# PHYSICS

CONCEPTS AND CONNECTIONS

COMBINED EDITION

## Solutions Manual


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# PART 1 Solutions to Applying the Concepts

In this section, solutions have been provided only for problems requiring calculation.

## Section 1.2

**4.** **a)** $c = 3.00 \times 10^8$ m/s
1 second = 9 192 631 770 vibrations
Therefore, in 3632 s, there are $3.34 \times 10^{13}$ vibrations.

**b)** 1 m = 1 650 763.73λ
$d = (.150 \text{ m})(1 \text{ m})$
$d = 2.48 \times 10^5\lambda$

## Section 1.3

**2.** **a)** 4
**b)** 5
**c)** 7
**d)** 1
**e)** 4
**f)** 6

**3.** **a)** 3.1 m
**b)** 3.2 m
**c)** 3.4 m
**d)** 3.6 m
**e)** 3.4 m

**4.** **a)** 3.745 m
**b)** 309.6 m
**c)** 120 s
**d)** 671.6 s
**e)** 461.7 s

**5.** **a)** 4.0 m
**b)** 3.3 m
**c)** 3.3333
**d)** 0.33
**e)** 0.333

## Section 1.4

**1.** **a)** 389 s = 6.4833 min = 0.10805 h = $4.502 \times 10^{-3}$ d = $1.50 \times 10^{-4}$ months = $1.25 \times 10^{-5}$ a
**i)** $1.50 \times 10^{-4}$ months
**ii)** 6.48 min
**iii)** $1.25 \times 10^{-5}$ a
**iv)** $3.89 \times 10^8$ μs

**b)** 5.0 a = 60 months = 1825 d = 43 800 h = 2 628 000 min = 157 680 000 s
**i)** 60 months
**ii)** $2.6 \times 10^6$ min
**iii)** $1.8 \times 10^3$ d
**iv)** $1.6 \times 10^8$ s

## Section 2.1

**1.** At $t = 2.0$ s, $v = 10$ m/s,
$d = \frac{1}{2}(10 \text{ m/s} + 20 \text{ m/s})2.0 \text{ s} = 30 \text{ m}$
At $t = 7.0$ s, $v = 15$ m/s, $d = \frac{1}{2}(4.0 \text{ s})(20 \text{ m/s}) + \frac{1}{2}(7.0 \text{ s} - 4.0 \text{ s})(15 \text{ m/s}) = 40 \text{ m} + 27.5 \text{ m} = 67.5 \text{ m}$

## Section 2.4

**1.** **a)** $a = 4.0 \text{ m/s}^2$
$t = 40.0$ s
$v_1 = 0$ m/s
$v_2 = (4.0 \text{ m/s}^2)(40.0 \text{ s})$
$v_2 = 160$ m/s

**b)** **i)** $\Delta\vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} \times \Delta t$
$\Delta d = 3200$ m

**ii)** $\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
$\Delta d = \frac{1}{2}(4.0 \text{ m/s}^2)(40.0 \text{ s})^2$
$\Delta d = 3200$ m

**2.** **a)** $\Delta d = 152$ m
$v_1 = 66.7$ m/s
$v_2 = 0$
$\Delta v = -66.7$ m/s

$$\Delta\vec{d} = \frac{\vec{v}_1 + \vec{v}_2}{2} \times \Delta t$$

$$\Delta t = \frac{2\Delta d}{v_1 + v_2}$$

$\Delta t = 4.5577$ s

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$$

$a = -14.6 \text{ m/s}^2$

**b)** $\Delta t = 4.56$ s

**c)** **i)** $\Delta\vec{d} = \frac{\vec{v}_2 + \vec{v}_1}{2} \times \Delta t$
$\Delta d = 152$ m

**ii)** $\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
$\Delta d = (66.7 \text{ m/s})(4.56 \text{ s}) + \frac{1}{2}(-14.6 \text{ m/s}^2)(4.56 \text{ s})^2$
$\Delta d = 152$ m

3. a) $v = \dfrac{3395 \text{ km/h}}{3.6} = 943.1 \text{ m/s}$

b) $\Delta t = 0.5$ s

$v = 943.1$ m/s

$\Delta d = 471.5$ m

c) $\vec{a}_{avg} = \dfrac{\Delta \vec{v}}{\Delta t}$

$a_{avg} = 78.59 \text{ m/s}^2$

d) $\Delta t = 8.7$ s

$v_2 = 943.1$ m/s

$a_{avg} = \dfrac{v_2 - v_1}{\Delta t}$

$78.59 \text{ m/s}^2 = \dfrac{943.1 \text{ m/s} - v_1}{8.7 \text{ s}}$

$v_1 = 2.6 \times 10^2$ m/s

4. a) 31 km × \$0.12/km = \$3.72

Total cost = \$3.72 + \$1.50 + \$2.00

= \$7.22

b) 19 min = 0.32 h

$\dfrac{31 \text{ km}}{0.32 \text{ h}} = 97 \text{ km/h}$

d) $\dfrac{20 \text{ km}}{100 \text{ km/h}} = 0.20 \text{ h}$

$\dfrac{10 \text{ km}}{125 \text{ km/h}} = 0.08 \text{ h}$

$\dfrac{10 \text{ km}}{0.12 \text{ h}} = 83 \text{ km/h}$

e) $\dfrac{31 \text{ km}}{9.1 \text{ km/L}} = 3.4 \text{ L} \times \$0.77\text{/L}$

= \$2.62

## Section 3.1

1. a) $d_x = 20 \sin 30°$

$d_x = 10$ km

$d_y = -20 \cos 30°$

$d_y = -17.32$ km

$d_y \cong -17$ km

b) $d_x = -40 \cos 60°$

$d_x = -20$ km

$d_y = 40 \sin 60°$

$d_y = 34.64$ km

$d_y \cong 35$ km

c) $d_x = 10 \sin 10°$

$d_x = 1.736$ km

$d_x \cong 1.7$ km

$d_y = 10 \cos 10°$

$d_y = 9.848$ km

$d_y \cong 9.8$ km

d) $d_x = -5 \sin 24°$

$d_x = -2.03$ km

$d_x \cong -2.0$ km

$d_y = -5 \cos 24°$

$d_y = -4.5677$ km

$d_y \cong -4.6$ km

e) $d_x = -12 \sin 45°$

$d_x = -8.5$ km

$d_y = 12 \cos 45°$

$d_y = 8.5$ km

f) $d_x = 10$ km

$d_y = 0$ km

2. $\Delta d_x = 20 \sin 20° - 120 \sin 50°$

$-150 + 30 \sin 75°$

$= -206.1$ m

$\Delta d_y = 20 \cos 20° + 120 \cos 50°$

$-30 \cos 75°$

$= 88$ m

$\Delta d = \sqrt{(-206.1 \text{ m})^2 + (88 \text{ m})^2}$

$\Delta d = 230$ m

$\theta = \tan^{-1} \dfrac{88}{206.1}$

$= 23°$

$\Delta \vec{d} = 230$ m [W23°N]

## Section 3.3

1. a) $g = -9.81 \text{ m/s}^2$

$\vec{v}_1 = 0$

$\Delta d = -100$ m

$\Delta \vec{d} = \vec{v}_1 t + \frac{1}{2}\vec{g}t^2$

$-100 \text{ m} = \frac{1}{2}(9.81 \text{ m/s}^2) \times t^2$

$t^2 = 20.387 \text{ s}^2$

$t = 4.52$ s

b) $v_1 = 10$ m/s

$\Delta d = -100$ m

$g = -9.81 \text{ m/s}^2$

$\Delta \vec{d} = \vec{v}_1 t + \frac{1}{2}\vec{g}t^2$

$-100 = 10t + \frac{1}{2}(-9.81) \times t^2$

$-4.905t^2 + 10t + 100 = 0$

$t = \dfrac{-10 \pm \sqrt{100 - 4(-4.905)(100)}}{2(-4.905)}$

$t = 5.6$ s

**c)** $v_1 = -10$ m/s
$\Delta d = -100$ m
$g = -9.81$ m/s$^2$
$\Delta\vec{d} = \vec{v}_1 t + \frac{1}{2}\vec{g}t^2$
$-100 = -10t + \frac{1}{2}(-9.81) \times t^2$

$$t = \frac{-10 \pm \sqrt{100 - 4(-4.905)(100)}}{2(-4.905)}$$

$t = 3.6$ s

**d)** $v_{x_1} = 5.0$ m/s
$a_x = 0$
$v_{y_1} = 0$
$a_y = -9.81$ m/s$^2$
$\Delta v = -100$ m/s
$d_x = v_{x_1}t + \frac{1}{2}a_x t^2$
$d_y = v_{y_1}t + \frac{1}{2}a_y t^2$
**i)** $d_x = 45$ m
**ii)** $d_x = 28$ m
**iii)** $d_x = 18$ m

**2.** **a)** At maximum height in trajectory, $v_2 = 0$.
$g = -9.81$ m/s$^2$
$\vec{v} = \vec{v}_o - \vec{g}t$

$$t = \frac{\vec{v}_o - \vec{v}}{\vec{g}}$$

$t = 1.08$ s

**b)** $\vec{v}^2 = \vec{v}_1^{\,2} - 2\vec{g}\Delta\vec{d}$

$$\Delta d_y = \frac{v_1^2 - v_2^2}{2g}$$

$\Delta d_y = 0.539$ m

**c)** $v_{1_y} = 0$
$v_{1_x} = 25 \cos 25°$
$v_{1_x} = 22.658$ m/s
$d_y = v_{1_y}\Delta t - \frac{1}{2}a_y t^2$
$0.539 = -\frac{1}{2}(-9.81) \times t^2$
$t = 0.331$ s

**d)** $d_x = v_x\Delta t$
$d_x = 25 \cos 25°(1.08 + 0.331)$
$d_x = 31.97$
$d_x \cong 32$ m away from the soccer player.

**e)** $\dfrac{v_{2_y} - v_{1_y}}{\Delta t} = g$
$v_{2_y} = g\Delta t + v_{1_y}$
$v_{2_y} = -3.25$ m/s
$v_{2_y} = 3.25$ m/s [down]
$v^2 = v_y^2 + v_x^2$
$v = 22.9$ m/s

$$\tan\theta = \frac{-22.658}{3.25}$$

$\theta = -81.8°$
$\vec{v} = 22.9$ m/s [S81.8°E]

**3.** **a)** $\vec{d} = \vec{v}\Delta t$
$d = (18.5 \text{ m/s})(\cos 18°)(10.9 \text{ s})$
$d = 191.84$ m
Therefore, the ball travels 192 m.

**b)** $v_{2_y} = v_{1_y}^{\,2} + 2a_y\Delta d_y$
At maximum height, $v_{2_y} = 0$.

$$\Delta d_y = \frac{-(v_{1_y}^{\,2})}{2a_y}$$

$$\Delta d_y = \frac{-(18.5 \sin 18°)^2}{2a_y}$$

$$\Delta d_y = \frac{-(32.68 \text{ m}^2/\text{s}^2)}{2(-9.8 \text{ m/s}^2)}$$

$\Delta d_y = 1.7$ m

**c)** **i)** $\vec{d} = \vec{v}\Delta t$
$d = (18.5 \cos 8°)(10.9 \text{ s})$
$d = 200$ m

**ii)** $v_{2_y} = v_{1_y}^{\,2} + 2a_y\Delta d_y$

$$\Delta d_y = \frac{-(v_{1_y}^{\,2})}{2a_y}$$

$$\Delta d_y = \frac{-(18.5 \sin 8°)^2}{2a_y}$$

$\Delta d_y = 0.34$ m

**4.** $\vec{d} = \vec{v}\Delta t$
$31 \text{ m} = (18.5 \text{ m/s})(\cos\theta)(3.66 \text{ s})$
$1.676 = \cos\theta(3.66 \text{ s})$
$\theta = 62.7°$
Therefore, the loft angle of the club is 63°.

## Section 3.4

**2.** $\vec{v}_{\text{wind}} = 80$ km/h
$\vec{v}_{\text{wind}} = 22.22$ m/s
$\vec{v}_{\text{plane}} = 200$ km/h
$\vec{v}_{\text{plane}} = 55.55$ m/s

**a)** $v_{og}{}^2 = (55.55)^2 + (22.22)^2$

$v_{og} = 59.84$ m/s

$\tan \alpha = \dfrac{22.22}{55.55}$

$\alpha = 21.8°$

$\vec{v}_{og} = 59.84$ m/s [N21.8°E]

**b)** $v_{og} = 50.86$ m/s

$\cos \theta = \dfrac{22.22}{55.55}$

$\theta = 66.42°$

$\vec{v}_{og} = 50.86$ m/s [N23.6°W]

**c)** $v_x = 22.22 - 55.55 \cos 70°$

$v_x = 3.22$ m/s

$v_y = 55.55 \sin 70°$

$v_y = 52.20$ m/s

$v^2 = (3.222)^2 + (52.202)^2$

$v = 52.30$ m/s

$\theta = 86.5°$

$v_{og}{}^2 = (22.22)^2 + (55.55)^2$
$- 2(22.22)(55.55)\cos 70°$

$v_{og} = 52.30$ m/s

$\dfrac{\sin 70°}{52.30} = \dfrac{\sin \theta}{55.55}$

$\theta = 86.45°$

$\theta \cong 86.5°$

$\vec{v}_{og} = 52.30$ m/s [E86.5°N]

## Section 3.5

**2. a)** $\Delta t = 0.5$ s

$\Delta v^2 = (120 \text{ km/h})^2 + (120 \text{ km/h})^2$

$\Delta v = 169.7$ km/h

$a = \dfrac{169.7 \text{ km/h}}{0.5 \text{ s}} = \dfrac{47.1 \text{ m/s}}{0.5 \text{ s}}$

$a = 94.3 \text{ m/s}^2 \cong 94 \text{ m/s}^2$

$\theta = \tan^{-1} \dfrac{120 \text{ km/h}}{120 \text{ km/h}}$

$\theta = 45°$

$\vec{a} = 94 \text{ m/s}^2$ [W45°N]

**b)** $\vec{v}_1 = 120$ km/h [E]

$\vec{v}_2 = 120$ km/h [N25°W]

$\Delta t = 0.5$ s

**Trigonometric Method**

$\Delta v^2 = (120 \text{ km/h})^2 + (120 \text{ km/h})^2$
$- 2(120 \text{ km/h})(120 \text{ km/h})\cos 115°$

$\Delta v = 202$ km/h

$\dfrac{\sin \theta}{120 \text{ km/h}} = \dfrac{\sin 115°}{202 \text{ km/h}}$

$\theta = 32.6°$

$a = \dfrac{202 \text{ km/h}}{0.5 \text{ s}}$

$a = \dfrac{56.1 \text{ m/s}}{0.5 \text{ s}}$

$\vec{a} = 112 \text{ m/s}^2$ [W33°N]

**Component Method**

$\Delta v_x = (-120 \cos 65°) \text{ km/h} - 120 \text{ km/h}$
$= -170.7$ km/h

$\Delta v_y = (120 \sin 65°) \text{ km/h} + 0$
$= 108.8$ km/h

$\Delta v^2 = (-170.7 \text{ km/h})^2 + (108.8 \text{ km/h})^2$

$\Delta v = 202$ km/h

$a = \dfrac{202 \text{ km/h}}{0.5 \text{ s}}$
$= 112 \text{ m/s}^2$

$\theta = \tan^{-1} \dfrac{108.8 \text{ km/h}}{170.7 \text{ km/h}}$

$\theta = 33°$

$\vec{a} = 112 \text{ m/s}^2$ [W33°N]

**c)** $\vec{v}_1 = 120$ km/h [E]

$\vec{v}_2 = 100$ km/h [N25°W] or [W65°N]

$\Delta v^2 = (120 \text{ km/h})^2 + (100 \text{ km/h})^2$
$- 2(120 \text{ km/h})(100 \text{ km/h})\cos 115°$

$\Delta v = 185.9$ km/h

$\Delta v \cong 186$ km/h

$\dfrac{\sin \theta}{100 \text{ km/h}} = \dfrac{\sin 115°}{186 \text{ km/h}}$

$\theta = 29.2°$

$\theta \cong 29°$

$\Delta v_x = (-100 \cos 65°) \text{ km/h} - 120 \text{ km/h}$
$= -162.3$ km/h

$\Delta v_y = (100 \text{ km/h} \sin 65°) + 0 = 90.6$ km/h

$\Delta v^2 = (162 \text{ km/h})^2 + (91 \text{ km/h})^2$

$\Delta v = 186$ km/h

$\theta = \tan^{-1} \dfrac{90.6 \text{ km/h}}{162.3 \text{ km/h}}$

$\theta = 29°$

$a = \dfrac{186 \text{ km/h}}{0.5 \text{ s}}$

$a = \dfrac{51.6 \text{ m/s}}{0.5 \text{ s}}$

$\vec{a} = 103 \text{ m/s}^2$ [W29°N]

## Section 4.3

**1.** **a)** 0

**b)** 0

**c)** +

**d)** −

**e)** $y$: $F_{net} = 0$

$a_y = 0$

$x$: $a_x = +$

**2.** **a)** $a_x = \dfrac{60\ \text{N}}{60\ \text{kg}}$

$a = 1.0\ \text{m/s}^2$

**b)** $F = 20\ \text{N}$

$a = \dfrac{20\ \text{N}}{60\ \text{kg}}$

$a = 0.33\ \text{m/s}^2$

**c)** $a = -0.33\ \text{m/s}^2$

**d)** $a = \dfrac{30\ \text{N}}{60\ \text{kg}}$

$a = 0.50\ \text{m/s}^2$

## Section 4.4

**1.** **a)** $\dfrac{F_{net}}{\sin 90°} = \dfrac{1.2 \times 10^5}{\sin 45°}$

$\vec{F}_{net} = 1.7 \times 10^5\ \text{N [N45°E]}$

**b)** $F_{net} = (1.2 \times 10^5 \cos 30°) \times 2$

$\vec{F}_{net} = 2.1 \times 10^5\ \text{N [E]}$

**c)** $F_x = 1.2 \times 10^5(\cos 20° + \cos 10°)$

$F_x = 2.3 \times 10^5\ \text{N}$

$F_y = 1.2 \times 10^5(\sin 20° - \sin 10°)$

$F_y = 2.0 \times 10^4\ \text{N}$

$F^2 = F_x{}^2 + F_y{}^2$

$F = 2.3 \times 10^5\ \text{N}$

$\theta = \tan^{-1} \dfrac{2.0 \times 10^4}{2.3 \times 10^5}$

$\theta = 5.0°$

$\vec{F} = 2.3 \times 10^5\ \text{N [N85°E]}$

**d.** **i)** $F_x = 1.2 \times 10^5 - 5.0 \times 10^4$

$F_x = 7.0 \times 10^4\ \text{N}$

$F_y = 2.1 \times 10^5\ \text{N}$

$F^2 = (1.2 \times 10^5)^2 + (7.0 \times 10^4)^2$

$F = 1.4 \times 10^5\ \text{N}$

$\theta = \tan^{-1} \dfrac{1.2 \times 10^5}{7.0 \times 10^4}$

$\theta = 59.7°$

$\vec{F} = 1.4 \times 10^5\ \text{N [N30°E]}$

**ii)** $F_x = (1.2 \times 10^5 \cos 30°)2 - 5 \times 10^4$

$F_x = 1.578 \times 10^5\ \text{N}$

$F_y = 0$

$\vec{F} = 1.6 \times 10^5\ \text{N [E]}$

**iii)** $F_x = 1.2 \times 10^5(\cos 20° - \cos 10°) - 5 \times 10^4$

$F_x = 1.81 \times 10^5\ \text{N}$

$F_y = 1.2 \times 10^5(\sin 20° - \sin 10°)$

$F_y = 2.02 \times 10^4\ \text{N}$

$\theta = \tan^{-1} \dfrac{2.02 \times 10^4}{1.8 \times 10^5}$

$\theta = 6.4°$

$\vec{F} = 1.8 \times 10^5\ \text{N [N83.6°E]}$

## Section 5.3

**1.** **a)** $F = (12\ 000\ \text{kg})(9.81\ \text{m/s}^2)$

$F = 1.18 \times 10^5\ \text{N}$

**b)** $F = \dfrac{Gm_1m_2}{r^2}$

$F = \dfrac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(12\ 000\ \text{kg})(5.98 \times 10^{24}\ \text{kg})}{(6.98 \times 10^6\ \text{m})^2}$

$F = 9.82 \times 10^4\ \text{N}$

**c)** distance from the surface $= 6.00 \times 10^5\ \text{N}$

**d)** On the Moon,

$F = \dfrac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(12\ 000\ \text{kg})(7.34 \times 10^{22}\ \text{kg})}{(1.74 \times 10^6\ \text{m})^2}$

$F = 1.94 \times 10^4\ \text{N}$

## Section 5.4

**1.** **a)** $\vec{a} = 0$

Therefore, $F_n = F_g$.

$F_n = (9.81)(70)$

$F_n = 686.7\ \text{N}$

$F_n \cong 6.9 \times 10^2\ \text{N}$

**b)** $\vec{a} = 0$

Therefore, $F_n = F_g$.

$F_n = 6.9 \times 10^2\ \text{N}$

**c)** $ma = F_n - F_g$

$(70\ \text{kg})(-2\ \text{m/s}^2) = F_n - (70\ \text{kg})(-9.81\ \text{m/s}^2)$

$F_n = 546.7\ \text{N}$

$F_n \cong 5.5 \times 10^2\ \text{N}$

**d)** $m(-9.81) = F_n - m(-9.81)$

$F_n = 0\ \text{N}$

## Section 5.5

**3.** **a)** There is a constant velocity; therefore,

$F_k = F$ and $F_k = \mu_k F_n$

$F = (0.5)(30\ \text{kg})(9.81\ \text{m/s}^2)$

$F = 147.15\ \text{N}$

$F = 1.5 \times 10^2\ \text{N}$

**b)** Since there is no motion, $F_s = F$.

$F = 100\ \text{N}$

**c)** $F_s = \mu_s F_n$

$$\mu_s = \frac{100\ \text{N}}{(30\ \text{kg})(9.81\ \text{m/s}^2)}$$

$\mu_s = 0.34$

**d)** $F_n = 20 + (30\ \text{kg})(9.81\ \text{m/s}^2)$

$F_n = 314\ \text{N}$

**i)** $F = (0.5)(314.3\ \text{N})$

$F = 157.15\ \text{N}$

$F = 1.6 \times 10^2\ \text{N}$

**ii)** $F = 100\ \text{N}$

**iii)** $\mu_s = \dfrac{100\ \text{N}}{314.3\ \text{N}}$

$\mu_s = 0.32$

**e)** $F_n = 274.3\ \text{N}$

**i)** $F = (0.5)(274.3\ \text{N})$

$F = 137.15\ \text{N}$

$F = 1.4 \times 10^2\ \text{N}$

**ii)** $F = 100\ \text{N}$

**iii)** $\mu_s = \dfrac{100\ \text{N}}{274.3\ \text{N}}$

$\mu_s = 0.36$

## Section 5.6

**2.** **a)** $F = 10\ \text{N}$

$x = 1.2\ \text{cm}$

$x = 0.012\ \text{m}$

$$k = \frac{10\ \text{N}}{0.012\ \text{m}}$$

$k = 8.3 \times 10^2\ \text{N/m}$

**b)** $k = 3.0\ \text{N/m}$

$x = 550\ \text{mm}$

$x = 0.55\ \text{m}$

$F = (3.0\ \text{N/m})(0.55\ \text{m})$

$F = 1.65\ \text{N}$

$F \cong 1.7\ \text{N}$

**c)** $F = 20\ \text{N}$

$k = 3.0\ \text{N/m}$

$$x = \frac{20\ \text{N}}{3.0\ \text{N/m}}$$

$x = 6.7\ \text{m}$

**d)** $F = (2\ \text{kg})(9.81\ \text{m/s}^2)$

$F = 19.62\ \text{N}$

$x = 0.04\ \text{m}$

$k = 4.9 \times 10^2\ \text{N/m}$

## Section 6.1

**1.** The only two unbalanced forces are $F_{||}$ and $F_f$.

$F_{net} = F_{||} - F_f$ (eq. 1)

$F_{||} = F_g \sin 25°$ (eq. 2)

$F_f = \mu F_n$

$F_f = \mu F_g \cos 25°$ (eq. 3)

Substituting equations 2 and 3 into equation 1,

$F_{net} = F_g \sin 25° - \mu F_g \cos 25°$

$F_{net} = F_g(\sin 25° - \mu \cos 25°)$

$F_{net} = (2.0\ \text{kg})(9.8\ \text{m/s}^2)(\sin 25° - \mu \cos 25°)$

$F_{net} = (19.6\ \text{N})(\sin 25° - \mu \cos 25°)$

$F_{net} = 6.51\ \text{N}$

$F_{net} = ma$

$6.51\ \text{N} = (2.0\ \text{kg})a$

$a = 3.26\ \text{m/s}^2$

$$\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$$

$$4.0\ \text{m} = \frac{1}{2}(3.26\ \text{m/s}^2)\Delta t^2$$

$$\Delta t = \sqrt{\frac{8.0\ \text{m}}{3.26\ \text{m/s}^2}}$$

$\Delta t = 1.6\ \text{s}$

**2.** Since there is no friction, the only force that prevents the CD case from going upward is the deceleration due to gravity, $F_{||}$.

$F_{net} = F_{||}$

$F_{net} = F_g \sin 20°$

Since $F_{net} = ma$,

$ma = mg \sin 20°$

$a = g \sin 20°$

$a = 3.35\ \text{m/s}^2$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$\Delta t = \frac{v_2 - v_1}{a}$$

$$\Delta t = \frac{4.0\ \text{m/s}}{3.35\ \text{m/s}^2}$$

$\Delta t = 1.2\ \text{s}$

**3.** To find the distance the skateboarder travels up the ramp, we need to find the velocity of the skateboarder entering the second ramp at $v_1$. Since there is no change in velocity on the horizontal floor, $v_1 = v_2$.

For the acceleration on ramp 1,

$$F_{net} = F_{||}$$
$$ma = mg \sin 30°$$
$$a = g \sin 30°$$
$$a = 4.9 \text{ m/s}^2$$
$$v_2^2 = v_1^2 + 2ad$$
$$v_2^2 = 0 \text{ m/s} + 2(4.9 \text{ m/s}^2)(10 \text{ m})$$
$$v_2 = 9.9 \text{ m/s}$$

For the deceleration on ramp 2,

$$F_{net} = F_{||} - \mu F_n$$
$$ma = mg \sin 25° - (0.1)mg \cos 25°$$
$$a = -5.02 \text{ m/s}^2$$

For $\Delta d$,

$$v_3^2 = v_2^2 + 2a\Delta d$$
$$(0 \text{ m/s})^2 = (9.9 \text{ m/s})^2 + 2(-5.02 \text{ m/s}^2)\Delta d$$
$$\Delta d = 9.8 \text{ m}$$

**4.** $F_{net} = m(0.60g)$

$F_{net}$ also equals the sum of all forces in the ramp surface direction:

$$\vec{F}_{net} = \vec{F}_{||} + \vec{F}_f + \vec{F}_{engine}$$
$$m(0.60g) = mg \sin 30° - \mu F_n + F_{engine}$$
$$m(0.60g) = mg \sin 30° - (0.28)mg \cos 30° + F_{engine}$$
$$F_{engine} = (0.60)mg - mg \sin 30° + (0.28)mg \cos 30°$$
$$F_{engine} = mg(0.60 - \sin 30° + (0.28) \cos 30°)$$
$$F_{engine} = 3.36m \text{ N}$$

## Section 6.2

**1. a)** For $m_1$,

$$F_{net} = m_1 a$$
$$T - \mu m_1 g = m_1 a \qquad \text{(eq. 1)}$$

For $m_2$,

$$F_{net} = m_2 a$$
$$m_2 g - T = m_2 a \qquad \text{(eq. 2)}$$

Adding equations 1 and 2,

$$m_2 g - \mu m_1 g = a(m_1 + m_2)$$
$$a = \frac{m_2 g - \mu m_1 g}{m_1 + m_2}$$
$$a = \frac{(15 \text{ kg})(9.8 \text{ m/s}^2) - 0.20(10 \text{ kg})(9.8 \text{ m/s}^2)}{25 \text{ kg}}$$
$$\vec{a} = 5.1 \text{ m/s}^2 \text{ [right]}$$

Substitute $a$ into equation 2:

$$T = m_2 g - m_2 a$$
$$T = 71 \text{ N}$$

**b)** For $m_1$,

$$F_{net} = m_1 a$$
$$T - m_1 g \sin 35° - \mu m_1 g \cos 35° = m_1 a \quad \text{(eq. 1)}$$

For $m_2$,

$$F_{net} = m_2 a$$
$$m_2 g - T = m_2 a \quad \text{(eq. 2)}$$

Adding equations 1 and 2,

$$m_2 g - m_1 g \sin 35° - \mu m_1 g \cos 35° = a(m_1 + m_2)$$
$$a = \frac{g(m_2 - m_1 \sin 35° - \mu m_1 \cos 35°)}{m_1 + m_2}$$
$$a = \frac{(9.8 \text{ m/s}^2)[5.0 \text{ kg} - (3.0 \text{ kg}) \sin 35° - 0.18(3.0 \text{ kg}) \cos 35°]}{8.0 \text{ kg}}$$
$$\vec{a} = 3.5 \text{ m/s}^2 \text{ [right]}$$

Substitute $a$ into equation 2:

$$T = m_2 g - m_2 a$$
$$T = (5.0 \text{ kg})(9.8 \text{ m/s}^2) - (5.0 \text{ kg})(3.5 \text{ m/s}^2)$$
$$T = 32 \text{ N}$$

**c)** For $m_1$,

$$F_{net} = m_1 a$$
$$T - m_1 g \sin 40° - \mu_1 m_1 g \cos 40° = m_1 a \quad \text{(eq. 1)}$$

For $m_2$,

$$F_{net} = m_2 a$$
$$m_2 g \sin 60° - T - \mu_2 m_2 g \cos 60° = m_2 a \quad \text{(eq. 2)}$$

Adding equations 1 and 2,

$$m_2 g \sin 60° - \mu_2 m_2 g \cos 60° - m_1 g \sin 40° - \mu_1 m_1 g \cos 40° = a(m_1 + m_2)$$
$$a = \frac{g(m_2 \sin 60° - \mu_2 m_2 \cos 60° - m_1 \sin 40° - \mu_1 m_1 \cos 40°)}{m_1 + m_2}$$
$$a = \frac{(9.8 \text{ m/s}^2)[(30 \text{ kg}) \sin 60° - 0.30(30 \text{ kg}) \cos 60° - (20 \text{ kg}) \sin 40° - 0.20(20 \text{ kg}) \cos 40°]}{50 \text{ kg}}$$
$$\vec{a} = 1.1 \text{ m/s}^2 \text{ [right]}$$

Substitute $a$ into equation 1:

$T = m_1a + m_1g \sin 40° + \mu_1 m_1 g \cos 40°$

$T = (20 \text{ kg})(1.1 \text{ m/s}^2) + (20 \text{ kg})(9.8 \text{ m/s}^2) \sin 40° + (0.20)(20 \text{ kg})(9.8 \text{ m/s}^2) \cos 40°$

$T = 1.8 \times 10^2 \text{ N}$

**d)** For $m_1$,

$$F_{net} = m_1a$$

$$m_1g \sin 30° - T_1 = m_1a \qquad \text{(eq. 1)}$$

For $m_2$,

$$F_{net} = m_2a$$

$$T_1 - T_2 = m_2a \qquad \text{(eq. 2)}$$

For $m_3$,

$$F_{net} = m_3a$$

$$T_2 - m_3g = m_3a \qquad \text{(eq. 3)}$$

Adding equations 1, 2, and 3,

$m_1g \sin 30° - m_3g = a(m_1 + m_2 + m_3)$

$$a = \frac{m_1g \sin 30° - m_3g}{m_1 + m_2 + m_3}$$

$$a = \frac{(30 \text{ kg})(9.8 \text{ m/s}^2)\sin 30° - (10 \text{ kg})(9.8 \text{ m/s}^2)}{60 \text{ kg}}$$

$\vec{a} = 0.82 \text{ m/s}^2$ [left]

Substitute $a$ into equation 3:

$T_2 = m_3a + m_3g$

$T_2 = (10 \text{ kg})(0.82 \text{ m/s}^2) + (10 \text{ kg})(9.8 \text{ m/s}^2)$

$T_2 = 106 \text{ N}$

Substitute $a$ into equation 2:

$T_1 = m_2a + T_2$

$T_1 = 106 \text{ N} - (20 \text{ kg})(-0.82 \text{ m/s}^2)$

$T_1 = 122 \text{ N}$

## Section 6.3

**1.** $a_c = \dfrac{v^2}{r}$

$a_c = \dfrac{(25 \text{ m/s})^2}{30 \text{ m}}$

$a_c = 21 \text{ m/s}^2$

**2.** $v = \dfrac{d}{t}$

$v = 25\left(\dfrac{2\pi r}{t}\right)$

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

$a_c = \dfrac{2500\pi^2 r}{t^2}$

$a_c = \dfrac{2500\pi^2(1.3 \text{ m})}{(60 \text{ s})^2}$

$a_c = 8.9 \text{ m/s}^2$

**3.** $a_c = \dfrac{v^2}{r}$

**a)** If $v$ is doubled, $a_c$ increases by a factor of 4.

**b)** If the radius is doubled, $a_c$ is halved.

**c)** If the radius is halved, $a_c$ is doubled.

**4. a)** $v = \dfrac{2\pi r}{T}$, where

$r = 3.8 \times 10^5 \text{ km}$

$r = 3.8 \times 10^8 \text{ m}$

$T = 27.3 \text{ days}$

$T = 2.36 \times 10^6 \text{ s}$

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

$a_c = \dfrac{4\pi^2 r}{T^2}$

$a_c = \dfrac{4\pi^2(3.8 \times 10^8 \text{ m})}{(2.36 \times 10^6 \text{ s})^2}$

$a_c = 2.7 \times 10^{-3} \text{ m/s}^2$

**b)** The Moon is accelerating toward Earth.

**c)** The centripetal acceleration is caused by the gravitational attraction between Earth and the Moon.

**5.** $r = 60 \text{ mm}$

$r = 0.06 \text{ m}$

$a_c = 1.6 \text{ m/s}^2$

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

$v = \sqrt{a_c r}$

$v = 0.31 \text{ m/s}$

**6.** Since $d = 500$ m, $r = 250$ m

$v = \dfrac{2\pi r}{T}$

$f = \dfrac{1}{T}$

$v = 2\pi r f$

$a_c = g$

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

$g = 4\pi^2 r f^2$

$f = \sqrt{\dfrac{g}{4\pi^2 r}}$

$f = \sqrt{\dfrac{9.8 \text{ m/s}^2}{4\pi^2(250 \text{ m})}}$

$f = 0.0315 \text{ rotations/s}$

$f = (0.0315 \text{ rotations/s}) \times \left(\dfrac{60 \text{ s}}{1 \text{ min}}\right)\left(\dfrac{60 \text{ min}}{1 \text{ h}}\right)\left(\dfrac{24 \text{ h}}{1 \text{ day}}\right)$

$f = 2724 \text{ rotations/day}$

## Section 6.4

**1.** **a)** $v = \dfrac{d}{t}$

$v = \dfrac{20(2\pi r)}{180\text{ s}}$

$v = 3.5\text{ m/s}$

**b)** $F_c = ma_c$

$F_c = (10\text{ kg})\dfrac{v^2}{r}$

$F_c = 24\text{ N}$

**c)** Friction holds the child to the merry-go-round and causes the child to undergo circular motion.

**2.** Tension acts upward and the gravitational force ($mg$) acts downward. $F_c = F_{net}$ and causes Tarzan to accelerate toward the point of rotation (at this instant, the acceleration is straight upward).

$$F_c = ma_c$$
$$T - mg = \frac{mv^2}{r}$$
$$T = m\left(\frac{v^2}{r} + g\right)$$
$$T = (60\text{ kg})\left[\frac{(4\text{ m/s})^2}{2.5\text{ m}} + 9.8\text{ m/s}^2\right]$$
$$T = 9.7 \times 10^2\text{ N}$$

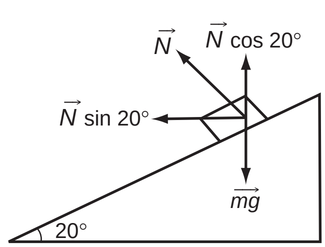
**3.** Both tension and gravity act downward.

$$F_c = ma_c$$
$$T + mg = \frac{mv^2}{r}$$

When $T = 0$,

$$mg = \frac{mv^2}{r}$$
$$v = \sqrt{gr}$$
$$v = \sqrt{(9.8\text{ m/s}^2)(1.2\text{ m})}$$
$$v = 3.4\text{ m/s}$$

**4.** **a)**




**b)** $F_c = mg\tan 20°$

$$\frac{mv^2}{r} = mg\tan 20°$$
$$v = \sqrt{rg\tan 20°}$$
$$v = \sqrt{(100\text{ m})(9.8\text{ m/s}^2)\tan 20°}$$
$$v = 19\text{ m/s}$$

**c)** The horizontal component of the normal force provides the centre-seeking force.

**d)** If the velocity were greater (and the radius remained the same), the car would slide up the bank unless there was a frictional force to provide an extra centre-seeking force. The normal force would not be sufficient to hold the car along its path.

**e)** Friction also provides a centre-seeking force.

**5.** $G = 6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2$,
$m_E = 5.98 \times 10^{24}\text{ kg}$

$$F_c = m_M a_c$$
$$\frac{Gm_E m_M}{r^2} = \frac{m_M v^2}{r}$$
$$Gm_E = v^2 r$$
$$Gm_E = \frac{4\pi^2 r^3}{T^2}\text{, where } v = \frac{2\pi r}{T}$$
$$T = \sqrt{\frac{4\pi^2 r^3}{Gm_E}}$$
$$T = \sqrt{\frac{4\pi^2(3.4 \times 10^8\text{ m})^3}{(6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\text{ kg})}}$$
$$T = 1.97 \times 10^6\text{ s}$$
$$T = 22.8\text{ days}$$

**6.** $G = 6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2$,
$m_E = 5.98 \times 10^{24}\text{ kg}$, $r_E = 6.37 \times 10^6\text{ m}$

$$F_c = m_H a_c$$
$$\frac{Gm_E m_H}{r^2} = \frac{m_H v^2}{r}$$
$$Gm_E = v^2 r$$
$$v = \sqrt{\frac{Gm_E}{r}}$$
$$r = \text{height of orbit} + r_E$$
$$r = 6.00 \times 10^5\text{ m} + 6.37 \times 10^6\text{ m}$$
$$r = 6.97 \times 10^6\text{ m}$$
$$v = \sqrt{\frac{Gm_E}{r}}$$
$$v = \sqrt{\frac{(6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\text{ kg})}{6.97 \times 10^6\text{ m}}}$$
$$v = 7.57 \times 10^3\text{ m/s}$$

7. $G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
$m_M = (0.013)m_E$
$m_M = 7.77 \times 10^{22}$ kg
$r_M = 1.74 \times 10^6$ m

$$F_c = m_{Apollo}a_c$$
$$\frac{Gm_M m_{Apollo}}{r^2} = \frac{m_{Apollo}v^2}{r}$$
$$Gm_M = v^2 r$$
$$Gm_M = \frac{400\pi^2 r^3}{T^2},\text{ where } v = \frac{10(2\pi r)}{T}$$

$r =$ height of orbit $+ r_M$
$r = 1.9 \times 10^5\ \text{m} + 1.74 \times 10^6$ m
$r = 1.93 \times 10^6$ m

$$T = \sqrt{\frac{400\pi^2 r^3}{Gm_M}}$$
$$T = \sqrt{\frac{400\pi^2(1.93 \times 10^6\ \text{m})^3}{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(7.77 \times 10^{22}\ \text{kg})}}$$
$$T = 7.4 \times 10^4\ \text{s}$$

## Section 6.5

1. a) $M_{Sun} = 1.99 \times 10^{30}$ kg,
$T = 76.1\ \text{a} = 2.4 \times 10^9$ s
$T^2 = ka^3$

$$a = \left[\frac{(2.4 \times 10^9\ \text{s})^2}{\frac{4\pi^2}{GM}}\right]^{\frac{1}{3}}$$
$$a = \left[\frac{(2.4 \times 10^9\ \text{s})^2}{\frac{4\pi^2}{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(1.99 \times 10^{30}\ \text{kg})}}\right]^{\frac{1}{3}}$$
$$a = 2.7 \times 10^{12}\ \text{m}$$

b) 0.97

c) $v = \frac{d}{t}$
$$v = \frac{2\pi(2.69 \times 10^{12}\ \text{m})}{2.4 \times 10^9\ \text{s}}$$
$$v = 7031\ \text{m/s}$$

2. $r_{altitude} = 10\ 000\ \text{km} = 1 \times 10^7$ m,
$r_{Jupiter} = 7.15 \times 10^7$ m, $m_{Jupiter} = 1.9 \times 10^{27}$ kg

$$v_{esc} = \sqrt{\frac{2GM}{r}}$$
$$v_{esc} = \sqrt{\frac{2(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(1.9 \times 10^{27}\ \text{kg})}{7.15 \times 10^7\ \text{m} + 1 \times 10^7\ \text{m}}}$$
$$v_{esc} = 56\ 000\ \text{m/s}$$

3. $m_{Moon} = 7.36 \times 10^{22}$ kg,
$m_{Earth} = 5.98 \times 10^{24}$ kg, $r = 3.82 \times 10^8$ m

$$v_{esc} = \sqrt{\frac{2GM}{r}}$$
$$v_{esc} = \sqrt{\frac{2(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})}{3.82 \times 10^8\ \text{m}}}$$
$$v_{esc} = 1445\ \text{m/s}$$

To find the current speed of the Moon,

$$\frac{1}{2}mv^2 = \frac{GMm}{2r}$$
$$v = \sqrt{\frac{GM}{r}}$$
$$v = \sqrt{\frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})}{3.82 \times 10^8\ \text{m}}}$$
$$v = 1022\ \text{m/s}$$

To find the additional speed required for escape,

$v_{add\ esc} = 1445\ \text{m/s} - 1022$ m/s
$v_{add\ esc} = 423$ m/s

4. Geostationary Earth satellites orbit constantly above the same point on Earth because their period is the same as that of Earth.

5. $M = 5.98 \times 10^{24}$ kg, $r = 6.378 \times 10^6$ m,
$v = 25$ m/s

To find the semimajor axis,

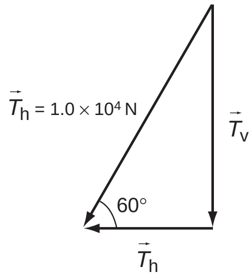
$$E_T = E_p + E_k$$
$$\frac{-GMm}{2a} = \frac{-GMm}{r} + \frac{1}{2}mv^2$$
$$\frac{-GM}{a} = \frac{-2GM}{r} + v^2$$
$$\frac{1}{a} = \frac{2}{r} - \frac{v^2}{GM}$$
$$\frac{1}{a} = \frac{2GM - v^2 r}{GMr}$$
$$a = \frac{GMr}{2GM - v^2 r}$$
$$a = \frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})(6.378 \times 10^6\ \text{m})}{2(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg}) - (25\ \text{m/s})^2(6.378 \times 10^6\ \text{m})}$$
$$a = 3.19 \times 10^6\ \text{m}$$

To find the period,

$$T^2 = ka^3,\text{ where } k = \frac{4\pi^2}{GM}$$
$$T = \sqrt{\frac{4\pi^2(3.19 \times 10^6\ \text{m})^3}{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})}}$$
$$T = 1792\ \text{s}$$

# Section 7.3

**1.**




Horizontal:

$T_h = T \cos 60°$

$T_h = (1.0 \times 10^4 \text{ N}) \cos 60°$

$T_h = 5.0 \times 10^3 \text{ N}$

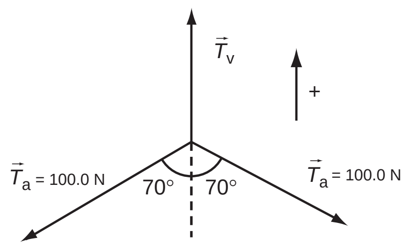
Vertical:

$T_v = T \sin 60°$

$T_v = (1.0 \times 10^4 \text{ N}) \sin 60°$

$T_v = 8.7 \times 10^3 \text{ N}$

**2.**




$F_{net} = T_v + T_A + T_A$

$F_{net} = ma$

$F_{net} = 0$

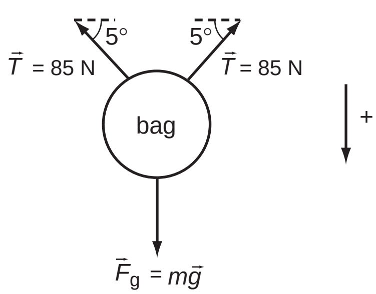
$T_v = -T_A - T_A$

$T_v = -2T_A$

$T_v = -2(-100.0 \text{ N}) \cos 70°$

$T_v = 68.4 \text{ N}$

**3. a)**




**b)** $d_v = (1.5 \text{ m}) \sin 1.5°$

$d_v = 0.039 \text{ m}$

$d_v = 3.9 \text{ cm}$

**c)** $F_{net} = 2T_v + F_g$

$F_{net} = ma$

$F_{net} = 0$

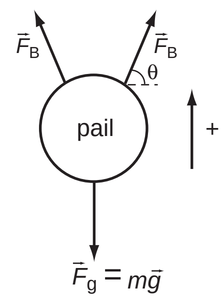
$F_g = -2T_v$

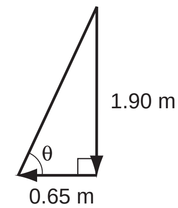
$$m = \frac{-2T \sin \theta}{g}$$

$$m = \frac{-2(85 \text{ N}) \sin 1.5°}{-9.8 \text{ N/kg}}$$

$m = 0.45 \text{ kg}$

**4. a)**




$$\tan \theta = \frac{1.90 \text{ m}}{0.650 \text{ m}}$$

$\theta = 71.1°$

$F_{net} = mg + 2F_{Bv}$

$F_{net} = ma$

$F_{net} = 0$

$0 = mg + 2F_B \sin \theta$

$$F_B = \frac{-mg}{2 \sin \theta}$$

$$F_B = \frac{-(4.0 \text{ kg})(-9.8 \text{ N/kg})}{2 \sin 71.1°}$$

$F_B = 20.7 \text{ N}$

**b)** $F_h = F_B \cos \theta$

$F_h = (20.7 \text{ N}) \cos 71.1°$

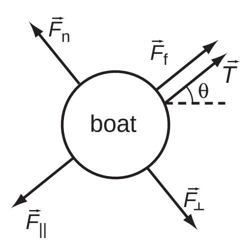
$F_h = 6.71 \text{ N}$

**c)** $F_v = F_B \sin \theta$

$F_v = (20.7 \text{ N}) \sin 71.1°$

$\vec{F}_v = 19.6$ N [down] (not including the weight of the beams)

**6.**




$F_{||} = mg \sin \theta$

$F_f = \mu mg \cos \theta$

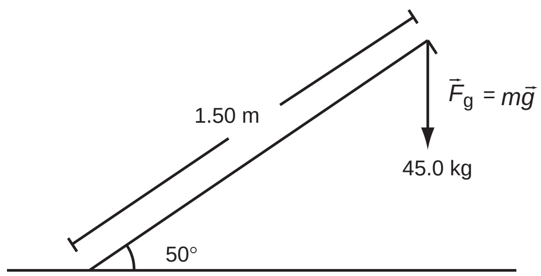
$F_{net} = T + F_f + F_{||}$

$F_{net} = ma$

$F_{\text{net}} = 0$
$T = -F_{||} + F_f$
$T = -mg \sin \theta + \mu mg \cos \theta$
$T = -mg(\sin \theta - \mu \cos \theta)$
$T = -(400.0 \text{ kg})(9.8 \text{ N/kg})$
$(\sin 30° - (0.25) \cos 30°)$
$T = 1.11 \times 10^3 \text{ N}$

## Section 7.4

**1. a)**




**b)** $\tau = rF \sin \theta$
$\tau = rmg \sin \theta$
$\tau = (1.50 \text{ m})(45.0 \text{ kg})(9.8 \text{ N/kg}) \sin 40°$
$\tau = 425 \text{ N} \cdot \text{m}$

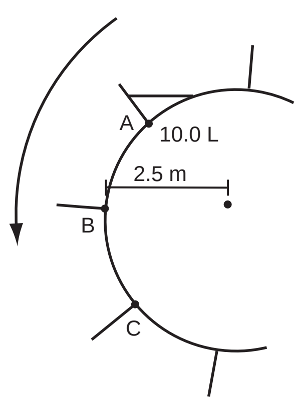
**2. a)** $\tau = 2.0 \times 10^3 \text{ N} \cdot \text{m}$
$r = 1.5 \text{ m}$
$\theta = 90°$
$F = ?$
$\tau = rF \sin \theta$

$$F = \frac{\tau}{r \sin \theta}$$

$$F = \frac{2.0 \times 10^3 \text{ N} \cdot \text{m}}{(1.5 \text{ m}) \sin 90°}$$

$F = 1.3 \times 10^3 \text{ N}$

**3.**




**a)** $V_w = 10.0 \text{ L}$
$\rho_w = 1000 \text{ kg/m}^3$

$$V_w = (10.0 \text{ L})\left(\frac{1000 \text{ cm}^3}{1 \text{ L}}\right)\left(\frac{1 \text{ m}^3}{1.00 \times 10^6 \text{ cm}^3}\right)$$

$V_w = 0.0100 \text{ m}^3$
$m_w = \rho_w \cdot V_w$
$m_w = (1000 \text{ kg/m}^3)(0.0100 \text{ m}^3)$
$m_w = 10.0 \text{ kg}$
$F_g = mg$
$F_g = (10.0 \text{ kg})(9.8 \text{ N/kg})$
$F_g = 98.0 \text{ N}$

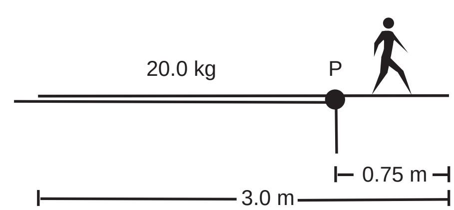
**b)** Position B provides the greatest torque because the weight is directed at 90° to the wheel's rotation.

