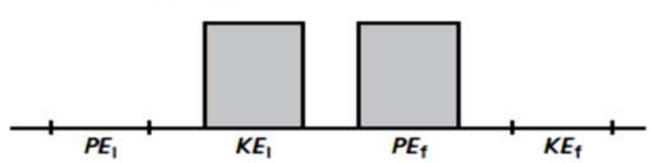
The total kinetic energy is not conserved. Part of it is lost in the smashing of the clay ball and the adhesion of the ball to the puck.

40. Draw energy bar graphs for the following processes. (11.2)

a. An ice cube, initially at rest, slides down a frictionless slope.



b. An ice cube, initially moving, slides up a frictionless slope and instantaneously comes to rest.



CHAPTER 12

Thermal Energy

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1. Convert the following Kelvin temperatures to Celsius temperatures.

a. 115 K

$T_C = T_K - 273 = 115 - 273 = -158°C$

b. 172 K

$T_C = T_K - 273 = 172 - 273 = -101°C$

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3. When you turn on the hot water to wash dishes, the water pipes have to heat up. How much heat is absorbed by a copper water pipe with a mass of 2.3 kg when its temperature is raised from 20.0°C to 80.0°C?

$$Q = mC\Delta T = (2.3\ \text{kg})(385\ \text{J/kg·K})(80.0°C - 20.0°C) = 5.3\times10^4\ \text{J}$$

4. The cooling system of a car engine contains 20.0 L of water (1 L of water has a mass of 1 kg).

a. What is the change in the temperature of the water if the engine operates until 836.0 kJ of heat is added?

$$Q = mC\Delta T$$

$$\Delta T = \frac{Q}{mC} = \frac{(8.36\times10^5\ \text{J})}{(20.0\ \text{kg})(4180\ \text{J/kg·K})} = 10.0\ \text{K}$$

2. Find the Celsius and Kelvin temperatures for the following.

a. room temperature

Room temperature is about 72°F, 22°C.

$T_K = T_C + 273 = 22 + 273 = 295$ K

b. a typical refrigerator

A refrigerator is kept at about 4°C.

$T_K = T_C + 273 = 4 + 273 = 277$ K

c. a hot summer day in North Carolina

A hot summer day is about 95°F, 35°C.

$T_K = T_C + 273 = 35 + 273 = 308$ K

28. Heat of Vaporization How much heat is needed to change 50.0 g of water at 80.0°C to steam at 110.0°C?

$$Q = mC_{water}\Delta T + mH_v + mC_{steam}\Delta T$$
$$= (0.500\ \text{kg})(4180\ \text{J/kg·°C})(100.0°C - 80.0°C) + (0.500\ \text{kg})(2.26\times10^6\ \text{J/kg}) + (0.500\ \text{kg})(2020\ \text{J/kg·°C})(110.0°C - 100.0°C)$$
$$= 1.18\times10^5\ \text{J}$$

6. A 2.00×10^2-g sample of water at 80.0°C is mixed with 2.00×10^2 g of water at 10.0°C. Assume that there is no heat loss to the surroundings. What is the final temperature of the mixture?

$$m_A C_A(T_f - T_{Ai}) + m_B C_B(T_f - T_{Bi}) = 0$$

Since $m_A = m_B$ and $C_A = C_B$,

there is cancellation in this particular case so that

$$T_f = \frac{T_{Ai} + T_{Bi}}{2} = \frac{80.0°C + 10.0°C}{2} = 45.0°C$$

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19. How much heat is absorbed by 1.00×10^2 g of ice at $-20.0°C$ to become water at $0.0°C$?

$$Q = mC\Delta T + mH_f$$
$$= (0.100\ \text{kg})(2060\ \text{J/kg·°C})(20.0°\text{C}) + (0.100\ \text{kg})(3.34\times10^5\ \text{J/kg})$$
$$= 3.75\times10^4\ \text{J}$$