**c)** $\tau_A = rF \sin \theta$
$\tau_A = (2.5 \text{ m})(10.0 \text{ kg})(9.8 \text{ N/kg}) \sin 45°$
$\tau_A = 1.7 \times 10^2 \text{ N} \cdot \text{m}$
$\tau_B = rF \sin \theta$
$\tau_B = (2.5 \text{ m})(10.0 \text{ kg})(9.8 \text{ N/kg}) \sin 90°$
$\tau_B = 2.4 \times 10^2 \text{ N} \cdot \text{m}$
$\tau_C = \tau_A$
$\tau_C = 1.7 \times 10^2 \text{ N} \cdot \text{m}$

**d)** A larger-radius wheel or more and larger compartments would increase the torque.

## Section 7.5

**1.**




$\theta = 90°$
$r_1 = ?$
$m_1 = 45.0 \text{ kg}$

$$m_2 = 20.0 \text{ kg}\left(\frac{0.75}{3.0}\right)$$

$m_2 = 5.0 \text{ kg}$

$$r_2 = \frac{0.75 \text{ m}}{2}$$

$r_2 = 0.375 \text{ m}$
$m_3 = 20.0 \text{ kg} - m_2$
$m_3 = 15.0 \text{ kg}$

$$r_3 = \frac{3.0\text{ m} - 0.75\text{ m}}{2}$$

$$r_3 = 1.12\text{ m}$$

$$0 = \tau_1 + \tau_2 + \tau_3$$

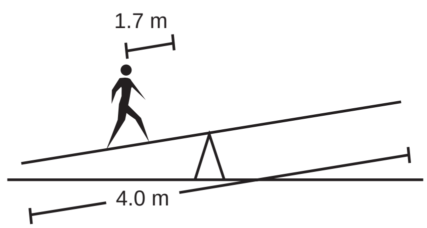
$$0 = r_1F_1 \sin\theta_1 + r_2F_2 \sin\theta_2 - r_3F_3 \sin\theta_3$$

$$r_1 = \frac{r_3F_3 - r_2F_2}{F_1}$$

$$r_1 = \frac{(1.12\text{ m})(15.0\text{ kg})(9.8\text{ N/kg}) - (0.375\text{ m})(5.0\text{ kg})(9.8\text{ N/kg})}{(45.0\text{ kg})(9.8\text{ N/kg})}$$

$$r_1 = 0.332\text{ m}$$

**2. a)**



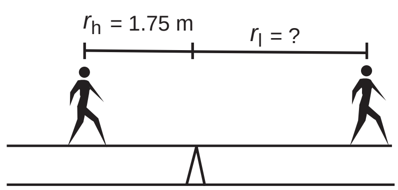

$$\tau_{\text{t-t}} = rF\sin\theta$$

$$\tau_{\text{t-t}} = \frac{(1.0\text{ m})(30.0\text{ kg})(9.8\text{ N/kg})}{2}$$

$$\tau_{\text{t-t}} = 147\text{ N}\cdot\text{m}$$

This torque applies to both sides of the teeter-totter, so the torques balance each other.

**b)**




$$\tau_H - \tau_L = 0$$

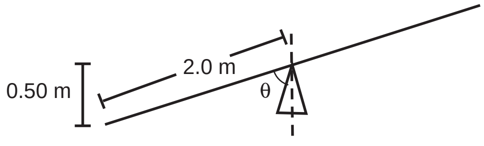
$$\tau_L = \tau_H$$

$$r_L = \frac{r_H m_H g}{m_L g}$$

$$r_L = \frac{(1.75\text{ m})(45.0\text{ kg})}{30.0\text{ kg}}$$

$$r_L = 2.63\text{ m}$$

**c)**




$$\cos\theta = \frac{0.5\text{ m}}{2.0\text{ m}}$$

$$\theta = 75.5°$$

At the horizontal position:

$$\tau_H = (1.75\text{ m})(45\text{ kg})(9.8\text{ N/kg})$$

$$\tau_H = 7.7 \times 10^2\text{ N}\cdot\text{m}$$

At maximum height:

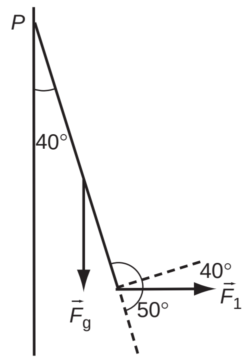
$$\tau_H = (1.75\text{ m})(45\text{ kg})(9.8\text{ N/kg})\sin 75.5°$$

$$\tau_H = 7.5 \times 10^2\text{ N}\cdot\text{m}$$

$$\% = \frac{(7.7 \times 10^2\text{ N}\cdot\text{m} - 7.5 \times 10^2\text{ N}\cdot\text{m})}{7.7 \times 10^2\text{ N}\cdot\text{m}} \times 100$$

$$\% = 2.6\%$$

**3.**




**a)** $\vec{\tau}_1 + \vec{\tau}_2 = 0$

$$r_1F_1\sin\theta = r_{cm}F_g\sin\theta$$

$$F_1 = \frac{r_{cm}F_g\sin\theta}{r_1\sin\theta}$$

$$F_1 = \frac{(0.375\text{ m})(5.00\text{ kg})(9.8\text{ N/kg})}{0.75\text{ m}}$$

$$\vec{F}_1 = 24.5\text{ N}$$

**b)** $F_{rv} + F_{v2} = 0$

$$F_{rv} = -F_{v2}$$

$$F_{rv} = -(5.00\text{ kg})(-9.8\text{ N/kg})$$

$$\vec{F}_{rv} = 49\text{ N [up]}$$

$$F_{rh} + F_{h1} = 0$$

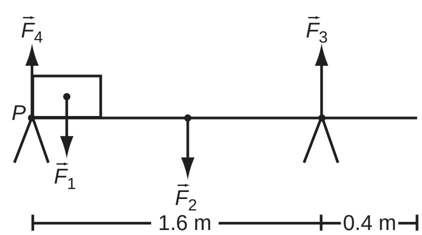
$$F_{rh} = -F_{h1}$$

$$F_{rh} = -24.5\text{ N}$$

$$\vec{F}_{rh} = 24.5\text{ N [left]}$$

The vertical reaction force is 49 N [up] and the horizontal reaction force is 24.5 N [left].

**4.**




$$\vec{\tau}_1 + \vec{\tau}_2 + \vec{\tau}_3 = 0$$

$$r_1F_1 + r_2F_2 + r_3F_{R3} = 0$$

$$r_1 = \frac{0.75\text{ m}}{2}$$

$$r_1 = 0.375\text{ m}$$

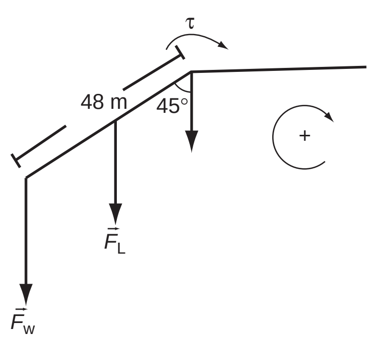
$$r_2 = \frac{2.0\text{ m}}{2}$$
$$r_2 = 1.0\text{ m}$$
$$r_3 = 1.60\text{ m}$$
$$\theta = 90°$$
$$\sin\theta = 1$$
$$F_3 = \frac{-r_1F_1 - r_2F_2}{r_3}$$
$$F_3 = \frac{-(0.375\text{ m})(120.0\text{ kg})(9.8\text{ N/kg}) - (1.0\text{ m})(5.0\text{ kg})(9.8\text{ N/kg})}{1.60\text{ m}}$$
$$\vec{F}_3 = 306\text{ N [up]}$$
$$F_4 = F_1 + F_2 - F_3$$
$$F_4 = (120.0\text{ kg})(9.8\text{ N/kg}) + (5.0\text{ kg})(9.8\text{ N/kg}) - 306\text{ N}$$
$$\vec{F}_{\text{RP}} = 919\text{ N [up]}$$

Left saw horse: 919 N [up]

Right saw horse: 306 N [up]

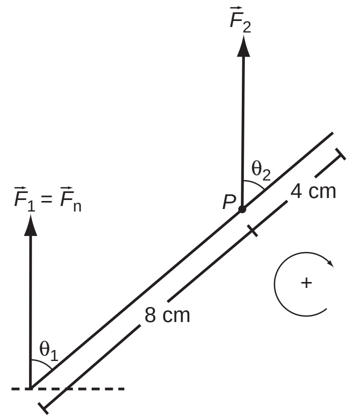
## Section 7.6

**1.**




$$\theta = 45°$$
$$r_w = 48.0\text{ cm}$$
$$r_w = 0.480\text{ m}$$
$$m_w = 10.0\text{ kg}$$
$$r_L = \frac{48.0\text{ cm}}{2}$$
$$r_L = 24.0\text{ cm}$$
$$r_L = 0.240\text{ m}$$
$$m_L = 5.00\text{ kg}$$
$$\vec{\tau} + \vec{\tau}_w + \vec{\tau}_L = 0$$
$$\tau = -\tau_w - \tau_L$$
$$\tau = -(-r_wF_w\sin 45°) - (-r_LF_L\sin 45°)$$
$$\tau = (0.480\text{ m})(10.0\text{ kg})(9.8\text{ N/kg})\sin 45° + (0.240\text{ m})(5.00\text{ kg})(9.8\text{ N/kg})\sin 45°$$
$$\vec{\tau} = 41.6\text{ N}\cdot\text{m [clockwise]}$$

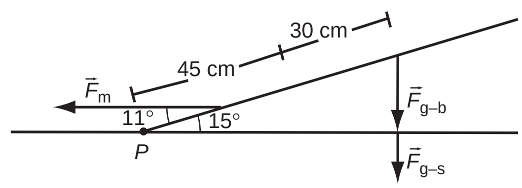
**2.**




$$\vec{\tau}_1 + \vec{\tau}_2 = 0$$
$$\tau_2 = -\tau_1$$
$$\tau_2 = \tau_1$$
$$r_2F_2\sin\theta_2 = r_1F_1\sin\theta_1$$
$$F_2 = \frac{r_1F_1\sin\theta_1}{r_2\sin\theta_2}$$
$$F_2 = \frac{(8.0\times10^{-2}\text{ m})(27\text{ kg})(9.8\text{ N/kg})\sin\theta}{(4.0\times10^{-2}\text{ m})\sin\theta}$$
$$F_2 = 529.2\text{ N}$$
$$F_2 = 5.3\times10^2\text{ N}$$

The angle makes no difference — it cancels out.

**3.**




**a)**
$$\vec{\tau}_m + \vec{\tau}_b + \vec{\tau}_s = 0$$
$$-\tau_m + \tau_b + \tau_s = 0$$
$$\tau_m = \tau_b + \tau_s$$
$$r_mF_m\sin\theta_m = r_bF_b\sin\theta_b + r_sF_s\sin\theta_s$$
$$F_m = \frac{r_bF_b\sin\theta_b + r_sF_s\sin\theta_s}{r_m\sin\theta_m}$$
$$F_m = \frac{r_bm_bg\sin\theta_b + r_sm_sg\sin\theta_s}{r_m\sin\theta_m}$$
$$F_m = \frac{rg\sin\theta(m_b + m_s)}{r_m\sin\theta_m}$$
$$F_m = \frac{(75\times10^{-2}\text{ m})(9.8\text{ N/kg})\sin 75°[(0.57)85\text{ kg}+19.0\text{ kg}]}{(45\times10^{-2}\text{ m})\sin 11°}$$
$$F_m = 5.57\times10^3\text{ N (tension)}$$

Reaction forces:

$$0 = \vec{F}_{py} + \vec{F}_{my} + \vec{F}_{by} + \vec{F}_{sy}$$
$$F_{py} = -F_{my} - F_{by} - F_{sy}$$
$$F_{py} = -(-5.57 \times 10^3\ \text{N})(\sin 4°) - (19.0\ \text{kg})(-9.8\ \text{N/kg}) - (0.57)(85\ \text{kg})(-9.8\ \text{N/kg})$$
$$F_{py} = 1049.6\ \text{N}$$
$$\vec{F}_{py} = 1.05 \times 10^3\ \text{N [up]}$$
$$0 = \vec{F}_{px} + \vec{F}_{mx} + \vec{F}_{bx} + \vec{F}_{sx}$$
$$F_{px} = -F_{mx} - F_{bx} - F_{sx}$$
$$F_{px} = -(5.57 \times 10^3\ \text{N})(\cos 4°) - 0 - 0$$
$$\vec{F}_{px} = 5.55 \times 10^3\ \text{N [right]}$$

Horizontal force: $1.49 \times 10^3$ N [right]; vertical force: $7.65 \times 10^2$ N [up]

## Section 7.7

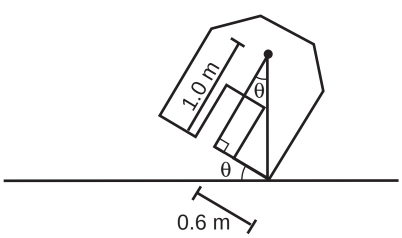
**1. a)** $\sin 43° = \dfrac{34.0\ \text{cm}}{h_{tipped}}$

$$h_{tipped} = \frac{34.0\ \text{cm}}{\sin 43°}$$
$$h_{tipped} = 49.8\ \text{cm}$$

**b)** $\tan 43° = \dfrac{34.0\ \text{cm}}{h_{straight}}$

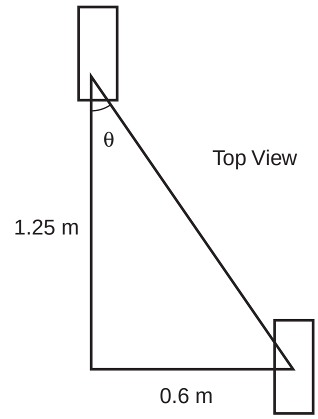
$$h_{straight} = \frac{34.0\ \text{cm}}{\tan 43°}$$
$$h_{straight} = 36.5\ \text{cm}$$

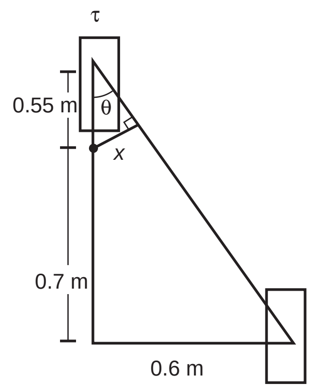
**2. a)** Four-wheeled ATV:

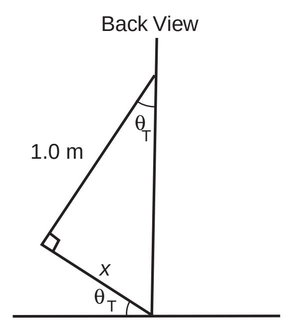



$$\tan \theta_T = \frac{0.60\ \text{m}}{1.0\ \text{m}}$$
$$\theta_T = 31.0°$$

Three-wheeled ATV:




$$\tan \theta = \frac{0.60\ \text{m}}{1.25\ \text{m}}$$
$$\theta = 25.64°$$
$$\sin \theta = \frac{x}{0.55\ \text{m}}$$
$$x = (0.55\ \text{m})(\sin 25.64°)$$
$$x = 0.237\ \text{m}$$
$$\tan \theta_T = \frac{0.237\ \text{m}}{1.00\ \text{m}}$$
$$\tan \theta_T = 13.3°$$

## Section 8.1

**1.** **a)** $p = (100\text{ kg})\left(\frac{12\text{ km}}{1\text{ h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{3600\text{ s}}\right)$

$p = 3.3 \times 10^2\text{ kg}\cdot\text{m/s}$

**b)** $m = 150$ tonne

$m = 150 \times 10^3\text{ kg}$

$v = \dfrac{30\text{ km/h}}{3.6\text{ m/s}}$

$v = 8.33\text{ m/s}$

$p = 1.2 \times 10^6\text{ kg}\cdot\text{m/s}$

**c)** $m = 8.7 \times 10^6\text{ kg}$

$v = 28\,000\left(\dfrac{1000}{3600}\right)$

$v = 7777.78\text{ m/s}$

$p = 6.8 \times 10^{10}\text{ kg}\cdot\text{m/s}$

## Section 8.2

**3.** **i)** $p = \frac{1}{2}(17\text{ N})(0.4\text{ s})$

$p = 3.4\text{ N}\cdot\text{s}$

Therefore, the impulse at 0.4 s is 3.4 N·s.

**ii)** $p = [\frac{1}{2}(25\text{ N})(1.2\text{ s})] - [\frac{1}{2}(8\text{ N})(0.2\text{ s})]$

$p = 15\text{ N}\cdot\text{s} - 0.8\text{ N}\cdot\text{s}$

$p = 14.2\text{ N}\cdot\text{s}$

Therefore, the impulse at 1.0 s is 14 N·s.

**4.** **a)** $J = (20\text{ kg})(3\text{ m/s})$

$J = 60\text{ kg}\cdot\text{m/s}$

**b)** $J = -60\text{ kg}\cdot\text{m/s}$

**c)** $J = 0\text{ kg}\cdot\text{m/s}$

**5.** **a)** $F = \dfrac{J}{\Delta t}$

$F = \dfrac{2.5 \times 10^3\text{ N}\cdot\text{s}}{0.2\text{ s}}$

$F = 1.3 \times 10^4\text{ N}$

**b)** $v_1 = 0$

$v_2 = 120\text{ km/h}$

$v_2 = 33.3\text{ m/s}$

$a = \dfrac{v_2 - v_1}{\Delta t}$

$a = \dfrac{33.3\text{ m/s} - 0\text{ m/s}}{0.2\text{ s}}$

$a = 166.7\text{ m/s}^2$

$\Delta d = v_1\Delta t + \dfrac{1}{2}a\Delta t^2$

$\Delta d = (0\text{ m/s})(0.2\text{ s}) + \dfrac{1}{2}(166.7\text{ m/s}^2)(0.2\text{ s})^2$

$\Delta d = 3.3\text{ m}$

**6.** **a)** $J = \dfrac{1}{2}bh$

$\vec{J} = \dfrac{1}{2}(5\text{ s})(25\text{ N [S]})$

$\vec{J} = 62.5\text{ N}\cdot\text{s [S]}$

**b)** $J =$ Area under triangle + rectangle

$\vec{J} = \dfrac{1}{2}(500 - 250\text{ N [W]})(3\text{ s}) +$

$(250\text{ N [W]})(6\text{ s})$

$\vec{J} = 1875\text{ N}\cdot\text{s [W]}$

**c)** $J =$ Area above − area below (counting the squares: approximately)

$J =$ (13 squares above) − (4 squares below)

$J = 9$ squares

Multiplying 9 by the length and width of each square,

$\vec{J} = 9(0.05\text{ s})(100\text{ N [E]})$

$\vec{J} = 45\text{ N}\cdot\text{s [E]}$

**7.** **b)** $F_{\text{thrust}} = v_{\text{gas}}\left(\dfrac{\Delta m}{\Delta t}\right)$

$= (2500\text{ m/s})(2.0\text{ kg/s})$

$= 5000\text{ N}$

$\Delta t = \dfrac{\Delta p}{F}$

$= \dfrac{780\text{ kg }(1000\text{ m/s} - 0\text{ m/s})}{5000\text{ N}}$

$= 156\text{ s}$

Therefore, the plane would take 156 s to reach a speed of 1000 m/s.

## Section 8.3

**1.** $m_1 = 1.5\text{ kg}$, $m_2 = 2.0\text{ kg}$

**a)** $1.5(3) + 2(0) = -1.5(1) + 2(v_{2f})$

$v_{2f} = 3.0\text{ m/s}$

**b)** $1.5(3) + 2(1.0) = 1.5(v_{2f}) + 2(2)$

$v_{2f} = 1.7\text{ m/s}$

**c)** $1.5(3) - 2(1) = 1.5(.5) + 2(v_{2f})$

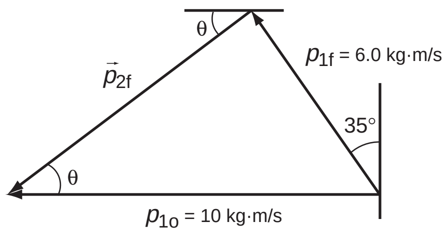
$v_{2f} = 0.88\text{ m/s}$

**d)** $1.5(3) - 2(1) = (3.5)v_f$

$v_f = 0.71\text{ m/s}$

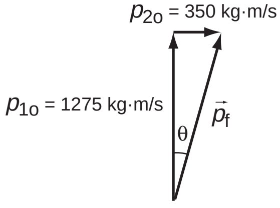
## Section 8.4

**1.** $m_1 = m_2 = 2.0\text{ kg}, \vec{v}_{1o} = 5.0\text{ m/s [W]}, \vec{v}_{2o} = 0,$
$\vec{v}_{1f} = 3.0\text{ m/s [N35°W]}, \vec{v}_{2f} = ?$
$\vec{p}_{1o} = (2.0\text{ kg})(5.0\text{ m/s [W]})$
$\vec{p}_{1o} = 10\text{ kg·m/s [W]}$
$\vec{p}_{1f} = (2.0\text{ kg})(3.0\text{ m/s [N35°W]})$
$\vec{p}_{1f} = 6.0\text{ kg·m/s [N35°W]}$
$\vec{p}_o = \vec{p}_f$
$\vec{p}_{1o} + \vec{p}_{2o} = \vec{p}_{1f} + \vec{p}_{2f}$, where $p_{2o} = 0$
$\vec{p}_{1o} = \vec{p}_{1f} + \vec{p}_{2f}$



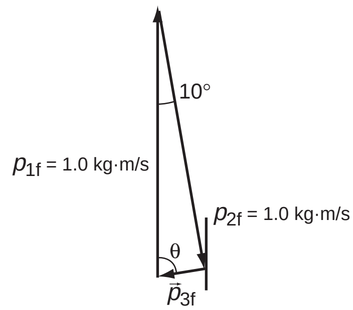

Using the cosine law,
$$p_{2f}^2 = (10\text{ kg·m/s})^2 + (6.0\text{ kg·m/s})^2 - 2(10\text{ kg·m/s})(6.0\text{ kg·m/s})\cos 55°$$
$p_{2f} = 8.2\text{ kg·m/s}$
$p = mv$
$$v_{2f} = \frac{8.2\text{ kg·m/s}}{2\text{ kg}}$$
$v_{2f} = 4.1\text{ m/s}$
Using the sine law to find direction,
$$\frac{\sin\theta}{6.0\text{ kg·m/s}} = \frac{\sin 55°}{8.2\text{ kg·m/s}}$$
$\theta = 37°$
$\vec{v}_{2f} = 4.1\text{ m/s [W37°S]}$

**2.** $m_1 = 85\text{ kg}, \vec{v}_{1o} = 15\text{ m/s [N]},$
$\vec{p}_{1o} = 1275\text{ kg·m/s [N]}, m_2 = 70\text{ kg},$
$\vec{v}_{2o} = 5\text{ m/s [E]}, \vec{p}_{2o} = 350\text{ kg·m/s [E]}$
$\vec{p}_o = \vec{p}_f$
$\vec{p}_{1o} + \vec{p}_{2o} = \vec{p}_f$



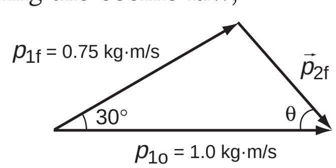

Using Pythagoras' theorem to solve for $p_f$,
$p_f^2 = (1275\text{ kg·m/s})^2 + (350\text{ kg·m/s})^2$
$p_f = 1322\text{ kg·m/s}$
$$\tan\theta = \frac{350\text{ kg·m/s}}{1275\text{ kg·m/s}}$$
$\theta = 15.4°$
$\vec{p}_f = m_f\vec{v}_f$
$$\vec{v}_f = \frac{1322\text{ kg·m/s [N15°E]}}{85\text{ kg} + 70\text{ kg}}$$
$\vec{v}_f = 8.5\text{ m/s [N15°E]}$

**3.** $m_1 = 0.10\text{ kg}, \vec{v}_{1f} = 10\text{ m/s [N]},$
$\vec{p}_{1f} = 1.0\text{ kg·m/s [N]}, m_2 = 0.20\text{ kg},$
$\vec{v}_{2f} = 5.0\text{ m/s [S10°E]},$
$\vec{p}_{2f} = 1.0\text{ kg·m/s [S10°E]}, m_3 = 0.20\text{ kg},$
$\vec{v}_{3f} = ?$
$\vec{p}_{To} = 0$
$\vec{p}_{To} = \vec{p}_{Tf}$
$0 = \vec{p}_{1f} + \vec{p}_{2f} + \vec{p}_{3f}$
Using the cosine law,




$$p_{3f}^2 = (1.0\text{ kg·m/s})^2 + (1.0\text{ kg·m/s})^2 - 2(1.0\text{ kg·m/s})(1.0\text{ kg·m/s})(\cos 10°)$$
$p_{3f} = 0.1743\text{ kg·m/s}$
$$v_{3f} = \frac{0.17\text{ kg·m/s}}{0.2\text{ kg}}$$
$v_{3f} = 0.87\text{ m/s}$
Using the sine law to find direction,
$$\frac{\sin\theta}{1.0\text{ kg·m/s}} = \frac{\sin 10°}{0.1743\text{ kg·m/s}}$$
$\theta = 85°$
$\vec{v}_{3f} = 0.87\text{ m/s [S85°W] or }0.87\text{ m/s [W5°S]}$

**4.** $m_1 = 0.5\text{ kg}, \vec{v}_{1o} = 2.0\text{ m/s [R]},$
$\vec{p}_{1o} = 1.0\text{ kg·m/s [R]}, m_2 = 0.30\text{ kg}, \vec{v}_{2o} = 0,$
$\vec{p}_{2o} = 0, \vec{v}_{1f} = 1.5\text{ m/s [R30°U]},$
$\vec{p}_{1f} = 0.75\text{ kg·m/s [R30°U]}, \vec{v}_{2f} = ?, \vec{p}_{2f} = ?$
$\vec{p}_{To} = \vec{p}_{Tf}$
$\vec{p}_{1o} + \vec{p}_{2o} = \vec{p}_{1f} + \vec{p}_{2f}$, where $p_{2o} = 0$
$\vec{p}_{1o} = \vec{p}_{1f} + \vec{p}_{2f}$
Using the cosine law,



$p_{2f}^2 = (1.0\ \text{kg}\cdot\text{m/s})^2 + (0.75\ \text{kg}\cdot\text{m/s})^2 - 2(1.0\ \text{kg}\cdot\text{m/s})(0.75\ \text{kg}\cdot\text{m/s})\cos 30°$

$p_{2f} = 0.513\ \text{kg}\cdot\text{m/s}$

$p = mv$

$v_{2f} = \dfrac{0.513\ \text{kg}\cdot\text{m/s}}{0.30\ \text{kg}}$

$v_{2f} = 1.7\ \text{m/s}$

Using the sine law to find direction,

$\dfrac{\sin\theta}{0.75\ \text{kg}\cdot\text{m/s}} = \dfrac{\sin 30°}{0.513\ \text{kg}\cdot\text{m/s}}$

$\theta = 47°$

$\vec{v}_{2f} = 1.7\ \text{m/s [R47°D] or } 1.7\ \text{m/s [D43°R]}$

## Section 9.2

**1.** **a)** $W = F\Delta d$

$W = (40\ \text{N})(0.15\ \text{m})$

$W = 6.0\ \text{J}$

**b)** $W = F\Delta d$

$W = mg\Delta d$

$W = (50\ \text{kg})(9.8\ \text{N/kg})(1.95\ \text{m})$

$W = 9.6 \times 10^2\ \text{J}$

**c)** $W = F\Delta d \cos\theta$

$W = (120\ \text{N})(4\ \text{m})(\cos 25°)$

$W = 4.4 \times 10^2\ \text{J}$

**2.** 45 km/h = 12.5 m/s

To find $\Delta d$,

$v_2^2 = v_1^2 + 2a\Delta d$

$\Delta d = \dfrac{(v_2^2 - v_1^2)}{2a}$

$\Delta d = \dfrac{(12.5\ \text{m/s})^2 - 0}{2(2.5\ \text{m/s}^2)}$

$\Delta d = 31.25\ \text{m}$

$W = F\Delta d$

$W = (5000\ \text{N})(31.25\ \text{m})$

$W = 1.6 \times 10^5\ \text{J}$

**3.** $W = F\Delta d \cos\theta$

$W = (78\ \text{N})(10\ \text{m})(\cos 55°)$

$W = 4.5 \times 10^2\ \text{J}$

**4.** $a = \dfrac{(v_2 - v_1)}{\Delta t}$

$a = \dfrac{(14\ \text{m/s} - 25\ \text{m/s})}{5.0\ \text{s}}$

$a = -2.2\ \text{m/s}^2$

$F = ma$

$F = (52\ 000\ \text{kg})(-2.2\ \text{m/s}^2)$

$F = -114\ 400\ \text{N}$

$\Delta d = \dfrac{(v_2^2 - v_1^2)}{2a}$

$\Delta d = \dfrac{[(14\ \text{m/s})^2 - (25\ \text{m/s})^2]}{2(-2.2\ \text{m/s}^2)}$

$\Delta d = 97.5\ \text{m}$

$W = F\Delta d$

$W = (-114\ 400\ \text{N})(97.5\ \text{m})$

$W = -1.1 \times 10^7\ \text{J}$

**5.** **a)** $W = F\Delta d$

$W = (175\ \text{N})(55\ \text{m})$

$W = 9625\ \text{J}$

**b)** The triangular areas above and below the axis are identical and cancel out, therefore,

$W = (0.040\ \text{m})(20\ \text{N})$

$W = 0.80\ \text{J}$

**6.** $F = ma$

$F = (3\ \text{kg})(9.8\ \text{N/kg})$

$F = 29.4\ \text{N}$

$\Delta d = \dfrac{W}{F}$

$\Delta d = \dfrac{480\ \text{J}}{29.4\ \text{N}}$

$\Delta d = 16\ \text{m}$

## Section 9.3

**1.** $m = 70\ \text{kg}$

$d = (0.2\ \text{m})(30)$

$d = 6\ \text{m}$

$F_g = 686.7\ \text{N}$

$t = 8.6\ \text{s}$

$W = \vec{F}\cdot\vec{d}$

$W = 4.1 \times 10^3\ \text{J}$

$P = \dfrac{W}{t}$

$P = 4.8 \times 10^2\ \text{N}\cdot\text{m/s}$

$P = 4.8 \times 10^2\ \text{J/s}$

**2.** $W = 0\ \text{J}$

## Section 9.4

**1.** **a)** $\text{kg}\cdot\text{m}^2/\text{s}^2$

**b)** $\text{N}\cdot\text{m}$

**3.** **a)** $E_k = \frac{1}{2}(2\ \text{kg})(4\ \text{m/s})^2$

$E_k = 16\ \text{J}$

**b)** $v = \dfrac{20}{3.6 \text{ m/s}}$

$v = 5.55$ m/s

$k = \frac{1}{2}(2 \text{ kg})(5.55 \text{ m/s})^2$

$k = 31$ J

**c)** $\Delta E_k = \frac{1}{2}m(v_2 - v_1)^2$

$\Delta E_k = \frac{1}{2}(2)(5.5 - 2.0)^2$

$\Delta E_k = 12.25$ J

$\Delta E_k = 12$ J

**d)** $W = E_k = Fd = (50 \text{ N})(2 \text{ m})$

$W = 100$ J

$W = 1.0 \times 10^2$ J

**e)** $E_k = 100$ J

$E_k = \frac{1}{2}m(v_2 - v_1)^2$

$100 \text{ J} = \frac{1}{2}m(v_2 - v_1)^2$

$v_2 = 10$ m/s

## Section 9.5

**1. a)** $E_p = (10)(9.81)(2.4)$

$E_p = 2.4 \times 10^2$ J

**b)** $E_p = (0.589)(9.81)(3.25)$

$E_p = 18.8$ J

**c)** $E_p = (10)(9.81)(135)$

$E_p = 1.32 \times 10^4$ J

**3.** $E_p = (4.54 \times 10^8 \text{ kg})(9.81)(55 \text{ m})$

$E_p = 2.45 \times 10^5$ MJ

## Section 9.6

**1. a)** $k = \dfrac{\text{rise}}{\text{run}}$

$k = \dfrac{20 \text{ N}}{0.1 \text{ m}}$

$k = 200$ N/m

$k = 2.0 \times 10^2$ N/m

**b)** Maximum elastic potential energy occurs at $x = 0.1$ m.

$E_p = \dfrac{1}{2}kx^2$

$E_p = \dfrac{1}{2}(200 \text{ N/m})(0.1 \text{ m})^2$

$E_p = 1.0$ J

**c)** $\Delta E_e = E_{e2} - E_{e1}$

$\Delta E = \dfrac{1}{2}(200 \text{ N/m})(0.04 \text{ m})^2 -$

$\dfrac{1}{2}(200 \text{ N/m})(0.03 \text{ m})^2$

$\Delta E_e = 7.0 \times 10^{-2}$ J

**2.**

$F_g = F_e$

$mg = kx$

$(0.500 \text{ kg})(9.8 \text{ N/kg}) = k(0.04 \text{ m})$

$k = 122.5$ N/m

**3. a)** $W = \Delta E$

$W = E_2 - E_1$ where $E_1 = 0$

$W = E_2$

$W = \dfrac{1}{2}kx^2$

$W = \dfrac{1}{2}(55 \text{ N/m})(-0.04 \text{ m})^2$

$W = 4.4 \times 10^{-2}$ J

**b)** $W = \Delta E$

$W = E_2 - E_1$ where $E_1 = 0$

$W = E_2$

$W = \dfrac{1}{2}kx^2$

$W = \dfrac{1}{2}(85 \text{ N/m})(0.08 \text{ m})^2$

$W = 2.7 \times 10^{-1}$ J

## Section 9.8

**1. a)** $E_{k_1} = \frac{1}{2}(6.5)(18)^2$

$E_{k_1} = 1053$ J

$E_{k_1} \cong 1.1 \times 10^3$ J

**b)** $E_{p_1} = (6.5 \text{ kg})(9.81 \text{ m/s}^2)(120)$

$E_{p_1} = 7651.8$ J

$E_{p_1} \cong 7.7 \times 10^3$ J

**c)** $E_{T_1} = 8.7 \times 10^3$ J

**d)** $E_{T_{halfway}} = 8.7 \times 10^3$ J

**e)** $E_p = (6.5)(9.81)(60)$

$E_p = 3825.9$ J

$E_k = 8704.8 - 3825.9$

$E_k = 4878.9$ J

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

$v = 39$ m/s

**f)** $8704.8 = \frac{1}{2}mv^2$

$v = 52$ m/s

**g)** $v_1 = 51.75$ m/s

$a = -9.81$ m/s

At maximum height, $v_2 = 0$.

$t = \dfrac{v_1 - v_2}{g}$

$t = \dfrac{51.75}{9.81}$

$t = 5.3$ s

$$\vec{d} = \vec{v}_1 t + \tfrac{1}{2}\vec{a}\Delta t^2$$
$$d = (51.75)\left(\frac{51.75}{9.81}\right) + \tfrac{1}{2}(-9.81)\left(\frac{51.75}{9.81}\right)^2$$
$$d = 136 \text{ m}$$

**3.** $E_p = (6.5)(9.81)(120)$
$E_p = 7651.8 \text{ J}$
$E_k = 8704.8 - 7651.8$
$E_k = 1053 \text{ J}$
$E_k = \tfrac{1}{2}mv^2$
$v = 18 \text{ m/s}$

## Section 9.9

**3. a)** $m_1 = 3000 \text{ kg}$
$\vec{v}_{1o} = 20 \text{ m/s [W]}$
$\vec{v}_{1f} = 10 \text{ m/s [W]}$
$m_2 = 1000 \text{ kg}$
$v_{2o} = 0$
$v_{2f} = ?$

$$p_{To} = p_{Tf}$$
$$m_1 v_{1o} + m_2 v_{2o} = m_1 v_{1f} + m_2 v_{2f}$$
$$(3000 \text{ kg})(20 \text{ m/s}) + 0 = (3000 \text{ kg})(10 \text{ m/s}) + (1000 \text{ kg})v_{2f}$$
$$v_{2f} = 30 \text{ m/s}$$

**b)** Since $E_{ko} = E_{kf}$, the collision is elastic ($E_{kTotal} = 6 \times 10^5$ J).

**c)** $W = \Delta E_{k-truck}$
$$W = \frac{1}{2}(3000 \text{ kg})(10 \text{ m/s})^2 - \frac{1}{2}(3000 \text{ kg})(20 \text{ m/s})^2$$
$$W = -4.5 \times 10^5 \text{ J}$$

**4.** $m_p = 0.5 \text{ kg}$
$m_g = 75 \text{ kg}$
$\Delta d_p = 0.03 \text{ m}$
$v_{po} = 33.0 \text{ m/s}$
$v_{go} = 0$
$v_{gf} = 0.30 \text{ m/s}$

**a)** $p_{go} = mv$
$p_{go} = (75 \text{ kg})(0)$
$p_{go} = 0$
$E_{kgo} = 0$
$p_{po} = mv$
$p_{po} = (0.5 \text{ kg})(33.0 \text{ m/s})$
$p_{po} = 16.5 \text{ kg·m/s}$
$$E_{kpo} = \frac{1}{2}(0.5 \text{ kg})(33.0 \text{ m/s})^2$$
$E_{kpo} = 272.25 \text{ J}$

**b)**
$$p_o = p_f$$
$$p_{po} + p_{go} = p_{pf} + p_{gf}$$
$$m_p v_{po} + 0 = m_p v_{pf} + m_g v_{gf}$$
$$(0.500 \text{ kg})(33.0 \text{ m/s}) = (0.500 \text{ kg})v_{pf} + (75 \text{ kg})(0.30 \text{ m/s})$$
$$v_{pf} = -12 \text{ m/s}$$

**c)** $$E_{k-p} = \frac{1}{2}m_p v_{pf}^2$$
$$E_{k-p} = \frac{1}{2}(0.500 \text{ kg})(12 \text{ m/s})^2$$
$$E_{k-p} = 36 \text{ J}$$
$$E_{k-g} = \frac{1}{2}m_g v_{gf}^2$$
$$E_{k-g} = \frac{1}{2}(75 \text{ kg})(0.30 \text{ m/s})^2$$
$$E_{k-g} = 3.4 \text{ J}$$

**d)** The collision is inelastic due to the loss of kinetic energy.

**5.** $m_1 = 10 \text{ g}$
$m_2 = 50 \text{ g}$
$v_{1o} = 5 \text{ m/s}$
$v_{2o} = 0$
$$v_{1f} = v_{1o}\frac{m_1 - m_2}{m_1 + m_2}$$
$$v_{1f} = (5 \text{ m/s})\frac{10 \text{ g} - 50 \text{ g}}{10 \text{ g} + 50 \text{ g}}$$
$$v_{1f} = -3.3 \text{ m/s}$$
$$v_{2f} = v_{1o}\frac{2m_1}{m_1 + m_2}$$
$$v_{2f} = (5 \text{ m/s})\frac{2(10 \text{ g})}{10 \text{ g} + 50 \text{ g}}$$
$$v_{2f} = 1.7 \text{ m/s}$$

**6.** $m_1 = 0.2 \text{ kg}$
$m_2 = 0.3 \text{ kg}$
$v_{1o} = 0.32 \text{ m/s}$
$v_{2o} = -0.52 \text{ m/s}$
Changing the frame of reference,
$v_{1o} = 0.84 \text{ m/s}$
$v_{2o} = 0 \text{ m/s}$
$$v_{1f} = (0.84 \text{ m/s})\frac{0.2 \text{ kg} - 0.3 \text{ kg}}{0.2 \text{ kg} + 0.3 \text{ kg}}$$
$$v_{1f} = -0.168 \text{ m/s}$$
$$v_{2f} = (0.84 \text{ m/s})\frac{2(0.2 \text{ kg})}{0.2 \text{ kg} + 0.3 \text{ kg}}$$
$$v_{2f} = 0.672 \text{ m/s}$$

Returning to the original frame of reference,
$v_{1f} = -0.168\ \text{m/s} - 0.52\ \text{m/s}$
$v_{1f} = -0.69\ \text{m/s}$
$v_{2f} = 0.672\ \text{m/s} - 0.52\ \text{m/s}$
$v_{2f} = 0.15\ \text{m/s}$

**8.** **a)** $E_{\text{stored}} = \frac{1}{2}bh$

$E_{\text{stored}} = \frac{1}{2}(0.06\ \text{m} - 0.02\ \text{m})(50\ \text{N})$

$E_{\text{stored}} = 1.0\ \text{J}$

**b)** $E_{\text{lost}} = 1.0\ \text{J} - \frac{1}{2}(0.005\ \text{m})(30\ \text{N}) - (0.005\ \text{m})(20\ \text{N}) - \frac{1}{2}(0.035\ \text{m})(20\ \text{N})$

$E_{\text{lost}} = 1.0\ \text{J} - 0.075\ \text{J} - 0.1\ \text{J} - 0.35\ \text{J}$
$E_{\text{lost}} = 0.475\ \text{J}$

**9.** **a)** Counting the squares below the top curve, there are about 16.5 squares, each with an area of (0.01 m)(166.7 N) = 1.6667 J. The amount of energy going into the shock absorber is (16.5)(1.6667 J) = 27.5 J.

**b)** There are roughly 6 squares below the lower curve. The energy returned to the shock absorber is (6)(1.6667 J) = 10 J

**c)** $\%\ \text{energy lost} = \frac{27.5\ \text{J} - 10\ \text{J}}{27.5\ \text{J}} \times 100$

$\%\ \text{energy lost} = 64\%$

## Section 9.10

**1.** **a)** At the equilibrium point, the bob's kinetic energy accounts for all the energy in the system. This total energy is the same as the maximum elastic potential energy.

$E_{\text{k equil}} = E_{\text{T}}$
$E_{\text{k equil}} = E_{\text{pmax}}$

$E_{\text{k equil}} = \frac{1}{2}kx^2$

$E_{\text{k equil}} = \frac{1}{2}(33\ \text{N/m})(0.23\ \text{m})^2$

$E_{\text{k equil}} = 0.87\ \text{J}$

**b)** 0

**c)** $E_{\text{k}} = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2E_{\text{k}}}{m}}$

$v = \sqrt{\frac{2(0.87\ \text{J})}{0.485\ \text{kg}}}$

$v = 1.9\ \text{m/s}$

**2.** **a)** To find the period of an object in simple harmonic motion,

$T = 2\pi\sqrt{\frac{m}{k}}$

$T = 2\pi\sqrt{\frac{0.485\ \text{kg}}{33\ \text{N/m}}}$

$T = 0.76\ \text{s}$

**b)** At 0.16 m, the elastic potential energy of the bob is

$E_{\text{p 0.16m}} = \frac{1}{2}kx^2$

$E_{\text{p 0.16m}} = \frac{1}{2}(33\ \text{N/m})(0.16\ \text{m})^2$

$E_{\text{p 0.16m}} = 0.42\ \text{J}$
$E_{\text{T}} = E_{\text{k}} + E_{\text{p}}$
$E_{\text{k}} = E_{\text{T}} - E_{\text{p}}$
$E_{\text{k}} = 0.87\ \text{J} - 0.42\ \text{J}$
$E_{\text{k}} = 0.45\ \text{J}$

$E_{\text{k}} = \frac{1}{2}mv^2$

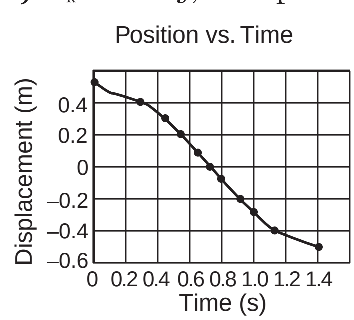
$v = \sqrt{\frac{2E_{\text{k}}}{m}}$

$v = \sqrt{\frac{2(0.45\ \text{J})}{0.485\ \text{kg}}}$

$v = 1.36\ \text{m/s}$

**c)** $E_{\text{k}} = 0.45\ \text{J}$, from part b

**3.**



## Section 10.1

**1.** **a)** $T = \frac{22\ 500\text{ s}}{5\text{ classes}}$

$T = 4.5 \times 10^3$ s

**b)** $T = \frac{6.7\text{ s}}{10\text{ swings}}$

$T = 0.67$ s

**c)** $T = \frac{60\text{ s}}{33.33\text{ turns}}$

$T = 1.8$ s

**d)** $T = \frac{57\text{ s}}{68\text{ situps}}$

$T = 0.84$ s

**2.** **a)** $f = \frac{120}{2}$

$f = 60$ Hz

**b)** $f = \frac{45}{60}$

$f = 0.75$ Hz

**c)** $f = \frac{40}{(1.2)(3600)}$

$f = 9.3 \times 10^{-3}$ Hz

**d)** $f = \frac{65\text{ words}}{48\text{ s}}$

$f = 1.4$ Hz

**3.** **i)** **a)** $2.2 \times 10^{-4}$ Hz, **b)** 1.5 Hz, **c)** 0.55 Hz, **d)** 1.05 Hz

**ii)** **a)** 0.017 s, **b)** 1.3 s, **c)** 108 s, **d)** 0.71 s

## Section 10.2

**1.** **a)** $f = \frac{3.0 \times 10^8\text{ m/s}}{640 \times 10^{-9}\text{ m}}$

$f = 4.69 \times 10^{14}$ Hz

**b)** $f = \frac{3.0 \times 10^8\text{ m/s}}{1.2\text{ m}}$

$f = 2.50 \times 10^8$ Hz

**c)** $f = \frac{3 \times 10^8\text{ m/s}}{2 \times 10^{-9}\text{ m}}$

$f = 1.50 \times 10^{17}$ Hz

**2.** **a)** $\lambda = 2.0 \times 10^{-5}$ m

**b)** $\lambda = 0.15$ m

**c)** $\lambda = 1.0 \times 10^{-14}$ m

## Section 10.6

**1.** **a)** $n = \frac{c}{v}$

$v = \frac{c}{n}$

$v = \frac{3.0 \times 10^8\text{ m/s}}{1.33}$

$v = 2.26 \times 10^8$ m/s

**b)** $v = 1.24 \times 10^8$ m/s

**c)** $v = 1.99 \times 10^8$ m/s

**2.** **a)** $n = 1.43$

**b)** $n = 2$

**c)** $n = 1.27$

## Section 10.7

**1.** **a)** $\sin \theta_2 = \frac{1.00(\sin 25°)}{1.33}$

$\theta_2 = 18.5°$

**b)** $\theta_2 = 10.1°$

**c)** $\theta_2 = 16.3°$

**2.** **a)** more dense

**b)** $n_1 \sin \theta_1 = n_2 \sin \theta_2$

$n_2 = 1.76$

**c)** $v_1 = \frac{c}{n_1}$

$v_1 = 2.26 \times 10^8$ m/s

$v_2 = \frac{c}{n_2}$

$v_2 = 1.70 \times 10^8$ m/s

**d)** less dense

$n_2 = 1.08$

$v_1 = 2.26 \times 10^8$ m/s

$v_2 = 2.78 \times 10^8$ m/s

## Section 10.9

**2.** **a)**

| | | |
|---|---|---|
| case 1: | $n_1 = 1.2$ | $n_2 = 2.3$ |
| case 2: | $n_1 = 1.2$ | $n_2 = 1.52$ |
| case 3: | $n_1 = 1.2$ | $n_2 = 1.65$ |
| case 4: | $n_1 = 1.52$ | $n_2 = 1.65$ |
| case 5: | $n_1 = 1.52$ | $n_2 = 2.3$ |
| case 6: | $n_1 = 1.65$ | $n_2 = 2.3$ |

**b)** $\theta_n = 31.4°, 41.4°, 45.8°, 46.7°, 52.1°, 67.1°$

## Section 10.11

**1.** $v_r = \left(\frac{\Delta f}{2f_1}\right)c$

$= \left(\frac{2000\ \text{Hz}}{2(9.2 \times 10\ \text{Hz})}\right) 3.0 \times 10^8\ \text{m/s}$

$= 32.6\ \text{m/s}$

**3. a)** $v_r = \left(\frac{\Delta\lambda}{\lambda_1}\right)c$

$= \left(\frac{(4.8 \times 10^{-7} - 4.5 \times 10^{-7})}{4.5 \times 10^{-7}}\right) 3.0 \times 10^8$

$= 2.00 \times 10^7\ \text{m/s}$

**b)** red shift

**c)** moving away

**d)** $v_r = -1.88 \times 10^7\ \text{m/s}$

## Section 10.12

**2. a)** $n\lambda = d \sin \theta_n$

$\sin \theta_n = \frac{2(5.50 \times 10^{-7}\ \text{m})}{2.5 \times 10^{-6}\ \text{m}}$

$\sin \theta_n = 0.44$

$\theta_n = 26°$

**b)** $\sin \theta_n = \frac{2(5.50 \times 10^{-7}\ \text{m})}{1.0 \times 10^{-4}\ \text{m}}$

$\sin \theta_n = 0.011$

$\theta_n = 0.63°$

**3. a)** $\sin 26° = \frac{x_2}{1.0\ \text{m}}$

$x_2 = 0.44$ m from centre line.

**b)** $\sin 0.63° = \frac{x_2}{1.0\ \text{m}}$

$x_2 = 0.011$ m from centre line.

## Section 10.13

**2. a)** $\lambda = 550$ nm

$w = 2.2 \times 10^{-5}$ m

$(n + \frac{1}{2})\ \lambda = w \sin \theta_n$

$\theta_{max} = 3.58°$

$\theta_{max} \cong 3.6°$

**b)** $\frac{n\lambda}{w} = \sin \theta_n$

$\theta_{min} = 2.87°$

$\theta_{min} \cong 2.9°$

**3. a)** $x = 0.06$ m

**b)** $x = 0.05$ m

## Section 11.1

**1. a)** $f = \frac{690\ \text{clicks}}{2.3\ \text{s}}$

$f = 300$ Hz

$T = \frac{1}{f}$

$T = 3.3 \times 10^{-3}$ s

**b)** $v = 344$ m/s

$\lambda = \frac{344\ \text{m/s}}{300\ \text{s}^{-1}}$

$\lambda = 1.15$ m

**2. a)** $f = \frac{60\ \text{pulses}}{0.3\ \text{s}}$

$f = 200$ Hz

$T = \frac{1}{200}$

$T = 5.0 \times 10^{-3}$ s

**b)** $\lambda = \frac{340\ \text{m/s}}{200\ \text{s}^{-1}}$

$\lambda = 1.7$ m

**3.** $f = \frac{7.5\ \text{clicks}}{0.3\ \text{s}}$

$f = 25$ Hz

$T = 0.04$ s

## Section 11.2

**2.** $d = 8000$ m

$t_{air} = 2.35$ s

$t_{wood} = 0.20$ s

$v_{air} = 3.4 \times 10^3$ m/s

$v_{wood} = 4.0 \times 10^4$ m/s

Therefore, sound travels 11.8 times faster through wood.

**3.** $t = 12.3$ s

$v = 332 + 0.6T$

**a)** $v_{0°C} = 332$ m/s

$d = 4.08 \times 10^3$ m

**b)** $v_{10°C} = 338$ m/s

$d = 4.16 \times 10^3$ m

**c)** $v_{30°C} = 350$ m/s

$d = 4.31 \times 10^3$ m

**d)** $v_{-10°C} = 326$ m/s

$d = 4.01 \times 10^3$ m

## Section 11.3

**1.** **a)** $v_{3°C} = 333.8$ m/s

$\text{Mach} = \frac{v_p}{v_s}$

$v_p = 2.1(333.8 \text{ m/s})$

$v_p = 7.0 \times 10^2$ m/s

**b)** $v_{35°C} = 353$ m/s

$v_p = (0.4)(353 \text{ m/s})$

$v_p = 1.4 \times 10^2$ m/s

**c)** $v_{0°C} = 332$ m/s

$v_p = 1.9(332 \text{ m/s})$

$v_p = 6.3 \times 10^2$ m/s

**d)** $v_{-2°C} = 330.8$ m/s

$v_p = 5.1(330.8 \text{ m/s})$

$v_p = 1.7 \times 10^3$ m/s

**2.** **a)** $2.5 \times 10^3$ km/h

**b)** $5.0 \times 10^2$ km/h

**c)** $2.3 \times 10^3$ km/h

**d)** $6.1 \times 10^3$ km/h

## Section 11.4

**2.** **a)** decrease by factor of 4

**b)** decrease by factor of 28

**c)** increase by factor of 9

**d)** increase by factor of 11

**3.** **a)** $\beta = 100$

$\beta = 10 \log\left[\frac{I}{I_o}\right]$

$10^{10} = \frac{I}{1 \times 10^{-12}}$

$I = 0.10$ W/m$^2$

**b)** $\beta = 20$ dB

$\beta = 10^2$

$\beta = \frac{I}{1 \times 10^{-12}}$

$I = 1.0 \times 10^{-10}$ W/m$^2$

**c)** 55 dB

$I = 3.2 \times 10^{-7}$ W/m$^2$

**d)** 78 dB

$I = 6.3 \times 10^{-5}$ W/m$^2$

**4.** **a)** 100 times louder

**b)** 100 times softer

**c)** $3.2 \times 10^6$ times louder

**d)** 891 times softer

## Section 11.5

**3.** 110 km/h = 30.6 m/s

**a)** $f' = 450 \text{ Hz}\left(\frac{343 \text{ m/s}}{343 \text{ m/s} - 30.6 \text{ m/s}}\right)$

$f = 494$ Hz

**b)** $f' = 450 \text{ Hz}\left(\frac{343 \text{ m/s}}{343 \text{ m/s} + 30.6 \text{ m/s}}\right)$

$f = 413$ Hz

## Section 12.3

**1.** **a)** $v_{\text{wood}} = 3850$ m/s

$v = \lambda f$

$\lambda = 15.4$ m

**b)** $v_{\text{water}} = 1498$ m/s

$\lambda = 6.0$ m

## Section 12.4

**2.** **a)** $\lambda = 0.3$ m

**b)** $f = 20$ Hz

$v = \lambda f$

$v = 6$ m/s

## Section 12.6

**1.** $L = 1.2$ m  $v = 343$ m/s

**a)** **i)** $\lambda = 2.4$ m

**ii)** $\lambda = 0.8$ m

**iii)** $\lambda = 0.4$ m

**b)** **i)** $f = 143$ Hz

**ii)** $f = 429$ Hz

**iii)** $f = 858$ Hz

**2.** **a)** 4.8 m, 0.96 m, 0.44 m

**b)** 71.7 Hz, 358 Hz, 782 Hz

**3.** $f = 400$ Hz

$L = 0.8$ m

$v = 640$ m/s

$f_2 = f_1\left(\frac{L_1}{L_2}\right)$

**a)** $f_2 = 400\left(\frac{0.8}{0.9}\right)$

$f_2 = 356$ Hz

**b)** $f_2 = 283$ Hz

**c)** $f_2 = 253$ Hz

**d)** $f_2 = 200$ Hz

## Section 12.8

**1.** $f_2 = 997$ Hz or 1003 Hz

## Section 13.4

**1.** $q_1 = 3.7 \times 10^{-6}$ C, $q_2 = -3.7 \times 10^{-6}$ C,
$d = 5.0 \times 10^{-2}$ m, $k = 9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2}$

$$F = \frac{kq_1q_2}{d^2}$$

$$F = \frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(3.7 \times 10^{-6}\ \mathrm{C})(-3.7 \times 10^{-6}\ \mathrm{C})}{(5.0 \times 10^{-2}\ \mathrm{m})^2}$$

$F = -49$ N
$F = 49$ N (attraction)

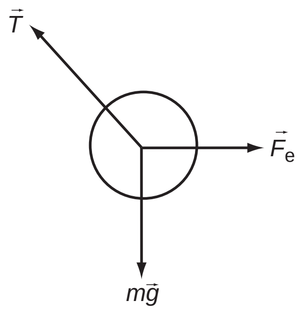
**2.** $F = 2(-49\ \mathrm{N})$
$F = -98$ N

$$r = \sqrt{\frac{kq_1q_2}{F}}$$

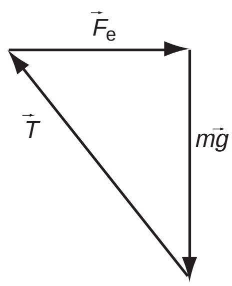
$$r = \sqrt{\frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(3.7 \times 10^{-6}\ \mathrm{C})(-3.7 \times 10^{-6}\ \mathrm{C})}{-98\ \mathrm{N}}}$$

$r = 3.5 \times 10^{-2}$ m

**3. a)**




**b)**




**c)** How close do the dust balls get and what is the charge on the tethered dust ball?
$m = 2.0 \times 10^{-10}$ kg , $l = 0.42$ m,
$d_{\text{wall-1}} = 0.35$ m, $q = 3.0 \times 10^{-6}$ C, $\theta = 21°$
$d_{\text{wall-2}} = 0.35\ \mathrm{m} - (0.42\ \mathrm{m})(\sin 21°)$
$d_{\text{wall-2}} = 0.35\ \mathrm{m} - 0.15\ \mathrm{m}$
$d_{\text{wall-2}} = 0.20$ m

From the force vector diagram,

$$\tan\theta = \frac{F_e}{mg}$$

$$F_e = mg\tan\theta$$

$$\frac{kq_1q_2}{r^2} = mg\tan\theta$$

$$q_1 = \frac{r^2 mg\tan\theta}{kq_2}$$

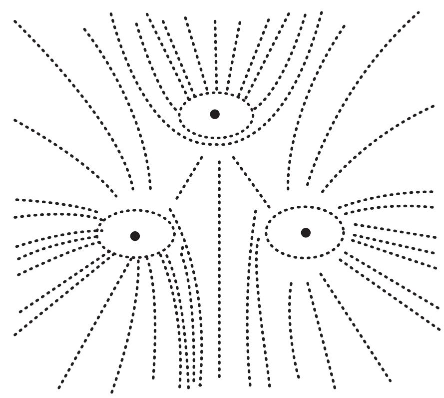
$$q_1 = \frac{(0.20\ \mathrm{m})^2(2.0 \times 10^{-10}\ \mathrm{kg})(9.8\ \mathrm{N/kg})(\tan 21°)}{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(3.0 \times 10^{-6}\ \mathrm{C})}$$

$q_1 = 1.1 \times 10^{-15}$ C

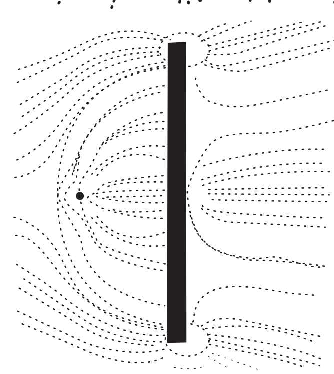
The dust balls are 0.20 m apart, and the charge on the tethered dust ball is $1.1 \times 10^{-15}$ C.

## Section 13.5

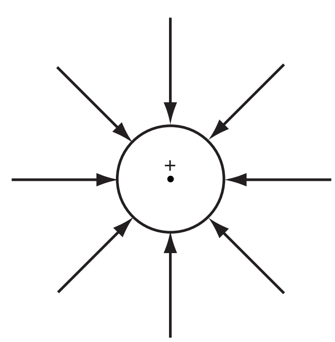
**1. a)**



**b)**



**c)**

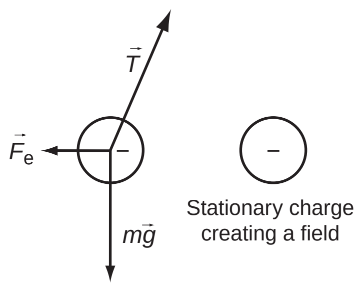


## Section 13.6

**1. a)** $q = -1.0 \times 10^{-6}$ C,
$\vec{\varepsilon} = 1.7 \times 10^{6}$ N/C [right]
Let right be the positive direction.
$\vec{F}_e = q\vec{\varepsilon}$
$F_e = (-1.0 \times 10^{-6}\ \text{C})(1.7 \times 10^{6}\ \text{N/C})$
$F_e = -1.7$ N
$\vec{F}_e = 1.7$ N [left]

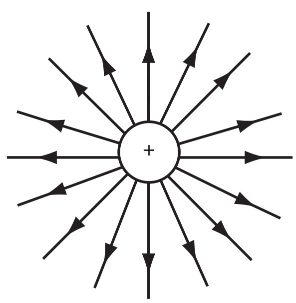
**b)** $q = 1.0 \times 10^{-6}$ C,
$\vec{\varepsilon} = 2(1.7 \times 10^{6}$ N/C) [right]
If right is still the positive direction,
$\vec{F}_e = q\vec{\varepsilon}$
$F_e = (1.0 \times 10^{-6}\ \text{C})[2(1.7 \times 10^{6}\ \text{N/C})]$
$F_e = 3.4$ N
$\vec{F}_e = 3.4$ N [right]

**2.**




$q = -1.0 \times 10^{-6}$ C, $\vec{\varepsilon} = 1.7 \times 10^{6}$ N/C [right]
$F_e = mg \tan \theta$
$\vec{F}_e = 1.7$ N [left]

**3. a)**




The field lines radiate outward, away from the charge.

**b)** $k = 9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$, $q = 3.0 \times 10^{-6}$ C
At 2 cm away from the charge:

$$\varepsilon = \frac{kq}{r^2}$$

$$\varepsilon = \frac{(9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2)(3.0 \times 10^{-6}\ \text{C})}{(2.0 \times 10^{-2}\ \text{m})^2}$$

$\varepsilon = 6.8 \times 10^{7}$ N/C

At 4 cm away:

$$\varepsilon = \frac{kq}{r^2}$$

$$\varepsilon = \frac{(9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2)(3.0 \times 10^{-6}\ \text{C})}{(4.0 \times 10^{-2}\ \text{m})^2}$$

$\varepsilon = 1.7 \times 10^{7}$ N/C

At 6 cm away:

$$\varepsilon = \frac{kq}{r^2}$$

$$\varepsilon = \frac{(9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2)(3.0 \times 10^{-6}\ \text{C})}{(6.0 \times 10^{-2}\ \text{m})^2}$$

$\varepsilon = 7.5 \times 10^{6}$ N/C

**c)** Doubling the distance,

$$\varepsilon_1 = \frac{kq}{(2r)^2}$$

$$\varepsilon_1 = \frac{1}{4}\varepsilon$$

Tripling the distance,

$$\varepsilon_2 = \frac{kq}{(3r)^2}$$

$$\varepsilon_2 = \frac{1}{9}\varepsilon$$

$\varepsilon_1$ decreases to $\frac{1}{4}$ and $\varepsilon_2$ decreases to $\frac{1}{9}$ of the original strength.

**d)** $\varepsilon \propto \frac{1}{r^2}$. The field strength varies as the inverse square of the distance away from the charge.

**e)** $q_1 = 1.0 \times 10^{-6}$ C, $q_2 = 3.0 \times 10^{-6}$ C,
$r = 8.0 \times 10^{-2}$ m

$$\varepsilon = \frac{kq_1}{r^2}$$

$$\varepsilon = \frac{(9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2)(3.0 \times 10^{-6}\ \text{C})}{(8.0 \times 10^{-2}\ \text{m})^2}$$

$\varepsilon = 4.22 \times 10^{6}$ N/C
$\vec{F}_e = q\vec{\varepsilon}$
$F_e = (1.0 \times 10^{-6}\ \text{C})(4.22 \times 10^{6}\ \text{N/C})$
$\vec{F}_e = 4.22$ N [right]

**4. a)** $q_1 = q_2 = 1.0 \times 10^{-6}$ C, $r = 0.20$ m
Let the positive direction be left.
At point A:
$r_1 = 0.05$ m, $r_2 = 0.25$ m

$\vec{\varepsilon}_{TA} = \vec{\varepsilon}_1 + \vec{\varepsilon}_2$

$\varepsilon_{TA} = \dfrac{kq_1}{r_1^2} + \dfrac{kq_2}{r_2^2}$

$\varepsilon_{TA} = (9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(1.0 \times 10^{-6}\ \text{C}) \left[\dfrac{1}{(0.05\ \text{m})^2} + \dfrac{1}{(0.25\ \text{m})^2}\right]$

$\vec{\varepsilon}_{TA} = 3.7 \times 10^6$ N/C [left]

At point B:

$r_1 = -0.10$ m, $r_2 = 0.10$ m

The addition of these two distances as was done in the previous question will yield a zero quantity.

$\varepsilon_{TB} = 0$ N/C

At point C:

$r_1 = -0.15$ m, $r_2 = 0.05$ m

$\vec{\varepsilon}_{TC} = \vec{\varepsilon}_1 + \vec{\varepsilon}_2$

$\varepsilon_{TC} = \dfrac{kq_2}{r_2^2} - \dfrac{kq_1}{r_1^2}$

$\varepsilon_{TC} = (9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(1.0 \times 10^{-6}\ \text{C}) \left[\dfrac{1}{(0.05\ \text{m})^2} - \dfrac{1}{(0.15\ \text{m})^2}\right]$

$\vec{\varepsilon}_{TC} = 3.2 \times 10^6$ N/C [left]

**b)** At the centre point, $\varepsilon_1$ is equal in magnitude but opposite in direction to $\varepsilon_2$, therefore there is no net field strength as the fields cancel out.

**c)** For all field strengths to cancel out, the magnitudes of the ratio of $\dfrac{q}{r^2}$ must be equal and pointing in opposite directions.

# Section 13.7

**1.** **a)** $E_e = \dfrac{kq_1q_2}{r}$

$E_e = \dfrac{(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(-5.0 \times 10^{-6}\ \text{C})(1.5 \times 10^{-6}\ \text{C})}{10 \times 10^{-2}\ \text{m}}$

$E_e = -6.8 \times 10^{-1}$ J

**b)** $V = \dfrac{E_e}{q}$

$V = \dfrac{-6.8 \times 10^{-1}\ \text{J}}{1.5 \times 10^{-6}\ \text{C}}$

$V = -4.5 \times 10^5$ V

**c)** $V = \dfrac{kq}{r}$

$V = \dfrac{(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(-5.0 \times 10^{-6}\ \text{C})}{5.0 \times 10^{-2}\ \text{m}}$

$V = -9.0 \times 10^5$ V

$\Delta V = V_2 - V_1$

$\Delta V = -9.0 \times 10^5\ \text{V} - (-4.5 \times 10^5\ \text{V})$

$\Delta V = -4.5 \times 10^5$ V

**2.** **a)** $m_1 = m_2 = 5.0 \times 10^{-9}\ \text{g} = 5.0 \times 10^{-12}$ kg, $q_1 = 4.0 \times 10^{-10}$ C, $q_2 = 1.0 \times 10^{-10}$ C

On particle 1:

$W_1 = qV$

$W_1 = (4.0 \times 10^{-10}\ \text{C})(50\ \text{V})$

$W_1 = 2.0 \times 10^{-8}$ J

On particle 2:

$W_2 = qV$

$W_2 = (1.0 \times 10^{-10}\ \text{C})(50\ \text{V})$

$W_2 = 5.0 \times 10^{-9}$ J

**b)** $W = E_k$

$W = \dfrac{1}{2}mv^2$

$v = \sqrt{\dfrac{2W}{m}}$

$\dfrac{v_1}{v_2} = \dfrac{\sqrt{\dfrac{2W_1}{m_1}}}{\sqrt{\dfrac{2W_2}{m_2}}}$ The similar masses cancel.

$\dfrac{v_1}{v_2} = \sqrt{\dfrac{W_1}{W_2}}$

$\dfrac{v_1}{v_2} = \sqrt{\dfrac{2.0 \times 10^{-8}\ \text{J}}{5.0 \times 10^{-9}\ \text{J}}}$

$\dfrac{v_1}{v_2} = 2$

**3.** **a)** Extensive: electric force, potential energy

Intensive: field strength, electric potential

**b)** Electric force — Charge and the field strength

Potential energy — Charge and the electric potential

**c)** **Extensive properties**

Product cost (per package)

Mass

Volume

Length

Force of gravity

Etc.

**Intensive properties**

Unit product cost (per unit weight or measure)

Density

Heat capacity

Indices of refraction
Gravitational field strength
Etc.

## Section 13.8

**1.** $q_A = +2e$, $q_B = +79e$,

$E_k = 7.7 \text{ MeV}$

$= (7.7 \times 10^6 \text{ eV})(1.602 \times 10^{-19} \text{ J})$

$\Delta E_e = \Delta E_k$

$$\Delta E_e = \frac{kq_Aq_B}{r}$$

$$r = \frac{kq_Aq_B}{\Delta E_e}$$

$$r = \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(1.602 \times 10^{-19} \text{ C})^2(2)(79)}{(7.7 \times 10^6 \text{ eV})(1.602 \times 10^{-19} \text{ J})}$$

$r = 2.96 \times 10^{-14} \text{ m}$

$r = 3.0 \times 10^{-14} \text{ m}$

**3.** $q = -1.5 \times 10^{-5} \text{ C}$

$$\frac{1}{2}mv^2 = q(V_2 - V_1)$$

$$v = \sqrt{\frac{2q(V_2 - V_1)}{m}}$$

$$v = \sqrt{\frac{2(-1.5 \times 10^{-5} \text{ C})(-12 \text{ V})}{(1.0 \times 10^{-5} \text{ kg})}}$$

$\vec{v} = 6.0 \text{ m/s [left]}$

**4. a)** $V = 1.5 \times 10^3 \text{ V}$, $m = 6.68 \times 10^{-27} \text{ kg}$,

$q = 2e = 3.204 \times 10^{-19} \text{ C}$

$E_k = E_e$

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

$$v = \sqrt{\frac{2Vq}{m}}$$

$$v = \sqrt{\frac{2(1.5 \times 10^3 \text{ V})(3.204 \times 10^{-19} \text{ C})}{6.68 \times 10^{-27} \text{ kg}}}$$

$v = 3.8 \times 10^5 \text{ m/s}$

**b)** $$\frac{1}{2}mv^2 = \frac{1}{2}Vq$$

$$v = \sqrt{\frac{Vq}{m}}$$

$$v = \sqrt{\frac{(1.5 \times 10^3 \text{ V})(3.204 \times 10^{-19} \text{ C})}{6.68 \times 10^{-27} \text{ kg}}}$$

$v = 2.7 \times 10^5 \text{ m/s}$

**5. a)** $V = 20 \text{ kV} = 2.0 \times 10^4 \text{ V}$,

$q = 1.602 \times 10^{-19} \text{ C}$, $m = 9.11 \times 10^{-31} \text{ kg}$

$E_k = E_e$

$E_k = Vq$

$E_k = (2.0 \times 10^4 \text{ V})(1.602 \times 10^{-19} \text{ C})$

$E_k = 3.2 \times 10^{-15} \text{ J}$

**b)** $$E_k = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2E_k}{m}}$$

$$v = \sqrt{\frac{2(3.2 \times 10^{-15} \text{ J})}{9.11 \times 10^{-31} \text{ kg}}}$$

$v = 8.4 \times 10^7 \text{ m/s}$

## Section 13.9

**1.** $W = 2.4 \times 10^{-4} \text{ J}$, $q = 6.5 \times 10^{-7} \text{ C}$

$$\Delta V = \frac{W}{q}$$

$$\Delta V = \frac{2.4 \times 10^{-4} \text{ J}}{6.5 \times 10^{-7} \text{ C}}$$

$\Delta V = 3.7 \times 10^2 \text{ V}$

**2.** $d = 7.5 \times 10^{-3} \text{ m}$, $V = 350 \text{ V}$,

$$\varepsilon = \frac{V}{d}$$

$$\varepsilon = \frac{350 \text{ V}}{7.5 \times 10^{-3} \text{ m}}$$

$\varepsilon = 4.7 \times 10^4 \text{ N/C}$

**3.** $m = 2.166 \times 10^{-15} \text{ kg}$, $V = 530 \text{ V}$,

$d = 1.2 \times 10^{-2} \text{ m}$

$F_e = F_g$

$$\frac{qV}{d} = mg$$

$$q = \frac{mgd}{V}$$

$$q = \frac{(2.166 \times 10^{-15} \text{ kg})(9.8 \text{ N/kg})(1.2 \times 10^{-2} \text{ m})}{530 \text{ V}}$$

$q = 4.8 \times 10^{-19} \text{ C}$

## Section 14.2

**2. a)** $I = 11 \text{ A}$

**b)** $I = 3.7 \times 10^{10} \text{ A}$

3. **a)** $I = 10\text{ A}$

$Q = 700\text{ C}$

$t = \frac{Q}{I}$

$t = 70$

**b)** number of electrons $= \frac{700\text{ C}}{1.6 \times 10^{-19}\text{ C}/e}$

$= 4.38 \times 10^{21}$ electrons

## Section 14.3

3. **a)** $V = 12\text{ V}$

$V = 12\text{ J/C}$

$Q = \frac{1.3 \times 10^{4}\text{ J}}{12\text{ V}}$

$Q = 1.1 \times 10^{3}\text{ C}$

**b)** number of electrons $= \frac{1.1 \times 10^{3}\text{ C}}{1.6 \times 10^{-19}\text{ C}/e}$

number of electrons $= 6.8 \times 10^{21}$ electrons

**c)** $I = \frac{1.1 \times 10^{3}\text{ C}}{2.5\text{ s}}$

$I = 4.4 \times 10^{2}\text{ A}$

4. $\Delta V = 1.3 \times 10^{8}\text{ V} \qquad E = 3.2 \times 10^{9}\text{ J}$

**a)** $Q = \frac{3.2 \times 10^{9}\text{ J}}{1.3 \times 10^{8}\text{ J/C}}$

$Q = 25\text{ C}$

**b)** number of electrons $= \frac{24.6\text{ C}}{1.6 \times 10^{-19}\text{ C}/e}$

number of electrons $= 1.5 \times 10^{20}$ electrons

**c)** $I = \frac{24.6\text{ C}}{25 \times 10^{-6}\text{ s}}$

$I = 9.8 \times 10^{5}\text{ A}$

## Section 14.5

2. **a)** $1.1 = 200x$

$x = 5.5 \times 10^{-3}$

$R_1 = 5.5 \times 10^{-3}(35)$

$R_1 = 0.19\ \Omega$

**b)** $1.1 = \frac{x}{\text{A}}$

$R_1 = \frac{1.1\text{ A}}{0.24\text{ A}}$

$R_1 = 4.6\ \Omega$

## Section 14.6

1. **a)** $R = 60\ \Omega$

**b)** $\frac{1}{R_{\text{T}}} = 3\left(\frac{1}{20}\right)$

$R_{\text{T}} = 6.7\ \Omega$

**c)** $R_{\text{T}} = 66.7\ \Omega$

2. $R_{\text{T}} = 26\ \Omega$

$R_{\text{T}} = 19\ \Omega$

$R_{\text{T}} = 22\ \Omega$

4. **a)** $R = 1.0 \times 10^{6}\ \Omega$

**b)** $R_{\text{T}} = 1.0\ \Omega$

## Section 14.7

1. **a)** $R_{\text{T}} = 10\ \Omega + 15\ \Omega + 20\ \Omega$

$R_{\text{T}} = 45\ \Omega$

$I = \frac{\text{V}}{\text{R}}$

$I = 0.11\text{ A}$

$I$ is constant at 0.11 A for each resistor.

$(I_1 = I_2 = I_3 = 0.11\text{ A})$

$V_1 = \left(\frac{1}{9}\right)(10\ \Omega)$

$V_1 = 1.1\text{ V}$

$V_2 = \left(\frac{1}{9}\right)(15\ \Omega)$

$V_2 = 1.7\text{ V}$

$V_3 = \left(\frac{1}{9}\right)(20\ \Omega)$

$V_3 = 2.2\text{ V}$

**b)** $R_{\text{T}} = 4.6\ \Omega$

$I = 1.08\text{ A}$

$I_1 = 0.5\text{ A}$

$I_2 = 0.33\text{ A}$

$I_3 = 0.25\text{ A}$

Voltage is constant throughout at 5 V.

$(V_1 = V_2 = V_3 = 5\text{ V})$

**c) i)** $R_{\text{T}} = 26\ \Omega$

$I_{\text{T}} = 0.192\text{ A}$

10 Ω: $I = 0.115\text{ A}$ $\quad V = 1.152\text{ V}$

15 Ω: $I = 0.0768\text{ A}$ $\quad V = 1.152\text{ V}$

20 Ω: $I = 0.192\text{ A}$ $\quad V = 3.84\text{ V}$

**ii)** $R_{\text{T}} = 18.57\ \Omega$

$I_{\text{T}} = 0.27\text{ A}$

10 Ω: $I = 0.27\text{ A}$ $\quad V = 2.7\text{ V}$

15 Ω: $I = 0.15\text{ A}$ $\quad V = 2.3\text{ V}$

20 Ω: $I = 0.115\text{ A}$ $\quad V = 2.3\text{ V}$

iii) $R_T = 21.67\ \Omega$
$I_T = 0.23$ A
10 Ω: $I = 0.153$ A  $V = 1.53$ V
15 Ω: $I = 0.23$ A  $V = 3.46$ V
20 Ω: $I = 0.077$ A  $V = 1.54$ V

## Section 14.8

1. a) $P = IV = 120$ W
   b) $P = 24$ W
2. a) $P = 1000$ W
   $V = 120$ V
   $I = 8.33$ A
   b) no chance of burnout
3. a) $t = 60$ s
   $I = 8.33$ C/s
   $Q = 500$ C
   b) number of electrons $= \dfrac{500\text{ C}}{1.6 \times 10^{-19}\text{ C}/e}$
   number of electrons $= 3.125 \times 10^{21}$ electrons
   c) $P = 1000$ J/s
   $E = 6.0 \times 10^4$ J
   d) $P = I^2R$
   $R = \dfrac{P}{I^2}$
   $R = 14.4\ \Omega$

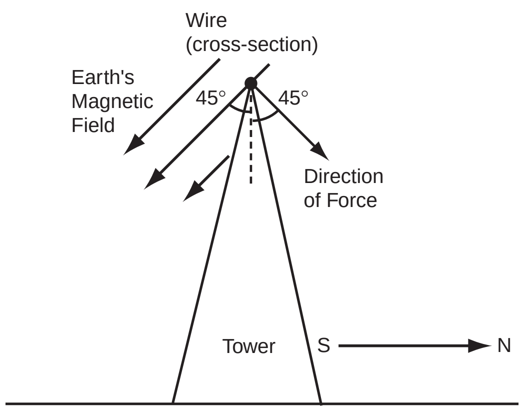
## Section 14.9

1. a) $I = 15$ A, $V = 240$ V, $t = 4320$ s
   $P = IV$
   $P = 3600$ W
   cost = ($0.082/kW·h)(1.2 h)(3.6 kW)
   cost = $0.354 = 35.4¢
   b) $I = 2.5$ A, $V = 120$ V, $t = 1.2$ h
   $P = (2.5)(120)$
   $P = 0.300$ kW
   cost = (8.2)(1.2)(0.3)
   cost = $0.03 = 3¢
2. a) cost = (0.08)(0.3)(5)
   cost = $0.12/day
   cost = $3.60/month
   b) cost = (0.08)(8)(0.06)(6.4)
   cost = $0.25/day
   cost = $7.50/month
   c) $I = \dfrac{120\text{ V}}{15\ \Omega}$
   $I = 8$ A
   $P = (120\text{ V})(8\text{ A})$
   $P = 0.96$ kW
   $t = 3$ min
   $t = 0.05$ h/day
   cost = (0.08)(0.96)(0.05)
   cost = $0.00384/day
   cost = $0.1152/month = 11.52¢/month
   d) $P = 15(240)$
   $P = 3.6$ kW
   $t = 6.42$ h
   cost = (0.08)(3.6)(6.42)
   cost = $1.85/month
   e) $P = 0.240$ kW, $t = 4$ h, cost = $0.08/day

## Section 15.5

1. $L = 0.30$ m
   $I = 12$ A
   $B = 0.25$ T
   $\theta = 90°$
   $F = BIL \sin\theta$
   $F = (0.25\text{ T})(12\text{ A})(0.30\text{ m}) \sin 90°$
   $F = 0.90$ N
2. $L = 0.15$ m
   $F = 9.2 \times 10^{-2}$ N
   $B = 3.5 \times 10^{-2}$ T
   $\theta = 90°$
   $I = \dfrac{F}{BL\sin\theta}$
   $I = \dfrac{(9.2 \times 10^{-2}\text{ N})}{(3.5 \times 10^{-2}\text{ T})(0.15\text{ m}) \sin 90°}$
   $I = 18$ A
3. a) $L = 50$ m
   $I = 100$ A
   $F = 0.25$ N
   $\theta = 45°$
   $B = \dfrac{F}{IL\sin\theta}$
   $B = \dfrac{(0.25\text{ N})}{(100\text{ A})(50\text{ m}) \sin 45°}$
   $B = 7.1 \times 10^{-5}$ T

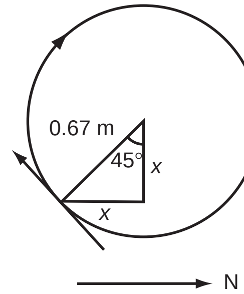
**b)**




4. $B = 3.0 \times 10^{-5}$ T
$L = 0.20$ m
$N = 200$
$\mu = 4\pi \times 10^{-7}$ T·m/A
$$I = \frac{BL}{\mu N}$$
$$I = \frac{(3.0 \times 10^{-5}\text{ T})(0.20\text{ m})}{(4\pi \times 10^{-7}\text{ T·m/A})(200)}$$
$I = 2.4 \times 10^{-2}$ A

5. **a)** $I = 100$ A
$L = 50$ m
$B = 3.0 \times 10^{-5}$ T
$\theta = 45°$
$$r = \frac{\mu I}{2\pi B}$$
$$r = \frac{(4\pi \times 10^{-7}\text{ T·m/A})(100\text{ A})}{2\pi(3.0 \times 10^{-5}\text{ T})}$$
$r = 0.67$ m

**b)** Referring to the diagram in question 3, Earth's field lies in a line that is crossing the wire at 45° below the horizontal. The magnetic field would form a circular ring in the clockwise direction (rising on the south side of the wire, descending on the north with a radius of 0.67 m). Therefore, the field will cancel that of Earth on the south side below the wire, as shown in the diagram.




$2x^2 = (0.67\text{ m})^2$
$x = 0.47$ m

The fields will cancel $4.7 \times 10^{-1}$ m south and $4.7 \times 10^{-1}$ m below the wire.

6. **a)** $r = 2.4 \times 10^{-3}$ m
$I = 13.0$ A
$L = 1$ m
$$F = \frac{\mu I^2 L}{2\pi r}$$
$$F = \frac{(4\pi \times 10^{-7}\text{ T·m/A})(13.0\text{ A})^2(1\text{ m})}{2\pi(2.4 \times 10^{-3}\text{ m})}$$
$F = 1.4 \times 10^{-2}$ N/m

7. $q = 20$ C
$B = 4.5 \times 10^{-5}$ T
$v = 400$ m/s
$\theta = 90°$
$F = qvB \sin\theta$
$F = (20\text{ C})(400\text{ m/s})(4.5 \times 10^{-5}\text{ T}) \sin 90°$
$F = 0.36$ N

8. $q = 1.602 \times 10^{-19}$ C
$v = 4.3 \times 10^4$ m/s
$B = 1.5$ T
$\theta = 90°$
$F = qvB \sin\theta$
$F = (1.602 \times 10^{-19}\text{ C})(4.3 \times 10^4\text{ m/s})(1.5\text{ T}) \sin 90°$
$\vec{F} = 1.0 \times 10^{-14}$ N [south]

## Section 16.4

1. **a)** turns ratio $= \dfrac{N_p}{N_s} = \dfrac{50}{250} = 0.2$

**b)** $\dfrac{N_1}{N_2} = \dfrac{I_2}{I_1}$
$$V_1 = \left(\frac{50}{250}\right)10\text{ V}$$
$V_1 = 2$ V

**c)** $\dfrac{N_1}{N_2} = \dfrac{I_2}{I_1}$

$I_1 = \left(\dfrac{250}{50}\right)2.5 \text{ A}$

$I_1 = 12.5 \text{ A}$

**d)** $P_{avg} = IV = (2 \text{ V})(12.5 \text{ A}) = 25 \text{ W}$

**e)** $P = 25 \text{ W}$

**f)** $V = IR$

$R = \dfrac{V}{I} = \dfrac{10 \text{ V}}{2.5 \text{ A}} = 4\ \Omega$

**2.** $V_1 = 120 \text{ V}, I_1 = 0.80 \text{ A}, \left(\dfrac{N_1}{N_2}\right) = \dfrac{13}{1}$

**a)** $\dfrac{N_1}{N_2} = \dfrac{V_1}{V_2}$

$V_2 = 120 \text{ V}\left(\dfrac{1}{13}\right)$

$V_2 = 9.2 \text{ V}$

**b)** $\dfrac{N_1}{N_2} = \dfrac{I_2}{I_1}$

$I_2 = \left(\dfrac{13}{1}\right)(0.8 \text{ A})$

$I_2 = 10.4 \text{ A}$

**c)** $R = \dfrac{V_2}{I_2}$

$R = \dfrac{9.2 \text{ V}}{10.4 \text{ A}}$

$R = 0.88\ \Omega$

**d)** $P = V_2 I_2 = 96 \text{ W}$

**e)** $P = V_1 I_1 = 96 \text{ W}$

## Section 17.2

**1.** $T = 12\,000 \text{ K}$

**a)** The maximum wavelength can be found using Wien's law:

$\lambda_{max} = \dfrac{2.898 \times 10^{-3}}{T}$

$\lambda_{max} = \dfrac{2.898 \times 10^{-3}}{12\,000 \text{ K}}$

$\lambda_{max} = 2.4 \times 10^{-7} \text{ m}$

The peak wavelength of Rigel is $2.4 \times 10^{-7}$ m. It is in the ultraviolet spectrum.

**b)** It would appear violet.

**c)** No: the living cells would be damaged by the highly energetic UV photons.

**2.** $T = 900 \text{ K}$

**a)** The maximum wavelength can be found using Wien's law:

$\lambda_{max} = \dfrac{2.898 \times 10^{-3}}{T}$

$\lambda_{max} = \dfrac{2.898 \times 10^{-3}}{900 \text{ K}}$

$\lambda_{max} = 3.2 \times 10^{-6} \text{ m}$

The peak wavelength of the light is $3.2 \times 10^{-6}$ m.

**b)** It would appear in the infrared spectrum.

**c)** Since the peak is in infrared, more energy is required to produce the light in the visual spectrum.

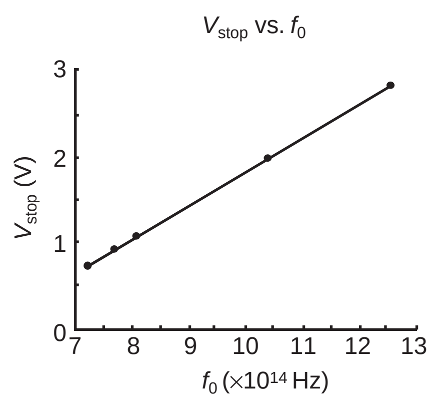
## Section 17.3

**1.** $V = \left(\dfrac{h}{e}\right)f_0 + \dfrac{W_0}{e}$

$eV = hf_0 + W_0$

Choosing two pairs of values from the table and subtracting,

$$\begin{aligned}
(1.6 \times 10^{-19} \text{ C})(0.95 \text{ V}) &= h(7.7 \times 10^{14} \text{ Hz}) + W_0 \\
(1.6 \times 10^{-19} \text{ C})(0.7 \text{ V}) &= h(7.2 \times 10^{14} \text{ Hz}) + W_0 \\
\hline
(1.6 \times 10^{-19} \text{ C})(0.25 \text{ V}) &= h(0.5 \times 10^{14} \text{ Hz}) \\
h &= 8 \times 10^{-34} \text{ J}\cdot\text{s} \\
W_0 &= 4.64 \times 10^{-19} \text{ J} \\
W_0 &= 2.9 \text{ eV}
\end{aligned}$$




**2.** **a)** Increasing the work function by 1.5 would cause a vertical shift of the line. Hence, potential would have to be greater, but the frequencies would not change.

**b)** The term $\dfrac{h}{e}$ is constant and hence the slope would not change.

3. $\lambda = 230 \text{ nm} = 2.3 \times 10^{-7}$ m

The energy can be found as follows:

$$E_\gamma = \frac{hc}{\lambda} - W_0$$

$$E_\gamma = \frac{(8 \times 10^{-34} \text{ J}\cdot\text{s})(3.0 \times 10^8 \text{ m/s})}{2.3 \times 10^{-7} \text{ m}} - 4.64 \times 10^{-19} \text{ J}$$

$$E_\gamma = 5.79 \times 10^{-19} \text{ J}$$

## Section 17.4

2. $E = 85$ eV, $\lambda = 214 \text{ nm} = 2.14 \times 10^{-7}$ m

**a)** Momentum of the original electron can be found using:

$$p = \frac{E}{c}$$

$$p = \frac{(85 \text{ eV})(1.6 \times 10^{-19} \text{ C})}{3.0 \times 10^8 \text{ m/s}}$$

$$p = 4.53 \times 10^{-26} \text{ N}\cdot\text{s}$$

**b)** Momentum of the resultant electron can be found using:

$$p = \frac{h}{\lambda}$$

$$p = \frac{6.626 \times 10^{-34} \text{ J}\cdot\text{s}}{2.14 \times 10^{-7} \text{ m}}$$

$$p = 3.1 \times 10^{-27} \text{ N}\cdot\text{s}$$

**c)** The energy imparted can be found by:

$$\Delta E = E - \frac{hc}{\lambda}$$

$$\Delta E = (85 \text{ eV})(1.6 \times 10^{-19} \text{ C}) - \frac{(6.626 \times 10^{-34} \text{ J}\cdot\text{s})(3.0 \times 10^8 \text{ m/s})}{2.14 \times 10^{-7} \text{ m}}$$

$$\Delta E = 1.27 \times 10^{-17} \text{ J}$$

The energy imparted to the electron was $1.27 \times 10^{-17}$ J.

**d)** The energy imparted increased the speed of the electron. Hence, it can be found using:

$$\Delta v = \sqrt{\frac{2E}{m}}$$

$$\Delta v = \sqrt{\frac{2(1.27 \times 10^{-17} \text{ J})}{9.11 \times 10^{-31} \text{ kg}}}$$

$$\Delta v = 5.27 \times 10^6 \text{ m/s}$$

The speed increase of the electron is $5.27 \times 10^6$ m/s.

## Section 17.5

1. $v = 1 \text{ km/s} = 1000$ m/s

The wavelength can be found using de Broglie's equation:

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{6.626 \times 10^{-34} \text{ J}\cdot\text{s}}{(9.11 \times 10^{-31} \text{ kg})(1000 \text{ m/s})}$$

$$\lambda = 7.27 \times 10^{-7} \text{ m}$$

Hence, the wavelength of the electron is $7.27 \times 10^{-7}$ m.

## Section 17.6

2. We shall first compute the change in energies and the wavelength of spectral lines emitted in each case. From that, the wavelength separation can be computed.

The energy change when the electron transfers from 8 to 1 is:

$$\Delta E_{8-1} = E_8 - E_1$$

$$\Delta E_{8-1} = \frac{-2.18 \times 10^{-18} \text{ J}}{8^2} + \frac{2.18 \times 10^{-18} \text{ J}}{1^2}$$

$$\Delta E_{8-1} = 2.15 \times 10^{-18} \text{ J}$$

The wavelength of the spectral lines is:

$$\lambda_{8-1} = \frac{hc}{\Delta E_{8-1}}$$

$$\lambda_{8-1} = \frac{(6.626 \times 10^{-34} \text{ J}\cdot\text{s})(3.0 \times 10^8 \text{ m/s})}{2.15 \times 10^{-18} \text{ J}}$$

$$\lambda_{8-1} = 9.25 \times 10^{-8} \text{ m}$$

Similarly, the energy change when the electron transfers from 7 to 2 is:

$$\Delta E_{7-2} = E_7 - E_2$$

$$\Delta E_{7-2} = \frac{-2.18 \times 10^{-18} \text{ J}}{7^2} + \frac{2.18 \times 10^{-18} \text{ J}}{2^2}$$

$$\Delta E_{7-2} = 5 \times 10^{-19} \text{ J}$$

$$\lambda_{7-2} = \frac{hc}{\Delta E_{7-2}}$$

$$\lambda_{7-2} = \frac{(6.26 \times 10^{-34} \text{ J}\cdot\text{s})(3.0 \times 10^8 \text{ m/s})}{5 \times 10^{-19} \text{ J}}$$

$$\lambda_{7-2} = 3.98 \times 10^{-7} \text{ m}$$

Hence the wavelength separation is

$$\Delta\lambda = \lambda_{7-2} - \lambda_{8-1}$$

$$\Delta\lambda = 3.98 \times 10^{-7} \text{ m} - 9.25 \times 10^{-8} \text{ m}$$

$$\Delta\lambda = 3.05 \times 10^{-7} \text{ m}$$

3. The change in energy can be computed using:

$\Delta E = E_f - E_i$

$\Delta E = \dfrac{-13.6 \text{ eV}}{n_f^2} + \dfrac{13.6 \text{ eV}}{n_i^2}$

For the Lyman series, the lower boundary is when the electron jumps from the second to the first orbital:

$\Delta E_{min} = \dfrac{-13.6 \text{ eV}}{2^2} + \dfrac{13.6 \text{ eV}}{1^2}$

$\Delta E_{min} = 10.2 \text{ eV}$

The higher boundary for the Lyman series is when the electron jumps from infinity to the first orbital:

$\Delta E_{max} = \dfrac{-13.6 \text{ eV}}{\infty^2} + \dfrac{13.6 \text{ eV}}{1^2}$

$\Delta E_{max} = 13.6 \text{ eV}$

For the Balmer series, the lower boundary is when the electron jumps from the third to the second orbital:

$\Delta E_{min} = \dfrac{-13.6 \text{ eV}}{3^2} + \dfrac{13.6 \text{ eV}}{2^2}$

$\Delta E_{min} = 1.89 \text{ eV}$

The higher boundary for the Balmer series is when the electron jumps from infinity to the second orbital:

$\Delta E_{max} = \dfrac{-13.6 \text{ eV}}{\infty^2} + \dfrac{13.6 \text{ eV}}{2^2}$

$\Delta E_{max} = 3.4 \text{ eV}$

For the Paschen series, the lower boundary is when the electron jumps from the fourth to the third orbital:

$\Delta E_{min} = \dfrac{-13.6 \text{ eV}}{4^2} + \dfrac{13.6 \text{ eV}}{3^2}$

$\Delta E_{min} = 0.66 \text{ eV}$

The higher boundary for the Paschen series is when the electron jumps from infinity to the third orbital:

$\Delta E_{max} = \dfrac{-13.6 \text{ eV}}{\infty^2} + \dfrac{13.6 \text{ eV}}{3^2}$

$\Delta E_{max} = 1.51 \text{ eV}$

For the Brackett series, the lower boundary is when the electron jumps from the fifth to the fourth orbital:

$\Delta E_{min} = \dfrac{-13.6 \text{ eV}}{5^2} + \dfrac{13.6 \text{ eV}}{4^2}$

$\Delta E_{min} = 0.31 \text{ eV}$

The higher boundary for the Brackett series is when the electron jumps from infinity to the fourth orbital:

$\Delta E_{max} = \dfrac{-13.6 \text{ eV}}{\infty^2} + \dfrac{13.6 \text{ eV}}{4^2}$

$\Delta E_{max} = 0.85 \text{ eV}$

Thus, the boundaries for the four series are:

Lyman: 10.2 eV to 13.6 eV

Balmer: 1.89 eV to 3.4 eV

Paschen: 0.66 eV to 1.51 eV

Brackett: 0.31 eV to 0.85 eV

## Section 17.8

1. $\Delta v = 1 \ \mu\text{m/s} = 1 \times 10^{-6} \text{ m/s}$,

$m_p = 1.673 \times 10^{-27} \text{ kg}$

The uncertainty in position can be found using:

$\Delta y \geq \dfrac{\hbar}{m\Delta v}$

$\Delta y \geq \dfrac{1.0546 \times 10^{-34} \text{ J}\cdot\text{s}}{(1.673 \times 10^{-27} \text{ kg})(1 \times 10^{-6} \text{ m/s})}$

$\Delta y \geq 6.3 \times 10^{-2} \text{ m}$

Hence, the uncertainty in position is $6.3 \times 10^{-2}$ m.

2. In the equation $\Delta E \Delta t \geq \hbar$, the units are J·s. This coincides with the units of $h$ in $\hbar = \dfrac{h}{2\pi}$, where $2\pi$ is a constant.

6. $E_k = 1.2 \text{ keV} = 1.92 \times 10^{-16} \text{J}$,

$m_p = 1.673 \times 10^{-27} \text{ kg}$

First we shall find the velocity using:

$v = \sqrt{\dfrac{2E_k}{m_p}}$

$v = \sqrt{\dfrac{2(1.92 \times 10^{-16} \text{ J})}{1.673 \times 10^{-27} \text{ kg}}}$

$v = 4.8 \times 10^5 \text{ m/s}$

The uncertainty in position can be found using:

$\Delta y \geq \dfrac{\hbar}{m\Delta v}$

$\Delta y \geq \dfrac{1.0546 \times 10^{-34} \text{ J}\cdot\text{s}}{(1.673 \times 10^{-27} \text{ kg})(4.8 \times 10^5 \text{ m/s})}$

$\Delta y \geq 1.32 \times 10^{-13} \text{ m}$

The uncertainty in the position is $1.32 \times 10^{-13}$ m.

7. The uncertainty does not affect the object at a macroscopic level.

## Section 18.2

3. Average atomic mass of Cl is
$0.758(35\text{ u}) + 0.242(37\text{ u}) = 35.48\text{ u}$,
compared to 35.453 u in the periodic table.

## Section 18.3

2. Since ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + \alpha$:
**a)** ${}^{234}_{90}\text{Th}$ **b)** ${}^{244}_{94}\text{Pu}$ **c)** ${}^{219}_{84}\text{Po}$ **d)** ${}^{240}_{92}\text{U}$ **e)** ${}^{60}_{27}\text{Co}$
3. Since ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^-$:
**a)** ${}^{32}_{16}\text{S}$ **b)** ${}^{23}_{11}\text{Na}$ **c)** ${}^{35}_{17}\text{Cl}$ **d)** ${}^{45}_{21}\text{Sc}$ **e)** ${}^{64}_{30}\text{Zn}$
4. Since ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + e^+$:
**a)** ${}^{19}_{9}\text{F}$ **b)** ${}^{22}_{10}\text{Ne}$ **c)** ${}^{46}_{23}\text{V}$ **d)** ${}^{239}_{92}\text{U}$ **e)** ${}^{64}_{28}\text{Ni}$

## Section 18.4

1. The amount eaten is:
$$\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32} + \frac{1}{128} + \frac{1}{256}$$
$= \frac{255}{256}$. The amount left is $1 - \frac{255}{256} = \frac{1}{256}$ or $\left(\frac{1}{2}\right)^8$.

2. $T_{\frac{1}{2}} = 1.28 \times 10^9\text{ a}$, $N_0 = 5\text{ mg}$, $N = 1\text{ mg}$
$$N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$
$$\log\left(\frac{N}{N_0}\right) = \frac{t}{T_{\frac{1}{2}}}\log\left(\frac{1}{2}\right)$$
$$t = T_{\frac{1}{2}}\frac{\log\left(\frac{N}{N_0}\right)}{\log\left(\frac{1}{2}\right)}$$
$$t = (1.28 \times 10^9\text{ a})\frac{\log\left(\frac{1\text{ mg}}{5\text{ mg}}\right)}{\log\left(\frac{1}{2}\right)}$$
$$t = 2.97 \times 10^9\text{ a}$$

3. $T_{235} = 7.04 \times 10^8\text{ a}$, $T_{238} = 4.45 \times 10^9\text{ a}$,
$$\frac{{}^{235}N}{{}^{238}N} = 0.0044,\ \left(\frac{{}^{235}N}{{}^{238}N}\right)_0 = 0.030$$
$$\frac{{}^{235}N}{{}^{238}N} = \frac{({}^{235}\text{N})_0\left(\frac{1}{2}\right)^{\frac{t}{T_{235}}}}{({}^{238}\text{N})_0\left(\frac{1}{2}\right)^{\frac{t}{T_{238}}}}$$
$$0.0044 = (0.030)\left(\frac{1}{2}\right)^{t\left(\frac{1}{7.04 \times 10^8\text{ a}} - \frac{1}{4.45 \times 10^9\text{ a}}\right)}$$
$$\log\left(\frac{0.0044}{0.030}\right) = t(1.196 \times 10^{-9}\text{ a}^{-1})\log\left(\frac{1}{2}\right)$$
$$t = \frac{-0.8337}{(-0.3010)(1.196 \times 10^{-9}\text{ a}^{-1})}$$
$$t = 2.3 \times 10^9\text{ a}$$

## Section 18.5

1. $235.043924 + 1.008665 \rightarrow 139.921620 + 93.915367 + 2(1.008665)$
$236.052589 \rightarrow 235.854317$
Therefore, the mass defect is 0.198272 kg.
$$\begin{aligned} E &= mc^2 \\ &= (0.198272\text{ kg})(3.0 \times 10^8\text{ m/s})^2 \\ &= 1.8 \times 10^{16}\text{ J for 1 kmol of nucleons } (6.02 \times 10^{26}) \end{aligned}$$
For $10^{20}$ reactions, $E = 3.0 \times 10^9$ J.

2. $2.014102 + 2.014102 \rightarrow 3.016030 + 1.008665$
$4.028204 \rightarrow 4.024695$
Therefore, the mass defect is 0.003509 kg.
$$\begin{aligned} E &= mc^2 \\ &= (0.003509\text{ kg})(3.0 \times 10^8\text{ m/s})^2 \\ &= 3.2 \times 10^{14}\text{ J for 1 kmol of nucleons } (6.02 \times 10^{26}) \end{aligned}$$
For $10^{20}$ reactions, $E = 5.3 \times 10^7$ J.

# PART 2 Answers to End-of-chapter Conceptual Questions

## Chapter 1

1. The more decimal places, the more precise the instrument. Remember that the decimal places are also contained within a prefix.
   - 1 m—unmarked metre stick
   - 1.0 m—a metre stick marked off in tenths
   - 1.000 m—a metre stick marked off in mm
   - 1.000 000 m—a graduated device like a micrometer
2. By dividing a value with two significant digits, you cannot create extra precision. The implication of the value 0.333333333 m is that the value is known to 9 decimal places. The answer should be 0.33 m.
3. When you add consistent units, the end result is consistent. Example: 2 dollars plus 1 dollar plus half a dollar equal three and a half dollars. But 2 dollars plus 1 dollar plus 50 cents does not equal 53 somethings.
4. Scalars are anything without direction (age, temperature, refractive index, dollars, cents, etc.). Vectors have both a magnitude and a direction (e.g., force, momentum, and electric, gravitational, and magnetic fields).
5. Both speedometers and odometers register only a scalar quantity. If you tie in GPS (Global Positioning System) and use the information relayed by the satellite, you can add a direction to your display and measure vector quantities.
6. Any time the displacement has an angle in one leg of its journey, it will not equal the distance travelled. In the extreme case, you can end up in the same place you started from. Thus, you will have a displacement of zero while still registering a distance travelled.
7. Use 5 km[N] and 5 km[E]. These vectors have equal magnitudes but are different vectors.
8. The key here is the definition of velocity. Velocity is displacement divided by time. Thus, if you travelled for 1 hour and ended up only 2 km from where you started, your average velocity would be 2 km/h. However, your odometer may have registered 180 km. You could have travelled north 91 km then turned around and gone south 89 km. Your average speed would then have been 180 km/h.
9. Because one person is travelling away from you and the other towards you, they have different directions and, therefore, different velocities. Their speeds are the same.
10. and **11.** In a 100-m dash, the sprinter tries to accelerate as long as possible to the maximum speed he can reach and then tries to maintain it. In a longer race, the key is to get to a competitive speed but to save some speed in reserve so you can accelerate near the end of the race. It is difficult to maintain the speed a 100-m sprinter reaches for any period of time. Thus, the strategies are different.
12. For average speed, take the total distance travelled and divide it by the time. For average velocity, connect the two points on the curve with a straight line and take its slope (essentially this is final position minus the initial position). To find instantaneous velocity (which is also the instantaneous speed) with a direction, draw a tangent at a given time to the curve and find its slope. The + or − indicates the direction.
13. **a)** At a distance of 300 km west of the origin, a person's instantaneous velocity is 50 km/h going east.
    **b)** The Superman ride moves with a positive velocity and covers a positive displacement on the way up to the top. At the top, the rider's displacement as measured from the top becomes negative during the descent. The rider's velocity is now downward or negative. As the rider goes across the level section, assume he is travelling to the right. Thus, his velocity and displacement are both positive in this dimension.
14. **a)** Yes. If you are located to the negative side of the origin but travelling back to the origin, you can have negative displacement and positive velocity.