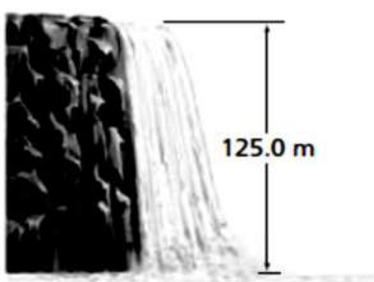
20. A 2.00×10^2-g sample of water at 60.0°C is heated to steam at 140.0°C. How much heat is absorbed?

$$Q = mC_{water}\Delta T + mH_v + mC_{steam}\Delta T$$
$$= (0.200\ \text{kg})(4180\ \text{J/kg·°C})(100.0°\text{C} - 60.0°\text{C}) + (0.200\ \text{kg})(2.26\times10^6\ \text{J/kg}) + (0.200\ \text{kg})(2020\ \text{J/kg·°C})(140.0°\text{C} - 100.0°\text{C})$$
$$= 502\ \text{kJ}$$

21. How much heat is needed to change 3.00×10^2 g of ice at $-30.0°C$ to steam at 130.0°C?

$$Q = mC_{ice}\Delta T + mH_f + mC_{water}\Delta T + mH_v + mC_{steam}\Delta T$$
$$= (0.300\ \text{kg})(2060\ \text{J/kg·°C})(0.0°\text{C} - (-30.0°\text{C})) + (0.300\ \text{kg})(3.34\times10^5\ \text{J/kg}) + (0.300\ \text{kg})(4180\ \text{J/kg·°C})(100.0°\text{C} - 0.0°\text{C}) + (0.300\ \text{kg})(2.26\times10^6\ \text{J/kg}) + (0.300\ \text{kg})(2020\ \text{J/kg·°C})(130.0°\text{C} - 100.0°\text{C})$$
$$= 9.40\times10^2\ \text{kJ}$$

32. Mechanical Energy and Thermal Energy Water flows over a fall that is 125.0 m high, as shown in **Figure 12-17.** If the potential energy of the water is all converted to thermal energy, calculate the temperature difference between the water at the top and the bottom of the fall.



■ **Figure 12-17**

$$PE_{gravity} = Q_{absorbed\ by\ water}$$
$$mgh = mC\Delta T$$
$$\Delta T = \frac{gh}{C}$$
$$= \frac{(9.80\ \text{m/s}^2)(125.0\ \text{m})}{4180\ \text{J/kg·°C}}$$

$= 0.293°C$ rise in temperature at the bottom

29. Heat of Vaporization The specific heat of mercury is 140 J/kg·°C. Its heat of vaporization is 3.06×10^5 J/kg. How much energy is needed to heat 1.0 kg of mercury metal from 10.0°C to its boiling point and vaporize it completely? The boiling point of mercury is 357°C.

$$Q = mC_{Hg}\Delta T + mH_v$$
$$= (1.0\ \text{kg})(140\ \text{J/kg·°C})(357°\text{C} - 10.0°\text{C}) + (1.0\ \text{kg})(3.06\times10^5\ \text{J/kg})$$
$$= 3.5\times10^5\ \text{J}$$

52. How much heat is needed to raise the temperature of 50.0 g of water from 4.5°C to 83.0°C?

$$Q = mC\Delta T$$
$$= (0.0500\ \text{kg})(4180\ \text{J/kg·°C})(83.0°\text{C} - 4.5°\text{C})$$
$$= 1.64\times10^4\ \text{J}$$

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22. A gas balloon absorbs 75 J of heat. The balloon expands but stays at the same temperature. How much work did the balloon do in expanding?

$\Delta U = Q - W$

Since the balloon did not change temperature, $\Delta U = 0$.

Therefore, $Q = W$.

Thus, the balloon did 75 J of work in expanding.

23. A drill bores a small hole in a 0.40-kg block of aluminum and heats the aluminum by 5.0°C. How much work did the drill do in boring the hole?