**b)** Yes. At the moment you reach the place you started from, your displacement is zero. However, if you are still moving in the negative direction, you have a negative instantaneous velocity.

**c)** Yes. By going the same distance in one direction as you did in the opposite direction, you cover a finite value of distance but have no displacement as you end up back in the same place you started from.

## Chapter 2

**1.** Assume for all the cases that north is positive and south is negative.

**i)** The $\vec{d}$-$t$ representation starts with the object sitting motionless south of the designated zero point. It then starts moving with a constant velocity northward crossing the zero point and ending up in a position north of the designated zero position.

The $\vec{v}$-$t$ representation shows the object moving with a constant velocity southward. It then starts to slow down, still moving southward, until it stops, changes direction, and speeds up in a northern direction.

**ii)** $\vec{d}$-$t$: The object speeds up, moving in a northern direction, then continues to move northward with a constant velocity.

$\vec{v}$-$t$: The object speeds up with a changing acceleration, moving northward. It then continues to speed up with a constant acceleration in a northern direction.

**iii)** $\vec{d}$-$t$: The object starts north of the zero position and moves south past the zero position with a constant velocity. It then changes its velocity abruptly to a smaller value but continues to move southward.

$\vec{v}$-$t$: The object is moving northward but slowing down until it comes to a complete stop. It changes direction and speeds up towards the south. It suddenly changes the acceleration to a smaller value but continues to speed up while moving southward.

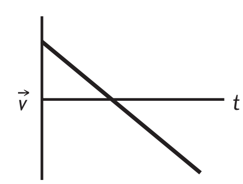
**iv)** $\vec{d}$-$t$: The object moves northward and slows down to a stop, where it sits motionless for a period of time. It then moves southward with a constant velocity, going past the zero position.

$\vec{v}$-$t$: The object speeds up while moving in a northern direction. The acceleration in this time period is decreasing. The object then continues to move northward with a constant velocity. It then slows down, moving northward until it comes to a stop. At this point, it turns around and speeds up in a southern direction.

**2.** $\vec{d}$-$t$: The $t$ axis locates a starting position from which you can measure the displacement. Example: the desk at the front of the classroom is the initial zero point. Displacements to the right of the desk are positive and displacements to the left are negative. By moving the axis up or down, the location of this zero point is changed. The actual motion itself does not change.

$\vec{v}$-$t$: The $t$ axis in this case alters the motion direction and type. A straight line above the $t$ axis with a positive slope means the object is speeding up and moving in a positive direction. If this same line occurs below the $t$ axis, then the object is moving south but slowing down. Thus, the time axis is extremely important in defining the type of motion the object undergoes.

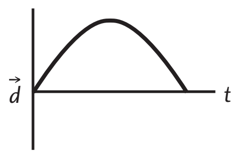
**3. a)**




**b)** The acceleration is constant because it is being produced by Earth and is a result of gravity. As the object undergoes the various stages of motion, Earth does not go away and gravity does not change significantly.

**c)** As the ball goes up, velocity is positive and acceleration is negative so the ball slows down.

As the ball goes down, the velocity is negative and the acceleration is still negative so the ball speeds up.

**d)** 

**4.** Yes. The ball at the highest point of its path stops moving but not accelerating. Since the force of gravity has not vanished, it is still acting on the ball, causing it to change its direction of motion. Thus, the three possible motions caused by an acceleration are speeding up, slowing down, and turning.

**5.** Converted to m/s, 10 370 km/h$^2$ is 0.8 m/s$^2$, which is a reasonable value. The original value is large because the unit implies an acceleration lasting one hour. Most accelerations last only a few seconds.

**6.** **a)** Air resistance acts on the large surface area of the sheet, causing it to fall slower than the bowling ball.

**b)** Reduce the air resistance of the object by crumpling the paper.

**c)** Since there is no air in a vacuum, the force of air resistance is zero and both objects would fall at the same rate.

**7.** No. Because the object is accelerating on the way down, it ends up covering more distance per unit time as it falls. The equation $\vec{d} = \frac{1}{2}\vec{a}t^2$ illustrates this. Just put values of time into the equation and check the distance covered over the same time period.

**8.** The five kinematics equations were derived from a $\vec{v}$-$t$ graph with a straight line motion. This means that the slope was constant and the acceleration was also constant.

**9.** Considerations would be the size of the intersection and the speed limit for the area. Some small amount must be added to the time for reaction to seeing the light change. The size of the intersection will determine the time needed for a car to comfortably clear the intersection at or slightly below the speed allowed in the area.

**10.** Impossible graphs include any graph: i) that has a place where two or more velocities are possible in one time, ii) that causes an object to travel backward in time, iii) that has negative time, iv) with velocities greater than the speed of light.

Unlikely graphs are those with major changes in motion over very short time periods.

**11.** Probably not as the final speed is twice that of the average, assuming the person started from rest and accelerated with a constant acceleration. However, it is difficult to maintain a top velocity for long.

**12.** Most of the accelerations have been constant. Thus, the graph would be comprised of only flat sections. However, in question 1 some $\vec{v}$-$t$ graphs had curved sections which would result in straight diagonal lines on the $\vec{a}$-$t$ graph. The transition is the same in shapes as for $\vec{d}$-$t$ to $\vec{v}$-$t$ graphs.

**13.** This is the second part of question 12. Rockets undergo changing accelerations regularly. Most objects do to some extent. A good example for visualizing the effect is that of a chain sliding off a table. As the chain falls, more mass overhangs the table. Thus, the force pulling the chain down is always increasing.

## Chapter 3

**1.** The motion is linear as opposed to parabolic. In outer space, if an object fires two jets at right angles to each other, it will move off in a straight line. The two vector velocities will add to produce the final velocity. Any event where the forces are equal in magnitude but not direction will cause velocities and accelerations that are also equal, resulting in linear motion.

**2.** Any self-powered object can accelerate in two directions. Examples are rockets, planes, balloons that are expelling air, and anything that can push itself in a given direction. (Acceleration due to gravity can be one direction and the propulsion unit of the object can cause it to accelerate in the other direction).

**3.** Because both objects fall at the same rate due to gravity (assuming negligible air resistance), the pea falls the same distance as the pail and will always hit it.

**4.** As soon as the ball leaves the pitcher's hand, it starts a trajectory downward. The radius of curvature of the trajectory varies with the initial speed of the ball. If the speed is great like that of a fastball, the ball drops a smaller distance than for a change up or curve ball as it arrives at the plate. The slower speeds result in greater drops. These effects are compounded by air resistance effects. The net effect is that the fast ball appears to rise rather than drop less. In some cases, when the pitcher pitches a ball side arm and gives the ball an initial vertical velocity, the ball can actually rise up, before falling.

**5.** No. The force of gravity is always present.

**6.** Air resistance and spin on the object. The spin creates greater stability for flight and, therefore, increases the range. Compare the flight of a bullet out of a modern gun to the flight of a blunderbuss circular mini cannonball. If the force of the gun on the projectile was the same for both and the mass of the objects was also the same, the spinning bullet would travel farther in air.

**7.** No-spin projectile sports: shot put, hammer throw, knuckleball in baseball, knuckleball in volleyball, darts, beanbag toss. Spin on projectiles occurs on almost all projectile sports. It increases distance in most cases and creates motion in different directions.

**8.** **a)** The maximum speed always occurs when the object is closest to the ground.

**b)** The minimum speed occurs at the highest point.

**9.** Hits 1, 2, and 3 land together first and hit 4 lands last. The initial velocities for the first three hits was the same (zero) in the $y$ direction while the fourth hit had a positive $y$ component causing it to spend more time in the air.

**10.** Inside the plane, the ball drops straight down. This is because both you and the ball have the same horizontal velocity. Standing on the ground, Superman sees projectile motion. The ball has a constant horizontal velocity and an ever– increasing vertical velocity because of the acceleration due to gravity.

**11.** A satellite in orbit continually falls but essentially misses Earth. It is still trapped by the gravitational pull of Earth and will continue to fall until its orbit erodes due to minute frictional effects of the thin atmosphere that exists even out in orbital distances above Earth.

## Chapter 4

**1.** and **2.** Place a soft, ironed tablecloth on a smooth, polished table. On top of the tablecloth, place a set of reasonably heavy dishes. The smooth table and ironed cloth minimize friction. The more massive dishes increase the inertia of the objects. The dishes should have smooth bottoms as well, minimizing drag. With a sharp tug, snap the tablecloth away from the table, making sure to pull horizontally. The sharp tug ensures the time is too short to allow the objects to slide with the cloth and the horizontal pull ensures no lifting of the dishes occurs. Because of Newton's law, the dishes remain in place while the cloth slides from under them.

To hinder the demonstration, you could use light plastic or paper dishes, have rough bottoms on the dishes, or have a rough tablecloth and table surface.

**3.** **a)** By Newton's first law, the condition of rest is equivalent to moving in a straight line with constant speed. These are called inertial reference frames. Thus, you feel the same in both conditions.

**b)** If the object around you (the car) accelerates forward, it actually tries to leave you behind (you have inertia). Thus, the back of the seat moves up to meet you. What you feel is the opposite effect of being pressed back. In the inertial reference frame, we see the car move forward while you oppose the motion. In the non-inertial frame (accelerated reference frame), you feel an apparent push pressing you back into the seat. The converse is true for braking.

**4.** **a) and b)** When the velocity is constant (moving either forward or backward), the objects will hang straight down. This is the inertial reference frame of Newton's laws.

**c), d), and e)** In the case of an acceleration, the object will hang in the opposite direction to the acceleration. Thus, if the car is speeding up, the objects are pulled back as the car pulls away from them. If the car breaks, the objects move forward as the car lags behind the object.

5. In the turning case, the acceleration, as observed in a reference frame outside the car, is towards the centre of the turn (centripetal acceleration). The objects will again move in the opposite direction. The experience is a centrifugal acceleration, which is the non-inertial reference frame acceleration. The effect is of the car turning underneath the hanging objects that are trying to go in a straight line. Thus, the position of the car is changed relative to the object, causing it to deflect towards the outside of the turn.
6. Whiplash occurs when a sudden acceleration causes the head to snap either forwards or backwards. The change in motion (Newton's second law) of the vehicle carrying the person causes the person to lurch in a given direction. The seat belt prevents the person from continuing the motion he or she has already obtained from the car's original velocity (Newton's first law). The head, which is free to move, continues slightly further until the neck muscles, ligaments, and skeletal structure stop it. There is a reaction force that then causes the head to snap back in the other direction, compounding the damage to the neck. The strain on these body parts results in whiplash. It is not necessary to be in a vehicle for whiplash to occur. Any sudden movement of the body relative to the head may cause whiplash. The head obeys the first law until the second law comes into play, changing the head's state over a short time period.
7. These are examples of Newton's third law. The gases burning in the fuel compartment of a rocket expand and are forced violently out of the rocket. This is the action force. The reaction force is the gases pushing back on the rocket. This force is larger than the force of gravity, air resistance, and skin friction of the rocket, causing the rocket to accelerate upwards.

   The balloon acts the same way. The air is forced out of the balloon by the elastic material of the balloon trying to get back to its relaxed state. The air in turn causes the balloon to fly in the opposite direction. This same principle is used in maneuvering the shuttle and astronauts in space. Small jets are directed in short bursts (to conserve energy), causing the shuttle to move in the opposite direction.
8. As a rocket moves upward, the thrust causing the acceleration remains constant as the rate of burning of the fuel is independent of the amount of fuel in the compartment. As the fuel is used up, the mass of the rocket decreases and the acceleration increases ($\vec{F} = m\vec{a}$). In cases where the stages are ejected as they are used up, the mass increases dramatically. The early Mercury and Apollo missions using the Atlas rocket used this method. Now, given budget constraints and environmental concerns, the solid fuel attachments to the shuttle are reusable. After they are spent, they parachute down to be collected and reworked for the next mission.
9. An action force, such as a person lifting an object, causes the object to move up because it is an unbalanced force. The lifting force is greater then the weight of the object. The floor creates a reaction force only—a force that exists only as long as the person is in contact with the surface. The force is equal in magnitude to the weight of the person. Thus, the force of gravity acting on the person and the normal force cancel out.
10. A person steps forward, pushing off the boat. The person pushes the boat back while the equal and opposite force of the boat pushes the person forward. In the first case, the tension in the rope balances out the person's push on the boat and stops it from moving. The net force on the boat is zero, though the two forces acting on the boat are not an action–reaction pair. In the case where the boat is not tied, only the resistance of the water acts against the push. The forces are unbalanced, causing the boat to move back as the person moves forward. This will most likely result in the person losing his or her balance and falling in the water.

**11.** Figure 4.28 shows that the fan exerts a forward driving force on the air, which pushes the sails, which push the boat. However, the reaction force of the air pushing on the fan counteracts the forward driving force of the fan.

If the sail was removed, then the boat would move much like a swamp buggy. If the fan was removed from the boat, then it would act like conventional wind, except for the long extension cord. Finally, if the fan was lowered into the water, it would act just like the prop of a motorboat.

**12.** Yes. The reaction force of Earth pulling you down is you pulling Earth up. However, in the FBD of Earth, the mass used is $5.38 \times 10^{24}$ kg with the force acting on it about 700 N (70-kg person). This means that Earth accelerates at about $10^{-21}$ m/s$^2$. Considering the size of a nucleus is about $10^{-15}$ m, Earth is hardly affected by this force. As an interesting offshoot, ask the students to calculate the total mass of humans on this planet and to determine if that number creates a significant force.

**13.** Again, by Newton's first law, the particle will travel in a straight line. The tunnel walls provide the force necessary to keep the particle moving like a corkscrew. Once it leaves the tunnel, it will continue to move in a straight line with a constant speed.

**14.** In order to get the car up to speed, an unbalanced force must have acted by way of the engine, causing the wheels to turn (Newton's second law). The turning wheels pressed the car against the ground, causing the ground to push the car forward (Newton's third law). The car then entered the corner and hit an icy patch, causing the unbalanced force of friction to vanish. Thus, the first law came into effect and the car continued to move in a straight line with constant speed. The tree is what brought the car to rest (Newton's second law). Both the car and the tree experienced a force because of the crash (Newton's third law) and suffered the consequences (damage from the crash).

**15.** The rocket sits on the launch pad (Newton's first law). The fuel ignites, expands, and is pushed out of the rocket. This force causes the gases to push the rocket up (Newton's third law). Because the force upward is greater than the force downward, the rocket accelerates upward (Newton's second law). After the rocket stages are released, the mass of the rocket is smaller, creating a greater acceleration (Newton's second law). The rocket, having reached its final velocity, continues on through outer space with a constant velocity (Newton's first law). When it nears Pluto, the gravitational forces pull the rocket towards the planet and possibly into orbit (Newton's second law).

**16.** The devices are activated by a sudden change in velocity. The mechanisms of each device have a component that slides forward when the car brakes. Similar to the furry dice hanging from the ceiling of the car, when the car brakes suddenly, the locking bar moves forward, slipping into the gear mechanism and locking the seat belt in place. In the case of the air bag, the locking bar is replaced by a pin, which is driven by a ball or similar device into a detonation cap. It explodes, causing the air bag to deploy.

**17.** Any time you experience free fall, you simulate weightlessness (Newton's second law). The butterflies in your stomach are caused by the stomach and contents tending to remain where they are while the body moves away from it (Newton's first law). This sensation is most prevalent when you are going up rapidly after a fast descent because the stomach and contents were moving downwards when all of a sudden they were forced upwards. Extra $g$ forces are created by sharp banked turns or loops where the sharper the radius of the turn, the greater the speed of the car. Persons moving in a straight line (Newton's first law) are forced around the turn by the vehicle. They feel the force of the seat causing them to turn (Newton's third law).

**18.** The load in the pickup truck stays in place because of inertia. The sudden impact causes the truck to accelerate from under the load. The net effect is that the load falls out of the truck.

# Chapter 5

1. Because the force of gravity varies directly as $\frac{1}{r^2}$, there is no finite value for $r$ that makes the force zero. Thus, in principle, you will be attracted to your friend. Very slowly, you will start to move toward each other as the force of gravity will be an unbalanced force. The time to actually move any appreciable speed can be calculated using $a = Gmr^{-2}$, where $m$ is the mass of your friend and $r$ is the distance separating the two of you.
2. Since weight is the force of gravity acting on a mass and is registered by the mass pressing down on a scale (causing a resultant normal force), if the scale and the mass are both falling at the same rate, no normal force exists as the mass cannot press down on the scale. Therefore, the scale reads zero.
3. The bathroom scale actually reads your weight because the force of gravity acting on the mass causes the scale to read. In outer space, it would read zero as no force would be acting on the scale. However, if the scale is calibrated to read in kg, then the weight reading has been adjusted to read the mass equivalent for a value of $g = 9.8$ m/s$^2$. This scale would read a different value on different planets and at different elevations on Earth.
4. This is good humour. The characters and elevator will accelerate at the same rate given no air resistance. Thus, the characters will continue to stay in the same place in the elevator as they fall. The characters will not be able to exert any force down on the floor and will feel weightless. The effect of air resistance on the elevator could cause the value of its acceleration to be less than 9.8 m/s$^2$. In this case, the characters will be standing on the floor and exerting a small force down on it.
5. Anything that requires a large force downward benefits a larger force of gravity. If you are pounding in posts with a large mass, it would become more difficult to do so with a smaller force of gravity. Remember, the resisting force of the material that the post is going into does not change just because gravity has decreased. However, raising objects up, such as concrete or steel girders in a construction project, will become easier. Here the downward force has decreased. Anything that generates a force downward by way of gravity would suffer. Anything that works against gravity will benefit as less effort will be required to move the mass.
6. As you go deeper into Earth and a significant portion of mass is above you, gravity applies a force in the opposite direction to the mass below you. In fact, you are being pulled in all directions. To find the force of gravity for this case, you must find the total mass in each direction from yourself using the integration process. In general, the force of gravity is a $\frac{1}{r}$ force. At the centre, assuming Earth is perfectly spherical and of constant density, the weight of any object becomes zero because all the forces balance out.
7. Because of the force of gravity, animals developed a skeleton in order to support their mass. Consider what a jellyfish looks like out of the water. This is what we would be like without the support of our skeletons. The jellyfish uses the water and buoyancy to keep its shape. It turns out that in outer space astronauts start losing calcium from their bones. Since the body's mass is no longer being pulled down, it does not require the same strength of skeletal bones. This results in brittle, weak bones in astronauts and cosmonauts who spend long periods of time in space. Exercise and supplements help counteract this effect.
8. The $g$ values in m/s$^2$ of the planets in our solar systems are as follows: Mercury (3.6), Venus (8.8), Earth (9.8), Mars (3.8), Jupiter (24.6), Saturn (10.4), Uranus (8.2), Neptune (11.2), Pluto (4.4). Thus, the order is J, N, S, E, V, U, P, MA, M. Note that the values are not just related to mass. The order of planets in terms of mass is J, S, N, U, E, V, MA, P, M. The order of planets in terms of radius is J, S, U, N, E, V, MA, P, M. The value of $g$ also depends on the size of the planet.
9. The effect of elevation is small compared to the size of Earth. If the elevation is increased by

2000 m, the value of $g$ is decreased by 0.9994 or about $\frac{6}{100}$ of a percent. Though this is a small value, many Olympic events are measured in thousandths of a unit so the effect of elevation could mean the difference between Olympic gold or silver!

**10.** Though a star's mass is huge, it is distributed over a large spherical shape (large radius). A black hole decreases this radius from values such as $10^{30}$ m to several metres and in some cases to the size of a pinhead. The force of gravity is proportional to $r^{-2}$. Thus, if the radius of the object shrinks by $10^{29}$, the force of gravity goes up by $10^{58}$!

**11.** It is easier to pull an object than to push it. In the FBD, the pull component in the $y$ direction is pointing up against gravity. Therefore, pulling an object decreases the normal force against it and also the force of friction ($F_f = \mu F_n$). In the case of pushing at an angle, the $y$ component is directed downward in the direction of the force of gravity. Therefore, pushing an object increases the normal force against it and also the force of friction.

**12.** If the value of $F_n$ becomes negative, the forces from the FBD in the up direction are greater than in the down direction. This is independent of the sign you assign for up (+ or −) because you set $F_{net}$ to be zero, then solve for the normal force. If the up forces are greater than the down forces, the object is actually being lifted off the surface and does not have a normal force.

**13. and 14. a)** The obvious benefit of friction in sports is traction. The drawback of losing traction is miscues. Playing on a slick field creates havoc in games such as football, baseball, and track. However, dome-covered stadiums are becoming more prevalent, using artificial turf rather than natural grass (less friction, harder to make cuts on the field).

In ice sports, friction is a drawback as it hinders players' ability to skate or causes curling rocks to grab and stop moving.

Tobogganing requires some friction with the snow as does skiing in order to have a measure of directional control.

Wrestling requires friction between wrestlers and the mat, and between the wrestlers in order to create the moves associated with the sport. However, if a wrestler becomes slippery because of sweat, the lack of friction becomes a benefit to that wrestler and a drawback to the other wrestler as the first wrestler becomes harder to grab and hold. Every sport can be analyzed in this manner.

**b)** A large part of the transportation industry is built on the friction concept. Tire manufacturers make tires with tread shapes, sizes, and materials suited to the frictional conditions between tire and road for different weather situations. Friction is required to maintain control of the vehicle on the road. The drawback is that frictional values vary for icy, snowy, rainy, oily, and dry roads (each having a variety of frictional coefficient possibilities). This means that no one tire can optimally meet the needs of a driver in all road conditions. A tire that grabs ice may be soft, wear out faster because of friction, and have greater fuel consumption (roll less freely). On the other hand, a dry pavement tire will allow for less wear and tear on the motor and last longer but offer poor handling on wet roads. All-season tires are a compromise, meeting reasonable handling requirements for the conditions created by different weather situations.

Much of the data obtained for tires comes from the sport of racing. Tires developed to meet the high stress conditions in a car race are modified for use in the auto industry.

**15.** The ride in a subway car is one of stops and starts and jolts and turns. Usually, the cars are packed and some passengers must stand. Without friction, the first law would cause havoc as passengers would slam into each other when the velocity of the car changed. Even seated passengers would slide off their seats or cram the last passenger on the seat in sudden motion changes. This still happens to some extent because of the slick vinyl seat coverings used (because they are easy to clean).

**16.** "Ground effects" is a broad term that includes "skirts", "air dams", and "spoilers" on racing cars. The net effect is to create an extra downward force on the racing car. This extra downward force increases the normal force and causes the force of friction to go up. More friction equals better handling. The fast, high-powered racing cars would be able to handle corners better and at higher speeds. The main drawback to this extra friction is that the older tracks and a driver's reaction time do not always accommodate the extra speed, increasing the risk of a crash.

**17.** The normal force is a reaction force; therefore, it cannot cause an object to lift off the surface. If an object lifts off a surface, the normal force has vanished.

**18.** **i)** By changing the spring constant, you change the characteristics of the spring. This could be disastrous in the case of a bungee cord. If the $k$ is too small, it will not provide enough resistive force to slow the jumper down in time to not hit the ground or the water at an acceptable speed. If the $k$ is too large, the slowing down process becomes too abrupt and could cause damage due to the sudden decrease in speed of the jumper.

**ii)** The pogo stick could become useless if $k$ is either too small or too large. If $k$ is too small, there is no bounce back. If $k$ is too large, the pogo stick will not compress.

**iii)** The slingshot with a smaller $k$ would become weaker. The restoring action with the smaller $k$ is less. In the case of a large $k$, the slingshot would become difficult to stretch. Because the time of interaction between the slingshot and projectile decreases in this case, the control of the projectile suffers.

**iv)** The slinky relies on a small $k$ value for its properties. Increase $k$ and you obtain a more conventional spring (more rigid). Decrease the $k$ value and the spring will be too weak to restore its shape and do tricks like walk down stairs.

**19.** Try this mini-experiment. Hang a known mass from a spring. Measure the stretch of the spring. Now attach another spring of the same strength in series. Hang the same mass and observe the stretch. Repeat the experiment with two springs in parallel and observe the stretch. The parallel combination stretches less because the springs share the load. In the series case, the load is still acting over the length of the springs. Thus, springs in parallel are stronger.

## Chapter 6

**1.** It is not possible to swing a mass in a horizontal circle above your head. Since gravity is always pulling down on the mass, an upward component of the tension force is required to balance gravity. As the speed of rotation increases, the angle relative to the horizontal may approach 0° but will never reach 0°.

**2.** Inertia causes the water in your clothing to try to move in a straight line. If the drum in the washing machine were solid, it would apply a centripetal force on the water, which would keep it moving in a circle. Since the drum has holes in it, however, the water is able to leave the drum as it spins.

**3.** The near side of the Moon is more massive than the far side, possibly due to impacted meteors. Over time this side was more attracted to Earth, so that eventually the more massive side came to face Earth all the time. This is also true for the moons of Jupiter and Saturn relative to their planets.

**4.** Assuming that the spacecraft is initially in orbit and that jettisoning a large piece of itself does not significantly alter its momentum, it will continue in the same orbit.

**5.** **a)** The escape speed required to leave Earth is approximately 11 km/s. The necessary upward acceleration, $a$, of a spacecraft during firing from an 80-m cannon is given by $a = \dfrac{(11\ 000\text{ m/s})^2}{2(80\text{ m})} = 756\ 250\text{ m/s}^2$.

This is more than 77 000 times the magnitude of the acceleration due to gravity, and would be experienced for about $\Delta t = \dfrac{11\ 000\ \text{m/s}}{756\ 250\ \text{m/s}^2} = 0.015$ s. The mission would not be survivable.

**b)** The downward force of the gun's recoil would be roughly equal to the upward force on the spacecraft. If the spacecraft had a mass of 5000 kg, the force of the recoil would be approximately
$(5000\ \text{kg})(756\ 250\ \text{m/s}^2) = 3.781 \times 10^9$ N.

## Chapter 7

**1.** Hydro lines and telephone cables cannot be run completely horizontally because the force of gravity acts downward on the entire wire and there is very little means of counterbalancing this force using supports.

**2.** **a)** The ladder is pushing directly into the wall on which it is resting, normal to the surface of the wall. With no friction, there is no force to prevent the ladder from sliding down the wall.

**b)** The force exerted by the ladder on the ground is exactly equal to the force of gravity (weight) of the ladder because there is no vertical force due to friction. The only force that acts vertically, upward or downward, is the force of gravity.

**3.** Standing with your feet together or wide apart makes no difference to the condition of static equilibrium, since in both cases all forces are balanced. In terms of stability, the wider stance is more stable. A wider stance means a lower centre of mass and a wider "footprint." This means there is a greater tipping angle for this wider stance.

**4.** High-heeled shoes force the centre of mass of the person wearing to move forward from its normal position. To maintain balance, the person must move the centre of mass back again, usually by leaning the shoulders backward. This effort can cause fatigue in the back muscles.

**5.** Line installers allow a droop in their lines when installing them because the droop allows a moderate upward vertical application of force as the wire curves upward to the support standards. This allows an upward force to support the wire when loaded with freezing rain and ice buildup. This droop means that the tension to support the load can be much less because of the greater angle.

**6.** A wrench can be made to more easily open a rusty bolt by adapting the wrench so as to apply more torque. More torque can be applied by the same force by adding length to the wrench handle.

**7.** The higher up on a ladder a person is, the farther he is from the pivot point, which is the point where the ladder touches the ground. Therefore, the ladder will be more likely to slide down the wall if the person stands on a higher rung.

**8.** The torque varies as $\sin\theta$, where $\theta$ is the angle between the pedal arm and the applied force. The torque is at a minimum (zero) when the pedals are vertical (one on top of the other), because the force (weight) is applied at $0°$ to the pedal arm, and $\sin 0° = 0$. The maximum torque is applied when the pedals are horizontal, because the angle between the pedal arm and the applied force is $90°$, and $\sin 90° = 1$.

**9.** There is no extra benefit for curls to be done to their highest position. As the forearm is raised, the angle of the force of gravity vector decreases at the same rate as the angle between the muscle of effort and the arm. As the forearm is raised, the effort required to lift the arm decreases, but so does the muscle's ability to provide the effort.

**10.** Your textbook is sitting in stable equilibrium when flat on your desk. When the book is balanced on its corner, it is in unstable equilibrium. Motion in any direction will cause a lowering of the centre of mass and a release of gravitational potential energy, making the tipping motion continue and thus making the book fall.

**11.** In terms of stability, a walking cane provides a wider base (footprint) over which the person is balancing. It is harder to force the person's centre of mass outside this wider support base.

**12.** When standing up from a sitting position, we first must lean forward to move our centre of mass over our feet to maintain stability. Unless we first lean forward, our centre of mass is already outside our support base and it is impossible to stand up.

**13.** A five-legged chair base is more stable because of the wider support base (footprint). The extra leg effectively increases the tipping angle, making the chair more stable.

**14.** Tall fluted champagne glasses must have a wide base to improve the stability of the glass. Recall that the tipping angle is given by the expression $\theta = \tan^{-1}\dfrac{(0.5)(\text{width of base})}{\text{height of centre of mass}}$. Therefore, the taller the glass, the greater the height of the centre of mass, and the smaller the tipping angle. A wider base increases the tipping angle by compensating for the taller glass.

**15.** The extra mass helps to mimic the mass of the cargo and lowers the centre of mass of the ship. Without this extra mass, the ship would be top-heavy and more prone to capsizing, especially in rough weather.

**16.** This figure is so stable because the design of the toy places the effective centre of mass below the balance point. A gentle push actually raises the centre of mass like a pendulum, which increases the gravitational potential energy, which tends to return the toy to its stable equilibrium position.

## Chapter 8

**1.** Momentum is the product of mass and velocity; $\vec{p} = m\vec{v}$. Since velocity is a vector quantity, so is momentum.

**2.** There can be a great deal of motion. As long as the momenta of all the objects cancel out, the total momentum can equal zero. However, individual objects are all moving.

**3.** Once the objects are moving and the force causing the motion is gone, the objects obey Newton's first law. They will maintain constant velocities unless acted upon by an external unbalanced force.

**4.** Before moving, the total momentum of the system is zero. As you move in one direction, the canoe moves in the other. The velocity of the canoe depends on your mass, the canoe's mass, and the velocity you are moving at. Thus, $(mv)_{\text{person}} = (mv)_{\text{canoe}}$ or $(mv)_{\text{person}} - (mv)_{\text{canoe}} = 0$.

**5.** As the bullet is pushed out of the gun, it applies an impulse back on the gun. The gun is then brought to rest by the shoulder. Once again, the total momentum before firing is equal to the momentum after firing. $(mv)_{\text{bullet}} - (mv)_{\text{gun}} = 0$. If the gun is slightly away from the shoulder at the time of the firing, it will slam back into the shoulder causing some pain. The time to bring the gun to rest is short and the stopping force is large. If the gun is pressed against the shoulder before firing, the recoil can be absorbed smoothly by the body. The experienced handler moves his or her body back when firing, increasing the time of interaction and requiring a smaller force to stop the gun.

**6.** Assume + is right and − is left.

| Mass 1 (initial) | Mass 2 (initial) | Mass 1 (final) | Mass 2 (final) | Example |
|---|---|---|---|---|
| moving (+) | stopped | stopped | moving (+) | billiard balls |
| moving (+) | stopped | moving (+) | moving (+) | curling rocks |
| moving (+) | moving (+) | moving (+) | moving (+) | bowling ball hits pins |
| moving (+) | moving (−) | moving (+) | moving (+) | truck hits car |
| moving (+) | moving (−) | moving (−) | moving (+) | car hits truck |
| moving (+) | stopped | stick together | | dart hits pendulum |
| moving (+) | moving (−) | stick together | | Plasticine balls |
| moving (+) | moving (+) | stick together | | Velcro balls |

**7.** The net force is used in the calculation of impulse; $J = F\Delta t$.

**8.** Impulse is the change in momentum; $J = \Delta p$.

**9.** The law of conservation of (linear) momentum states that the total momentum of an isolated system before a collision is equal to the total momentum of the system after the collision.

This can be expressed algebraically as $p_{\text{totalinitial}} = p_{\text{totalfinal}}$. Equivalently, in an isolated system the change in momentum is zero; $\Delta p = 0$.

**10.** Yes, a ball thrown upward loses momentum as it rises because there is a net external force downward (gravity) acting on the ball, slowing it down.

**11.** Assuming that the net external force acting on the grenade during the explosion is zero (ignoring gravity), the sum of the 45 momentum vectors after the explosion is equal to the momentum vector of the grenade before the explosion, since $p_{\text{totalinitial}} = p_{\text{totalfinal}}$.

**12.** Assume that the astronaut's initial momentum is zero as he floats in space. By throwing the monkey wrench in the opposite direction of the space station, he would be propelled toward the space station. This is an example of Newton's third law: The total momentum of the astronaut–wrench system would still be zero after he threw the wrench.

**13.** The lemming–Earth system has a total momentum of zero before the fall. As the lemming falls towards the net on Earth, Earth and the net move up toward the lemming. Since the lemming has a mass of about 1 kg and Earth has a mass of about $10^{24}$ kg, Earth gains a tiny, imperceptible velocity.

**14.** The gas–rocket system has a total momentum of zero before the launch. As the rocket fires, it gains upward momentum. The gases expelled out gain downward momentum. The two momenta cancel at all times, even as the rocket loses mass. The velocity of the rocket increases as it loses mass. For the most part, the gases are expelled at a constant rate. After the gases have burned off, the rocket continues with a constant momentum. The other momentum was carried off by the gases and must be included if you are to discuss the original system.

**15.** The aerosol can plus the mass of the astronaut and the contents of the can have a total momentum of zero. If the astronaut sprays out the contents of the aerosol can, their mass times their velocity will create a momentum in one direction. The astronaut plus the aerosol can will move off (much slower) in the opposite direction. The total momentum of this system remains zero. Questions 15 and 21 can also be discussed in terms of impulse and Newton's third law.

**16.** A rocket can change its course in space by ejecting any object or matter such as a gas. Assuming that the total momentum of the rocket–gas system is conserved, the momentum of the rocket will change as the gas is ejected. This change in momentum will correspond to an impulse, which will change the course of the rocket.

**17.** Assume that the total momentum of the system is conserved:

$$p_{\text{To}} = p_{\text{Tf}}$$
$$p_{1\text{o}} + p_{2\text{o}} = p_{1\text{f}} + p_{2\text{f}}$$
$$mv_{1\text{o}} + mv_{2\text{o}} = mv_{1\text{f}} + mv_{2\text{f}}$$
$$mv_{1\text{o}} + m(-v_{1\text{o}}) = mv_{1\text{f}} + mv_{2\text{f}}$$
$$(\text{substituting } v_{2\text{o}} = -v_{1\text{o}})$$
$$0 = m(v_{1\text{f}} + v_{2\text{f}})$$

Therefore, the general equation for the total momentum before and after the collision is $p_{\text{To}} = 0 = m(v_{1\text{f}} + v_{2\text{f}}) = p_{\text{Tf}}$.

**18.** As rain falls into the open-top freight car, the car will slow down. Assuming that momentum is conserved as the rain falls into the car, the combined mass of the car and the water will move along the track at a slower speed.

**19.** Object A is moving faster before the collision. Assuming that the momentum of the A-B system is conserved, the final velocity of the objects, $v_{\text{f}}$, is equal to the average of their initial velocities, $v_{\text{Ao}}$ and $v_{\text{Bo}}$:

$$p_{\text{To}} = p_{\text{Tf}}$$
$$mv_{\text{Ao}} + mv_{\text{Bo}} = mv_{\text{Af}} + mv_{\text{Bf}}$$
$$v_{\text{Ao}} + v_{\text{Bo}} = v_{\text{f}} + v_{\text{f}}$$
$$\frac{v_{\text{Ao}} + v_{\text{Bo}}}{2} = v_{\text{f}}$$

Since the angle between $v_{\text{Bo}}$ and $v_{\text{f}}$ is greater than the angle between $v_{\text{Ao}}$ and $v_{\text{f}}$, the magnitude of $v_{\text{Ao}}$ is greater than the magnitude of $v_{\text{Bo}}$.

**20.** The component method would be preferred for solving momentum problems in which trigonometry could not be used readily — for instance, problems involving more than two objects colliding, or non-linear problems.

**21.** A person of certain mass has a forward momentum during the accident. The air bag deploys with a momentum in the opposite direction. It causes an impulse to be applied to the person. The time of interaction is relatively short and the stopping force is large. However, the impulse is still smaller in force and longer in time than if the person was to hit the windshield. This gives the person a better chance to survive.

A smaller person receives this impulse to the head. Such an impulse can break the neck. The impulse also causes a greater change in velocity to a person of small mass, leading to more physical damage.

**22.** Though two pushes can have the same force, the impulse can cause more damage locally if the time of interaction is shorter as the force is distributed over a shorter time period (and probably area).

**23.** Offensive linemen use quick short thrusts to ward off defensive players. The impulse time in these cases is short and the force is large. This forces the opposing lineman back, winning more time for the quarterback. The linemen on both sides of the play hit quick and hard off the snap in order to get an advantage over their oponents. Holes in the opposition's defence must be opened up quickly so the runner can get through. If the time of interaction is long, there is a good chance holding is taking place, incurring a penalty.

Kickers use a short time and large force in transferring the momentum of their foot to that of the ball. The motion of the kick is such that the force generated is large if the foot is moving fast. Thus, the slower the foot motion, the longer the time of interaction but the smaller the force.

Longer times involve impulses that require control. When he throws the ball, the quarterback holds on to it for a couple of seconds, ensuring that the ball gains a controlled velocity. The follow through ensures that the fingers and ball stay in contact for the longest possible time allowed within the time constraints of the play. The passer must bring the ball in under control. As the passer's hands make contact with the ball, they draw back in the direction of the ball, allowing more time to be used in stopping the ball (transferring the momentum to the player).

**24.** **a)** and **b)** By virtue of just standing on the ground, Superman relies on friction to stop the train. Assuming Superman's mass is about 100 kg and the rubber on the suit has a large kinetic coefficient of about 3, the force of friction is $(9.8\ \text{m/s}^2)(100\ \text{kg})(3) = 2940$ N. A cement truck of mass $1.0 \times 10^4$ kg moving at 90 km/h has a momentum of $2.5 \times 10^5$ kg·m/s. This momentum must be brought to zero by the force applied by Superman. The time taken is

$\frac{(2.5 \times 10^5\ \text{kg}\cdot\text{m/s})}{2940\ \text{N}} = 85$ s. This translates to a distance of 1062 m or just over half a mile for Superman to stop the cement truck.

Given that the runaway cement truck is probably an emergency, this is not an acceptable distance in which to stop it.

**c)** If Superman also had a velocity in the opposite direction, his momentum would be larger and he could generate a larger impulse force. He could also dig his heels into the pavement and create a larger retarding force than that of just friction (at the expense of the pavement).

**d)** Too large a force and too short a stopping time would result in trauma to the driver as he would also come to a sudden stop. The best bet would be for Superman to move with the truck, lift it up in the air, and slowly bring the truck to a stop. (Maybe by blowing air out of his mouth to create the force required).

**25.** The duck and raft constitute a system with total momentum of zero. As the duck moves forward, the raft moves back. The resistance of the water does not allow the raft to move significantly.

**26.** This is like question 25 with the major addition that the mass of the cruise ship is so large that its momentum is not affected significantly by any movement of passengers on board.

27. One system is just the two masses and spring. The total momentum is conserved when the two masses spring apart. The next step is to include each object's interaction with its environment. One object gives up its momentum quickly to the sandpaper, losing mass and generating heat (motion of particles on a microscopic level), the other more gradually. For each object and environment, momentum is still conserved. The transfer of momentum leads to effects such as heating and breakup of materials. It is more usual to treat such cases using energy considerations.

## Chapter 9

1. The equation for work ($W = \vec{F}\Delta\vec{d}$) clearly shows that for work to be done, the force applied must result in a displacement in the direction that the force is applied. No work is done on the wall because the force applied to it does not result in any displacement. You feel tired because your muscles have been doing work on themselves. The individual muscle fibres have been moving with respect to each other with no overall visible motion of the muscle itself.
2. When the pendulum is pulled sideways at some displacement from the rest position, it is also raised slightly, giving it some gravitational potential energy. After release, the gravitational potential energy is transferred to kinetic energy as it "falls" and picks up speed. At the rest position, the lowest position, the gravitational potential energy is at a minimum because the energy has been transferred to kinetic energy. As the pendulum rises again, the kinetic energy is once again transferred back into gravitational potential energy. If the energy were totally conserved, the pendulum would continue to oscillate forever, always returning to the same height before starting the cycle over again. The fact that a pendulum eventually stops shows that some energy is being permanently transferred to kinetic energy of the air around it.
3. **Case 1:** The energy from the Sun has caused water from Earth to evaporate and condense to make rain clouds. The rain falls to Earth, landing on higher ground, compared to the lake from which it first came, giving it a greater amount of gravitational potential energy. Gathering into a river that feeds a waterfall, the rain water transfers its energy to kinetic energy which does work on a turbine in a hydroelectric generating station. The kinetic energy does work on the turbine and generator, transferring electrical energy to the electric charge that flows to your home to finally transfer the energy to heat to make your coffee.
   **Case 2:** The Sun's energy has been trapped by the process of photosynthesis as carbohydrates in plants. These plants, which have long since died, have been covered over by soil and earth and have undergone a chemical process, leaving the energy stored as chemical potential energy in the chemical bonds of oil and natural gas still buried under the earth as fossil fuels. These fuels are then burned in a thermal-electric generating station, transferring the energy to heat and creating steam. The energy of the expanding steam is transferred to a turbine that does work on an electric generator, resulting in electrical energy being delivered to your home for your morning coffee.
   **Case 3:** The energy to run a steam turbine as in case 2 could have come from nuclear potential energy. This energy was stored in the nucleus of atoms at the time that Earth was made. This energy is released to heat water to steam in what is called a nuclear reactor.
4. Work is not done on an object when:
   **i)** a force is applied to an object but the object is not displaced (no motion occurs). When a student leans against the back wall of an auditorium during an assembly, there is an applied force on the wall but the wall does not move so no work is being done on the wall.
   **ii)** the applied force is not responsible for the observed motion of an object. When a delivery person brings a pizza to your door, he or she is applying a force up to keep the pizza from falling and a horizontal force to move him or herself and the pizza to your door. Although motion is occurring, the work is

not done by the upward applied force. The force that does the work must be along the same axis of motion, either acting with the motion or against it.

**iii)** an object may be moving but is not experiencing any applied force. When any object is coasting at a constant speed, like a car sliding on an icy road, the object is being displaced but there is no applied force, so no work is being done.

**5.** The tennis ball has the most efficient bounce because it is able to retain a greater percentage of its original energy. Both balls impact the ground at the same speed, gaining energy from their similar falls. During impact, the kinetic energy is temporarily transferred to elastic potential energy as well as heat and sound energy. The elastic potential energy is partially returned to the system as the balls regain their shapes and begin their ascents. The less efficient bounce of the squash ball would result in less kinetic energy being transferred back to gravitational potential energy. Less gravitational potential energy would mean less height on the way back up.

**6.** The doubling of the speed of an object without a change in its mass would result in four times as much kinetic energy. If $E_k = \frac{1}{2}mv^2$, a doubling of the speed would yield $E_k = \frac{1}{2}m(2v)^2 = \frac{1}{2}m(4)v^2 = 4(\frac{1}{2}mv^2)$ or $4(E_k)$.

**7.** To do work on the spring, the winder is transferring the chemical potential energy from some food that he or she has eaten into kinetic energy to wind the spring. The work on the spring stores elastic potential energy as the metal is being bent. During release, the stored energy in the spring is transferred to kinetic energy of the toy car as the spring applies a force that does work on the toy car.

**8.** The ball in motion will transfer its kinetic energy of motion into elastic potential energy of the side cushion as the cushion is compressed. When the cushion returns to its normal shape, the force it applies back on the ball does work to increase the kinetic energy of the ball, which we see as a bounce.

**9.** The kinetic energy ($E_k = \frac{1}{2}mv^2$) of any object is determined by considering both the mass of the object and its speed. If the kinetic energy of a baseball and a car are the same and their masses are obviously quite different, then the speeds of the two objects must also be different. The speed of the ball must be quite a bit greater than that of the car.

**10.** During typical energy transformations, energy is conserved but it is being transferred to forms that are either unrecoverable or useful. None of the energy stored in the gasoline in a car will ever be totally lost. It will be transferred to kinetic energy of the car, heat and sound energy in the engine, and kinetic energy of the air that it disturbs. Although the kinetic energy of the car is useful to us, most of the heat and sound, as well as the energy of the air wake, will be dispersed in the atmosphere. Although this energy still exists, it will probably end up being radiated out as heat into space and will, therefore, become useless to us. The end result is that, although the total amount of energy in the universe is constant, the amount of useful energy on Earth is decreasing.

**11.** The amount of energy from stored fat that is not directly used to do mechanical work during a workout is used to power many biological processes. The energy is used to maintain the body by supplying energy to help the muscles of the heart and the diaphragm and by keeping our blood oxygenated and moving. The chemical reactions in our bodies also liberate heat energy that does not do any mechanical work. It seems that just the daily business of living is enough to transfer energy out of storage in body fat.

**12.** The momentum, $p$, of an object with mass $m$ is related to its kinetic energy, $E_k$, according to the equation $p = \sqrt{2mE_k}$. If a golf ball and a football have the same kinetic energy then the football has the greater momentum, since the mass of the football is greater than the mass of the golf ball.

**13.** A negative area under a force–displacement graph represents negative work, which means that the displacement is in the opposite direction of the force applied. For example, when friction is slowing down a car, there is a positive displacement but a negative force.

**14.** After work is done on an object, it has gained energy.

**15.** When a spring diving board is compressed by a diver jumping on it, the diving board possesses elastic potential energy. As the diving board straightens out, it transfers its elastic potential energy to the diver, who gains kinetic and gravitational potential energy. As the diver rises in the air, her kinetic energy is transformed into potential energy until she only has gravitational potential energy as she reaches her highest point. As she descends toward the pool, her potential energy is transformed into kinetic energy and she increases her speed as she falls. As she enters the pool and slows down in the water, her kinetic energy is transferred to the water as kinetic energy, potential energy, and heat energy.

**16.** $E_k = \frac{1}{2}mv^2$

$(\text{J}) = (\text{kg})[(\text{m/s})^2]$

$(\text{J}) = (\text{kg} \cdot \text{m}^2/\text{s}^2)$

$(\text{J}) = (\text{kg} \cdot \text{m/s}^2 \cdot \text{m})$

$(\text{J}) = (\text{N} \cdot \text{m})$

$(\text{J}) = (\text{J})$

**17.** The equation $-\Delta E_e = \Delta E_k$ means that a loss of elastic potential energy becomes a gain in kinetic energy.

**18.** Yes, since gravitational potential energy is measured relative to a point which could change. That point could be the ground level, the basement level, or any other arbitrary point.

**19.** In an elastic collision the total kinetic energy is conserved, whereas in an inelastic collision the total kinetic energy is not conserved. An example of an (almost) elastic collision is a collision between two billiard balls. An example of an inelastic collision is a collision between two vehicles in which their kinetic energy is transferred to heat energy, sound energy, and energy used to permanently deform the vehicles.

**20.** No, the equation $E_k = \frac{p^2}{2m}$ shows that if an object has momentum then it must have kinetic energy. The converse is also true, as the equation also shows.

## Chapter 10

**1.** If you consider transverse spring vibration, then the velocity is perpendicular to the propagation direction just as it is for the electric and magnetic fields of the e/m wave. Raising the spring above the ground and allowing it to vibrate in different planes is analogous to the unpolarized light wave.

**2.** The sine wave indicates the important parts of a cyclic action. These are the wavelength, amplitude (both negative and positive), phase relationships, and (if plotted against time) the period and frequency (hence the velocity).

**3.** Electricity is electron flow in conductive wires. Being a particle, the electron cannot move near the speed of light in this medium due to the resistive properties of the conductor. Thus, any information it is carrying is limited in transmission by its speed. Light, on the other hand, moves at $\frac{c}{n}$ where $n$ is the refractive index of the material. At about $10^8$ m/s, this order of magnitude is faster and more efficient (losses are not as large due to little or no heating effect by the light moving through the optical material). The extra speed allows computers to process more complicated tasks more efficiently.

**4.** Because of the laws of reflection, a ray travelling from the foot to the eye reflects part way up the mirror. Similarly, the ray from the top of the head reflects part way down the mirror. The triangles formed by the incident and reflected rays are isosceles, which eliminates the need for half the mirror. If you have a longer mirror, you will see more of the background, such as the floor or ceiling.

**5.** The light inside a silvered box does not last through many reflections because some light always manages to penetrate the silvered layer. There are losses upon reflection of about 30%. If one used thin films instead where almost

100 % reflection occurs, the light would still disappear due to losses from the evanescent wave.

**6.** The angles of the stealth aircraft are designed so that they reflect the radar waves away from the source/receiver.

**7.** The image of the duck is upright because of the double reflection, virtual, and the same size as the actual duck, viewed from whatever distance using the periscope.

**8.** The speed of the image is the same as your speed, only approaching you. Thus, the relative speed is two times your speed.

**9.** Because the Moon has no atmosphere, the light from stars does not get refracted. Therefore, a star seen on the Moon does not twinkle.

**10.** **a)** Light entering the air from water, originating from the fish gets bent away from an imaginary normal perpendicular to the medium boundary. The light enters our eyes. Since we construct images based on light travelling in straight lines, we see the fish farther away from us than it really is. Thus, you should aim the spear behind the image of the fish.

**b)** If you used a laser, then you would aim directly at the image of the fish. Lasers send out coherent pulses of electromagnetic radiation in the light part of the spectrum (although the term "laser" is now used in a broader context). The light from the laser will refract at the boundary and hit the fish. This illustrates the fact that the arrows on rays can be reversed without affecting the physics of the situation.

**11.** Mirages can be captured on film as the light coming from the actual object is only bent away from its true origin. Because the light from the camera lens focusses the light onto the film, the image is real.

**12.** At the critical angle and beyond, the person's legs would not be visible. The water–air boundary becomes a mirror at this point. Most pools are painted blue so the boundary would reflect the colour blue; only the parts of the body under water are visible.

**13.** In total internal reflection, almost 100 % of the light is reflected. With conventional mirrors, where a shiny metallic layer is evaporated onto a sheet of glass, some of the light is transmitted through the surface. Only about 70 % of the light is reflected.

**14.** Our eyes are designed to operate with air as the incident medium. About 70 % of the refraction occurs at the air–cornea boundary (the cornea has a refractive index of about 1.38). Given that water has a refractive index of 1.33, little bending (therefore, focussing) occurs. Thus, one sees a blurred image. However, when goggles are used, an air–cornea boundary is produced. This means that the eye is once again working in a normal environment and will produce a sharp image.

**15.** The diamond–air critical angle is smaller than the water–diamond angle ($\sin^{-1}\left(\frac{1.00}{2.42}\right) = 24.4°$: $\sin^{-1}\left(\frac{1.33}{2.42}\right) = 33.3°$). Thus, more reflections are possible with the diamond–air boundary and the diamond sparkles more out of water.

**16.** To get more internal reflections than diamond, the substance must be optically more dense. Thus, it will have a refractive index greater than 2.42. The critical angle then becomes smaller and more reflections can take place inside the object, creating a greater sparkle.

**17.** Because the Sun is below the horizon when we see it, due to refraction, the day is longer than if the Sun was viewed without refraction.

**18.** When looking into a fish tank obliquely, the surface of the glass acts like a mirror and one sees objects in the room reflected by the glass. The fish are seen inside the tank and appear closer than they really are. The light is bent away from the normal as it enters from water (glass) to air and, as a result, the rays are projected to a point closer than their actual location. Normally, when looking into a fish tank, one can see right through it. By viewing the tank at different angles, one will reach a point where the far side water(glass)–air boundary becomes mirror-like (total internal reflection). This occurs at the critical angle. For glass with $n = 1.50$, the critical angle is about 42°.

**19.** All appearances and disappearances of objects placed in mediums with different optical densities relative to air involve the light from the object bending as it exits the medium and enters air. When the ray bends, it either becomes accessible to our eyes (becomes visible), or it bends away from the position of our eyes (disappears). A transparent object made of a material such as glass can be made to vanish by putting it into a liquid with a refractive index the same as the glass. The light does not distinguish between the two substances as it traverses the medium boundaries. Therefore, the substance cannot be defined. It effectively becomes invisible.

**20.** In all cases, the light slows down as the greatest speed of light occurs when it is travelling in a vacuum. The wave equation is $v = \lambda f$. Since the frequency is determined by the source, it will remain constant as the light travels across the boundary between the two substances. Since $f = \frac{v}{\lambda}$, as the speed decreases, so does the wavelength.

**21.** The wavelengths of visible light increase as you move from violet to red in the spectrum. 750 nm is the red end of the spectrum and 400 nm is the blue end. On Earth, using spectroscopic techniques, the processes of fusion create signature spectrums with the colours located at distinct values of the wavelength. When light is viewed from a distant celestial object, the corresponding spectrum for the same nuclear process looks the same, except it is shifted toward the red end of Earth's reference spectrum. This implies the object is moving away from us. If the object were moving towards us, this signature spectrum would be shifted to the blue end.

**22.** An observer standing still watching a car go by at 60 km/h would measure the speed relative to his or her own speed (0 km/h). If he or she were in a moving car, going in the same direction as the car at 60 km/h, the observer would measure a relative velocity of 0 km/h. This means that the car ahead or behind would not be changing its position relative to the observer. If the two cars were approaching each other, their relative position would be decreasing at a rate determined by both their speeds. Therefore, the relative speed would be 120 km/h.

**23.** The red shift formula can only tell us that the two objects are separating relative to each other. Thus, in theory, Earth could be moving away from the celestial object.

**24.** Light has a wavelength in the order of $10^{-7}$m, too small to be affected by large objects. Sound, on the other hand, has a wavelength comparable to large objects. Therefore, sound will show diffraction effects.

**25.** To form interference patterns, the light sources must be close together (the headlights are too far apart) and tied together in their phase, i.e., coherent. Coherence is a condition that must exist if there is to be a steady-state interference pattern. To obtain this effect, one source can have an opening cut in an opaque screen in front of the other source, or two modulated tunable lasers can be used where the phase of each laser can be controlled. Two separate light sources cannot produce the pattern because light from any one source is emitted randomly with phase changes occuring in very short intervals of time ($10^{-8}$ s). Thus, interference patterns will shift and change rapidly. The net effect is no fringes will be seen.

**26.** Television and radio stations need to target audiences geographically. If the station is north of a city, broadcasting further north with sparse populations is a waste of energy and not cost-effective. By using arrays of antennae, the station creates interference patterns that negate the signal in areas where the station does not wish to transmit and enhance the signal to areas where it does wish to transmit.

**27.** Shifting the phase between coherent sources of light will shift the physical position of the pattern. In the extreme case, where the phase shift is half a wavelength, the maxima become minima and the minima become maxima. (Example: Path difference creates a half wavelength difference that normally results in destructive interference. However, the extra shift at the sources adds to this effect to produce two waves shifted by half a wavelength, causing constructive interference.)

**28.** Waves having a longer wavelength than the bobber's length will cause the bobber to move with the wave motion (circular in the vertical direction). They will not cause the bobber to produce secondary wavelets around it. For waves smaller or close to the same size as the bobber, diffraction effects will occur at the edges of the bobber, causing waves to bend and move off in different directions from the bobber.

## Chapter 11

**1.** Sound is not a transverse wave because the particles of air cannot sustain the motion perpendicular to the velocity direction. Since the particles in a gaseous state are free to move and are attached to one another, there is no restoring force to slow the particles down as a group and bring them back to the starting point. Instead, sound is a series of alternating different pressure areas, created by the air particles vibrating back and forth, bumping into each other, and transmitting the energy along at the wave velocity. Thus, each molecule stays basically fixed in a small area, executing simple harmonic motion rather than being carried along the wave. Sound is not a net motion of actual air particles.

**2.** Sound requires a vibrating source and a medium through which to travel. The physical motion of particles causes sound. Remove the medium and the sound vanishes. The classic demonstration is of a bell ringing in a jar. When the air is pumped out of the jar, the sound vanishes even though the bell is still mechanically operating.

**3.** As per question 1, the answer is no. The phase relationship between particles travels at this speed.

**4.** The flaps of skin in the vocal chords vibrate as air is forced out by the diaphragm; the reed in a woodwind instrument vibrates because of the air forced through it by the player; the speaker cone vibrates because of the magnetic pickup coil reacting to signals sent to the speaker from the amplifier; the rapid expansion of air caused by the heat generated by a lightning bolt, etc.

**5.** In the simplified case, where the speed of sound is related to the state of the material, the speed will decrease as the ice melts.

**6.** In space, there is nothing to absorb the energy of the wave. In air, the molecules and particles absorb some of the energy of the wave and do not pass it on. Hence, the amplitude of the wave decreases with distance.

**7.** $SF_6$ has a greater density than helium and will cause the sound to travel at a different velocity. Although the frequency remains the same (the cause of the sound does not change), the wavelength will change and the sound heard will be different.

**8.** Because the source of sound remains the same (440 Hz), the wavelength must increase as the speed of sound increases in water.

**9.** To hear the slap twice, you first hear it while underwater. Since the speed of sound is much slower in air, you now raise your head out of the water to hear the sound a second time.

**10.** In air, as the temperature decreases, the speed of sound decreases. Since the frequency is constant, the wavelength also decreases.

**11.** Sound is a physical movement of air particles. If the sound builds up from a loud source (such as a plane moving at Mach 1), the pressure builds up. A continual build-up results in a physical pressure wall ahead of the plane that must be pierced in order for the plane to pass through.

**12.** The "crack" of the towel is the pressure wave reaching our ears after the tip of the towel passes through the sound barrier. The energy is not great enough to cause any ear damage.

**13.** After you first see the plane, count until you hear the sound of the engines. Since sound travels approximately 1 km every three seconds, you can use ratios to find the distance.

**14.** The sound emanating from the mouth of the pilot is moving through air that is moving with the plane. Therefore, the sound moving out of his mouth is moving with a velocity relative to that medium. Therefore, the velocity of the plane is not important and the pilot does not form another sound barrier. The pilot can hear his own singing.

**15.** 0 dB is a relative value where the threshold of human hearing is set at $10^{-12}$ W/m$^2$ ($I_0$). All other sounds are compared to this value. As a comparative value, the 0 dB indicates that there is no difference in sound intensities between sources.

**16.** Since decibels are a ratio, it is possible to have negative values. A negative decibel value means that the sound is lower in intensity than the threshold of hearing.

**17.** You must take into account the new speed of sound as it is now combined with the velocity of the medium. By having the medium stationary, we can also measure speed relative to Earth.

**18.** As long as the observer and the source have different velocities with respect to the medium the sound travels in, the pitch (frequency) of the sound detects changes. Thus, it makes a difference if the objects are approaching or moving apart. If you are driving toward each other, you will hear a higher pitched sound; if you are driving apart, you will hear a lower pitched sound. Interestingly, the effect was tested in 1845 by Buy Ballot in Holland by using a locomotive pulling an open car with some trumpeters in it.

**19.** As per the answer to question 18, you would not hear the Doppler effect as the speed of the observer relative to the source is zero.

**20.** Animals that rely on hearing have large pinna that can be moved to help collect the sound in any direction. Animals that rely on other senses have no ears at all (fish, birds) or much smaller ears which, in most cases, cannot move to accommodate sounds emanating from different areas.

**21.** The wax impinges on the ear drum and stops it from vibrating freely.

**22.** The proximity of the Walkman to your inner ear means that you get the full intensity of sound from the Walkman, without the benefit of the $\frac{1}{r^2}$ decrease in sound with distance, which would happen if you were listening to your stereo.

# Chapter 12

**1.** Other examples of mechanical resonance:
The rattling of a part of a car while driving at a certain speed. At low speeds, the rattle may be absent but as the frequency reaches a similar value to that of the particular item, it begins to oscillate or rattle. The rattle may disappear as the frequency (speed) of the car increases and then return when the car slows again.

The vibration of a house window or the cups in the china cabinet when a stereo is turned up to a loud volume. When the frequency of the stereo, especially with bass, matches that of the window/china, the vibration begins.

In the case of shaken baby syndrome, even minor oscillations from a caregiver, at the specific frequency that relates to that of a child's neck, can cause large amplitude oscillations and can eventually cause neck and head injuries.

**2.** The broken wine glass is related to mechanical resonance. Any singer attempting to break a wine glass with his or her voice must be able to listen for the appropriate pitch coming from the glass and be able to reproduce it with sufficient intensity and for a specific period of time to cause the damage.

**3.** The vibration of the mirror only occurs when the frequency of the road vibration and that of the mirror are the same. This is another example of mechanical resonance.

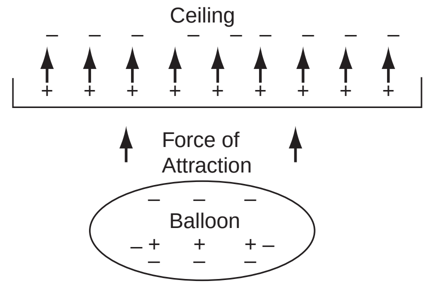
**4.** If all forces on the car from the engine as well as from the good Samaritans were timed to the apparent natural frequency with which the car was rocking, large amplitude oscillations would result due to mechanical resonance.

**5.** Striking a tuning fork of known frequency with an instrument would cause beats to occur only if the instrument was out of tune. The frequency of beats would correspond to the frequency difference between the instrument's pitch and that of the tuning fork. Adjusting the instrument until no beats are heard would bring the instrument into proper tune.

6. a) Blowing over a pop bottle causes the air in this column to begin to vibrate with a standing wave, eventually causing the walls of the bottle itself to vibrate.
   b) On a drum, it is the skin on the drum that vibrates.
   c) In a pipe organ, the air in the columns begins to vibrate with a standing wave, eventually causing the walls of the pipes themselves to vibrate.
   d) The strings in the piano vibrate.
   e) When knocking on the door, it is the door that vibrates.
7. The increasing pitch in the filling noise during re-fuelling is due to the decreasing length of the air column as the fuel is rising. Like a trombone being shortened, the decreasing length of the air column changes the wavelength of the sound wave that can form a standing wave in that column. The result is that a higher pitch is heard as the air column decreases in size.
8. Guitar strings made with substances of different densities create different pitches. The greater the density of the material, the lower the pitch/frequency that can be heard if all other variables are controlled. The frequency varies as the inverse square root of the density of the guitar string.
9. The muffler's tubes allow certain frequencies to resonate. These frequencies are set up so that, when sounded together, they destroy one another by the principle of superposition. Each compression or rarefaction is cancelled out or destroyed by another rarefaction or compression created in another tube of the muffler.

## Chapter 13

1. A neutral object is attracted to a charged object because the charged object induces a charge separation in the neutral object. The electrons in the neutral object are forced away from or toward the charged object, depending on whether the charged object has a negative or positive charge, inducing an opposite charge which acts to attract the two objects by way of the law of electric forces.
2. The function of an electroscope is to detect an electric field. An electric field will cause the movement of electrons within an electroscope, inducing similar charges to cluster at each of the two pieces of dangling foil. The two pieces of foil will repel each other, indicating the presence of the electric field.
3. Rubbing the balloon against your dry hair charges the balloon electrostatically. When the balloon approaches the wall, the negative charge forces the electrons in the ceiling away, leaving the positive charges close to the surface. The result is that the negatively charged balloon attracts the now positively charged ceiling surface.




4. The electrostatic series identifies silk as having a greater affinity for electrons than acetate does. When acetate and silk are rubbed together, electrons move from the acetate to the silk because of the different affinity the materials have for electrons.
5. Choose two materials listed at either end of the electrostatic series, such as acetate and silk, and rub them together to place the predictable negative charge on the silk. Neutralize the acetate and then rub it with the mystery substance. Place the mystery substance next to the silk and judge whether the mystery substance has a negative charge (repulsion) or a positive charge (attraction). A negative charge would place the mystery substance below acetate in the electrostatic series. Similarly, rubbing the mystery substance with silk would help to place the mystery substance in the series compared to silk. By selectively choosing different substances, you could narrow down the appropriate spot for the mystery substance in the electrostatic series.

6. Computer technicians touch the metallic part of a computer before repair, assuming it is still plugged into the wall outlet, so that they ground themselves from any excess charge. Otherwise, a static electric discharge could damage the computer's micro-circuitry.

7.

| Criterion | Newton's law of universal gravitation | Coulomb's law of electrostatic forces |
|---|---|---|
| Equation | $F = \frac{Gm_1m_2}{r^2}$ | $F = \frac{kq_1q_2}{r^2}$ |
| Constant of proportionality | $G = 6.67 \times 10^{-11}$ N·m²/kg² | $k = 9.0 \times 10^9$ N·m²/C² |
| Type of force(s) | Attraction only | Attraction and repulsion |
| Conditions for use | Acts between any two masses | Acts between any two electrostatic charges |

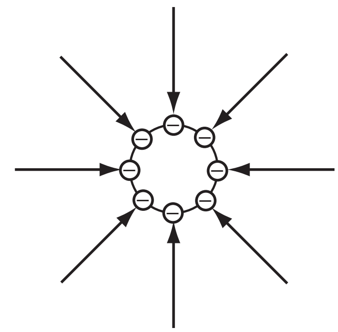
8. Field lines show the direction of the net force on a test charge in an electric field. Two crossed field lines would mean that there would be two net forces acting on a test charge in two different directions at the same time. This is impossible, since there is only one net force at any point, which is only one force in one direction by definition.

9. In an electric field, charges always move along the direction described by the field lines. The direction in which a charge moves along a field line depends on the sign of the charge. A positive charge will move in the direction described by the arrows in a field diagram, whereas a negative charge will move in the opposite direction.

10. **a)** When a polar charged rod is placed perpendicular to electric field lines, the rod will tend to rotate such that it will become parallel to the field lines. The positive end of the rod will point in the same direction in which the field lines are oriented.

**b)** When a polar charged rod is placed parallel to electric field lines, the rod will tend to stay in the same orientation if its positive end is pointing in the same direction as the field lines. Otherwise, the rod will tend to rotate 180° and point in the opposite direction (still parallel to the field lines).

11. Each point charge experiences an identical force of repulsion from all of the other point charges, so that they are all repelled symmetrically outward from the centre of the orientation. A test charge placed outside of the circle would experience a net force directed along radial lines inward to the centre of the circle, as shown in the diagram. A test charge placed inside of the circle would experience no net force, and therefore there would be no electric field inside the circle at all.



This charge distribution models the electric field inside a coaxial cable because the outer braided conductor in a coaxial cable acts as the site modelled by the ring of charge described above. This ring acts to eliminate the field within the entire cable.

12. By definition, the electric potential is the same at any point along an equipotential line. Therefore, no force is required, and no work is done, to move a test charge along this line. In a situation like this, a constant force causes the constant acceleration of the test charge.

13. We use the term "point charge" to imply that the charge has no larger physical dimensions. Larger dimensions would mean that the charge would exist within a region of space instead of at a specific location. This implication reduces the number of variables and simplifies questions that deal with the distribution of charges within a three-dimensional space. Any other approach would require some way of accounting for the variability of distances between charges.

14. **Statement:** In each case the field gets stronger as you proceed from left to right. **False**
**Reasoning:** The field lines remain the same distance apart as you move from left to right in the field in (b), so the field does not change in strength.

**Statement:** The field strength in (a) increases from left to right but in (b) it remains the same everywhere. **True**

**Reasoning:** The field lines become closer together as you move from left to right in the field in (a), so the field does increase in strength, whereas the field lines in (b) are parallel, so the field strength does not change.

**Statement:** Both fields could be created by a series of positive charges on the left and negative ones on the right. **False**

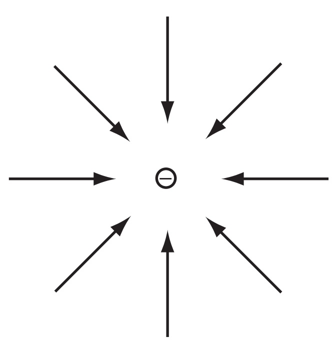
**Reasoning:** Although true for (b), (a) must be created by a single positive point charge at the base of the four arrows.

**Statement:** Both fields could be created by a single positive point charge placed on the right. **False**

**Reasoning:** As described above, a point charge could be responsible for (a), but (b) would require rows of parallel opposites such as those in oppositely charged parallel plates.

**15.** Electric fields are more complicated to work with because the forces that charges exert on each other are all significant. In contrast, the gravitational force between small masses is negligible compared with the gravitational force exerted on them by large masses like Earth.

**16.** The field shape around a single negative point charge is exactly like that around a single positive point charge with the exception that for a negative point charge, the arrows are all pointing inward instead of outward, as shown in the following diagram.



**17.** Doubling the value of the test charge will do nothing to the measurement of the strength of the electric field. The force on the test charge will double because of the change to the test charge, but the field strength is measured as the force experienced per unit charge, $\vec{\varepsilon} = \dfrac{\vec{F}}{q_t}$. Therefore, the doubling of the test charge and the doubling of the force will cancel, leaving the measurement of the field strength unchanged.

**18.** The stronger an electric field is, the closer together the field lines are. Therefore, a weak electric field has field lines that are farther apart than the field lines of a strong electric field.

**19.** Both gravitational fields and electric fields are made up of lines of force that are directed in a way that a test "item" would be forced. Gravitational fields are created by and influence masses, whereas electric fields involve charges. Gravitational fields are always attractive. Electric fields can be attractive or repulsive, since they can exert forces in opposite directions depending on the charge of the object that is experiencing the field.

**20.** The direction of an electric field between a positive charge and a negative charge is from the positive charge toward the negative charge, since electric fields are always directed the way that a positive test charge would be forced.

**21.** The electric potential energy is greater between two like charges than between two unlike charges the same distance apart because of the differing sign of the electric potential energy. The calculation of the electric potential energy involves multiplying the two charges. The product of two like charges is positive and therefore greater than the product of two unlike charges, which is negative.

**22.** A high-voltage wire falling onto a car produces a situation in which there is a high-potential source (the wire) very close to a low-potential region (the ground). The people in the car will be safe from electrocution as long as they do not complete a circuit between this high and low electric potential. They should not open the car door, for example, and step to the ground while maintaining contact with the car.

**23.** Although opposite electric charges occur at the two plates of a parallel-plate apparatus when it is connected to a power supply, the overall charge on the apparatus remains zero. For every charge at one plate, there is an opposite charge at the other plate, which balances the overall charge to zero.

**24. a)** If the distance between the plates is doubled then the field strength between the plates will be halved.

**b)** If the charge on each plate is doubled then the field strength will double.

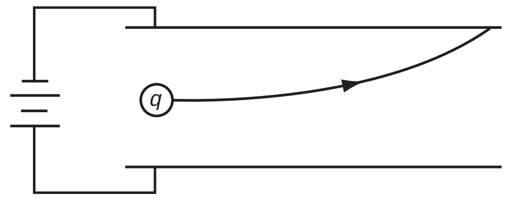
**c)** If the plates are totally discharged and neutral then the field strength will drop to zero.

**25.** Two point charges of like charge and equal magnitude should be placed side by side so that both the electric field strength and the electric potential will be zero at the midpoint between the charges. If one of the two like charges were doubled, the field strength and the potential would both be zero at a point two-thirds the separation distance away from the doubled charge.

**26.** In the presence of electric fields, a field strength and a potential of zero would exist at a point where the sum of all electric forces was zero. In question 25, the sum of the repulsive forces from each of the two like charges is zero at some point between the two charges.

**27.** If a proton and an electron were released at a distance and accelerated toward one another, the electron would reach the greater speed just before impact. The reason is that both particles would be acted upon by the same force of attraction, but the electron has less mass. The acceleration of each particle is described by the formula $\vec{a} = \frac{\vec{F}}{m}$, which shows that for the same force, the smaller mass would have the greater acceleration over the same time period and therefore the greater final speed.

**28.**




This type of motion is like upside-down projectile motion, since the charge moves in a parabolic path. This is the type of motion that an object would take if it were thrown horizontally in Earth's gravitational field. The only difference here is that this charge appears to be "falling upward" instead of downward.

**29.** No, a parallel-plate capacitor does not have uniform electric potential. It does have uniform field strength between the two plates, but the potential varies in a linear fashion from one plate to the other. By definition, the electric potential is uniform along any equipotential line, which in this case is any line parallel to the two plates.

**30.**

| Charge Distribution | Equipotential Lines |
|---|---|
| (a) | (iii) |
| (b) | (i) |
| (c) | (ii) |

**31. a)** The electrostatic interaction responsible for the large potential energy increase at very close distances is the repulsion between the two positive nuclei.

**b)** This repulsion of the nuclei, and the associated increase in electric potential energy, is one of the main stumbling blocks for generating energy through nuclear fusion. This repulsion between nuclei means that a very large amount of energy is required to begin the reaction process.

**c)** The smaller increase in electric potential energy upon separation of the two atoms is caused by the attraction between the positively charged nucleus in each atom and the negatively charged electron in the other atom.

**d)** A stable bond is formed when two hydrogen atoms are about 75 pm apart because this is the distance at which the electric potential energy is minimized — any closer and the repulsion between nuclei pushes the atoms apart, any farther away and the nucleus-electron attraction draws the atoms closer together.

**32.** A positive test charge moving along a line between two identical negative point charges would experience a topography similar to a vehicle moving up a hill (away from one charge), increasing the vehicle's gravitational potential energy, and then rolling down the other side of the hill (toward the other charge).

**a)** If the two identical point charges were both positive, the hill would change to a valley with the lowest part in the middle.

**b)** If a negative test charge was placed between the two identical positive charges, the topography would still resemble a valley but now there would be a very deep crater at the lowest part of the valley.

## Chapter 14

**1. a)** Batteries that are installed end to end are connected in series.

**b)** A device requiring two 1.5-V batteries in series has a voltage requirement of 3.0 V.

**c)** Batteries installed side by side are connected in parallel and will provide a lower voltage over a longer period of time.

**2.** A convention is a custom approved by general agreement, in our case, by a group of scientists. In science, the metric system is another example of a convention. The units are an agreed-upon standard so that ideas and discoveries can be easily communicated.

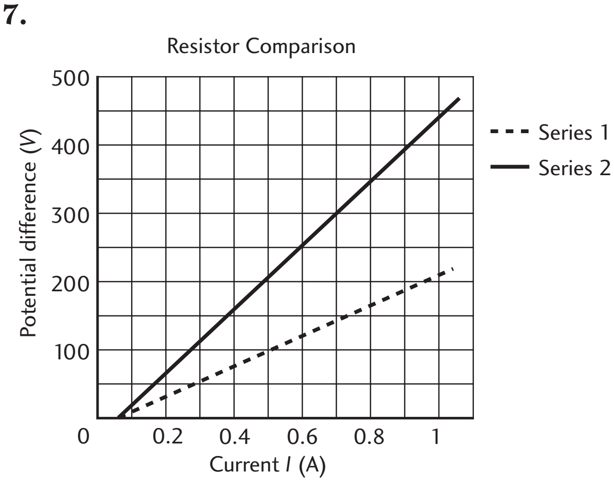
**3.** Many of the electronic components such as resistors or even the wires themselves may be affected at extreme temperatures. The resistance value of some resistors are temperature dependant; the higher the temperature, the greater the resistance. Changes in resistance could result in subtle changes in current flow in the circuit, making the device function improperly.

**4.** Boosting another car is always done by wiring the batteries in parallel. A parallel connection ensures that the engine "sees" the same 12 V, but the second battery can provide the needed current to start a difficult engine.

**5.** Our homes are wired using parallel circuits. This means that when certain components are not connected, such as a light bulb burning out, the current to other circuit branches is left unchanged. In other words, when a bulb burns out, the others on the circuit not only remain lit, but the voltage drop across each light bulb remains the same and each light bulb keeps the same brightness.

**6.** This warning means that the bulbs are wired in series. When a series bulb burns out, current is disrupted in the rest of the circuit. Some bulbs have a built-in shunt that triggers when the bulb burns out. As a result, current that normally would have been disrupted in a series circuit continues to flow. These shunted bulbs must be replaced immediately because, for every burnt out and shunted bulb, the resulting voltage drop across the other bulbs will increase. In general, the more burnt out bulbs in a series, the greater the voltage drop across the remaining bulbs, which may now be damaged due to higher current.

**7.**




The series 2 resistor has a steeper slope, meaning that it has the greatest resistance.

**8.** The energy consumption in your home is measured in kWh and not joules because it is a far more appropriate unit. Running a simple 1500-W hair dryer for 5 minutes (300 s) would yield an energy value of $E = Pt = (1500\ \text{W})(300\ \text{s}) = 450\ 000\ \text{J}$, and each joule of energy would not cost very much ($2.22 \times 10^{-6}$ cents each). A more appropriate unit is the kWh. The same hair dryer would yield an energy value of 0.125 kWh and cost about 8¢/kWh.

## Chapter 15

**1.** The law of magnetic forces states that like (similar) magnetic poles repel one another and different (dissimilar) poles attract one another, even at a distance.

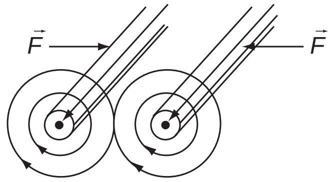
**2.** A magnet can attract non-magnetic materials as long as they are ferromagnetic in nature. The magnet causes the internal domains (small magnets) of a ferromagnetic substance to line up in such a way that a new magnet is induced in the substance such that there are opposite magnetic poles which attract one another.

**3.** A material that is attracted to a magnet or that can be magnetized is called ferromagnetic. Examples of ferromagnetic materials include materials made from iron, nickel, or cobalt. These materials are ferromagnetic because they have internal domains that can be readily aligned, due to the fact that these materials have unpaired electrons in their outermost electron energy level.

**4.** Magnets can lose their strength over time because their domains, which initially are aligned (pointing in the same direction), can become randomized and point in other directions. This randomizing of the domains reduces the overall strength of the entire magnet.

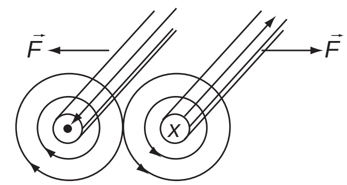
**5.** When a magnet is dropped or heated up, the domains of the magnet, which initially are aligned (pointing in the same direction), can be disrupted and forced to point in other, random directions. This randomizing of the domains reduces the overall strength of the entire magnet.

**6.** **a)**




Currents in the same direction
wires forced together

**b)**




Currents in opposite directions
wires forced apart

**7.** The electrons in the beam that is illuminating your computer monitor's screen are directed from the back of the monitor forward to the front of the screen, toward your face. This is the direction of the thumb of the left hand when applying left-hand rule #1 for current flow. From your perspective, the magnetic field forms circular formations in the clockwise direction in and around the computer monitor. Relative to the direction of the electron beam, the magnetic field is directed in the counter-clockwise direction around the beam.

**8.** A wire possessing an eastbound electron current has an associated circular magnetic field that points upward on the north side of the wire and downward on the south side.

**9.** The magnetic field strength of a coil (an insulated spring) varies inversely with the length of the coil. Therefore, a reduction in the coil length to half its original length will cause a doubling of the magnetic field strength. This all depends on the assumption that the length of the coil is considerably larger than its diameter.

**10.** **a)** For the force applied to a current-carrying conductor to be at a maximum, the magnetic field must cross the conductor at an angle of 90°.

**b)** For the force applied to a current-carrying conductor to be at a minimum, the magnetic field must cross the conductor at an angle of 0°.

**11.** According to left-hand rule #3 for the motor principle, the direction of the force on the conductor is to the south.

**12.** An electron moving vertically downward that enters a northbound magnetic field will be forced toward the west.

**13.** A current-carrying solenoid produces a magnetic field coming directly out of one end of the coil and into the other end. An electron passing by either end of this coil experiences a force that is at right angles to its motion. As this force changes the direction of motion (a centripetal force), the electron takes on a curved path (circular motion). Application of the appropriate left-hand rules predicts that the electron's motion will curve in the same direction as the direction of electron current flow through the coil.

**14.** The cathode rays will be deflected toward the current-carrying wire, moving in a plane that contains the wire.

**15.** Current passing through a helical spring will produce a situation very similar to having two parallel conductors with a current flowing in the same direction. Application of the appropriate left-hand rules predicts that the magnetic field interaction between each pair of the helical loops will force the spring to compress, reducing its length.

**16.** Current passing through a highly flexible wire loop will tend to result in magnetic field interactions that will force apart nearby sections of the wire, so that the wire loop will most likely (if the proper conditions exist) straighten out.

## Chapter 16

**1.** Faraday's principle complements Oersted's principle. Faraday's principle or *law of induction* describes how a moving magnetic field or one that is changing (increasing or decreasing in strength) near a conductor causes charge to flow in that conductor.

**2.** The induced electromotive force in a conductor could be improved by using a magnet with a large field strength. The effect is greater if the wire is coiled because the strong magnetic field contacts a larger surface area of the conductor. Finally, the greater the rate of field change, the greater the electromotive force.

**3.** Inducing current to flow in a conductor requires that two conditions be met. First, a magnetic field must be present such that the field lines cut through a conductor at 90°. Second, this magnetic field must be changing either by moving the source magnet or by increasing or decreasing the strength of the electromagnetically induced field.

**4.** According to Lenz's law, the energy transferred to the current in the conductor comes from the kinetic energy of the source magnet or from the energy in the current of an electromagnet. Reduction in these forms of inducing energies can only be caused by an induced magnetic field. The work done to reduce the energy comes from the source of the induction. Manually moving a magnet in a coil of wire meets the resistance of the induced field. The energy lost from the source is gained by the induced current. This energy transfer from one form to another is governed by the law of conservation of energy.

**5.** The induced magnetic field cannot "boost" the motion, which would be a violation of the law of the conservation of energy. The simple motion of a magnet cannot create or induce a magnetic field that would further draw the inducing magnet along. Where would this energy come from? It would be a case of energy created from nothing.

**6.** In Fig. 16.18, the conductor moving in a magnetic field would have no induced current moving through it. The field lines are parallel, meaning that the motion from the north pole to the south pole would not cause the strength of the field to change sufficiently to cause current flow. Induced current would flow if the conductor were moved either up or down.

**7.** Besides the type of current produced, the main difference between AC and DC generators is the way in which current is tapped off the spinning armature. Both generators produce alternating current in the armature. An AC generator employs two slip rings and brushes to draw the current out of the armature. A DC generator uses a split-ring commutator that is designed to reverse the direction of current flow as it comes out of the brushes. At the correct time, the commutator re-reverses the current that was reversed in the generation process. This double reversal produces a direct current.

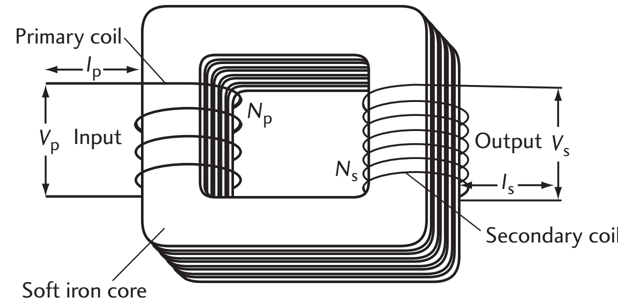
8. a) Electromagnetic induction brakes work on the principle that the electrical energy created in the generators comes from the kinetic energy of the vehicle being slowed. A generator offers resistance to motion when it is being turned, and this resistance is used to slow moving vehicles.

   b) With standard friction brakes, the energy of motion is transferred to heat in the brake pads. One benefit of electromagnetic brakes is that electrical energy could be recovered from the vehicle's motion and used to charge a battery for use at a later time. Originally, brake pads were embedded with asbestos fibres, but more recent pads use metal. Less wear and tear on the brake pads would mean lower demand, less manufacturing materials and energy, as well as fewer spent pads in landfill sites.

9. The ring apparatus has secondary current only when the magnetic field is changing. With direct current (DC), secondary current occurs only when you turn the circuit on or off. At this time, the magnetic field increases to its full strength or shuts down, respectively. To make the ring operate continuously, alternating current (AC) is required so that the magnetic fields are always changing. The resulting current produced in the secondary side is also an alternating current.

10. According to Faraday's principle, a transformer can only operate with alternating current. Alternating current produces a constantly changing magnetic field in the primary coil, which is required for any induced current to flow in the secondary side. Without AC, the transformer would be nothing but an elaborate electromagnet.

11.




Summary:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{I_s}{I_p}$$

12. A step-up transformer transforms an AC voltage from a low value to a high value. A step-up transformer differs from a step-down transformer in the number of turns of wire on its primary and secondary sides. A step-up transformer has more turns on its secondary side, with a turns ratio of less than 1 $\left(\frac{N_p}{N_s} < 1\right)$. A step-down transformer has more turns on its primary side, with a turns ratio greater than 1 $\left(\frac{N_p}{N_s} > 1\right)$.

    Note: When voltage is stepped up, the current is stepped down and vice versa. "Step up" refers to the change in voltage, not in current.

13. Over great distances, large current results in great power loss. With the use of a step-up transformer, the current can be stepped down while the voltage is stepped up. By analogy, we put fewer delivery trucks on the road but pack them to capacity with goods so that the same amount of material is delivered.

14. The energy is transferred because electrons do not exist in isolation. The electrons in your light bulb are in a massive electron traffic jam or line-up, "backed up" on either side all the way to the power source. When even one coulomb of charge is energized at the power source, it "pushes" momentarily on this "charge queue" and the mutual repulsion of like charge passes this push down the line to the light bulb. At the same time, the power supply pulls on the charge at the other terminal. Like a large circle of people holding hands around a campfire oscillating back and forth,

the energy is passed through the oscillation over great distances.

**15.** The voltage is stepped up at the generating station to lower the current and the associated power loss during travel to your home. At your home, it is once again transformed from high voltage and low current to a safer, easier-to-use form of alternating current. To conserve power loss, the current is kept low (and the voltage high) for as long as possible. Gradually stepping the current up as the power enters residential areas conserves power while maximizing safety.

## Chapter 17

**1.** A photon is a unit particle (as opposed to wave) of electromagnetic radiation that moves at the speed of light. Its energy is proportional to the frequency of the radiation.

**2.** Ultraviolet radiation from the Sun is very energetic due to its high frequency. The photons that possess this energy are the cause of sunburn. These photons are energetic enough to remove electrons from our body cells, causing a change in our skin biology and in severe cases causing cancer.

**3.** Visual light is mostly in the infrared-visual spectrum. The energy of these photons is not sufficient to damage skin cells.

**4.** If $h = 0$, quantization would not exist. There would be no energy levels in atoms. Electrons in atoms would therefore not attain any real value for energy, resulting in the absence of orbitals in atoms.

**5.** The electron volt (eV) corresponds to the energy of an electron at a potential of one volt. Hence, one electron volt is the energy equalling the charge of an electron multiplied by the potential of one volt: $1\text{ eV} = q_e \times 1\text{ V}$.

**6.** Wien's law relates the wavelength of photons to the temperature of the black body.

**7.** $W_0$, the work function, is the amount of energy required to produce the photoelectric effect in a given metal. It is the minimum energy required to liberate electrons from a metal.

**8.** Since the photons have detectable linear momentum, their mass equivalence can be computed. Momentum is an intrinsic property of matter, therefore we can assume that mass equivalency is correct.

**9.** An empirical relationship is a relationship that is determined experimentally. It is not backed up by theory.

**10.** Determinacy is a condition of a measurement being characterized definitely. An example of an everyday event could be a repetitive measurement of the length of a table. Each time the measurement is made, errors are encountered. If determinacy existed at the macroscopic level, we would get the same length every time.

**11.** The computation of uncertainties using Heisenberg's uncertainty principle yields minute values for speed and position. The limitations of human perception prevent us from experiencing such minute variances at the macroscopic level.

**12.** Another device besides the STM that operates using the principle of quantum tunnelling is the electron tunnelling transistor, which is an on-off switch that uses the ability of an electron to pass through impenetrable energy obstacles.

**13.** The energy of an orbital varies as the inverse square of the radius. Hence, the spectral lines are closer together farther away from the nucleus.

**14.** **a)** The peak wavelength emitted by a mercury lamp lies in the visual spectrum. However, this implies that there is a tail in the ultraviolet spectrum. The ultraviolet photons are energetic enough to damage skin cells.

**b)** An appropriate shielding that blocks ultraviolet light but allows photons in the visual spectrum to pass through could be used.

**15.** Consider two particles that have the same de Broglie wavelength $\lambda$ and masses $m_1$ and $m_2$ such that $m_1 > m_2$. According to de Broglie's equation, $\lambda = \dfrac{h}{m_1 v_1}$ and $\lambda = \dfrac{h}{m_2 v_2}$, where $v_1$ and $v_2$ are the velocities of the two particles. Since $\lambda$ is the same for both particles, the following equation can be written:

$$\frac{h}{m_1v_1} = \frac{h}{m_2v_2}$$

This equation can be simplified:

$m_1v_1 = m_2v_2$

Since $m_1 > m_2$, it follows that $v_2 > v_1$. If the mass of the first particle is much greater than that of the second particle, the velocity of the second particle must be much greater than that of the first particle.

**16.** According to Planck, the energy is quantized. The angular momentum is certainly related to the energy. Hence, the angular momentum needs to be quantized as well. To quantize $L$, Bohr had to quantize both the velocity, $v$, and the radius, $r$.

**17.** Although the initial and the final speed and the scatter angles are known, the manner in which the actual collision occurs cannot be precisely predicted, and the exact position of the particles during the collision is not known. Hence, the uncertainty principle is not violated.

## Chapter 18

**1.** Generating electrical energy on a large scale requires the production of steam to drive a steam turbine that turns an electromagnetic generator. The steam turbine and electromagnetic generator are common parts of both nuclear power generating stations and thermal electric stations. All power plants heat water to steam to drive the turbine. Thermal electric plants heat water by burning fossil fuels (e.g., coal, oil, gas) and nuclear plants heat the water by way of a sustained nuclear fission reaction. All power plants are placed next to large bodies of water so that the water can be used to cool the reactors.

**2.** Every atom of the same element has the same number of protons, and the number of protons in the nucleus, $Z$, determines the chemical properties of the atom. However, atoms of different isotopes of the same element have different numbers of neutrons (and thus different $A$ values), which results in different physical properties such as nuclear stability or decay.

**3.** Many elements are composed of several naturally occurring isotopes, each with a different atomic mass number, $A$. The weighted average of the isotopes' mass numbers often results in a non-integral value for the atomic mass of that element.

**4.** Each nuclear isotope has a unique total binding energy determined by its nuclear structure. This binding energy is equivalent to the mass difference between the nucleus and its constituent nucleons (protons and neutrons) according to $E = mc^2$.

**5.** The missing mass was converted to energy of various forms such as gamma radiation emitted during the formation of the deuterium atom.

**6.** Your body, composed of many elements, likely has more neutrons than protons, since stable atoms with $A > 20$ have more neutrons than protons.

**7.** During a nuclear reaction, nucleons may be converted from one type to another, such as neutrons to protons in beta decay. However, the total nucleon number is conserved or remains constant. On the other hand, various forms of energy may be absorbed or emitted, resulting in an equivalent change in mass.

**8.** During alpha decay of a uranium-238 nucleus, for example, the $\frac{N}{Z}$ ratio of the parent nucleus is $\frac{146}{92}$ or about 1.59, and the ratio of the daughter nucleus, $\frac{N-2}{Z-2}$, is $\frac{144}{90}$ or about 1.60. This leads to greater nuclear stability by reducing the electrical repulsion of the protons relative to the nuclear attraction of nucleons. During beta decay, the $\frac{N}{Z}$ ratio of the parent nucleus, $\frac{146}{92}$ or about 1.59, is greater than the ratio of the daughter nucleus, $\frac{N-1}{Z+1}$, which is $\frac{145}{93}$ or about 1.56.

Although the greater ratio of protons to neutrons in the daughter tends to increase the electrical repulsive forces, the beta-decay process can lead to greater nuclear stability through the pairing of previously unpaired neutrons or protons in the nuclear shells.

**9.** During alpha decay, the daughter nucleus has a mass, $M$, that is much larger than the mass of the alpha particle, $m$. Since momentum is conserved, the velocity of the daughter nucleus, $v$, is much smaller than the velocity of the alpha particle, $V$ ($Mv = mV$). Therefore, the kinetic energy of the alpha particle, $0.5mV^2$, is much greater than that of the daughter nucleus, $0.5Mv^2$.

**10.** If an alpha particle had enough initial kinetic energy to contact a gold nucleus then a nuclear process such as fusion or fission could occur, because at that closeness the short-range nuclear force would overpower the electrical force of proton repulsion that is responsible for scattering.

**11.** The strong nuclear force differs from the electrical force in that: (i) the strong nuclear force is very short-range, acting over distances of only a few femtometres ($10^{-15}$ m); (ii) the strong nuclear force is much stronger than the electrical force over nuclear distances of 1 or 2 fm; (iii) the strong nuclear force does not vary with distance $r$ as $\frac{1}{r^2}$ as does the electrical force; and (iv) the strong nuclear force is attractive only, acting between all nucleons (proton–proton, proton–neutron, and neutron–neutron).

**12.** The rate of decay of radioactive isotopes was not affected by combining them in different molecules or by changing the temperature. These changes usually affect the rate of chemical reactions, thus radioactivity must be found deeper within the atom (in the nucleus).

**13.** Alpha particles are ions, since they are helium atoms stripped of their electrons.

**14.** If human life expectancy were a random process like radioactive decay then you would expect 25 % of the population to live to 152 years. However, this is not the case. As humans age, their expected number of years left to live decreases.

**15.** Carbon-14 undergoing beta decay results in the daughter isotope nitrogen-14.

**16.** Industrialization and automobile emissions have effected changes in our atmosphere such as global warming and ozone-layer depletion. Such changes in the past 100 years may be altering the $^{14}C:^{12}C$ ratio in the air.

**17.** Potassium salts are rapidly absorbed by brain tumours, making them detectable. The short half-life of potassium-42 means that the dosage decays to a safe, insignificant level quickly. The transmutation to a stable calcium salt by beta decay is not harmful to the body.

**18.** Aquatic creatures do not respire or breathe atmospheric gases directly. The $^{14}C:^{12}C$ ratio in the ocean is different than in the air.

**19.** Relics that are more than 60 000 years old have lasted more than 10.5 half-lives of carbon-14. The $^{14}C:^{12}C$ ratio in these relics is about 1500 times smaller now and is difficult to determine.

**20.** The more massive lead atoms scatter the radiation particles more effectively than do the less massive water molecules, and may also present a larger "target" for a high-speed electron or alpha particle.

**21.** Transmutation involves a change in the proton number, $Z$. This occurs during alpha and beta decay but does not occur during gamma decay, in which a nucleus merely becomes less energized.

**22.** Alpha particles are more massive than beta or gamma particles and transfer more energy to a molecule of the body during a collision. This has a much more disastrous effect upon the cells of the body.

**23.** The matches are as follows: gases–wind; liquids–water; plasmas–fire; and solids–earth.

**24.** The high temperature in fusion means that the ions have a very high speed, which allows them to approach one another very closely during collisions. If the ions' kinetic energy is sufficient to overcome the electrical repulsion of the nuclei, and the nuclei touch, then fusion is possible.

**25.** Critical mass in fission involves the existence of enough fuel so that the fast neutrons emitted during fission are slowed and absorbed within the fuel itself before they escape. In this way the reaction is sustained by a continual source of slow neutrons.

**26.** Natural uranium is not concentrated enough ("it's too wet") to provide the critical mass needed to slow down any fast neutrons ("the spark needed") and capture them to create a sustainable reaction.

**27.** Thermal pollution is the expulsion of excess warm water into lakes and oceans from the cooling of large-scale power plants. This warm water raises the average ambient temperature of the lakes and oceans, which affects their ecosystems. Warmer water holds less dissolved oxygen and increases the metabolism of some aquatic species. Most of the electrical generation in North America produces waste heat.

**28.** Solar panels are a good source of electrical energy in certain circumstances but are dependent on the amount of direct sunlight they receive. The manufacture of solar panels requires melting glass and metal, usually by burning fossil fuels, which creates the air pollution the solar panels were designed to eliminate. A risk/cost benefit analysis must be done to weigh benefits and risks. The most dangerous form of generating electrical energy, measured in deaths/kWh, is wind turbines. The number of people and animals (birds) that die on wind turbines would be astronomical if there were enough of them around to generate the amount of energy that is presently required.

**29.** A fission reaction is the splitting of a heavy nucleus into two smaller and lighter nuclei, releasing 2–3 fast neutrons and energy. A fusion reaction is the combining or fusing of two smaller and lighter nuclei to make one larger nucleus, producing energy. The two reactions are similar in that they both release energy, although the energy released by fusion is much greater. The two processes are different in that fission is a separation of nuclei and fusion is a combining of nuclei.

**30.** Although fission reactions take place in naturally occurring uranium, chain reactions do not. A chain reaction requires one reaction to cause another and so on. For a chain reaction to occur, the fast neutrons produced from one naturally occurring fission reaction have to be slowed down (moderated) just before they hit other uranium nuclei. This sequence of events would have to be repeated a few times, the probability of which is extremely small. Chain reactions can occur only when purified uranium with the correct isotopes is combined such that a consistent number of neutrons can be moderated to cause further reactions.

**31.** The acronym CANDU stands for **CAN**adian **D**euterium **U**ranium. It means that the reactor is Canadian, and that it uses heavy water as a moderator and uranium as fuel.

**32.**


**Hydrogen**
1 proton
1 electron
**(a)**

**Deuterium**
1 proton
1 electron
1 neutron
**(b)**

**33.** Deuterium or deuterated heavy water is really just water formed with two atoms of deuterium and one of oxygen: $D_2O$ instead of $H_2O$. It is used in a reactor to moderate the neutrons (slow them to create further fission reactions) and to absorb the heat of the nuclear reaction.

**34.** A Hiroshima-style bomb requires a specially contained fission chain reaction. The types of bombs that went off at Hiroshima and Nagasaki required purified uranium or plutonium that was rapidly compressed or pushed together by standard explosives in order to reach critical mass. Critical mass is the minimum amount of material that needs to be present in order for a nuclear reaction to moderate itself. In a nuclear reactor, there could never be enough material contained for a long enough period of time for this type of reaction to occur.

At Chernobyl, the reactor in the former Soviet republic of the Ukraine, the reactor moderator was made of graphite. Graphite is carbon, a combustible material. When the reactor at Chernobyl became overheated, the graphite caught fire, releasing smoke filled with radioactive isotopes.

Neither of these conditions (i.e., critical mass and graphite) exists in a CANDU nuclear reactor.

**35.** The major short-term safety concern for a CANDU reactor involves the production of radioactive steam. If not controlled, the heat of a CANDU reactor in the presence of so much water (heavy or regular) creates a risk of producing steam containing radioactive material. The safety systems that prevent steam build-up involve the continued cooling of the reactor to avoid the creation of steam altogether. Control rods and proper reaction monitoring ensure that the existing moderator/coolant or the auxiliary coolant supply is not required. In the event of steam build-up, the steam would be drawn out of the reactor building by pressure differential to the vacuum building where it would be doused and condensed by a cool water shower. The thick concrete containment structure would prevent any steam from escaping into the environment.

# PART 3 Solutions to End-of-chapter Problems

## Chapter 1

**15. a)** $20 \text{ min} \times \dfrac{60 \text{ s}}{1 \text{ min}} = 1200 \text{ s}$

**b)** $6.5 \text{ h} \times \dfrac{60 \text{ min}}{1 \text{ h}} = 390 \text{ min}$

**c)** $0.6 \text{ day} \times \dfrac{24 \text{ h}}{1 \text{ day}} = 14.4 \text{ h}$

**d)** $4.5 \text{ a} \times \dfrac{365.25 \text{ days}}{1 \text{ a}} \times \dfrac{24 \text{ h}}{1 \text{ day}} \times \dfrac{60 \text{ min}}{1 \text{ h}} \times \dfrac{60 \text{ s}}{1 \text{ min}}$

$= 1.4 \times 10^8 \text{ s}$

**e)** $453 \text{ s} \times \dfrac{1 \text{ min}}{60 \text{ s}} \times \dfrac{1 \text{ h}}{60 \text{ min}} = 0.126 \text{ h}$

**f)** $0.35 \text{ min} \times \dfrac{1 \text{ h}}{60 \text{ min}} \times \dfrac{1 \text{ day}}{24 \text{ h}} \times \dfrac{1 \text{ a}}{365.25 \text{ days}}$

$= 6.7 \times 10^{-7} \text{ a}$

**16. a)** $250 \text{ s} \times 10^6 \text{ µs/s}$
$= 2.50 \times 10^8 \text{ µs}$; 250 000 000 µs

**b)** $250 \text{ s} \times 10^3 \text{ ms/s}$
$= 2.50 \times 10^5 \text{ ms}$; 250 000 ms

**c)** $250 \text{ s} \times 10^{-3} \text{ ks/s}$
$= 2.50 \times 10^{-1} \text{ ks}$; 0:250 ks

**d)** $250 \text{ s} \times 10^{-6} \text{ Ms/s}$
$= 2.50 \times 10^{-4} \text{ Ms}$; 0.000250 Ms

**17. a)** $25 \text{ km/h} \times \dfrac{1000 \text{ m}}{1 \text{ km}} \times \dfrac{1 \text{ h}}{60 \text{ min}} \times \dfrac{1 \text{ min}}{60 \text{ s}}$

$= 6.9 \text{ m/s}$

**b)** $150 \text{ km/h} \times \dfrac{1000 \text{ m}}{1 \text{ km}} \times \dfrac{1 \text{ h}}{60 \text{ min}} \times \dfrac{1 \text{ min}}{60 \text{ s}}$

$= 41.7 \text{ m/s}$

**c)** $2.0 \text{ m/s} \times \dfrac{1 \text{ km}}{1000 \text{ m}} \times \dfrac{60 \text{ min}}{1 \text{ h}} \times \dfrac{60 \text{ s}}{1 \text{ min}}$

$= 7.2 \text{ km/h}$

**d)** $50 \text{ m/s} \times \dfrac{1 \text{ km}}{1000 \text{ m}} \times \dfrac{60 \text{ min}}{1 \text{ h}} \times \dfrac{60 \text{ s}}{1 \text{ min}}$

$= 180 \text{ km/h}$

**18. a)** $175 \text{ cm} = 1.75 \text{ m}$

So, $\dfrac{553 \text{ m}}{1.75 \text{ m/person}} = 316$ people.