$\Delta U = Q - W_{block}$; **since** $W_{drill} = -W_{block}$

and assume no heat added to drill:

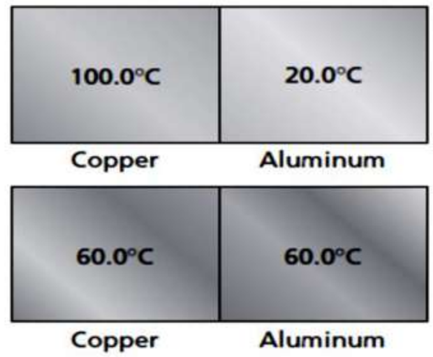
$= 0 + W_{drill} = mC\Delta T$

$= (0.40\ \text{kg})(897\ \text{J/kg}\cdot{}^\circ\text{C})(5.0^\circ\text{C})$

$= 1.8\times10^3\ \text{J}$

Level 2

71. A block of copper at 100.0°C comes in contact with a block of aluminum at 20.0°C, as shown in **Figure 12-21.** The final temperature of the blocks is 60.0°C. What are the relative masses of the blocks?



The heat lost from the copper equals the heat gained by the aluminum. The ΔT for the copper is −40.0°C and the aluminum heats by +40.0°C.

therefore,

$m_{copper}C_{copper} = m_{aluminum}C_{aluminum}$

and $\dfrac{m_{copper}}{m_{aluminum}} = \dfrac{C_{aluminum}}{C_{copper}}$

$= \dfrac{897\ \text{J/kg}\cdot\text{K}}{385\ \text{J/kg}\cdot\text{K}} = 2.3$

55. A 1.00×10^2-g mass of tungsten at 100.0°C is placed in 2.00×10^2 g of water at 20.0°C. The mixture reaches equilibrium at 21.6°C. Calculate the specific heat of tungsten.

$\Delta Q_T + \Delta Q_W = 0$

or $m_T C_T \Delta T_T = -m_W C_W \Delta T_W$

$$C_T = \frac{-m_W C_W \Delta T_W}{m_T \Delta T_T} = \frac{-(0.200\ \text{kg})(4180\ \text{J/kg}\cdot\text{K})(21.6^\circ\text{C} - 20.0^\circ\text{C})}{(0.100\ \text{kg})(21.6^\circ\text{C} - 100.0^\circ\text{C})}$$

$= 171\ \text{J/kg}\cdot\text{K}$

61. Years ago, a block of ice with a mass of about 20.0 kg was used daily in a home icebox. The temperature of the ice was 0.0°C when it was delivered. As it melted, how much heat did the block of ice absorb?

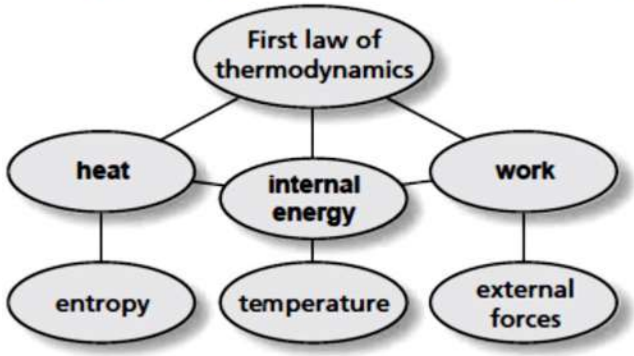
$Q = mH_f = (20.0\ \text{kg})(3.34\times10^5\ \text{J/kg}) = 6.68\times10^6\ \text{J}$

62. A 40.0-g sample of chloroform is condensed from a vapor at 61.6°C to a liquid at 61.6°C. It liberates 9870 J of heat. What is the heat of vaporization of chloroform?