**b)** $553 \text{ m} \times \dfrac{100 \text{ cm}}{1 \text{ m}} \times \dfrac{1 \text{ in}}{2.54 \text{ cm}} \times \dfrac{1 \text{ ft}}{12 \text{ in}}$

$= 1810 \text{ ft}$

**19. a)** $14.7 \text{ m/s} \times \dfrac{1 \text{ km}}{1000 \text{ m}} \times \dfrac{60 \text{ s}}{1 \text{ min}} \times \dfrac{60 \text{ min}}{1 \text{ h}}$

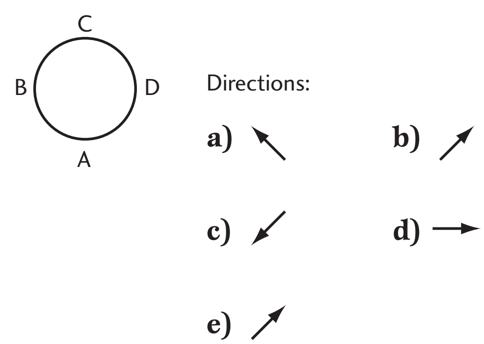
$= 52.9 \text{ km/h}$

$14.7 \text{ m/s} = 52.9 \text{ km/h}$
Yes, she would get a ticket.

**b)** $3 \text{ km/h} \times \dfrac{1}{100} = 0.03 \text{ km/h}$

So, the snail is $\dfrac{52.9 \text{ km/h}}{0.03 \text{ km/h}} = 1763$ times slower.

**20.** The distances are all $\frac{1}{4}$ the diameter. The displacements are all chords in magnitudes.




**21.** A = 20.0 m
B = 12 m
C = 20.005 m
D = 11.99998 m

**a)** perimeter P = A + B + C + D
$= 20.0 \text{ m} + 12 \text{ m} + 20.005 \text{ m} + 11.99998 \text{ m}$
$= 64 \text{ m}$
$= 64 \text{ m} \times \dfrac{10^3 \text{ mm}}{1 \text{ m}}$
$= 64\,000 \text{ mm}$

**b)** A + B = 20.0 m + 12 m = 32 m

**c)** C + D = 20.005 m + 11.99998 m
= 32.005 m

**d)** B + D = 12 m + 11.99998 m = 24 m

**e)** The different number of decimal places is due to measuring techniques and measuring instruments that give varied accuracy. Also consider the purpose of the measurement and the required accuracy.

**22. a)** $50.7 \text{ m} - 30.2 \text{ m} = 20.5 \text{ m}$

**b)** $50.7 \text{ m} - 2 \text{ m} = 48.7 \text{ m} \cong 49 \text{ m}$

**c)** $2356.9076 \text{ cm} \times \dfrac{1 \text{ m}}{100 \text{ cm}} = 23.569076 \text{ m}$

so $3567.2 \text{ m} - 23.569076 \text{ m} = 3543.6 \text{ m}$

**d)** $\dfrac{30.9 \text{ mm} \times 10^{-6} \text{ km}}{1 \text{ mm}} = 3.09 \times 10^{-7} \text{ km}$

so $30.9 \text{ km} - 3.09 \times 10^{-7} \text{ km} = 30.9 \text{ km}$

**23. a)** 2.5 cm → 125 m [E]

**b)** 1.5 cm → 75 m [N]

**c)** 1.9 cm → 95 m [W]

**d)** 1.9 cm → 95 m [S]

**e)** 0

**24. a)** 1.9 cm → 28 m/s [N] (negative)

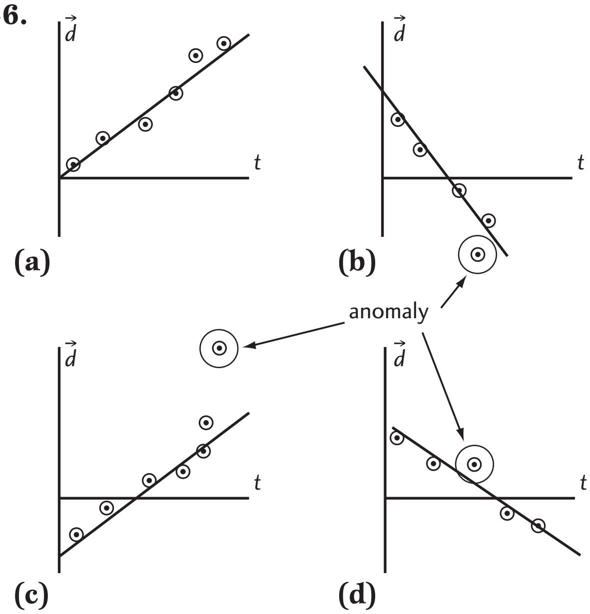
**b)** 1.5 cm → 22 m/s [S] (positive)

**c)** 2.2 cm → 33 m/s [E] (positive)

**d)** 1.8 cm → 27 m/s [S] (positive)

**25.** If the person is walking in the direction of the train's motion, the speed will be 73 km/h [W]. If the person is walking in the opposite direction of the train's motion, the speed will be 67 km/h [W[.

**26.**




**27. a)** slope: km/h  area: km·h

**b)** slope: (no units)  area: $m^2$

**c)** slope: $kg/m^3$  area: $kg \cdot m^3$

**d)** slope: $kg/s^2$  area: $kg \cdot m^2/s^2$

**28.** A, C, F, H: person is standing

B: person is moving forward, constant velocity

D, E: person is moving backward, speeding up

G: person is moving forward, speeding up

A, F, H: person is stopped.

**29. a)** section I: slope $= \dfrac{\Delta y}{\Delta x} = \dfrac{150 \text{ m} - 0 \text{ m}}{60 \text{ s} - 0 \text{ s}}$

$= 2.5 \text{ m/s}$

section II: slope $= 0$

section III: slope $= \dfrac{\Delta y}{\Delta x} = \dfrac{75 \text{ m} - 150 \text{ m}}{160 \text{ s} - 100 \text{ s}}$

$= -1.2 \text{ m/s}$

**b)** section I:

area $= \frac{1}{2}(150 \text{ m})(60 \text{ s}) = 4500 \text{ m} \cdot \text{s}$

section II:

area $= (150 \text{ m})(100 \text{ s} - 60 \text{ s}) = 6000 \text{ m} \cdot \text{s}$

section III:

area $= \frac{1}{2}(150 \text{ m} + 75 \text{ m})(160 \text{ s} - 100 \text{ s})$

$= 6750 \text{ m} \cdot \text{s}$

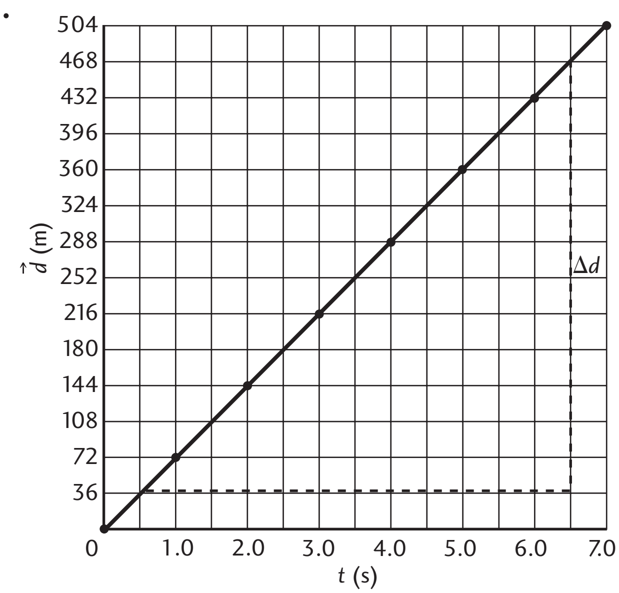
**30.** Here, velocity, $v$, is slope so:

I: $v = 2.5$ m/s

II: $v = 0$

III: $v = -1.2$ m/s

**31.**

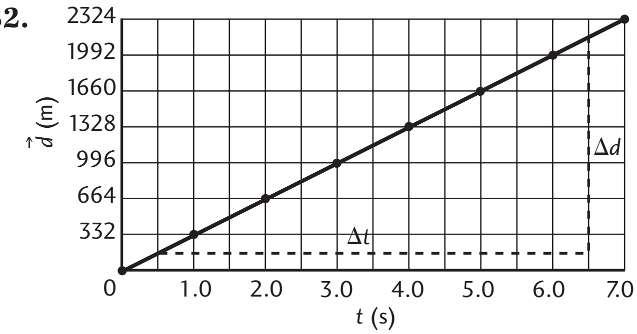


**a)** velocity = slope = $\dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{468\text{ m} - 36\text{ m}}{6.5\text{ s} - 0.5\text{ s}}$

$= 72\text{ m/s}$

**b)** $= 260\text{ km/h}$

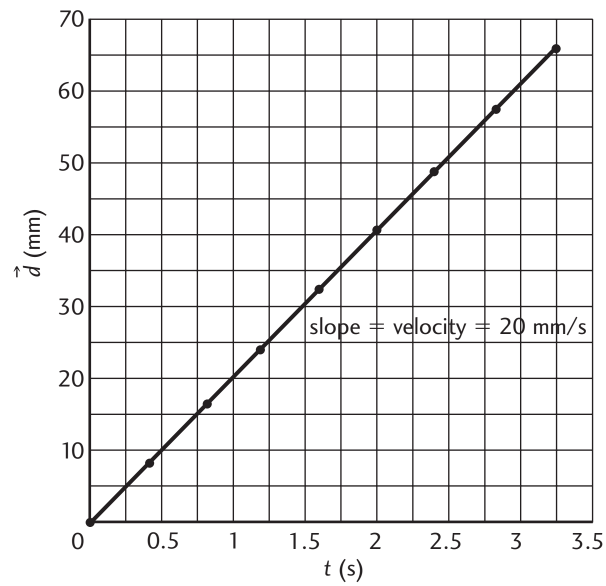
**32.**




velocity = slope = $\dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{2158\text{ m} - 166\text{ m}}{6.5\text{ s} - 0.5\text{ s}}$

$= 332\text{ m/s} \cong 1200\text{ km/h}$

**33.**



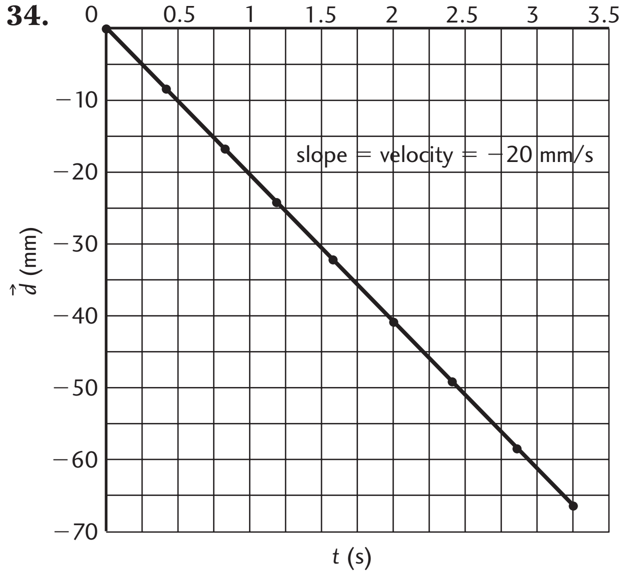

**$\vec{d}$-t chart**

| t(s) | $\vec{d}$(mm) |
|---|---|
| 0 | 0 |
| 0.4 | 8.0 |
| 0.8 | 16.5 |
| 1.2 | 24.5 |
| 1.6 | 33.0 |
| 2.0 | 41.0 |
| 2.4 | 49.0 |
| 2.8 | 57.5 |
| 3.2 | 65.5 |

velocity = slope = $\dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{65.5\text{ mm} - 0.0\text{ mm}}{3.2\text{ s} - 0.0\text{ s}}$

$= 20.5\text{ mm/s} \cong 20\text{ mm/s}$

**34.**

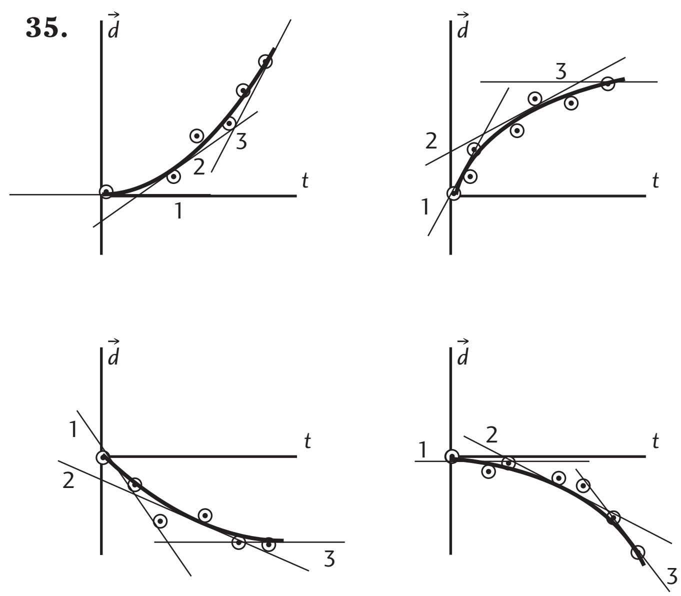



There is increasing negative displacement; therefore, negative velocity. Slope and velocity are −20 mm/s.

**$\vec{d}$-t chart**

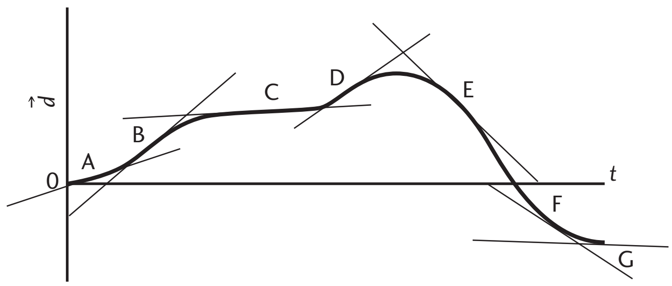
| t(s) | $\vec{d}$(mm) |
|---|---|
| 0 | 0 |
| 0.4 | −8.0 |
| 0.8 | −16.5 |
| 1.2 | −24.5 |
| 1.6 | −33.0 |
| 2.0 | −41.0 |
| 2.4 | −49.0 |
| 2.8 | −57.5 |
| 3.2 | −65.5 |

**35.**



**36.** **A:** speeding up [UP] $[v > 0, a > 0]$
**B:** speeding up [UP] $[v > 0, a = 0]$
**C:** slowing down [UP] $[v > 0, a = 0]$
**D:** speeding up [UP] $[v > 0, a = 0]$
**E:** speeding up [DOWN] $[v < 0, a < 0]$
**F:** slowing down [DOWN] $[v < 0, a > 0]$
**G:** slowing down [DOWN] $[v < 0, a > 0]$

**37.**




**38.** see graph for tangents; slope, $m$, is calculated as follows:

**A)** $m = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{9\text{ m} - 3\text{ m}}{30\text{ s} - 10\text{ s}} = 0.3\text{ m/s}$

**B)** $m = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{5\text{ m} - (-4\text{ m})}{17\text{ s} - 0\text{ s}} = 0.5\text{ m/s}$

**C)** $m = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{0.5\text{ m} - 1.5\text{ m}}{4\text{ s} - 1\text{ s}} = -0.3\text{ m/s}$

**D)** $m = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{-25\text{ m} - 25\text{ m}}{40\text{ s} - 0\text{ s}} = -1.2\text{ m/s}$

**39.** at 2.0 s, $m = \dfrac{30\text{ m} - 8.0\text{ m}}{3.2\text{ s} - 1.4\text{ s}}$

$= \dfrac{22\text{ m}}{1.8\text{ s}}$

$= \dfrac{22\text{ m}}{1.8\text{ s}} \times \dfrac{1\text{ km}}{1000\text{ m}} \times \dfrac{3600\text{ s}}{1\text{ h}}$

$= 44\text{ km/h}$

at 4.0 s, $m = \dfrac{82\text{ m} - 24\text{ m}}{5.4\text{ s} - 2.4\text{ s}}$

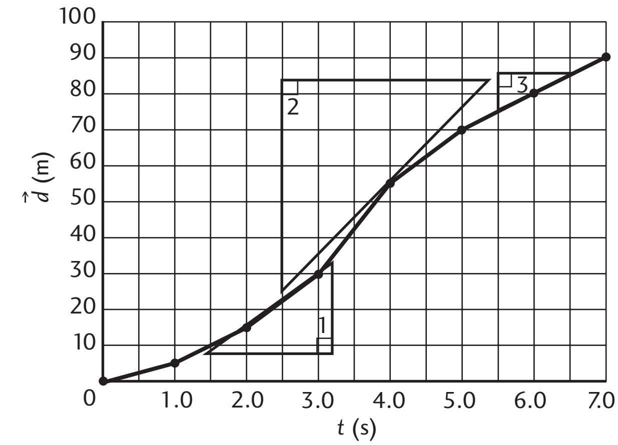
$= \dfrac{58\text{ m}}{3.0\text{ s}}$

$= 70\text{ km/h}$

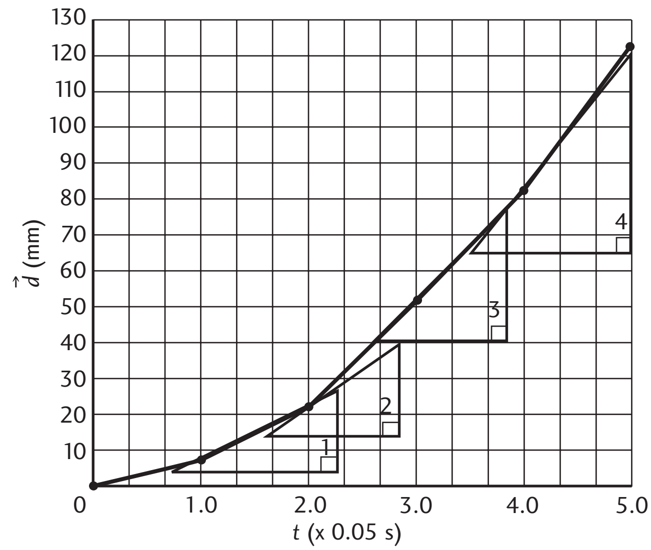
at 6.0 s, $m = \dfrac{86\text{ m} - 76\text{ m}}{66\text{ s} - 5.6\text{ s}}$

$= \dfrac{10\text{ m}}{1.0\text{ s}}$

$= 36\text{ km/h}$




**40.**




**a)** at $1.0 \times 0.05\text{ s} = 0.05\text{ s}$,

$m_1 = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{24\text{ mm} - 4\text{ mm}}{(2.4 \times 0.05\text{ s}) - (0.6 \times 0.05\text{ s})}$

$= \dfrac{20\text{ mm}}{0.09\text{ s}}$

$= 222.\overline{2}\text{ mm/s}$

$= 2.2 \times 10^2\text{ mm/s}$

at $2.0 \times 0.05\text{ s} = 0.1\text{ s}$,

$m_2 = \dfrac{\Delta\vec{d}}{\Delta t} = \dfrac{40\text{ mm} - 14\text{ mm}}{0.14\text{ s} - 0.08\text{ s}}$

$= \dfrac{26\text{ mm}}{0.06\text{ s}}$

$= 433.\overline{3}\text{ mm/s}$

$= 4.3 \times 10^2\text{ mm/s}$

at $3.0 \times 0.05\text{ s} = 0.15\text{ s}$,

$$m_3 = \frac{\Delta \vec{d}}{\Delta t} = \frac{78\text{ mm} - 40\text{ mm}}{0.19\text{ s} - 0.13\text{ s}}$$
$$= \frac{38\text{ mm}}{0.06\text{ s}}$$
$$= 633.\overline{3}\text{ mm/s}$$
$$= 6.3 \times 10^2\text{ mm/s}$$

at $4.0 \times 0.05\text{ s} = 0.2\text{ s}$,

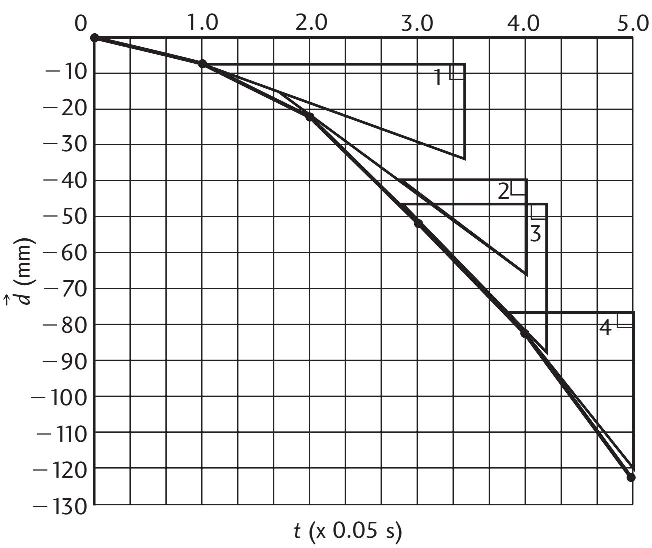
$$m_4 = \frac{\Delta \vec{d}}{\Delta t} = \frac{120\text{ mm} - 64\text{ mm}}{0.25\text{ s} - 0.17\text{ s}}$$
$$= \frac{56\text{ mm}}{0.08\text{ s}}$$
$$= 700\text{ mm/s}$$
$$= 7.0 \times 10^2\text{ mm/s}$$

**$\vec{d}$-*t* chart**

| $t$(s) | $\vec{d}$ (mm) |
|---|---|
| 0 | 0 |
| 5 | 8 |
| 10 | 22 |
| 15 | 52 |
| 20 | 85 |
| 25 | 123 |
| — | — |

The object is speeding up in the positive direction.

**b)**




at $1.0 \times 0.05\text{ s} = 0.05\text{ s}$,

$$m_1 = \frac{\Delta \vec{d}}{\Delta t} = \frac{(-36\text{ mm}) - (-8\text{ mm})}{0.18\text{ s} - 0.05\text{ s}}$$
$$= \frac{-28\text{ mm}}{0.13\text{ s}}$$
$$= -215.38\text{ mm/s}$$
$$\cong -2.2 \times 10^2\text{ mm/s}$$

at $2.0 \times 0.05\text{ s} = 0.1\text{ s}$,

$$m_2 = \frac{\Delta \vec{d}}{\Delta t} = \frac{(-66\text{ mm}) - (-40\text{ mm})}{0.2\text{ s} - 0.14\text{ s}}$$
$$= \frac{-26\text{ mm}}{0.06\text{ s}}$$
$$= -433.\overline{3}\text{ mm/s}$$
$$\cong -4.3 \times 10^2\text{ mm/s}$$

at $3.0 \times 0.05\text{ s} = 0.15\text{ s}$,

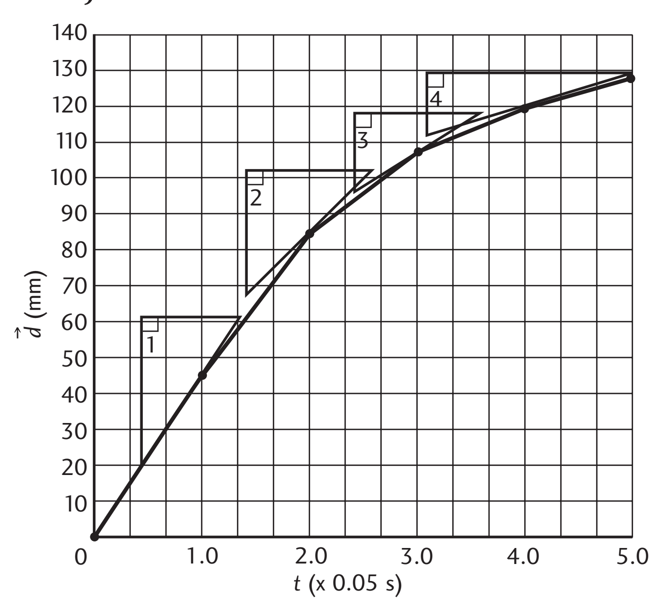
$$m_3 = \frac{\Delta \vec{d}}{\Delta t} = \frac{(-90\text{ mm}) - (-46\text{ mm})}{0.21\text{ s} - 0.14\text{ s}}$$
$$= \frac{-44\text{ mm}}{0.07\text{ s}}$$
$$= -628.57\text{ mm/s}$$
$$\cong -6.3 \times 10^2\text{ mm/s}$$

at $4.0 \times 0.05\text{ s} = 0.2\text{ s}$,

$$m_4 = \frac{\Delta \vec{d}}{\Delta t} = \frac{(-120\text{ mm}) - (-78\text{ mm})}{0.25\text{ s} - 0.19\text{ s}}$$
$$= \frac{-42\text{ mm}}{0.06\text{ s}}$$
$$= -700\text{ mm/s}$$
$$= -7.0 \times 10^2\text{ mm/s}$$

Displacements are reversed (negative). The object is speeding up in the opposite (negative) direction.

**41. a)**



at 1.0 × 0.05 s = 0.05 s,

$$m_1 = \frac{\Delta\vec{d}}{\Delta t} = \frac{62\text{ mm} - 20\text{ mm}}{0.07\text{ s} - 0.02\text{ s}}$$
$$= \frac{42\text{ mm}}{0.05\text{ s}}$$
$$= 840\text{ mm/s}$$
$$= 8.4 \times 10^2\text{ mm/s}$$

at 2.0 s × 0.05 s = 0.1 s,

$$m_2 = \frac{\Delta\vec{d}}{\Delta t} = \frac{102\text{ mm} - 66\text{ mm}}{0.13\text{ s} - 0.07\text{ s}}$$
$$= \frac{36\text{ mm}}{0.06\text{ s}}$$
$$= 600\text{ mm/s}$$
$$= 6.0 \times 10^2\text{ mm/s}$$

at 3.0 s × 0.05 s = 0.15 s,

$$m_3 = \frac{\Delta\vec{d}}{\Delta t} = \frac{118\text{ mm} - 98\text{ mm}}{0.18\text{ s} - 0.12\text{ s}}$$
$$= \frac{20\text{ mm}}{0.06\text{ s}}$$
$$= 333.\overline{3}\text{ mm/s}$$
$$= 3.3 \times 10^2\text{ mm/s}$$

at 4.0 s × 0.05 s = 0.2 s,

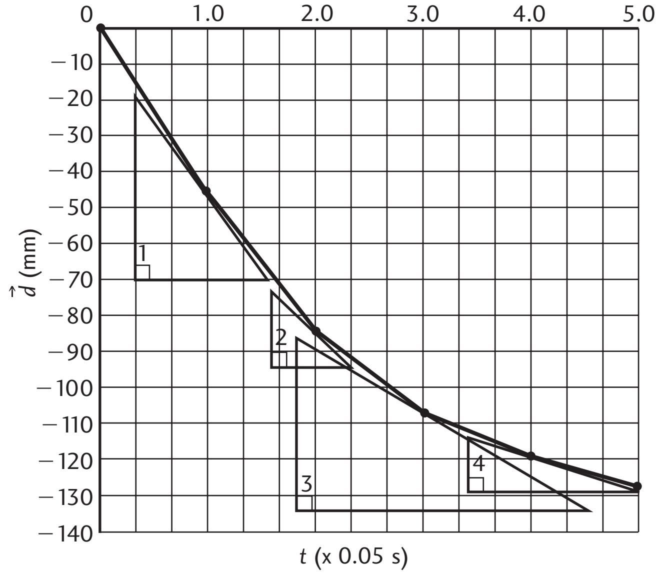
$$m_4 = \frac{\Delta\vec{d}}{\Delta t} = \frac{128\text{ mm} - 112\text{ mm}}{0.25\text{ s} - 0.16\text{ s}}$$
$$= \frac{16\text{ mm}}{0.09\text{ s}}$$
$$= 177.\overline{7}\text{ mm/s}$$
$$\cong 1.8 \times 10^2\text{ mm/s}$$

**$\vec{d}$-*t* chart**

| $t$(s) | $\vec{d}$(mm) |
|---|---|
| 0 | 0 |
| 2 | 45 |
| 4 | 84 |
| 6 | 108 |
| 8 | 119 |
| 10 | 126 |

All times are obtained by multiplying the time by 0.05 s.
The object is moving forward and slowing down.

**b)**




at 1.0 × 0.05 s = 0.05 s,

$$m_1 = \frac{\Delta\vec{d}}{\Delta t} = \frac{(-70\text{ mm}) - (-20\text{ mm})}{0.08\text{ s} - 0.02\text{ s}}$$
$$= \frac{-50\text{ mm}}{0.06\text{ s}}$$
$$= -833.\overline{3}\text{ mm/s}$$
$$= -8.3 \times 10^2\text{ mm/s}$$

at 2.0 × 0.05 s = 0.1 s,

$$m_2 = \frac{\Delta\vec{d}}{\Delta t} = \frac{(-96\text{ mm}) - (-72\text{ mm})}{0.12\text{ s} - 0.08\text{ s}}$$
$$= \frac{-24\text{ mm}}{0.04\text{ s}}$$
$$= -600\text{ mm/s}$$
$$= -6.0 \times 10^2\text{ mm/s}$$

at 3.0 × 0.05 s = 0.15 s,

$$m_3 = \frac{\Delta\vec{d}}{\Delta t} = \frac{(-134\text{ mm}) - (-88\text{ mm})}{0.23\text{ s} - 0.09\text{ s}}$$
$$= \frac{-46\text{ mm}}{0.14\text{ s}}$$
$$= -328.57\text{ mm/s}$$
$$\cong -3.3 \times 10^2\text{ mm/s}$$

at $4.0 \times 0.05 \text{ s} = 0.2 \text{ s}$,

$$m_4 = \frac{\Delta \vec{d}}{\Delta t} = \frac{(-128 \text{ mm}) - (-114 \text{ mm})}{0.25 \text{ s} - 0.17 \text{ s}}$$

$$= \frac{-14 \text{ mm}}{0.08 \text{ s}}$$

$$= -175 \text{ mm/s}$$

$$\cong -1.8 \times 10^2 \text{ mm/s}$$

The object is moving backward, but is slowing down.

**42.** average velocity, $v_{\text{avg}} = \dfrac{d_2 - d_1}{t_2} - t_1$

AB: $v_{\text{avg}} = \dfrac{50 \text{ m} - 20 \text{ m}}{8 \text{ s} - 1 \text{ s}} \cong 4.3 \text{ m/s}$

BC: $v_{\text{avg}} = \dfrac{50 \text{ m} - 50 \text{ m}}{14 \text{ s} - 8 \text{ s}} = 0 \text{ m/s}$

BD: $v_{\text{avg}} = \dfrac{20 \text{ m} - 50 \text{ m}}{16 \text{ s} - 8 \text{ s}} \cong -3.8 \text{ m/s}$

AD: $v_{\text{avg}} = \dfrac{20 \text{ m} - 20 \text{ m}}{16 \text{ s} - 1 \text{ s}} = 0 \text{ m/s}$

AE: $v_{\text{avg}} = \dfrac{-20 \text{ m} - 20 \text{ m}}{20 \text{ s} - 1 \text{ s}} = -2.1 \text{ m/s}$

BE: $v_{\text{avg}} = \dfrac{-20 \text{ m} - 50 \text{ m}}{20 \text{ s} - 8 \text{ s}} = -5.8 \text{ m/s}$

**43.** average velocity, $v_{\text{avg}} = \dfrac{d_2 - d_1}{t_2 - t_1}$

AB: $v_{\text{avg}} = \dfrac{6 \text{ m} - 1 \text{ m}}{8 \text{ s} - 1.5 \text{ s}} \cong 0.8 \text{ m/s}$

instantaneous velocity:

at A, slope $= \dfrac{\Delta \vec{d}}{\Delta t} = \dfrac{3.7 \text{ m} - (-2 \text{ m})}{2.8 - 0 \text{ s}}$

$= 2.04 \text{ m/s}.$

at B, slope $= \dfrac{\Delta \vec{d}}{\Delta t} = 0$

Therefore, the average velocity

$= \dfrac{v_{\text{A}} + v_{\text{B}}}{2} = \dfrac{2.04 \text{ m/s} + 0}{2} = 1.0 \text{ m/s}.$

Compare to 0.8 m/s, obtained graphically.

CD: $v_{\text{a}} = \dfrac{8 \text{ m} - 0.5 \text{ m}}{11 \text{ s} - 2 \text{ s}} = 0.83 \text{ m/s}$

instantaneous velocity:

at C, slope $= \dfrac{\Delta \vec{d}}{\Delta t} = \dfrac{1.1 \text{ m} - 0 \text{ m}}{4 \text{ s} - 0 \text{ s}} \cong 0.28 \text{ m/s}$

at D, slope $= \dfrac{\Delta \vec{d}}{\Delta t} = \dfrac{9.5 \text{ m} - 6 \text{ m}}{12.0 \text{ s} - 9.6 \text{ s}}$

$\cong 1.46 \text{ m/s}$

Therefore, the average velocity $= \dfrac{v_{\text{C}} + v_{\text{D}}}{2}$
$= 0.87 \text{ m/s}$

Compare to 0.8 m/s, obtained graphically.

# Chapter 2

**14. a)** A: speeding up eastbound; B: constant speed of 25 m/s eastbound; C: slowing down eastbound; D: speeding up westbound; E: constant speed of 75 m/s westbound; F: speeding up westbound

**b)** instantaneous speed, $v$:
at 60 s, $v = 12$ m/s $= 43$ km/h
at 240 s, $v = 25$ m/s $= 90$ km/h
at 420 s, $v = 0$ m/s $= 0$ km/h
at 480 s, $v = -45$ m/s $= -162$ km/h
at 720 s, $v = -138$ m/s $= -496.8$ km/h
$\cong 497$ km/h

**c)** acceleration, $a = \dfrac{v_2 - v_1}{t_2 - t_1}$

$$a_A = \frac{25 \text{ m/s} - 0 \text{ m/s}}{12.0 \text{ s} - 0 \text{ s}} \cong 0.21 \text{ m/s}^2$$

$$a_B = \frac{25 \text{ m/s} - 25 \text{ m/s}}{300 \text{ s} - 120 \text{ s}} = 0 \text{ m/s}^2$$

$$a_C = \frac{0 \text{ m/s} - 25 \text{ m/s}}{420 \text{ s} - 300 \text{ s}} \cong -0.21 \text{ m/s}^2$$

$$a_D = \frac{-75 \text{ m/s} - 0 \text{ m/s}}{525 \text{ s} - 420 \text{ s}} = -0.71 \text{ m/s}^2$$

$$a_E = 0 \text{ m/s}^2$$

$$a_F = \frac{-130 \text{ m/s} - (-75 \text{ m/s})}{720 \text{ s} - 600 \text{ s}} \cong -0.46 \text{ m/s}^2$$

**d)** displacement travelled ($\Delta d$) is given by the area under the graph:

$\Delta d_A = \frac{1}{2}(25 \text{ m/s})(120 \text{ s}) = 1500$ m

$\Delta d_B = (25 \text{ m/s})(300 \text{ s} - 120 \text{ s}) = 4500$ m

$\Delta d_C = \frac{1}{2}(25 \text{ m/s})(420 \text{ s} - 300 \text{ s}) = 1500$ m

$\Delta d_D = \frac{1}{2}(-75 \text{ m/s})(525 \text{ s} - 420 \text{ s})$
$= -3937.5 \text{ m} \cong 3900$ m
(i.e., westbound)

$\Delta d_E = (-75 \text{ m/s})(600 \text{ s} - 525 \text{ s})$
$= -5600$ m (i.e., westbound)

$\Delta d_F$
$= \frac{1}{2}(-138 \text{ m/s} - [-75 \text{ m/s}])(720 \text{ s} - 600 \text{ s})$
$+ (-75 \text{ m/s})(720 \text{ s} - 600 \text{ s}) = -21\,800$ m

**e)** total displacement,

$\Delta d_{tot} = \Delta d_A + \Delta d_B + \Delta d_C + \Delta d_D + \Delta d_E + \Delta d_F$

$\Delta d_{tot} = -23\,800$ m

**f)** average velocity given by the displacement travelled ($\Delta d$) over time ($\Delta t$); displacement is the area under graph (see part d).

**A:** $v_{avg} = \dfrac{\Delta d}{\Delta t} = \dfrac{1500 \text{ m}}{120 \text{ s}} = 12.5$ m/s

**B:** $v_{avg} = \dfrac{\Delta d}{\Delta t} = \dfrac{4500 \text{ m}}{180 \text{ s}} = 25$ m/s

**C:** $v_{avg} = \dfrac{1500 \text{ m}}{120 \text{ s}} = 12.5$ m/s

**D:** $v_{avg} = \dfrac{-3900 \text{ m}}{105 \text{ s}} \cong -37$ m/s

**E:** $v_{avg} = \dfrac{-5600 \text{ m}}{75 \text{ s}} = -75$ m/s

**F:** $v_{avg} = \dfrac{-21\,800 \text{ m}}{120 \text{ s}} = -180$ m/s

**g)** average velocity for the whole trip:

$$v_{avg_{tot}} = \frac{\Delta d_{tot}}{\Delta t_{tot}} = \frac{-23\,800 \text{ m}}{720 \text{ s}}$$

$$v_{avg_{tot}} = -33 \text{ m/s}$$

**h)** For average speed, take absolute values for all distances and repeat procedure in g).

$$v_{avg_{tot}} = \frac{\Delta d_{tot}}{\Delta t_{tot}} = \frac{38\,800 \text{ m}}{720 \text{ s}}$$

$$v_{avg_{tot}} = 54 \text{ m/s}$$

**15. a)** instantaneous velocities, $v$:
at 4 s, $v = 10$ m/s
at 12 s, $v = 47$ m/s
at 18 s, $v = 31$ m/s
at 28 s, $v = -9$ m/s

**b)** instantaneous acceleration, $a$, given by slope, $m$, of tangent at time, $t$:

at 4 s, $a = \dfrac{v_2 - v_1}{t_2 - t_1} = \dfrac{15 \text{ m/s} - 5 \text{ m/s}}{5.8 \text{ s} - 2 \text{ s}}$
$= 2.6 \text{ m/s}^2$

at 12 s, $a = 0$ (constant slope)

at 18 s, $a = \dfrac{0\text{ m/s} - 47\text{ m/s}}{26\text{ s} - 14\text{ s}} = -3.9\text{ m/s}^2$

at 28 s, $a = \dfrac{-17\text{ m/s} - 0\text{ m/s}}{30\text{ s} - 26\text{ s}} = -4.2\text{ m/s}^2$

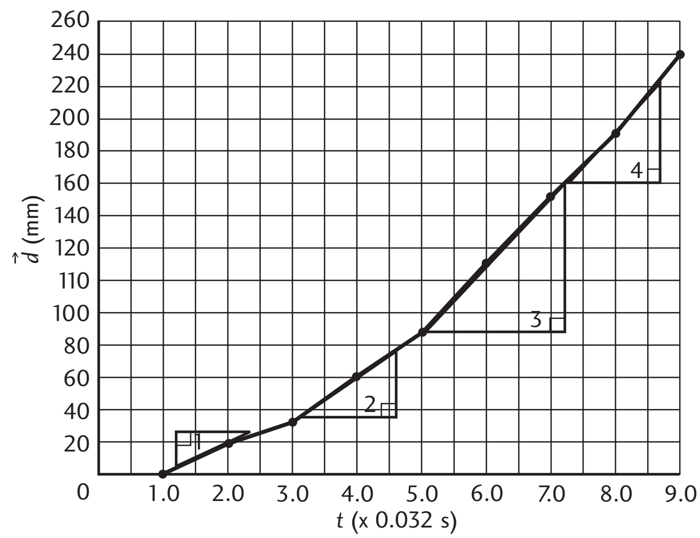
**c)** $v_{max} = 40$ m/s between $t = 10$ s$-14$ s

**d)** $v_{min} = 0$ m/s at $t = 0$ s, 26 s

**e)** $a_{max}$ at $t = 10$ s

**f)** $a = 0$ at $t = 10$ s$-14$ s, 32 s

**16. i)**




at $2.0 \times 0.032$ s $= 0.064$ s,

$$m_1 = \frac{\Delta\vec{d}}{\Delta t} = \frac{26\text{ mm} - 6\text{ mm}}{0.0768\text{ s} - 0.0384\text{ s}}$$
$$= \frac{20\text{ mm}}{0.0384\text{ s}}$$
$$= 520.8\overline{3}\text{ mm/s}$$
$$= 5.2 \times 10^2\text{ mm/s}$$

at 0.128 s,

$$m_2 = \frac{\Delta\vec{d}}{\Delta t} = \frac{74\text{ mm} - 38\text{ mm}}{0.1472\text{ s} - 0.1024\text{ s}}$$
$$= \frac{36\text{ mm}}{0.0448\text{ s}}$$
$$= 803.5714\text{ mm/s}$$
$$= 8.0 \times 10^2\text{ mm/s}$$

at 0.192 s,

$$m_3 = \frac{\Delta\vec{d}}{\Delta t} = \frac{156\text{ mm} - 88\text{ mm}}{0.2304\text{ s} - 0.1664\text{ s}}$$
$$= \frac{68\text{ mm}}{0.064\text{ s}}$$
$$= 1062.5\text{ mm/s}$$
$$= 1.1 \times 10^3\text{ mm/s}$$

at 0.256 s,

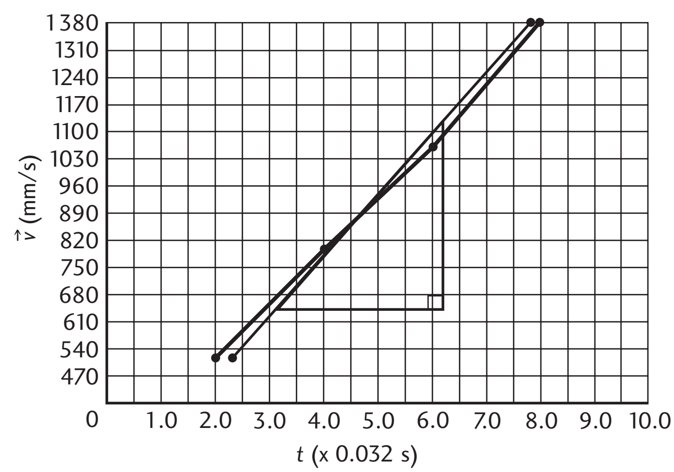
$$m_4 = \frac{\Delta\vec{d}}{\Delta t} = \frac{222\text{ mm} - 160\text{ mm}}{0.2752\text{ s} - 0.2304\text{ s}}$$
$$= \frac{62\text{ mm}}{0.0448\text{ s}}$$
$$= 1383.9286\text{ mm/s}$$
$$= 1.4 \times 10^3\text{ mm/s}$$

**ii)** calculating acceleration:

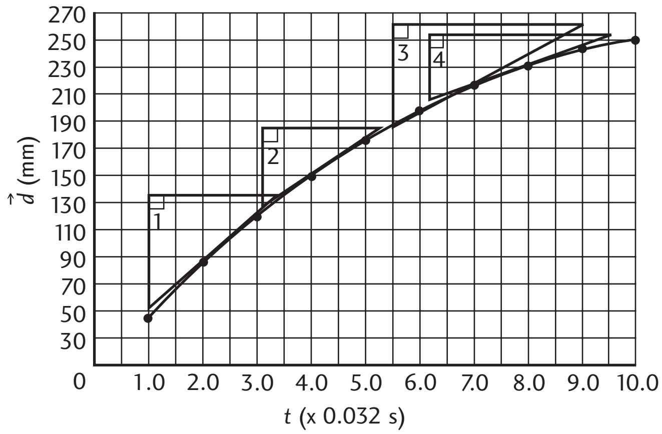
$$a = \frac{1125\text{ mm/s} - 695\text{ mm/s}}{0.1984\text{ s} - 0.1088\text{ s}}$$
$$= \frac{430\text{ mm/s}}{0.0896\text{ s}}$$
$$= 4799.107\text{ mm/s}^2$$
$$= 4.80\text{ m/s}^2$$

| $t$(x 0.032 s) | $\vec{d}$(mm) |
|---|---|
| 0 | 0 |
| 1 | 5 |
| 2 | 19 |
| 3 | 34 |
| 4 | 59 |
| 5 | 85 |
| 6 | 115 |
| 7 | 153 |

All runs were multiplied by 0.032 s times the dot number.



**17.**




**i)** at 2.0 × 0.032 s = 0.064 s,

$$m_1 = \frac{\Delta \vec{d}}{\Delta t} = \frac{136\text{ mm} - 48\text{ mm}}{0.1088\text{ s} - 0.032\text{ s}}$$
$$= \frac{88\text{ mm}}{0.0768\text{ s}}$$
$$= 1145.8\overline{3}\text{ mm/s}$$
$$= 1.1 \times 10^3\text{ mm/s}$$

at 0.128 s,

$$m_2 = \frac{\Delta \vec{d}}{\Delta t} = \frac{184\text{ mm} - 126\text{ mm}}{0.1664\text{ s} - 0.1024\text{ s}}$$
$$= \frac{58\text{ mm}}{0.064\text{ s}}$$
$$= 906.25\text{ mm/s}$$
$$= 9.1 \times 10^2\text{ mm/s}$$

at 0.192 s,

$$m_3 = \frac{\Delta \vec{d}}{\Delta t} = \frac{262\text{ mm} - 192\text{ mm}}{0.288\text{ s} - 0.1792\text{ s}}$$
$$= \frac{70\text{ mm}}{0.1088\text{ s}}$$
$$= 643.38\text{ mm/s}$$
$$= 6.4 \times 10^2\text{ mm/s}$$

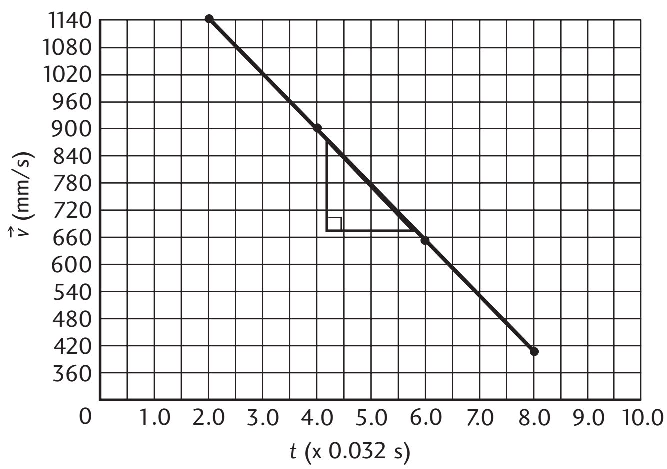
at 0.256 s,

$$m_4 = \frac{\Delta \vec{d}}{\Delta t} = \frac{254\text{ mm} - 210\text{ mm}}{0.3072\text{ s} - 0.1984\text{ s}}$$
$$= \frac{44\text{ mm}}{0.1088\text{ s}}$$
$$= 404.41176\text{ mm/s}$$
$$= 4.0 \times 10^2\text{ mm/s}$$

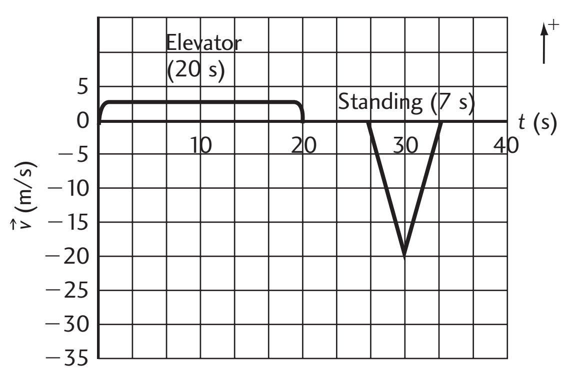
**ii)** calculating acceleration:

$$a = \frac{675\text{ mm/s} - 875\text{ mm/s}}{0.1856\text{ s} - 0.1344\text{ s}}$$
$$= \frac{-200\text{ mm/s}}{0.0512\text{ s}}$$
$$= -3906.25\text{ mm/s}^2$$
$$= -3.91\text{ m/s}^2$$

| $t$(x 0.032 s) | $\vec{d}$(mm) |
|---|---|
| 0 | 0 |
| 1 | 45 |
| 2 | 85 |
| 3 | 119 |
| 4 | 149 |
| 5 | 177 |
| 6 | 200 |
| 7 | 218 |
| 8 | 233 |
| 9 | 244 |
| 10 | 250 |




**18.** Assume no wind resistance; therefore, constant acceleration.



**19. a)** **A:** take-off and engine cut-off at $t = 5.0$ s
**B:** coasting forward to stop at $t = 13.0$ s
**C:** free fall downward
**D:** deployment of first parachute and consequent slowing
**E:** deployment of second parachute and consequent slowing

**b)** Acceleration is given by slope, $m$, of $\vec{v}$-$t$ graph, where $m = \frac{\Delta\vec{v}}{\Delta t}$ (up is positive).

$$a_A = \frac{700 \text{ cm/s} - 0 \text{ cm/s}}{50 \text{ s} - 4 \text{ s}} = 15.2 \text{ cm/s}^2$$
$$\cong 0.15 \text{ m/s}^2$$
$$a_B = a_C = \frac{-600 \text{ cm/s} - 700 \text{ cm/s}}{20.0 \text{ s} - 5.0 \text{ s}}$$
$$\cong -87 \text{ cm/s}^2 = -0.87 \text{ m/s}^2$$
$$a_D = \frac{-200 \text{ cm/s} - (-600 \text{ cm/s})}{40.0 \text{ s} - 20.0 \text{ s}}$$
$$= 20 \text{ cm/s}^2 = 0.20 \text{ m/s}^2$$
$$a_E = \frac{0\text{cm/s} - (-200 \text{ cm/s})}{60.0 \text{ s} - 40.0 \text{ s}} = 10 \text{ cm/s}$$
$$= 0.10 \text{ m/s}^2$$

**20. a)** Displacement, $\Delta d$, is given by area under the graph (up is positive).

$\Delta d_A = \frac{1}{2} \times 700 \text{ cm/s} \times 5.0 \text{ s} = 1750 \text{ cm}$

$\Delta d_B = \frac{1}{2} \times 700 \text{ cm/s} \times (13.0 \text{ s} - 5.0 \text{ s})$
$= 2800 \text{ cm}$

$\Delta d_C = \frac{1}{2} \times (-600 \text{ m/s}) \times (20.0 \text{ s} - 13.0 \text{ s})$
$= -2100 \text{ cm}$

$\Delta d_D = \frac{1}{2} \times (-600 \text{ m/s} - 200 \text{ m/s})$
$\times (40.0 \text{ s} - 20.0 \text{ s}) = -8000 \text{ cm}$

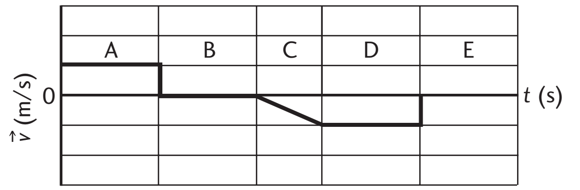
$\Delta d_E = \frac{1}{2} \times (-200 \text{ m/s}) \times (60.0 \text{ s} - 40.0 \text{ s})$
$= -2000 \text{ cm}$

**b)** $\Delta d_{total} = 1750 \text{ cm} + 2800 \text{ cm} - 2100 \text{ cm} - 8000 \text{ cm} - 2000 \text{ cm} = -7550 \text{ cm}$

**21. a)** A was stopped; B was moving at 15 m/s and slowing up.
**b)** 3.8 s
**c)** no
**d)** A accelerates, then travels at a constant velocity, B decelerates.
**e)** The area of A is greater than the area of B; therefore; A passed B.
**f)** **B:** $\frac{(15 \text{ m/s} + 12 \text{ m/s})}{2} \times 3.8 \text{ s} = 51.3 \text{ m}$

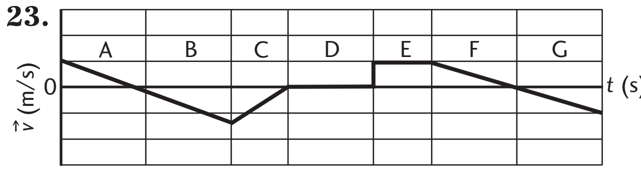
**A:** $\frac{1}{2} \times 3.8 \text{ s} \times 12 \text{ m/s} = 22.8 \text{ m}$
Therefore, B is ahead of A by 28.5 m.
**g)** Areas would be the same.

**22.**



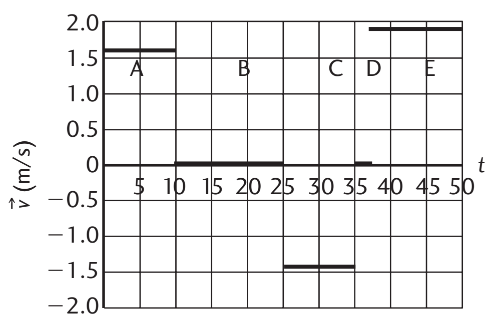

Motion:
A: constant motion forward; B: stopped; C: speeding up backward; D: constant velocity backward; E: stopped

**23.**



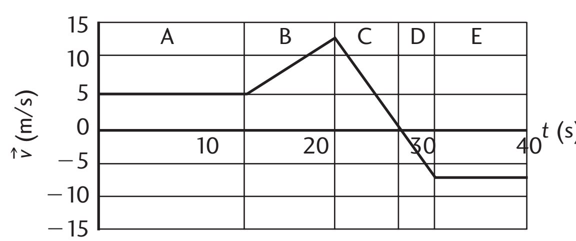

Motion:
A: forward motion but slowing down to stop; B: speeding up backwards; C: slowing down backwards to stop; D: stopped; E: constant motion forward; F: slowing down forward; G: speeding up backward

**24.**



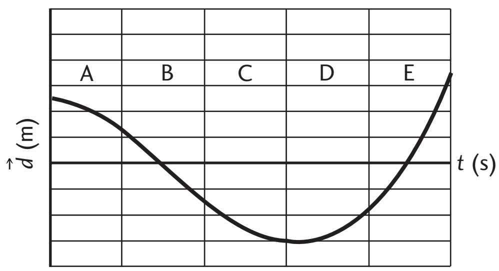

Motion:
A: constant velocity forward; B: stopped; C: constant velocity backward; D: stopped; E: constant velocity forward

**25.**



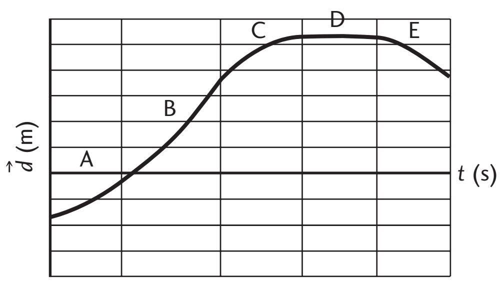
Motion:
A: constant forward motion; B: speeding up forward; C: slowing down forward; D: speeding up backwards; E: constant speed backward

**26.**



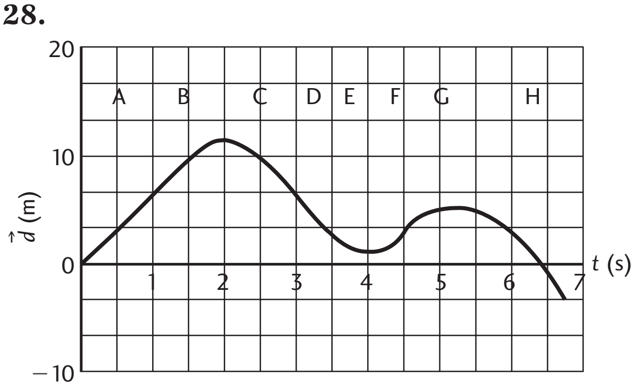

Motion:
A: speeding up backward; B: constant speed backward; C: slowing down backward;
D: speeding up forward; E: speeding up at a higher rate forward

**27.**



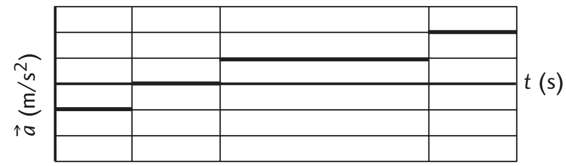

Motion:
A: speeding up forward; B: speeding up forward; C: slowing down forward; D: stopped; E: speeding up backward

**28.**

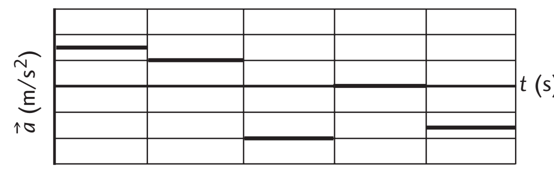



Motion:
A: constant velocity forward; B: slowing down forward; C: speeding up backward; D: constant velocity backward; E: slowing down backward; F: speeding up forward; G: slowing down forward; H: speeding up backward

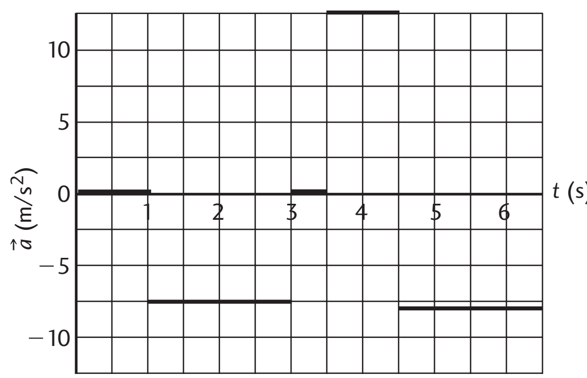
**29.** from problem 26




from problem 27




**30.**




**31.** $xy = p$

$z = px$

We need the following combinations:

| | | |
|---|---|---|
| $xp$ | $py$ | $yz$ |
| $xy$ | $pz$ | |
| $xz$ | | |

(Boxed values are already given.)

$yp$: substitute: $x = \dfrac{p}{y}$ into $z = px$

therefore: $z = \dfrac{p^2}{y}$

$xz$: $p = \dfrac{z}{x}$

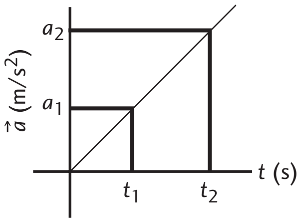
$pz$: $x = \dfrac{z}{p}$

$yz$: substitute: $x = \dfrac{z}{p}$ into $p = xy$,

$$p = \frac{zy}{p}$$

$$p = \sqrt{zy}$$

**32. a)**




$$\text{Slope} = \frac{a_2 - a_1}{\Delta t}$$

Therefore, $\Delta\vec{a} = (\text{Jerk})\Delta t$

**b)** Area units are m/s$^2$ × s = m/s, which is velocity

Therefore, $\Delta v = \dfrac{(a_1 + a_2)}{2}\Delta t$

Area is change in velocity.

**33.**

| Bailey: | Johnson: |
|---|---|
| $\Delta d = 100$ m | $\Delta d_1 = 200$ m |
| $\Delta t = 9.84$ s | $\Delta t_1 = 19.32$ s |
| | $\Delta d_2 = 400$ m |
| | $\Delta t_2 = 43.49$ s |

$$v_{avg} = \frac{\Delta d}{\Delta t}$$

Bailey: (100 m) $v_{avg} = \dfrac{100\text{ m}}{9.84\text{ s}} \cong 10.2$ m/s

Johnson: (200 m) $v_{avg} = \dfrac{200\text{ m}}{19.32\text{ s}} \cong 10.4$ m/s

(400 m) $v_{avg} = \dfrac{400\text{ m}}{43.49\text{ s}} \cong 9.20$ m/s

**34.** $\Delta t = 45$ s

$v = 140$ m/s

$$v = \frac{\Delta d}{\Delta t}$$

$$\begin{aligned}\Delta d &= v\Delta t\\ &= 140\text{ m/s} \times 45\text{ s}\\ &= 6300\text{ m}\\ \Delta d &= 6.3\text{ km}\end{aligned}$$

**35.** $\Delta t = 0.5$ s

$$v = 30\text{ km/h} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{3600\text{ s}}$$

$$= 8.3\text{ m/s}$$

$$v = \frac{\Delta d}{\Delta t}$$

$$\begin{aligned}\Delta d &= v\Delta t\\ &= 8.3\text{ m/s} \times 0.5\text{ s}\\ \Delta d &\cong 4.2\text{ m}\end{aligned}$$

**36.** $\Delta d = 1.0$ m

$$v = \frac{100\ \mu\text{m}}{1\text{ s}} \times \frac{10^{-6}\text{ m}}{1\ \mu\text{m}}$$

$$= 1.00 \times 10^{-4}\text{ m/s}$$

$$v = \frac{\Delta d}{\Delta t}$$

$$\begin{aligned}\Delta t &= \frac{\Delta d}{v}\\ &= \frac{1.0\text{ m}}{1.0 \times 10^{-4}\text{ m/s}}\\ &= 10\ 000\text{ s}\\ \Delta t &\cong 2.8\text{ h}\end{aligned}$$

**37.** $\Delta t = 4.8$ s

$v_1 = 14.0$ m/s

$v_2 = 16.0$ m/s (Assume constant acceleration.)

$$a_{avg} = \frac{\Delta v}{\Delta t}$$

$$\Delta d = v_1\Delta t + \tfrac{1}{2}a_{avg}\Delta t^2$$

$$a_{avg} = \frac{2\text{ m/s}}{4.8\text{ s}}$$

$$\cong 0.42\text{ m/s}^2$$

$$\Delta d = (14.0\text{ m/s}) \times (4.8\text{ s}) + \tfrac{1}{2}(0.42\text{ m/s}^2) \times (4.8\text{ s})^2$$

$$\Delta d = 72\text{ m}$$

**38.** $\Delta t = 8.0$ s

$v_1 = 15$ m/s

$v_2 = 10$ m/s

(1) $a_{avg} = \dfrac{\Delta v}{\Delta t}$

(2) $\Delta d = v_1\Delta t + \tfrac{1}{2}a_{avg}\Delta t^2$

(1) $a_{avg} = \dfrac{10\text{ m/s} - 15\text{ m/s}}{8.0\text{ s}}$

$= -0.62$ m/s$^2$

(2) $\Delta d = (15\text{ m/s}) \times (8.0\text{ s}) + \tfrac{1}{2}(-0.62\text{ m/s}^2) \times (8.0\text{ s})^2$

$\Delta d = 100$ m

**39.** $\Delta d = 3.0 \times 10^6$ m

$v_1 = 39\ 897$ km/h

$= 11\ 082$ m/s

$v_2 = 0$

(Assume constant acceleration.)

$\Delta d = \frac{1}{2}(v_1 + v_2)\Delta t$

$$\Delta t = \frac{2\Delta d}{(v_1 + v_2)}$$

$$= \frac{2(3.0 \times 10^6 \text{ m})}{11\ 082 \text{ m/s}} + 0 \text{ m/s}$$

$\Delta t \cong 540$ s

**40.** $c = 3.0 \times 10^8$ m/s

$\Delta d = 1.0 \times 10^4$ m

$v_s = 344$ m/s

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta t = \frac{\Delta d}{v}$$

$$\Delta t_1 = \frac{1.0 \times 10^4 \text{ m}}{3.0 \times 10^8 \text{ m/s}}$$

$= 3.3 \times 10^{-5}$ s

$$\Delta t_s = \frac{1.0 \times 10^4 \text{ m}}{344 \text{ m/s}}$$

$= 29$ s

**41.** $c = 3.0 \times 10^8$ m/s

$\Delta d = 3.8 \times 10^8$ m

$\Delta t = ?$

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta t = \frac{\Delta d}{v}$$

$$= \frac{3.8 \times 10^8 \text{ m}}{3.0 \times 10^8 \text{ m/s}}$$

$\cong 1.3 \text{ s} \times 2 = 2.6$ s

**42.** $r = 6400$ km

$= 6\ 400\ 000$ m

$$\Delta t = 80 \text{ d} \times \frac{24 \text{ h}}{1 \text{ d}} \times \frac{3600 \text{ s}}{1 \text{ h}}$$

$= 6.91 \times 10^6$ s

(1) $\Delta d = 2\pi r$

(2) $v = \dfrac{\Delta d}{\Delta t}$

(1) $\Delta d = 2(6\ 400\ 000 \text{ m})\cdot\pi$

$= 4.02 \times 10^7$ m

(2) $v = \dfrac{4.02 \times 10^7 \text{ m}}{6.91 \times 10^6 \text{ s}}$

$= 5.8$ m/s

$= 21$ km/h

**43.** $\Delta d = 120$ m

$\Delta t = 5.60$ s

$v_1 = ?$

$v_2 = 15.0$ m/s

(Assume constant acceleration.)

$$a_{avg} = \frac{\Delta v}{\Delta t}$$

$$\frac{v_1 + v_2}{2} = \frac{\Delta d}{\Delta t}$$

$$v_1 = \frac{2\Delta d}{\Delta t} - v_2$$

$$= \frac{2 \times (120 \text{ m})}{5.60 \text{ s}} - 15.0 \text{ m/s}$$

$v_1 \cong 28$ m/s

Therefore, the object was slowing down.

**44.** $v_2 = 10.2$ m/s, $v_1 = 0.0$ m/s,

$\Delta t = 2.5$ s, $a = ?$

$$a = \frac{\Delta v}{\Delta t} = \frac{10.2 \text{ m/s}^2 - 0}{2.5 \text{ s}} \cong 4.1 \text{ m/s}^2$$

**45.** $a = 2.2$ m/s$^2$

$\Delta t = 2.5$ s

$v_1 = 0$ (assumed)

$v_2 = ?$

$v_2 = v_1 + a\Delta t$

$= 0 + (2.2 \text{ m/s}^2) \times (2.5 \text{ s})$

$v_2 = 5.5$ m/s

**46.** $\Delta t = 0.08$ s

$v_1 = 13.0$ m/s

$v_2 = 0$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{0 - 13.0 \text{ m/s}}{0.08 \text{ s}}$$

$a \cong -162$ m/s$^2$

**47.** $\Delta t = 1.5\text{ s}$

$v_1 = 0$

$v_2 = 100\text{ km/h}$

$= 27.8\text{ m/s}$

$a = ?$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{27.8\text{ m/s} - 0}{1.5\text{ s}}$$

$a \cong 19\text{ m/s}^2$

**48.** $\Delta t = 12\text{ s}$

$v_1 = +10\text{ m/s}$ (Let north be positive.)

$v_2 = -10\text{ m/s}$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{-10\text{ m/s} - 10\text{ m/s}}{12\text{ s}}$$

$a \cong -1.7\text{ m/s}^2$

**49.** $\Delta t = 3.5\text{ s}$

$v_1 = 3.2 \times 10^4\text{ km/h}$

$= 8.9 \times 10^3\text{ m/s}$

$v_2 = 0$

$a = ?$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{0 - 8.9 \times 10^3\text{ m/s}}{3.5\text{ s}}$$

$a \cong -2500\text{ m/s}^2$

**50.** $\Delta t = ?$

$v_1 = 4.5\text{ m/s}$

$v_2 = 19.4\text{ m/s}$

$a = 9.8\text{ m/s}^2$ (Assume down is positive.)

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$\Delta t = \frac{v_2 - v_1}{a}$$

$$= \frac{19.4\text{ m/s} - 4.5\text{ m/s}}{9.8\text{ m/s}^2}$$

$\Delta t \cong 1.5\text{ s}$

**51.** $\Delta t = 2.3\text{ s}$

$v_1 = 50\text{ km/h}$

$= 14\text{ m/s}$

$v_2 = ?$

$a = 2.0\text{ m/s}^2$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$v_2 = v_1 + a\Delta t$

$= 14\text{ m/s} + (2.0\text{ m/s}^2) \times (2.3\text{ s})$

$v_2 \cong 19\text{ m/s}$

**52.** $\Delta t = 2.3\text{ s}$

$v_1 = 50\text{ km/h}$

$= 14\text{ m/s}$

$v_2 = ?$

$a = -2.0\text{ m/s}^2$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$v_2 = v_1 + a\Delta t$

$= 14\text{ m/s} + (-2.0\text{ m/s}^2) \times (2.3\text{ s})$

$v_2 = 9.4\text{ m/s}$

**53.** $\Delta t = 2.3\text{ s}$

$v_1 = ?$

$v_2 = -50\text{ km/h}$

$= -14\text{ m/s}$

$a = 2.0\text{ m/s}^2$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$v_2 = v_1 + a\Delta t$

$v_1 = v_2 - a\Delta t$

$= -14\text{ m/s} - (2.0\text{ m/s}^2) \times (2.3\text{ s})$

$v_1 = -18.6\text{ m/s}$

$\cong -19\text{ m/s}$

**54.** $\Delta d = 553\text{ m}$

$\Delta t = ?$

$v_1 = 0$

$a = 9.8\text{ m/s}^2$

$\Delta d = v_1\Delta t + \frac{1}{2}a\Delta t^2$

$\Delta d = \frac{1}{2}a\Delta t^2$

$$\Delta t^2 = \frac{2\Delta d}{a}$$

$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$

$$= \sqrt{\frac{2 \times 553 \text{ m}}{9.8 \text{ m/s}^2}}$$

$\Delta t = 10.6$ s

**55.** $\Delta d = 553$ m

$v_1 = 5.0$ m/s

$a = 9.8$ m/s$^2$

$\Delta d = v_1\Delta t + \frac{1}{2}a\Delta t^2$

$\frac{1}{2}a\Delta t^2 + v_1\Delta t - \Delta d = 0$

$\frac{1}{2}(9.8 \text{ m/s}^2)\Delta t^2 + (5.0 \text{ m/s})\Delta t - 553 \text{ m} = 0$

$(4.9 \text{ m/s}^2)\Delta t^2 + (5.0 \text{ m/s})\Delta t - 553 \text{ m} = 0$

$$\Delta t = \frac{-5.0 \text{ m/s} \pm \sqrt{(5.0 \text{ m/s})^2 - 4 \times (4.9 \text{ m/s}^2)(-553 \text{ m})}}{2(4.9 \text{ m/s}^2)}$$

$$= \frac{-5.0 \text{ m/s} \pm 104 \text{ m/s}}{(9.8 \text{ m/s}^2)}$$

$= 10$ s or $-11$ s

$\Delta t = 10$ s is valid.

**56.** $\Delta d = ?$

$v_1 = 40$ km/h

$= 11$ m/s

$a = 2.3$ m/s$^2$

$\Delta t = 2.7$ s

(1) $\Delta d = v_1\Delta t + \frac{1}{2}a\Delta t^2$

(2) $v_2 = v_1 + a\Delta t \left(\text{from } a = \frac{v_2 - v_1}{\Delta t}\right)$

(1) $\Delta d = (11 \text{ m/s}) \times (2.7 \text{ s}) + \frac{1}{2}(2.3 \text{ m/s}^2) \times (2.7 \text{ s})^2$

$\Delta d = 38$ m

(2) $v_2 = (11 \text{ m/s}) + (2.3 \text{ m/s}^2) \times (2.7 \text{ s})$

$v_2 \cong 17$ m/s

**57.** $\Delta d = ?$

$v_1 = 40$ km/h

$= 11$ m/s

$v_2 = ?$

$a = -2.3$ m/s$^2$

$\Delta t = 2.7$ s

(1) $\Delta d = v_1\Delta t + \frac{1}{2}a\Delta t^2$

(2) $v_2 = v_1 + a\Delta t \left(\text{from } a = \frac{v_2 - v_1}{\Delta t}\right)$

(1) $\Delta d = (11 \text{ m/s}) \times (2.7 \text{ s}) + \frac{1}{2}(-2.3 \text{ m/s}^2) \times (2.7 \text{ s})^2$

$\Delta d \cong 21$ m

(2) $v_2 = (11 \text{ m/s}) - (2.3 \text{ m/s}^2) \times (2.7 \text{ s})$

$v_2 \cong 4.8$ m/s

**58.** $\Delta d = 100$ m

$v_1 = 0$

$a = 2.8$ m/s$^2$

$\Delta t = 3.5$ s

(1) $\Delta d = v_1\Delta t + \frac{1}{2}a\Delta t^2$

(2) $v_2 = v_1 + a\Delta t \left(\text{from } a = \frac{v_2 - v_1}{\Delta t}\right)$

(3) $v = \frac{\Delta d}{\Delta t} \rightarrow \Delta t = \frac{\Delta d}{v}$

(i) (1) $\Delta d = 0 + \frac{1}{2}(2.8 \text{ m/s}^2) \times (3.5 \text{ s})^2$

$\Delta d = 17.2 \text{ m} \cong 17$ m

(ii) (2) $v_2 = 0 = (2.8 \text{ m/s}) \times (3.5 \text{ s})$

$v_2 = 9.8$ m/s

(1) $\Delta d_2 = 100 \text{ m} - 17.2$ m

$= 82.8$ m

(3) $\Delta t_2 = \frac{82.8 \text{ m}}{9.8 \text{ m/s}}$

$\Delta t_2 \cong 8.5$ s

total race time:

$\Delta t_{tot} = 8.5 \text{ s} + 3.5$ s

$\Delta t_{tot} = 12$ s

**59.** $v_1 = 1000$ km/h

$v_2 = 0$

$a = ?$

$\Delta d = 2.0$ km

$v_2^2 = v_1^2 + 2a\Delta d$

$$a = \frac{{v_2}^2 - {v_1}^2}{2\Delta d}$$

$$a = \frac{0 - (1000 \text{ km/h})^2}{2 \times (2.0 \text{ km})}$$

$a_{avg} = -2.5 \times 10^5$ km/h$^2$ (i.e., slowing down)

**60.** $v_1 = 10$ m/s (Up is positive.)

$v_2 = -20$ m/s

$a = -9.8$ m/s$^2$

$\Delta d = ?$

$\Delta t = ?$

(1) $v_2^2 = v_1^2 + 2a\Delta d$

$$\Delta d = \frac{v_2{}^2 - v_1{}^2}{2a}$$

(2) $v_2 = v_1 + a\Delta t$

$$\Delta t = \frac{v_2 - v_1}{a}$$

(i) (1) $\Delta d = \dfrac{(-20 \text{ m/s})^2 - (10 \text{ m/s})^2}{2 \times (-9.8 \text{ m/s}^2)}$

$\Delta d = -15$ m

(ii) (2) $\Delta t = \dfrac{(-20 \text{ m/s}) - (10 \text{ m/s})}{(-9.8 \text{ m/s}^2)}$

$\Delta t \cong 3.1$ s

**61.** $v_2 = 0$

$a = -0.8 \text{ m/s}^2$

$\Delta d = ?$

$0 = v_1^2 + 2a\Delta d$

$-v_1^2 = 2a\Delta d$

$$\Delta d = \frac{-v_1{}^2}{2a}$$

**a)** $v_1 = 10$ km/h

$= 2.8$ m/s

$\Delta d = \frac{1}{2} \times \dfrac{-(2.8 \text{ m/s})^2}{(-0.8 \text{ m/s}^2)}$

$= 4.9$ m

**b)** $v_1 = 50$ km/h

$= 14$ m/s

$\Delta d = \frac{1}{2} \times \dfrac{-(14 \text{ m/s})^2}{(-0.8 \text{ m/s}^2)}$

$= 120$ m

**c)** $v_1 = 90$ km/h

$= 25$ m/s

$\Delta d = \frac{1}{2} \times \dfrac{-(25 \text{ m/s})^2}{(-0.8 \text{ m/s}^2)}$

$\cong 390$ m

**d)** $v_1 = 140$ km/h

$= 39$ m/s

$\Delta d = \frac{1}{2} \times \dfrac{-(39 \text{ m/s})^2}{(-0.8 \text{ m/s}^2)}$

$\cong 950$ m

**62.** $v_1 = 0$

$v_2 = 100$ km/h

$= 27.8$ m/s

$a = ?$

$\Delta d = ?$

$\Delta t = 7.0$ s

(1) $v_2 = v_1 + a\Delta t$

$$a = \frac{v_2 - v_1}{\Delta t}$$

(2) $v_2^2 = v_1^2 + 2a\Delta d$

$$\Delta d = \frac{v_2{}^2 - v_1{}^2}{2a}$$

(i) (1) $a = \dfrac{27.8 \text{ m/s} - 0}{7.0 \text{ s}}$

$a \cong 4.0 \text{ m/s}^2$

$a = 0.4\, g$

(ii) (2) $\Delta d = \dfrac{(27.8 \text{ m/s})^2 - 0}{2 \times (4.0 \text{ m/s}^2)}$

$\Delta d \cong 97$ m

**63.** $v_1 = 50$ km/h

$= 14$ m/s

$v_2 = 5$ m/s

$a = -20 \text{ km/h} \cdot \text{s}$

$= -5.6 \text{ m/s}^2$

$\Delta d = ?$

$v_2^2 = v_1^2 + 2a\Delta d$

$$\Delta d = \frac{v_2{}^2 - v_1{}^2}{2a}$$

$$\Delta d = \frac{(5 \text{ m/s})^2 - (14 \text{ m/s})^2}{2 \times (-5.6 \text{ m/s}^2)}$$

$\Delta d \cong 15$ m

**64.** $v_1 = 10$ m/s

$a = -10 \text{ m/s}^2$

| $t$(s) | $\vec{d}$(m) | $\vec{v}$(m/s) |
|---|---|---|
| 0 | 0 | 10 |
| 0.2 | 1.8 | 8 |
| 0.4 | 3.2 | 6 |
| 0.6 | 4.2 | 4 |
| 0.8 | 4.8 | 2 |
| 1 | 5 | 0 |
| 1.2 | 4.8 | 22 |
| 1.4 | 4.2 | 24 |
| 1.6 | 3.2 | 26 |
| 1.8 | 1.8 | 28 |
| 2 | 0 | 210 |
| 2.2 | 22.2 | 212 |

slope of velocity curve, $m$, is given by:

$$a_{avg} = \frac{\Delta v}{\Delta t}$$
$$= \frac{0 - 10\ \text{m/s}}{1\ \text{s} - 0\ \text{s}}$$
$$= -10\ \text{m/s}^2$$

At end of motion,

$\Delta d = -3$ m

$v = -12$ m/s

**65.** step 1: $v_1 = 0$, $a = 14\ \text{m/s}^2$, $\Delta d = 450$ m

step 2: $v_2 = 0$, $a = -7.0\ \text{m/s}^2$

(1) $v_2^2 = v_1^2 + 2a\Delta d$

(2) $v_2^2 = v_1^2 + 2a\Delta d$

$$\Delta d = \frac{{v_2}^2 - {v_1}^2}{2a}$$

(1) $v_2^2 = 0 + 2 \times (14\ \text{m/s}^2) \times (450\ \text{m})$

$= 12\ 600\ \text{m}^2/\text{s}^2$

$v_2 = 112\ \text{m/s} = v_1(\text{step 2})$

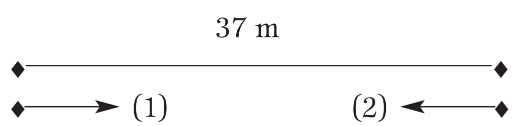
(2) $$\Delta d = \frac{0 - (112\ \text{m/s})^2}{2 \times (-7.0\ \text{m/s}^2)}$$

$\Delta d = 896$ m

$\Delta d_{tot} = 450\ \text{m} + 896\ \text{m} = 1300$ m

**66.** $\Delta d = 37$ m

$a = 0.5\ \text{m/s}^2$




$a_1 = 0.5\ \text{m/s}^2$, $v_1 = 0$

$a_2 = 0$, $v_2 = -3.1$ m/s

**a)** $\Delta d = \frac{1}{2}a\Delta t^2 - v_2\Delta t$

$\frac{1}{2} \times (0.5\ \text{m/s}^2)\Delta t^2 - (-3.1\ \text{m/s})\Delta t - 37\ \text{m} = 0$

$0.25\ \text{m/s}^2 \times \Delta t^2 + 3.1\ \text{m/s}\ \Delta t - 37\ \text{m} = 0$

$$\Delta t = \frac{-3.1\ \text{m/s} \pm \sqrt{(3.1\ \text{m/s})^2 - 4(0.25\ \text{m/s}^2)(-37\ \text{m})}}{2(0.25\ \text{m/s}^2)}$$

$= 7.5$ s or $-19.9$ s

$\Delta t = 7.5$ s

Therefore, collision occurs $\Delta t = 7.5$ s after (1) starts running.

**b)** $v_2 = v_1\Delta t + a\Delta t$

$= (0.5\ \text{m/s}^2) \times (7.5\ \text{s})$

$= 3.75$ m/s

**c)** $d_1 = \Delta d - \Delta d_2$

$= (37\ \text{m}) - (3.1\ \text{m/s}) \times (7.5\ \text{s})$

$= 13.75$ m

Therefore, $d_2 = 23.25$ m.

Therefore, (1) has travelled 13.75 m $\cong$ 14 m; and (2) has travelled 23.25 m $\cong$ 23 m in the opposite direction.

**67.** $v_T = 140$ km/h

$= 38.9$ m/s

$\Delta d = 1000$ m

time to reach ground:

$$\Delta t_p = \frac{\Delta d}{v}$$
$$= \frac{1000\ \text{m}}{38.9\ \text{m/s}}$$
$$= 25.7\ \text{s}$$

Superwoman takes action after 1.9 s.

$\Delta t_S = 25.7\ \text{s} - 1.9\ \text{s}$

$\Delta t_S = 23.8$ s

$\Delta d = v_1\Delta t + \frac{1}{2}a\Delta t^2$

$\Delta d_S = \frac{1}{2}a_S{\Delta t_S}^2$

$$a_S = \frac{2\Delta d_S}{{\Delta t_S}^2}$$
$$= \frac{2 \times (1000\ \text{m})}{(23.8\ \text{s})^2}$$

$a_S = 3.53\ \text{m/s}^2$

**68.** $v_s = 100$ km/h

$= 27.8$ m/s

$v = 3.6\ \text{m/s}^2$

$v_1 = 0$

(1) $\Delta d_s = v_s\Delta t$

$\Delta d_p = v_1\Delta t + \frac{1}{2}a_p\Delta t^2$

(2) $v_2 = v_1 + a\Delta t \left(\text{from } a = \frac{v_2 - v_1}{\Delta t}\right)$

**a)** Cars meet at:

$$(1)\ \Delta d_s = \Delta d_p$$
$$v_s\Delta t = \tfrac{1}{2}a_p\Delta t^2$$
$$\tfrac{1}{2}a_p\Delta t^2 - v_s\Delta t = 0$$
$$\Delta t \times (\tfrac{1}{2}a_p\Delta t - v_s) = 0$$
$$\Delta t = 0$$
$$\text{or } v_s = \tfrac{1}{2}v_p\Delta t$$
$$\Delta t = \frac{2v_s}{a_p}$$
$$= \frac{2 \times (27.8\ \text{m/s})}{(3.6\ \text{m/s}^2)}$$
$$\Delta t = 15.4\ \text{s}$$

Therefore, it will take 15 s to catch up.

**b)** (1) $\Delta d = \tfrac{1}{2}a\Delta t^2$

$$= \tfrac{1}{2} \times (3.6\ \text{m/s}^2) \times (15.4\ \text{s})^2$$
$$\cong 427\ \text{m}$$

**c)** (2) $v_p = a_p\Delta t$

$$= (3.6\ \text{m/s}^2) \times (15.4\ \text{s})$$
$$v_p = 55\ \text{m/s}$$

= 198 km/h (possible but not reasonable)

**69.** We can use the information given to find the speed of the flower pot at the top of the window, and then use the speed to find the height above the window from which the pot must have been dropped.

Since the pot accelerates at a constant rate of 9.8 m/s$^2$, we can write:

$$\Delta d = v_1\Delta t + \frac{a\Delta t^2}{2}$$
$$v_1 = \frac{\Delta d}{\Delta t} - \frac{a\Delta t}{2}$$
$$v_1 = \frac{19\ \text{m}}{0.20\ \text{s}} - \frac{(9.8\ \text{m/s}^2)(0.20\ \text{s})}{2}$$
$$v_1 = 8.5\ \text{m/s}$$

Now we can find the distance above the window:

$$v_1{}^2 = v_o{}^2 + 2a\Delta d$$
$$\Delta d = \frac{(v_1{}^2 - v_o{}^2)}{2a}$$
$$\Delta d = \frac{((8.5\ \text{m/s})^2 - (0\ \text{m/s})^2)}{2(9.8\ \text{m/s}^2)}$$
$$\Delta d = 3.7\ \text{m}$$

**70. a)** The only force acting on the ball while it is falling is that of gravity, so its acceleration is 9.8 m/s$^2$ downward.

**b)** Since the ball is being constantly accelerated downward, it cannot slow down.

**c)** $\Delta d = v_1\Delta t + \dfrac{a\Delta t^2}{2}$

$$\Delta d = (8.0\ \text{m/s})(0.25\ \text{s}) + \frac{(9.8\ \text{m/s}^2)(0.25\ \text{s})^2}{2}$$
$$\Delta d = 2.3\ \text{m}$$

**71.**

$$\Delta d = v_1\Delta t + \frac{a\Delta t^2}{2}$$
$$(-4.0\ \text{m}) = (4.0\ \text{m/s})\Delta t + \frac{(-9.8\ \text{m/s}^2)\Delta t^2}{2}$$
$$(4.9\ \text{m/s}^2)\Delta t^2 - (4.0\ \text{m/s})\Delta t - 4.0\ \text{m} = 0$$
$$\Delta t = \frac{4 \pm \sqrt{16 - 4(4.9)(-4)}}{9.8}$$
$$\Delta t = 1.4\ \text{s}$$

# Chapter 3

**14.** $\vec{v}_1 = 4$ m/s [E]

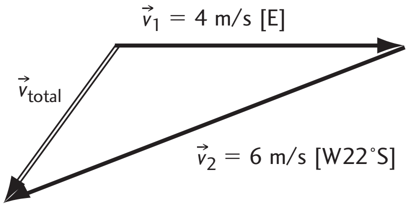
$\vec{v}_2 = 6$ m/s [E]

**a)** Maximum velocity occurs when $\vec{v}_2 = 6$ m/s [E]; $\vec{v}_{total} = 10$ m/s [E].

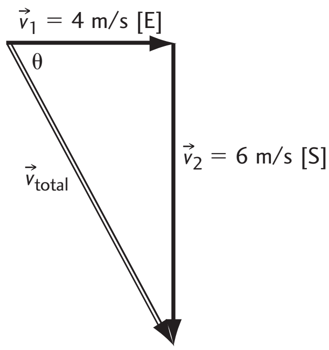
Minimum velocity occurs when $\vec{v}_2 = 6$ m/s [W]; $\vec{v}_{total} = 2$ m/s [W].

**b)**

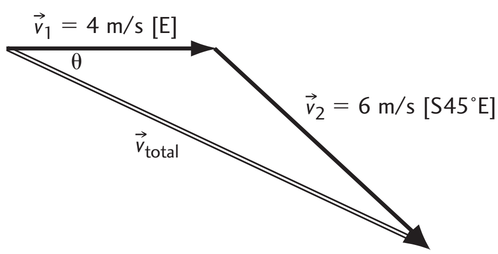
**(i)**



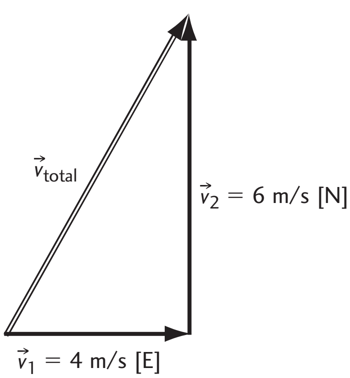

**(ii)**




**(iii)**




**(iv)**




**c) i)** By scale diagram, 1 cm = 1 m/s, $\vec{v}_{total} = 2.8$ m/s [W52°S].

**ii)** Using Pythagoras' theorem,

$$|\vec{v}_{total}| = |\vec{v}_1|^2 + |\vec{v}_2|^2$$

$$|\vec{v}_{total}| = \sqrt{(4\text{ m/s})^2 + (6\text{ m/s})^2}$$

$$\tan\theta = \frac{6\text{ m/s}}{4\text{ m/s}} \rightarrow 56° = \theta$$

$$|\vec{v}_{total}| = 7.2\text{ m/s}$$

$$\vec{v}_{total} = 7.2\text{ m/s [E56°S]}$$

**iii)** $|\vec{v}_{total}|^2 = |\vec{v}_1|^2 + |\vec{v}_2|^2 - 2|\vec{v}_1|\,|\vec{v}_2|\cos\theta$

$$= (4\text{ m/s})^2 + (6\text{ m/s})^2 - 2(4\text{ m/s})(6\text{ m/s})\cos 135°$$

$$|\vec{v}_{total}| = 9.3\text{ m/s}$$

$$\frac{\sin\theta}{|\vec{v}_{total}|} = \frac{\cos\theta}{|\vec{v}_2|}$$

$$\cos\theta = \frac{|\vec{v}_2|}{|\vec{v}_{total}|}\cdot\sin\theta$$

$$= \frac{6\text{ m/s}}{9.3\text{ m/s}}\sin 135°$$

$$\theta = 63°$$

$$\vec{v}_{total} = 5.3\text{ m/s [E63°S]}$$

**iv)** Use Pythagoras' theorem.

$$|\vec{v}_{total}|^2 = |\vec{v}_1|^2 + |\vec{v}_2|^2$$

$$= (6\text{ m/s})^2 + (4\text{ m/s})^2$$

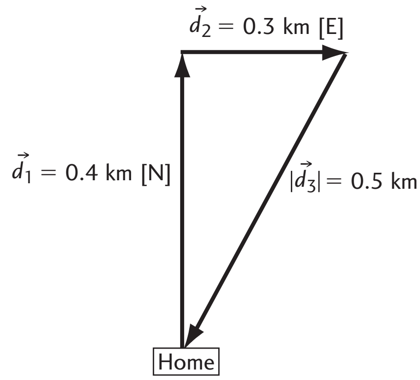
$$|\vec{v}_{total}| = 7.2\text{ m/s}$$

$$\tan\theta = \frac{6\text{ m/s}}{4\text{ m/s}}$$

$$\theta = 56°$$

Therefore, $\vec{v}_{total} = 7.2$ m/s [E56°N]

**15.**




$\Delta t = 0.5$ h

**a)** total displacement for walk:

$$\vec{d}_{total} = 0\text{ km}$$

**b)** $|\vec{d}_1 + \vec{d}_2|^2 = |\vec{d}_1|^2 + |\vec{d}_2|^2$

$$|\vec{d}_1 + \vec{d}_2| = \sqrt{(0.4\text{ km})^2 + (0.3\text{ km})^2}$$

$$= 0.5\text{ km}$$

$$\theta = \tan^{-1}\frac{0.4}{0.3} = 53°$$

$$\vec{d}_1 + \vec{d}_2 = 0.5\text{ km [E53°N]}$$

**c)** $|\vec{d}_3|^2 = |\vec{d}_1|^2 + |\vec{d}_2|^2$

$|\vec{d}_3|^2 = (0.4 \text{ km})^2 + (0.3 \text{ km})^2$

$|\vec{d}_3| = 0.5 \text{ km}$

$\theta = \tan^{-1} \dfrac{0.4 \text{ km}}{0.3 \text{ km}} = 53°$

$\vec{d}_3 = 0.5 \text{ km [W53°S]}$

**d)** total distance travelled:

$\Delta d = |\vec{d}_1| + |\vec{d}_2| + |\vec{d}_3|$

$= 0.4 \text{ km} + 0.3 \text{ km} + 0.5 \text{ km}$

$= 1.2 \text{ km}$

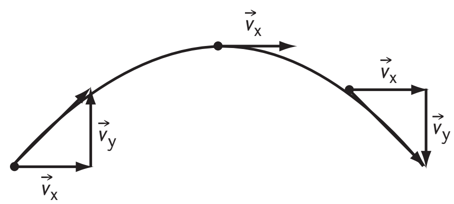
$v_{avg} = \dfrac{\Delta d}{\Delta t} = \dfrac{1.2 \text{ km}}{0.5 \text{ h}} = 2.4 \text{ km/h}$

**e)** average velocity for the first two segments:
Assume average velocity was constant throughout the trip.

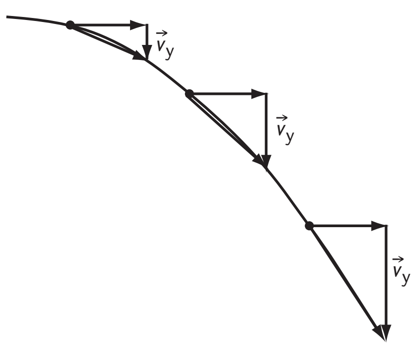
$\vec{v}_{avg} = 2.4 \text{ km/h [E53°N]}$

(This direction is opposite to that of $\vec{d}_3$.)

**16.**




**17.**




**18.** ***x***} $v_{1_x} = 50 \text{ km/h} = 13.9 \text{ m/s}$

$a_x = 0$

$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$

***y***} $v_{1_y} = 0$

$a_y = 9.8 \text{ m/s}^2$

$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$

**a)** at $t = 1.0$ s,

$v_x = 13.9 \text{ m/s}$

$v_y = a_y t$

$= (9.8 \text{ m/s}^2)(1.0 \text{ s})$

$v_y = 9.8 \text{ m/s}$

at $t = 2.0$ s,

$v_x = 13.9 \text{ m/s}$

$v_y = a_y t$

$= (9.8 \text{ m/s}^2)(2.0 \text{ s})$

$= 19.6 \text{ m/s}$

$v_y \cong 20 \text{ m/s}$

at $t = 3.0$ s,

$v_x = 13.9 \text{ m/s}$

$v_y = a_y t$

$= (9.8 \text{ m/s}^2)(3.0 \text{ s})$

$= 29.4 \text{ m/s}$

$v_y \cong 29 \text{ m/s}$

at $t = 4.0$ s,

$v_x = 13.9 \text{ m/s}$

$v_y = a_y t$

$= (9.8 \text{ m/s}^2)(4.0 \text{ s})$

$= 39.2 \text{ m/s}$

$v_y \cong 39 \text{ m/s}$

**b)** at $t = 1.0$ s,

$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$

$= \sqrt{(13.9 \text{ m/s})^2 + (9.8 \text{ m/s})^2}$

$v = 17 \text{ m/s}$

$\theta = \tan^{-1} \dfrac{v_y}{v_x}$

$= \tan^{-1} \dfrac{9.8 \text{ m/s}}{13.9 \text{ m/s}}$

$= 35°$

Therefore, $\vec{v} = 17 \text{ m/s [R35°D]}$.

at $t = 2.0$ s,

$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$

$= \sqrt{(13.9 \text{ m/s})^2 + (20 \text{ m/s})^2}$

$= 24.3 \text{ m/s}$

$\cong 24 \text{ m/s}$

$\theta = \tan^{-1} \dfrac{v_y}{v_x}$

$= \tan^{-1} \dfrac{20 \text{ m/s}}{13.9 \text{ m/s}}$

$= 55°$

Therefore, $\vec{v} = 24 \text{ m/s [R55°D]}$.

at $t = 3.0$ s,

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$$
$$= \sqrt{(13.9 \text{ m/s})^2 + (29 \text{ m/s})^2}$$
$$= 32 \text{ m/s}$$
$$\theta = \tan^{-1} \frac{v_y}{v_x}$$
$$= \tan^{-1} \frac{29 \text{ m/s}}{13.9 \text{ m/s}}$$
$$= 64°$$

Therefore, $\vec{v} = 32$ m/s [R64°D].

at $t = 4.0$ s,

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$$
$$= \sqrt{(13.9 \text{ m/s})^2 + (39 \text{ m/s})^2}$$
$$= 41 \text{ m/s}$$
$$\theta = \tan^{-1} \frac{v_y}{v_x}$$
$$= \tan^{-1} \frac{39 \text{ m/s}}{13.9 \text{ m/s}}$$
$$= 70°$$

Therefore, $\vec{v} = 41$ m/s [R70°D].

**19.** ***x***} $v_{1_x} = 35.4 \text{ km/h} = 9.8 \text{ m/s}$

$a_x = 0$

***y***} $v_{1_y} = -35.4 \text{ km/h} = -9.8 \text{ m/s}$

$a_y = 9.8 \text{ m/s}^2$

$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$

**a) and b)**

at $t = 1.0$ s,

$$v_x = 9.8 \text{ m/s}$$
$$v_y = v_{1y} + a_y t$$
$$= (-9.8 \text{ m/s}) + (9.8 \text{ m/s}^2)(1.0 \text{ s})$$
$$v_y = 0 \text{ m/s}$$

at $t = 2.0$ s,

$$v_x = 9.8 \text{ m/s}$$
$$v_y = (-9.8 \text{ m/s}) + (9.8 \text{ m/s}^2)(2.0 \text{ s})$$
$$v_y = 9.8 \text{ m/s}$$

at $t = 3.0$ s,

$$v_x = 9.8 \text{ m/s}$$
$$v_y = v_{1_y} + a_y t$$
$$= (-9.8 \text{ m/s}) + (9.8 \text{ m/s}^2)(3.0 \text{ s})$$
$$v_y \cong 20 \text{ m/s}$$

at $t = 4.0$ s,

$$v_x = 9.8 \text{ m/s}$$
$$v_y = (-9.8 \text{ m/s}) + (9.8 \text{ m/s}^2)(4.0 \text{ s})$$
$$v_y \cong 29 \text{ m/s}$$

**c)** at $t = 1.0$ s,

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$$
$$= \sqrt{(9.8 \text{ m/s})^2 + (0 \text{ m/s})^2}$$
$$= 9.8 \text{ m/s}$$
$$\theta = \tan^{-1} \frac{v_y}{v_x}$$
$$= \tan^{-1} \frac{0 \text{ m/s}}{9.8 \text{ m/s}}$$
$$= 0°$$

Therefore, $\vec{v} = 9.8$ m/s [E].

at $t = 2.0$ s,

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$$
$$= \sqrt{(9.8 \text{ m/s})^2 + (9.8 \text{ m/s})^2}$$
$$\cong 14 \text{ m/s}$$
$$\theta = \tan^{-1} \frac{v_y}{v_x}$$
$$= \tan^{-1} \frac{9.8 \text{ m/s}}{9.8 \text{ m/s}}$$
$$= 45°$$

Therefore, $\vec{v} = 14$ m/s [R45°D].

at $t = 3.0$ s,

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$$
$$= \sqrt{(9.8 \text{ m/s})^2 + (20 \text{ m/s})^2}$$
$$\cong 22 \text{ m/s}$$
$$\theta = \tan^{-1} \frac{v_y}{v_x}$$
$$= \tan^{-1} \frac{20 \text{ m/s}}{9.8 \text{ m/s}}$$
$$= 64°$$

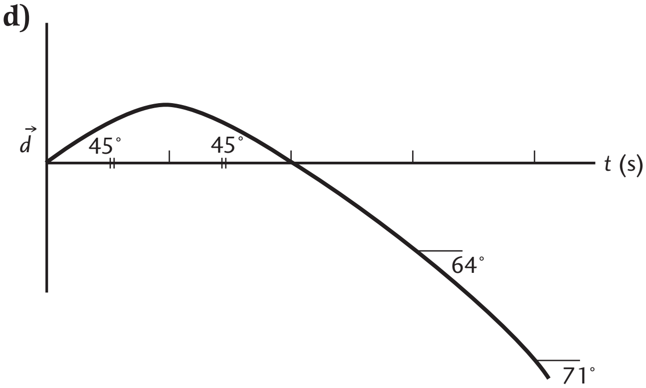
Therefore, $\vec{v} = 22$ m/s [R64°D].

at $t = 4.0$ s,

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$$
$$= \sqrt{(9.8 \text{ m/s})^2 + (29 \text{ m/s})^2}$$
$$\cong 31 \text{ m/s}$$
$$\theta = \tan^{-1} \frac{v_y}{v_x}$$
$$= \tan^{-1} \frac{29 \text{ m/s}}{9.8 \text{ m/s}}$$
$$= 71°$$

Therefore, $\vec{v} = 31$ m/s [R71°D].

**d)**




**20.** Assume $v_x = 0$ and motion is purely vertical with no wind resistance.

$v_{1_y} = 0$
$a_y = g = 9.8\ \text{m/s}^2$
$\Delta t = 5.5\ \text{s}$
$\Delta d_y = v_{1_y}\Delta t + \frac{1}{2}a_y\Delta t^2$
$\Delta d_y = 0 + \frac{1}{2}(9.8\ \text{m/s}^2)(5.5\ \text{s})^2$
$\Delta d_y = 148\ \text{m}$
$\Delta d_y \cong 150\ \text{m}$

Therefore, the cliff is 150 m high.

**21.** $\boldsymbol{x}\}$ $v_{1_x} = 26\ \text{m/s}$
$a_x = 0$
$\Delta d_x = ?$
$\boldsymbol{y}\}$ $v_{1_y} = 0$
$a_y = 9.8\ \text{m/s}^2$
$\Delta d_y = 150\ \text{m}$
$\Delta t = 5.5\ \text{s}$

$$v_x = \frac{\Delta d_x}{\Delta t}$$
$$\Delta d_x = v_x\Delta t$$
$$= (26\ \text{m/s})(5.5\ \text{s})$$
$$\Delta d_x \cong 140\ \text{m}$$

**22.** $\boldsymbol{x}\}$ $v_{1_x} = 325\ \text{m/s}$
$\Delta d_x = ?$
$\Delta t_x = ?$
$\boldsymbol{y}\}$ $v_{1_y} = 0$
$a_y = g = 9.8\ \text{m/s}^2$
$\Delta d_y = 2.0\ \text{m}$

$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$\Delta t = \sqrt{\frac{2\Delta d_y}{a_y}}$$
$$v_x = \frac{\Delta d_x}{\Delta t} \rightarrow \Delta d_x = v_x\Delta t$$

**a)** $\Delta t = \sqrt{\dfrac{2(2.0\ \text{m})}{(9.8\ \text{m/s})}}$
$= 0.64\ \text{s}$

Therefore, the total time spent in flight by the bullet is 0.64 s.