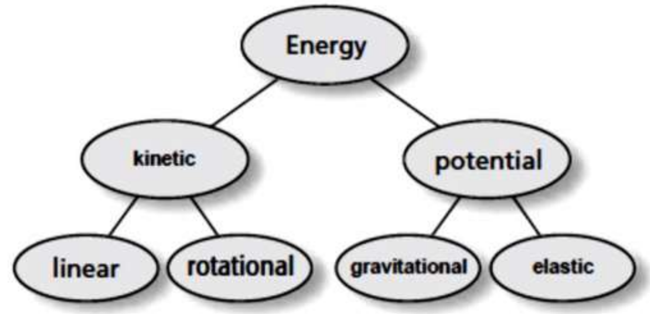
$Q = mH_v$

$H_v = \dfrac{Q}{m} = \dfrac{9870\ \text{J}}{0.0400\ \text{kg}} = 2.47\times10^5\ \text{J/kg}$

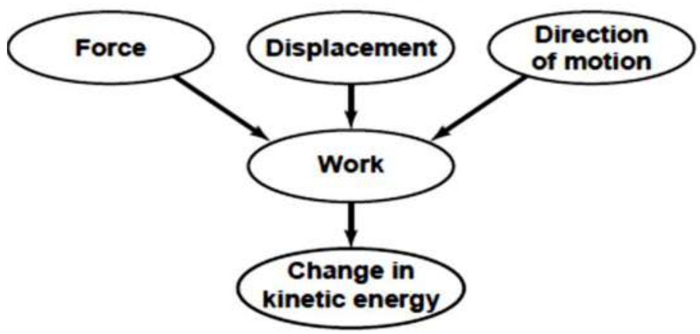
35. Complete the following concept map using the following terms: *heat, work, internal energy.*



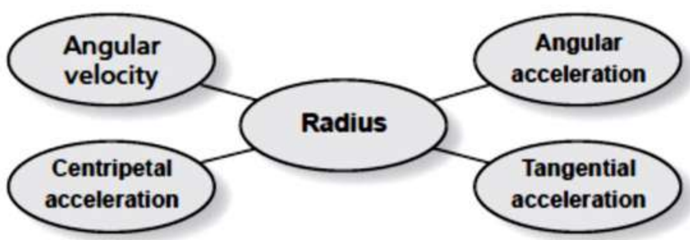
29. Complete the concept map using the following terms: *gravitational potential energy, elastic potential energy, kinetic energy.*

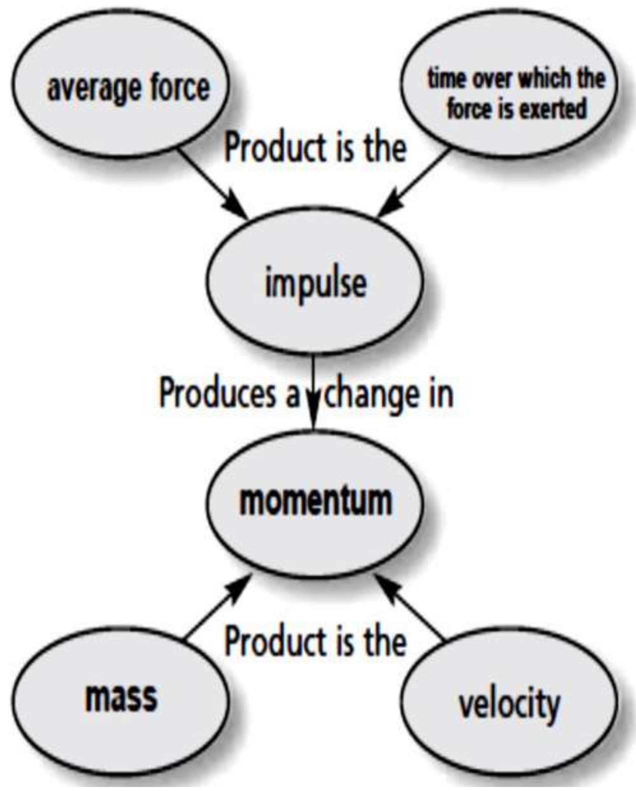


34. Create a concept map using the following terms: *force, displacement, direction of motion, work, change in kinetic energy.*



47. Complete the following concept map using the following terms: *angular acceleration, radius, tangential acceleration, centripetal acceleration.*





32. Use the following terms to complete the concept map below: *constant speed, horizontal part of projectile motion, constant acceleration, relative-velocity motion, uniform circular motion.*