**b)** Therefore, $\Delta d_x = (325\ \text{m/s})(0.64\ \text{s})$
$= 208\ \text{m}$
$\cong 210\ \text{m}$

Therefore, the bullet travels 210 m in the horizontal direction before hitting the ground.

**23.** $\boldsymbol{x}\}$ $v_{1_x} = 160\ \text{km/h} = 44.4\ \text{m/s}$
$a_x = 0$
$\Delta d_x = ?$
$\Delta t = ?$
$\boldsymbol{y}\}$ $v_{1_y} = 0$
$a_y = g = 9.8\ \text{m/s}^2$
$\Delta d_y = 2.5\ \text{m}$

$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$\Delta t = \sqrt{\frac{2\Delta d_y}{a_y}}$$

First, we need the time of flight, which is dictated by the vertical distance travelled, $\Delta d_y$.

$$\Delta t = \sqrt{\frac{2(2.5\ \text{m})}{(9.8\ \text{m/s}^2)}}$$
$$= 0.71\ \text{s}$$

Now we can calculate the horizontal distance travelled.

$$v_x = \frac{\Delta d_x}{\Delta t} \rightarrow \Delta d_x = v_x\Delta t$$
$$\Delta d_x = (44.4\ \text{m/s})(0.71\ \text{s})$$
$$\Delta d_x \cong 32\ \text{m}$$

Therefore, the ball lands 32 m from the player.

**24.** $\boldsymbol{x}\}$ $v_{1_x} = 140\ \text{km/h} = 38.9\ \text{m/s}$
$a_x = 0$
$\Delta d_x = 28.3\ \text{m}$
$\Delta t = ?$
$\boldsymbol{y}\}$ $v_{1_y} = 0$
$a_y = g = 9.8\ \text{m/s}^2$
$\Delta d_y = ?$

$$v_x = \frac{\Delta d_x}{\Delta t} \rightarrow \Delta t = \frac{\Delta d_x}{v_x}$$

The time of flight to travel 28.3 m is:

$$\Delta t = \frac{\Delta d_x}{v_x}$$
$$= \frac{28.3 \text{ m}}{38.9 \text{ m/s}}$$
$$= 0.727 \text{ s}$$

The vertical distance fallen is:

$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$\Delta d_y = \tfrac{1}{2}a_y\Delta t^2$$
$$= \tfrac{1}{2}(9.8 \text{ m/s}^2)(0.727 \text{ s})^2$$
$$\Delta d_y = 2.6 \text{ m}$$

Therefore, the ball drops 2.6 m after travelling 28.3 m horizontally.

**25. a)** Both pennies land at the same time. Time of flight is dictated only by the vertical velocity profile, which is the same for both pennies since the pushed penny left the table horizontally.

**b)** for the pushed penny:

$\boldsymbol{x}\}$ $v_{1_x} = 4.1 \text{ m/s}$

$a_x = 0$

$\Delta d_x = ?$

$\Delta t = ?$

$\boldsymbol{y}\}$ $v_{1_y} = 0$

$a_y = g = 9.8 \text{ m/s}^2$

$\Delta d_y = 1.2 \text{ m}$

$\Delta t = ?$

$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$\Delta t = \frac{\Delta d_x}{v_x} \rightarrow \Delta t = \sqrt{\frac{2\Delta d_y}{a_y}}$$

(to calculate the time of flight)

$$v_x = \frac{\Delta d_x}{\Delta t} \rightarrow \Delta d_x = v_x\Delta t$$

(to calculate the horizontal distance travelled)

$$\Delta t = \sqrt{\frac{2\Delta d_y}{a_y}}$$
$$= \sqrt{\frac{2(1.2 \text{ m})}{(9.8 \text{ m/s}^2)}}$$
$$= 0.49 \text{ s}$$
$$\Delta d_x = (4.1 \text{ m/s})(0.49 \text{ s})$$
$$\Delta d_x = 2.0 \text{ m}$$

Therefore, the penny lands 2.0 m from the table.

**26. i)** $v_{2_y}{}^2 = v_{1_y}{}^2 + 2a\Delta d_y$

$$v_{2_y} = 0 + \sqrt{2a\Delta d_y}$$
$$v_{2_y} = \sqrt{2(9.81 \text{ m/s}^2)(2.0 \text{ m})}$$
$$v_{2_y} = 6.3 \text{ m/s}$$
$$v_{2_x} = 325 \text{ m/s}$$
$$|\vec{v}_2| = \sqrt{v_{2_x}{}^2 + v_{2_y}{}^2}$$
$$|\vec{v}_2| = \sqrt{(325 \text{ m/s})^2 + (6.3 \text{ m/s})^2}$$
$$= 330 \text{ m/s}$$
$$\theta = \tan^{-1}\frac{v_{2_y}}{v_{2_x}}$$
$$= \tan^{-1}\frac{6.3 \text{ m/s}}{325 \text{ m/s}}$$
$$= 1.1°$$

Therefore, $\vec{v}_2 = 330$ m/s [R1.1°D].

**ii)** $v_{2_y}{}^2 = v_{1_y} + 2a\Delta d_y$

$$v_{2_y} = 0 + \sqrt{2(9.8 \text{ m/s}^2)(2.5 \text{ m})}$$
$$v_{2_y} = 7.0 \text{ m/s}$$
$$v_{2_x} = 44.4 \text{ m/s}$$
$$|\vec{v}_2| = \sqrt{v_{2_x}{}^2 + v_{2_y}{}^2}$$
$$|\vec{v}_2| = \sqrt{(44.4 \text{ m/s})^2 + (7.0 \text{ m/s})^2}$$
$$= 45 \text{ m/s}$$
$$\theta = \tan^{-1}\frac{v_y}{v_x}$$
$$= \tan^{-1}\frac{7.0 \text{ m/s}}{44.4 \text{ m/s}}$$
$$= 9.0°$$

Therefore, $\vec{v}_2 = 45$ m/s [R9.0°D].

**iii)** $v_{2_y}{}^2 = \text{v}_{1_y}{}^2 + 2a\Delta d_y$

$$v_{2_x} = 38.9 \text{ m/s}$$
$$v_{2_y} = 0 + \sqrt{2(9.81 \text{ m/s}^2)(2.6 \text{ m})}$$
$$v_{2_y} = 7.1 \text{ m/s}$$
$$|\vec{v}_2| = \sqrt{v_{2_x}{}^2 + v_{2_y}{}^2}$$
$$|\vec{v}_2| = \sqrt{(7.1 \text{ m/s})^2 + (38.9 \text{ m/s})^2}$$
$$= 40 \text{ m/s}$$

$$\theta = \tan^{-1} \frac{v_{2_y}}{v_{2_x}}$$

$$= \tan^{-1} \frac{7.1 \text{ m/s}}{38.9 \text{ m/s}}$$

$$= 10°$$

Therefore, $\vec{v}_2 = 40$ m/s [R10°D].

**27.** The frame of reference is the ground.

$x\}$ $v_{1_x} = 90$ m/s

$a_x = 0$

$\Delta d_x = ?$

$\Delta t = 10.6$ s

$y\}$ $v_{1_y} = 0$

$a_y = 0$

$\Delta d_y = ?$

$\Delta t = ?$

Assume there is no wind resistance.

**a)** $\Delta d_y = v_{1_y}\Delta t + \frac{1}{2}a_y\Delta t^2$

$= 0 + \frac{1}{2}(9.8 \text{ m/s}^2)(10.6 \text{ s})^2$

$\Delta d_y = 550$ m

Therefore, the skydiver falls 550 m in 10.6 s.

**b)** $\Delta v_x = \frac{\Delta d_x}{\Delta t}$

$\Delta d_x = v_x\Delta t$

$\Delta d_x = (90 \text{ m/s})(10.6 \text{ s})$

$\Delta d_x \cong 950$ m

Therefore, the skydiver moves 950 m horizontally.

**c)** $\Delta v_{2_y} = \sqrt{{v_{1_y}}^2 + 2a_y d_y}$

$= \sqrt{2(9.8 \text{ m/s}^2)(550 \text{ m})}$

$= \sqrt{10\ 780 \text{ m}^2/\text{s}^2}$

$\Delta v_{2_y} \cong 100$ m/s

Therefore, the vertical velocity is 100 m/s after 10.6 s.

**d)** $|\vec{v}| = \sqrt{{v_x}^2 + {v_y}^2}$

$= \sqrt{(90 \text{ m/s})^2 + (100 \text{ m/s})^2}$

$= 130$ m/s

$$\theta = \tan^{-1} \frac{v_y}{v_x}$$

$$\theta = \tan^{-1} \frac{100 \text{ m/s}}{90 \text{ m/s}}$$

$\theta = 48°$

Therefore, the final velocity is 130 m/s [R48°D].

**28.** $x\}$ $v_{x_1} = 80$ m/s

$a_x = 0$

$\Delta d_x = ?$

$\Delta t = ?$

$y\}$ $v_{1_y} = 0$

$a_y = 9.8 \text{ m/s}^2$

$\Delta d_y = 1000$ m

$v_{2_y} = ?$

Assume there is no wind resistance.

**a)** $\Delta d_y = v_{1_y}\Delta t + \frac{1}{2}a_y\Delta t^2$

$$\Delta t = \sqrt{\frac{2\Delta d_y}{a_y}}$$

(to calculate the time of flight)

$$\Delta t = \sqrt{\frac{2(1000 \text{ m})}{(9.8 \text{ m/s}^2)}}$$

$\Delta t = 14$ s

Therefore, the time to hit the ground is 14 s.

**b)** $\Delta v_x = \frac{\Delta d_x}{\Delta t}$

$\Delta d_x = v_x\Delta t$

$\Delta d_x = (80 \text{ m/s})(14 \text{ s})$

$\Delta d_x = 1100$ m

Therefore, the horizontal distance travelled is 1100 m.

**c)** ${v_{2_y}}^2 = {v_{1_y}}^2 + 2a_y\Delta d_y$

(to obtain final vertical velocity)

$v_{2_y} = \sqrt{2a_y\Delta d_y}$

$= \sqrt{2(9.8 \text{ m/s}^2)(1000 \text{ m})}$

$= 140$ m/s

$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$

$|\vec{v}| = \sqrt{(80 \text{ m/s})^2 + (140 \text{ m/s})^2}$

$\cong 160$ m/s

$$\theta = \tan^{-1} \frac{v_y}{v_x}$$

$$= \tan^{-1} \frac{140 \text{ m/s}}{80 \text{ m/s}}$$

$= 60°$

Therefore, the final velocity is 160 m/s [R60°D].

**29.** $|\vec{v}| = 100$ m/s

**a) Case 1**: given:

$v_x = 100$ m/s
$\Delta d_x = ?$
$\Delta t = ?$

$v_y = 0$
$\Delta d_y = 500$ m
$a_y = 9.81$ m/s$^2$

$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$

$$\Delta t = \sqrt{\frac{2\Delta d_y}{a_y}}$$

$$= \sqrt{\frac{2(500\text{ m})}{9.81\text{ m/s}^2}}$$

$= 10$ s

$\Delta d_x = v_x\Delta t$
$= (100\text{ m/s})(10\text{ s})$
$\Delta d_x = 1000$ m

Therefore, the range is 1000 m.

**b) Case 2**: $v_x = (100\text{ m/s})\cos 60°$
$= 50$ m/s

$v_{1_y} = (-100\text{ m/s})\sin 60°$
$= -87$ m/s
$a_y = 9.81$ m/s$^2$
$\Delta d_y = 500$ m/s

$$\Delta d = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$

$$500\text{ m} = (-87\text{ m/s})\Delta t + \tfrac{1}{2}(9.81\text{ m/s}^2)\Delta t^2$$

$$(4.9\text{ m/s}^2)\Delta t^2 + (-87\text{ m/s})\Delta t - 500\text{ m} = 0$$

$$\Delta t = \frac{87\text{ m/s} \pm \sqrt{(-87\text{ m/s})^2 - 4(4.9\text{ m/s}^2)(-500\text{ m})}}{2(4.9\text{ m/s}^2)}$$

$= 22.3$ s or $-4.6$ s

Therefore, $\Delta t = 22$ s.

Therefore, $\Delta d_x = v_x\Delta t$.

$\Delta d_x = (50\text{ m/s})(22\text{ s}) = 1100$ m

Therefore, the range is 1100 m.

**c)** $v_x = 50$ m/s (above)
$v_{1_y} = +87$ m/s (above)
$a_y = 9.81$ m/s$^2$
$\Delta d_y = 500$ m

$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$

$$500\text{ m} = (87\text{ m/s})\Delta t + \tfrac{1}{2}(9.81\text{ m/s}^2)\Delta t^2$$

$$(4.9\text{ m/s}^2)\Delta t^2 + (87\text{ m/s})\Delta t - 500\text{ m} = 0$$

$$\Delta t = \frac{-87\text{ m/s} \pm \sqrt{(87\text{ m/s})^2 - 4(4.9\text{ m/s}^2)(-500\text{ m})}}{2(4.9\text{ m/s}^2)}$$

$= 4.6$ s or $-22$ s

Therefore, $\Delta t = 4.6$ s.

$\Delta d_x = v_x\Delta t$
$= (50\text{ m/s})(4.6\text{ s})$
$\Delta d_x = 230$ m

Therefore, the range is 230 m.

**30.** ***x***} $v_{1_x} = 10$ m/s
$a_x = 0$
$\Delta d_x = 15$ m
$\Delta t = ?$

***y***} $v_{1_y} = 13$ m/s
$a_y = g = -9.8$ m/s$^2$
$\Delta d_y = ?$

Assume there is no wind resistance.

$$v_x = \frac{\Delta d_x}{\Delta t} \rightarrow \Delta t = \frac{\Delta d_x}{v_x}$$

(to calculate time of flight)

$$\Delta t = \frac{15\text{ m}}{10\text{ m/s}}$$

$\Delta t = 1.5$ s

$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$

$$\Delta d_y = (13\text{ m/s})(1.5\text{ s}) + \tfrac{1}{2}(-9.8\text{ m/s}^2)(1.5\text{ s})^2$$

$\Delta d_y = 8.5$ m

Therefore, the balcony is 8.5 m high.

**31.** ***x***} $v_{1_x} = 9.0$ m/s
$a_x = 0$
$\Delta d_x = 20$ m

***y***} $v_{1_y} = 14.0$ m/s
$a_y = g = -9.8$ m/s$^2$
$\Delta d_y = 3.0$ m/s

**Method 1**

$$v_x = \frac{\Delta d_x}{\Delta t} \rightarrow \Delta t = \frac{\Delta d_x}{v_x}$$

(time to travel 20 m horizontally)

(Determine $\Delta d_y$ at $\Delta d_x = 10$ m.)

$$\Delta t = \frac{\Delta d_x}{v_x}$$
$$= 2.2 \text{ s}$$
$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$= (14.0 \text{ m/s})(2.2 \text{ s}) + \tfrac{1}{2}(-9.8 \text{ m/s}^2)(2.2 \text{ s})^2$$
$$\Delta d_y = 7.1 \text{ m} > 3.0 \text{ m}$$

Therefore, the ball will clear the post.

**Method 2**

Determine the minimum initial vertical velocity required to clear the post. Compare it to the given initial velocity.

$$\Delta d_y = v_{1_y}\,\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$v_{1_y} = \frac{\Delta d_y - \tfrac{1}{2}a_y\Delta t^2}{\Delta t}$$
$$\Delta t = 2.2 \text{ s (from method 1)}$$
$$v_{1_y} = \frac{3.0 \text{ m} - \tfrac{1}{2}(-9.8 \text{ m/s}^2)(2.2 \text{ s})^2}{2.2 \text{ s}}$$
$$v_{1_y} = 12 \text{ m/s} < 14.0 \text{ m/s}$$

Therefore, the ball will clear the post.

**32.** ***x***} $v_{1_x} = 100$ km/h

$= 27.8$ m/s

$a_x = 0$

$\Delta d_x = 10$ m

***y***} $v_{1_y} = 0$

$a_y = g = -9.8 \text{ m/s}^2$

$\Delta d_y = ?$

**Method 1**

Determine the vertical position at $\Delta d_x = 10$ m.

$$v_x = \frac{\Delta d_x}{\Delta t} \rightarrow \Delta t = \frac{\Delta d_x}{v_x}$$

(to find time to reach $\Delta d_x = 10$ m).

$$\Delta t = \frac{10 \text{ m}}{27.8 \text{ m/s}}$$
$$= 0.36 \text{ s}$$
$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$\Delta d_y = \tfrac{1}{2}a_y\Delta t^2$$
$$= \tfrac{1}{2}(-9.8 \text{ m/s}^2)(0.36 \text{ s})^2$$
$$= -0.64 \text{ m}$$
$$2.2 \text{ m} - 0.64 \text{ m} = 1.6 \text{ m}$$
$$\Delta d_y = 1.6 \text{ m} > 0.9 \text{ m}$$

Therefore, the ball will clear the net.

**Method 2**

Determine the minimum vertical velocity required to clear the net.

The ball can drop *at most*

$$\Delta d_y = 0.9 \text{ m} - 2.2 \text{ m}$$
$$= -1.3 \text{ m to clear the net.}$$
$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$

($\Delta t = 0.36$ s from method 1)

$$v_{1_y} = \frac{\Delta d_y - \tfrac{1}{2}a_y\Delta t^2}{\Delta t}$$
$$= \frac{-1.3 \text{ m} - \tfrac{1}{2}(-9.8 \text{ m/s}^2)(0.36 \text{ s})^2}{0.36 \text{ s}}$$
$$= -1.8 \text{ m/s} < 0 \text{ m/s}$$

Therefore, the ball will clear the net since the minimum velocity in the vertical direction exceeds the velocity required.

**33.** ***x***} $v_x = v \cos \theta$

$= (27 \text{ m/s})\cos 53°$

$= 16.2$ m/s

$a_x = 0$

$\Delta d_x = 69$ m

$\Delta t = ?$

***y***} $v_{1_y} = v \sin \theta$

$= (27 \text{ m/s})\sin 53°$

$= 21.6$ m/s

$a_y = -9.8 \text{ m/s}^2$

$\Delta d_y = 0$

**a)** $v_{2_y}{}^2 = v_{1_y}{}^2 + 2a_y\Delta d_y$

$v_{2_y}{}^2 = 0$ at maximum height

$$\Delta d_y = \frac{-v_{1_y}{}^2}{2a_y}$$
$$= \frac{-(21.6 \text{ m/s})^2}{2(-9.8 \text{ m/s}^2)} = 24 \text{ m}$$

Therefore, maximum height is 24 m.

**b) Method 1**

Using horizontal velocity,

$$v_x = \frac{\Delta d_x}{\Delta t} \rightarrow \Delta t = \frac{\Delta d_x}{v_x}$$
$$\Delta t = \frac{69 \text{ m}}{16.2 \text{ m/s}}$$
$$\Delta t = 4.3 \text{ s}$$

**Method 2**

Using vertical velocity,

$$\Delta d_y = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$0 = v_{1_y}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$
$$0 = v_{1_y} + \tfrac{1}{2}a_y\Delta t$$
$$\Delta t = \frac{-2v_{1_y}}{a_y}$$
$$= \frac{-2(21.6 \text{ m/s})}{(-9.8 \text{ m/s}^2)}$$
$$\Delta t = 4.4 \text{ s}$$

**c)** By logic, final velocity should be the same as initial velocity, but with a declination rather than an inclination, that is, $\vec{v}_2 = 27$ m/s [R53°D].

By computation, we know $v_x = 16.2$ m/s throughout the flight.

To calculate $v_{2y}$,

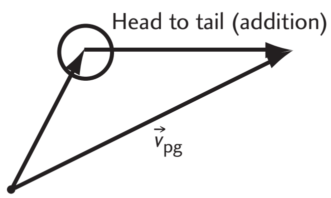
$$v_{2_y}^{\,2} = v_{1_y}^{\,2} + 2a_y\Delta d$$
$$v_{2_y} = \pm\sqrt{v_{1_y}^{\,2} + 2a_y\Delta d}$$
$$= \pm\sqrt{(21.6 \text{ m/s})^2 + 0}$$
$$v_{2_y} = \pm 21.6 \text{ m/s}$$

Because motion is downward, $v_{2_y} = -21.6$ m/s.

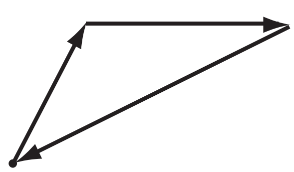
$$|\vec{v}_2| = \sqrt{v_{2_x}^{\,2} + v_{2_y}^{\,2}}$$
$$= \sqrt{(16.2 \text{ m/s})^2 + (-21.6 \text{ m/s})^2}$$
$$= 27 \text{ m/s}$$
$$\theta = \tan^{-1}\frac{v_{2_y}}{v_{2_x}}$$
$$\theta = \tan^{-1}\frac{(21.6 \text{ m/s})}{(16.2 \text{ m/s})}$$
$$= 53°$$

Therefore, $\vec{v}_2 = 27$ m/s [R53°D].

**34.** **(a)**




**(b)**



**35.** The person's maximum velocity = 100 km/h + 1.5 km/h = 101.5 km/h and minimum velocity = 100 km/h − 1.5 km/h = 98.5 km/h relative to the ground.

**36.** **a)** Relative to A, $v_B = -35$ km/h ($v_A = 0$).
**b)** Relative to B, $v_A = 35$ km/h.
**c)** Relative to A, $v_B = 125$ km/h.
**d)** Relative to B, $v_A = 125$ km/h.

**37.** Using Pythagoras' theorem,

$$|\vec{v}_{BG}| = \sqrt{|\vec{v}_{BW}|^2 - |\vec{v}_{WG}|^2}$$
$$= \sqrt{(30 \text{ km/h})^2 - (10 \text{ km/h})^2}$$
$$|\vec{v}_{BG}| = 28 \text{ km/h}$$
$$\theta = \tan^{-1}\frac{10 \text{ km/h}}{28 \text{ km/h}}$$
$$= 19.7°$$

Therefore, $\vec{v}_{BG} = 28$ km/h [E20°S] as it would appear for a spectator on the ground.

**38.** $\vec{v}_{PG} = \vec{v}_{PA} + \vec{v}_{AG}$

cosine law:

$$|\vec{v}_{PA}|^2 = |\vec{v}_{AG}|^2 + |\vec{v}_{PG}|^2 - 2|\vec{v}_{AG}||\vec{v}_{PG}|\cos 30°$$
$$= (150 \text{ km/h})^2 + (300 \text{ km/h})^2$$
$$- 2(150 \text{ km/h})\cos 30°$$
$$|\vec{v}_{PA}| = 186 \text{ km/h}$$

To calculate heading through θ, use sine law.

$$\frac{\sin\theta}{|\vec{v}_{AG}|} = \frac{\sin 30°}{|\vec{v}_{PG}|}$$
$$\sin\theta = \frac{\sin 30°\,|\vec{v}_{AG}|}{|\vec{v}_{PA}|}$$
$$= \frac{\sin 30°(150 \text{ km/h})}{(156 \text{ km/h})}$$
$$= 0.40$$
$$\theta = 24°$$

Therefore, φ = 90° − 24° − 30° = 36°.
Therefore, $\vec{v}_{PA} = 186$ km/h [W36°S].

**39.** Using Pythagoras' theorem,

**a)** $\theta = \tan^{-1}\dfrac{8.0 \text{ km/h}}{34 \text{ km/h}}$

$\theta = 13°$

Heading is [S13°E].

**b)** $|\vec{v}_{BG}| = \sqrt{|\vec{v}_{BW}|^2 - |\vec{v}_{WG}|^2}$

$= \sqrt{(34.0\text{ km/h})^2 - (8.0\text{ km/h})^2}$

$|\vec{v}_{BG}| = 33.0\text{ km/h}$

$\vec{v}_{BG} = 33\text{ km/h [S]}$

**c)** $v = \dfrac{\Delta d}{\Delta t}$

$\Delta t = \dfrac{|\vec{v}_{BG}|}{\Delta d} = \dfrac{21\text{ km}}{33\text{ km/h}} = 0.64\text{ h}$

Therefore, it took 0.64 h to cross the lake.

**40. i)** Swim straight across, fighting the current.

$|\vec{v}_{PG}| = \sqrt{|\vec{v}_{PW}|^2 - |\vec{v}_{WG}|^2}$

$= \sqrt{(2.2\text{ m/s})^2 - (1.6\text{ m/s})^2}$

$|\vec{v}_{PG}| = 1.5\text{ m/s}$

Therefore, $v = \dfrac{\Delta d}{\Delta t}$

$\Delta t = \dfrac{\Delta d}{|\vec{v}_{PG}|}$

$= \dfrac{1000\text{ m}}{1.5\text{ m/s}}$

$\Delta t \cong 670\text{ s}$

**ii)** Do not fight the current and point yourself in the N-S direction.

Therefore, time to cross is $\Delta t = \dfrac{1000\text{ m}}{2.2\text{ m/s}}$

$\Delta t \cong 450\text{ s}$

time saved $= 670\text{ s} - 450\text{ s} = 220\text{ s}$

Therefore, not fighting the current saves 220 s.

**41.** Using Pythagoras' theorem,

$|\vec{v}_{PW}| = \sqrt{|\vec{v}_{CW}|^2 + |\vec{v}_{PC}|^2}$

$= \sqrt{(15\text{ km/h})^2 + (6\text{ km/h})^2}$

$|\vec{v}_{PW}| = 16.2\text{ km/h}$

$\theta = \tan^{-1}\dfrac{6\text{ km/h}}{15\text{ km/h}}$

$= 22°$

Therefore, $\vec{v}_{PW} = 16\text{ km/h [E22°N]}$.

**42. a)** Using Pythagoras' theorem,

$|\vec{v}_{BG}| = \sqrt{|\vec{v}_{BP}|^2 + |\vec{v}_{PG}|^2}$

$= \sqrt{(35\text{ m/s})^2 + (2.0\text{ m/s})^2}$

$|\vec{v}_{BG}| = 34.9\text{ m/s} \cong 35\text{ m/s}$

$\theta = \tan^{-1}\dfrac{34.9\text{ m/s}}{2.0\text{ m/s}}$

$\theta = 87°$

$\gamma = 90° - 87° = 3°$

Therefore, he should throw the ball 3° in the opposite direction of motion where 0° is the line perpendicular to the direction of travel.

**b)** $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$

$\Delta t = \dfrac{|\Delta\vec{d}_{BG}|}{|\vec{v}_{BG}|} = \dfrac{20\text{ m}}{35\text{ m/s}} = 0.57\text{ s}$

Therefore, time of flight is 0.57 s.

**43.** Solve $\vec{v}_{PG}$ for each segment of travel. Assume no time is lost during turning maneuvers.

**i)** $\vec{v}_{PG} = \vec{v}_{PA} + \vec{v}_{AG}$

$= -80\text{ km/h [E]} + (-20\text{ km/h [E]})$

$= -100\text{ km/h [E]}$

$= 100\text{ km/h [W]}$

$|\vec{v}_{PG}| = \dfrac{\Delta d}{\Delta t}$

$\Delta t_1 = \dfrac{\Delta d}{|\vec{v}_{PG}|} = \dfrac{1.5\text{ km}}{100\text{ km/h}} = 0.015\text{ h} = 54\text{ s}$

**ii)** $\vec{v}_{PG} = \vec{v}_{PA} + \vec{v}_{AG}$

$|\vec{v}_{PG_2}| = \sqrt{|\vec{v}_{PA}|^2 - |\vec{v}_{AG}|^2}$

$= \sqrt{(80\text{ km/h})^2 - (20\text{ km/h})^2}$

$= 77.5\text{ km/h}$

$\Delta t_2 = \dfrac{1.5\text{ km}}{77.5\text{ km/h}} = 0.019\text{ h} \cong 70\text{ s}$

**iii)** $\vec{v}_{PG} = \vec{v}_{PA} + \vec{v}_{AG}$

$= +80\text{ km/h [E]} - 20\text{ km/h [E]}$

$= 60\text{ km/h [E]}$

$\Delta t_3 = \dfrac{1.5\text{ km}}{60\text{ km/h}} = 0.025\text{ h} = 90\text{ s}$

**iv)** $\vec{v}_{PG} = \vec{v}_{PA} + \vec{v}_{PG}$

$|\vec{v}_{PG_3}| = \sqrt{|\vec{v}_{PA}|^2 - |\vec{v}_{AG}|^2}$

$= \sqrt{(80\text{ km/h})^2 - (20\text{ km/h})^2}$

$= 77.5\text{ km/h}$

$\Delta t_4 = \dfrac{1.5\text{ km}}{77.5\text{ km/h}} = 0.019\text{ h} = 70\text{ s}$

$\Delta t_{TOT} = \Delta t_1 + \Delta t_2 + \Delta t_3 + \Delta t_4$

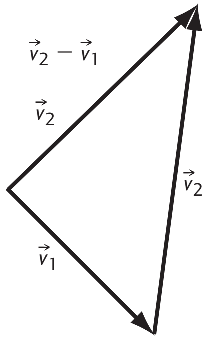
$= 54\text{ s} + 70\text{ s} + 90\text{ s} + 70\text{ s}$

$= 284\text{ s}$

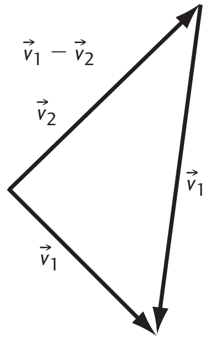
Therefore, $\Delta t_{TOT} \cong 280\text{ s}$.

**44.**

**(a)**



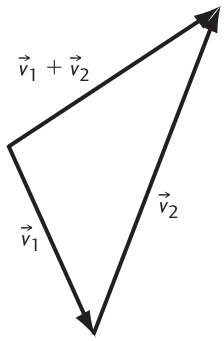

**(b)**




**(c)** $\vec{a} = \dfrac{\vec{v}_2 - \vec{v}_1}{\Delta t}$

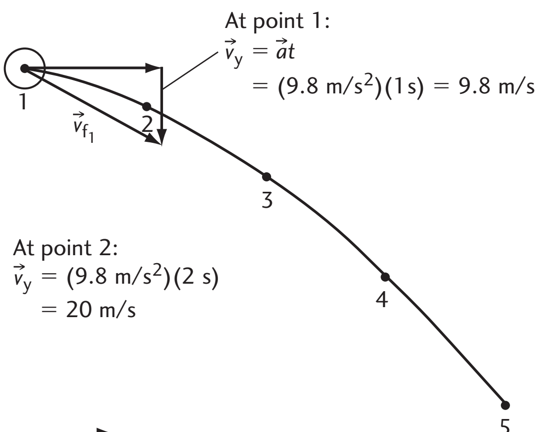
$$v_2 - v_1 = 5.8\ \text{cm} \cdot \frac{5\ \text{m/s}}{1\ \text{cm}}$$
$$= 29\ \text{m/s}$$
$$\vec{a} = \frac{29\ \text{m/s}}{3.0\ \text{s}}$$
$$= 9.7\ \text{m/s}^2\ [\text{N}7°\text{E}]$$

**(d)**

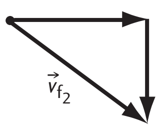



**45.**

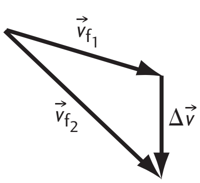
**(i)**




**(ii)**

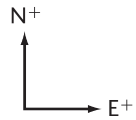



**(iii)** Then combine $\vec{v}_{f_2}$ and $\vec{v}_{f_1}$ tail to tail (subtraction).

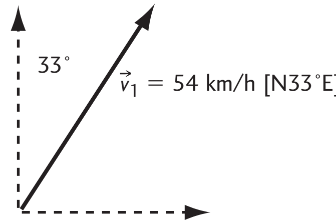



($\Delta\vec{v}$ is in same direction as $\vec{a}$.)

**46.** Let N be the positive $y$ direction and E be the positive $x$ direction.

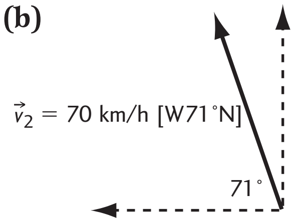



**(a)**



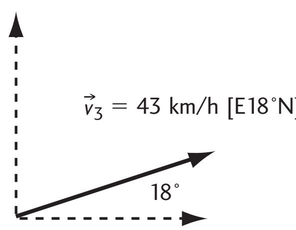

$$v_{1_x} = (54\ \text{km/h})\sin 33° = 29\ \text{km/h}$$
$$v_{1_y} = (54\ \text{km/h})\cos 33° = 45\ \text{km/h}$$

**(b)**



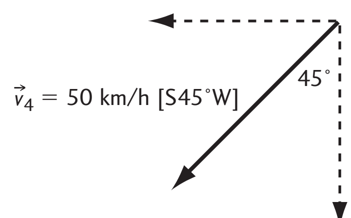

$$v_{2_x} = -(70\ \text{km/h})\cos 71° = -23\ \text{km/h}$$
$$v_{2_y} = (70\ \text{km/h})\sin 71° = 66\ \text{km/h}$$

**(c)**



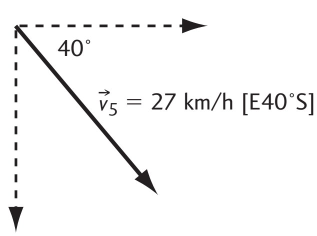

$$v_{3_x} = (43\ \text{km/h})\cos 18° = 41\ \text{km/h}$$
$$v_{3_y} = (43\ \text{km/h})\sin 18° = 13\ \text{km/h}$$

**(d)**




$$v_{4_x} = -(50\ \text{km/h})\sin 45° = -35\ \text{km/h}$$
$$v_{4_y} = -(50\ \text{km/h})\cos 45° = -35\ \text{km/h}$$

**(e)**




$$v_{5_x} = -(27\ \text{km/h})\cos 40° = -21\ \text{km/h}$$
$$v_{5_y} = -(27\ \text{km/h})\sin 40° = -17\ \text{km/h}$$

**47. a)** $v_S = (8.0 \text{ km/h})\cos 40°$

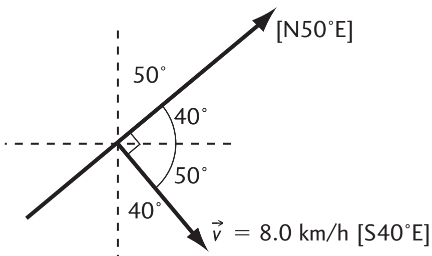
$v_S = 6.1 \text{ km/h}$

**b)** $v_E = (8.0 \text{ km/h})\sin 40°$

$v_E = 5.1 \text{ km/h}$

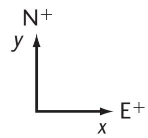
**c)** $v_{[N50°E]} = (8.0 \text{ km/h})\cos 90°$

$v_{[N50°E]} = 0$ (perpendicular)




**48.** $\vec{v}_1 = 50 \text{ km/h [N]}$

$\vec{v}_2 = 50 \text{ km/h [W]}$




**a)** $x\}\Delta v_x = v_{2_x} - v_{1_x}$

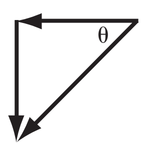
$= -50 \text{ km/h} - 0 = -50 \text{ km/h}$

$y\}\Delta v_y = v_{2_y} - v_{1_y}$

$= 0 - 50 \text{ km/h} = -50 \text{ km/h}$

$|\Delta\vec{v}| = \sqrt{(-50 \text{ km/h})^2 + (-50 \text{ km/h})^2}$

$\cong 71 \text{ km/h}$




$\theta = \tan^{-1}\dfrac{50 \text{ km/h}}{50 \text{ km/h}}$

$\theta = 45°$

Therefore, $\Delta\vec{v} = 71 \text{ km/h [W45°S]}$.

**b)** $\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t} = \dfrac{71 \text{ km/h [W45°S]}}{5.0 \text{ s}}$

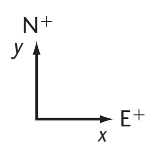
$\vec{a} = 14 \text{ km/h·s [W45°S]} \times 3600 \text{ s/h}$

$\vec{a} = 5.0 \times 10^4 \text{ km/h}^2 \text{ [W45°S]}$

**49.** $\vec{v}_1 = 50 \text{ km/h [N]}$

$\vec{v}_2 = 50 \text{ km/h [N20°E]}$

$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$




$x\}\ \Delta v_x = v_{2_x} - v_{1_x}$

$= (50 \text{ km/h})\sin 20° - 0$

$= 17 \text{ km/h}$

$y\}\ \Delta v_y = v_{2_y} - v_{1_y}$

$= (50 \text{ km/h})\cos 20° - 50 \text{ km/h}$

$= -3.0 \text{ km/h}$

$|\Delta\vec{v}| = \sqrt{(\Delta v_x)^2 + (\Delta v_y)^2}$

$= \sqrt{(17 \text{ km/h})^2 + (3.0 \text{ km/h})^2}$

$= 17.3 \text{ km/h}$

$\theta = \tan^{-1}\dfrac{3.0 \text{ km/h}}{17 \text{ km/h}}$

$\theta = 10°$

Therefore, $\Delta\vec{v} = 17 \text{ km/h [E10°S]}$.

$\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t} = \dfrac{17 \text{ km/h [E10°S]}}{5.0 \text{ s}} \times \dfrac{3600 \text{ s}}{\text{h}}$

$\vec{a} = 12\,000 \text{ km/h}^2 \text{ [E10°S]}$

**50.** $\vec{v}_1 = 30 \text{ m/s [S10°W]}$

$\vec{v}_2 = 5.0 \text{ m/s [S30°E]}$

$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$

**Component Method**

$x\}\ \Delta v_x = v_{2_x} - v_{1_x}$

$= (5.0 \text{ m/s})\sin 30° - (-30 \text{ m/s})\sin 10°$

$= 7.7 \text{ m/s}$

$y\}\ \Delta v_y = v_{2_y} - v_{1_y}$

$= (-5.0 \text{ m/s})\cos 30° - (-30 \text{ m/s})\cos 10°$

$= 25 \text{ m/s}$

$|\Delta\vec{v}| = \sqrt{(\Delta v_x)^2 + (\Delta v_y)^2}$

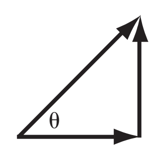
$= \sqrt{(7.7 \text{ m/s})^2 + (25 \text{ m/s})^2}$

$|\Delta\vec{v}| = 26 \text{ m/s}$

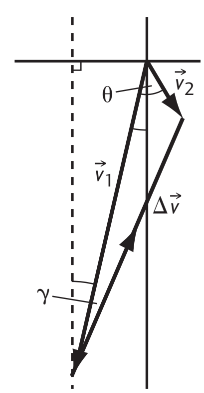
$\theta = \tan^{-1}\dfrac{\Delta v_y}{\Delta v_x}$

$= \tan^{-1}\dfrac{25 \text{ m/s}}{7.7 \text{ m/s}}$

$= 73°$




**Trigonometric Method**




cosine law

$|\Delta\vec{v}|^2 = |\vec{v}_1|^2 + |-\vec{v}_2|^2 - 2|-\vec{v}_1||\vec{v}_2|\cos\theta$

$= (30 \text{ m/s})^2 + (5.0 \text{ m/s})^2$

$- 2(30 \text{ m/s})(5.0 \text{ m/s})\cos 40°$

$|\Delta\vec{v}| = 26 \text{ m/s}$

sine law

$$\frac{\sin 40°}{|\vec{v}_1|} = \frac{\sin \gamma}{|\vec{v}_2|}$$

$$\sin \gamma = \frac{|\vec{v}_2|}{|\vec{v}_1|}\sin 40° = \frac{5.0 \text{ m/s}}{30 \text{ m/s}} \sin 40°$$

$$\gamma = 6.1°$$

Therefore, the angle $= 6.1° + 10°$
$= 16°$.

Therefore, $\Delta\vec{v} = 26$ m/s [N16°E]
$= 26$ m/s [E74°N].

**51. a)** In 60 s, the tip of the second hand will travel $2\pi$r.

Therefore,

$$\Delta d = 2\pi r$$

$$= 2\pi(0.050 \text{ m})$$

$$= 0.31 \text{ m}$$

$$\Delta t = 60 \text{ s}$$

$$v = \frac{0.31 \text{ m}}{60 \text{ s}}$$

$$v = 5.2 \times 10^{-3} \text{ m/s}$$

**b)** At the 12 position, the hand has a velocity of $\vec{v}_1 = 5.2 \times 10^{-3}$ m/s [E] and at the 3 position, the hand has a velocity of $\vec{v}_1 = 5.2 \times 10^{-3}$ m/s [S].

$$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$$

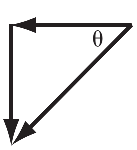
$\boldsymbol{x}\}$ $\Delta v_x = v_{2_x} - v_{1_x}$
$= 0 - 5.2 \times 10^{-3}$ m/s
$\Delta v_x = -5.2 \times 10^{-3}$ m/s

$\boldsymbol{y}\}$ $\Delta v_y = v_{2_y} - v_{1_y}$
$= -5.2 \times 10^{-3}$ m/s $- 0$
$= -5.2 \times 10^{-3}$ m/s

$$|\Delta\vec{v}| = \sqrt{\Delta v_x^2 + \Delta v_y^2}$$

$$= \sqrt{2(-5.2 \times 10^{-3} \text{ m/s})^2}$$

$$= 7.4 \times 10^{-3} \text{ m/s}$$




$$\theta = \tan^{-1}\frac{5.2 \times 10^{-3} \text{ m/s}}{5.2 \times 10^{-3} \text{ m/s}}$$

$$\theta = 45°$$

Therefore, $\Delta\vec{v} = 7.4 \times 10^{-3}$ m/s [S45°W].
There are 15 s between the 12 and the 3 positions.

Therefore,

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \frac{7.4 \times 10^{-3} \text{ m/s [S45°W]}}{15 \text{ s}}$$

$$\vec{a}_{avg} = 4.9 \times 10^{-4} \text{ m/s}^2 \text{ [S45°W]}$$

**c)** $\vec{a}_{avg} = 4.9 \times 10^{-4}$ m/s$^2$ [N45°E].
(Note the acceleration is centre-seeking.)

**52. a)** In 3600 s, the tip of the second hand will travel a distance of $2\pi$r, where $r$ is the radius.

$$\Delta d = 2\pi r = 2\pi(0.25 \text{ m})$$

$$= 1.6 \text{ m}$$

$$\Delta t = 3600 \text{ s} = 1 \text{ h}$$

$$v = \frac{1.6 \text{ m}}{3600 \text{ s}}$$

$$v = 4.4 \times 10^{-4} \text{ m/s}$$

**b)** The hand moves through $\frac{2}{12}(360°) = 60°$

**c)** Let the velocity at the 12 position.
be $\vec{v} = 4.4 \times 10^{-4}$ m/s [E].
Let the velocity at the 2 position
be $\vec{v} = 4.4 \times 10^{-4}$ m/s [E60°S].

$$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$$

$\boldsymbol{x}\}$ $\Delta v_x = v_{2_x} - v_{1_x}$
$= (4.4 \times 10^{-4}$ m/s$)\cos 60° -$
$4.4 \times 10^{-4}$ m/s
$= -2.2 \times 10^{-4}$ m/s

$\boldsymbol{y}\}$ $\Delta v_y = v_{2_y} - v_{1y}$
$= (-4.4 \times 10^{-4}$ m/s$)\sin 60° - 0$
$= -3.8 \times 10^{-4}$ m/s

$$|\Delta\vec{v}| = \sqrt{\Delta v_x^2 + \Delta v_y^2}$$

$$= \sqrt{(-2.2 \times 10^{-4} \text{ m/s})^2 + (-3.8 \times 10^{-4} \text{ m/s})^2}$$

$$|\Delta\vec{v}| = 4.4 \times 10^{-4} \text{ m/s}$$

$$\theta = \tan^{-1}\frac{\Delta v_y}{\Delta v_x}$$

$$= \tan^{-1}\frac{3.8 \times 10^{-4} \text{ m/s}}{2.2 \times 10^{-4} \text{ m/s}}$$

$$\theta = 60°$$

Therefore, $\Delta\vec{v} = 4.4 \times 10^{-4}$ m/s [W60°S]

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = \frac{4.4 \times 10^{-4} \text{ m/s [W60°S]}}{600 \text{ s}}$$

$$\vec{a}_{avg} = 7.3 \times 10^{-7} \text{ m/s}^2 \text{ [W60°S]}$$

**53.** $r = 40$ m

$\Delta t = 12.5$ s (per lap)

Let the vehicle start in an easterly direction.

The speed of the vehicle is $v = \dfrac{\Delta d}{\Delta t}$

where $\Delta d = 2\pi r$

Therefore, $\Delta d = 2 \times \pi \times (40 \text{ m})$

$\cong 250$ m

Therefore, $v = \dfrac{250 \text{ m}}{12.5 \text{ s}} = 20$ m/s.

Therefore, $\vec{v}_1 = 20$ m/s [W].

$\vec{v}_2 = 20$ m/s [W60°N]

$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$

$x\}\ \Delta v_x = v_{2_x} - v_{1_x}$

$= -(20 \text{ m/s})\cos 60° - (-20 \text{ m/s})$

$= 10$ m/s

$y\}\ \Delta v_y = v_{2_y} - v_{1_y}$

$= (20 \text{ m/s})\sin 60° - 0$

$= 17.3$ m/s

$|\Delta\vec{v}| = \sqrt{\Delta v_x^{\,2} + \Delta v_y^{\,2}}$

$= \sqrt{(10 \text{ m/s})^2 + (17.3 \text{ m/s})^2}$

$|\Delta\vec{v}| = 20$ m/s

$\theta = \tan^{-1} \dfrac{\Delta v_y}{\Delta v_x}$

$\theta = \tan^{-1} \dfrac{17.3 \text{ m/s}}{10 \text{ m/s}}$

$\theta = 60°$

$\Delta\vec{v} = 20$ m/s [E60°N]

$\vec{a}_{avg} = \dfrac{\Delta\vec{v}}{\Delta t}$

$= \dfrac{20 \text{ m/s [E60°N]}}{12.5 \text{ s}\left(\frac{60°}{360°}\right)}$

$= 9.6 \text{ m/s}^2$ [E60°N]

Therefore, $\vec{a}_{avg} = 9.6 \text{ m/s}^2$ [E60°N].

**54.** $\vec{d}_1 = 120$ km [E60°N]

$\vec{d}_2 = 60$ km [N]

$\vec{d}_3 = 40$ km [W30°N]

$\Delta\vec{d} = \vec{d}_1 + \vec{d}_2 + \vec{d}_3$

$x\}\ \Delta d_x = d_{1_x} + d_{2_x} + d_{3_x}$

$= (120 \text{ km})\cos 60° + 0$

$- (40 \text{ km})\cos 30°$

$= 25$ km

$y\}\ \Delta d_y = d_{1_y} + d_{2_y} + d_{3_y}$

$= (120 \text{ km})\sin 60° + 60 \text{ km}$

$+ (40 \text{ km})\sin 30°$

$= 184$ km

$|\Delta\vec{d}| = \sqrt{\Delta d_x^{\,2} + \Delta d_y^{\,2}}$

$|\Delta\vec{d}| = \sqrt{(25 \text{ km})^2 + (184 \text{ km})^2}$

$|\Delta\vec{d}| = 186$ km

$\cong 190$ km

$\theta = \tan^{-1} \dfrac{\Delta d_y}{\Delta d_x}$

$= \tan^{-1} \dfrac{184 \text{ km}}{25 \text{ km}}$

$= 82°$

Therefore, $\Delta\vec{d} = 190$ km [E82°N].

**55.** $\vec{d}_1 = 12$ km [N30°E]

$\vec{d}_2 = 15$ km [E]

$\vec{d}_3 = 5$ km [N]

$\vec{d}_4 = 20$ km [S70°E]

$\Delta\vec{d} = \sum_{i=1}^{n} \vec{d}_i$

$|\Delta\vec{d}| = \sqrt{\Delta d_x^{\,2} + \Delta d_y^{\,2}}$

$x\}\ \Delta d_x = d_{1_x} + d_{2_x} + d_{3_x} + d_{4_x}$

$= (12 \text{ km})\cos 60° + 15 \text{ km} + 0$

$+ (20 \text{ km})\cos 20°$

$= 40$ km

$y\}\ \Delta d_y = d_{1_y} + d_{2_y} + d_{3_y} + d_{4_y}$

$= (12 \text{ km})\sin 60° + 0 + 5 \text{ km}$

$- (20 \text{ km})\sin 20°$

$= 8.6$ km

$|\Delta\vec{d}| = \sqrt{\Delta d_x^{\,2} + \Delta d_y^{\,2}}$

$|\Delta\vec{d}| = \sqrt{(40 \text{ km})^2 + (8.6 \text{ km})^2}$

$|\Delta\vec{d}| = 41.1$ km

$\cong 40$ km

$\theta = \tan^{-1} \dfrac{\Delta d_y}{\Delta d_x}$

$= \tan^{-1} \dfrac{8.6 \text{ km}}{40 \text{ km}}$

$= 12°$

Therefore, $\Delta\vec{d} = 40$ km [E12°N].

**56.** $\vec{d}_1 = 50\text{ m [N47°E]}$
$\vec{d}_2 = 22\text{ m [W43°N]}$
$\vec{d}_3 = 30\text{ m [E60°S]}$
$\vec{d}_4 = 30\text{ m [E]}$
$\vec{d}_5 = 44\text{ m [N75°E]}$

**a)** total distance travelled:
$$\Delta d_{\text{total}} = |\vec{d}_1| + |\vec{d}_2| + |\vec{d}_3| + |\vec{d}_4| + |\vec{d}_5|$$
$$= 50\text{ m} + 22\text{ m} + 30\text{ m} + 30\text{ m} + 44\text{ m}$$
$$\Delta d_{\text{total}} = 176\text{ m}$$

**b)** $x\}$ $\Delta d_x = d_{1_x} + d_{2_x} + d_{3_x} + d_{4_x} + d_{5_x}$
$$= (-50\text{ m})\cos 43° - (22\text{ m})\cos 43° + (30\text{ km})\cos 60° + (30\text{ m}) + (44\text{ m})\cos 15°$$
$$= 35\text{ m}$$

$y\}$ $\Delta d_y = (50\text{ m})\sin 43° + (22\text{ m})\sin 43° - (30\text{ km})\sin 60° - 0 + (44\text{ m})\sin 15°$
$$= 35\text{ m}$$
$$|\Delta\vec{d}| = \sqrt{\Delta d_x^2 + \Delta d_y^2}$$
$$|\Delta\vec{d}| = \sqrt{(35\text{ m})^2 + (35\text{ m})^2}$$
$$|\Delta\vec{d}| = 49\text{ m}$$
$$\theta = \tan^{-1}\frac{\Delta d_y}{\Delta d_x} = \tan^{-1}\frac{35\text{ m}}{35\text{ m}} = 45°$$

Therefore, $\Delta\vec{d} = 49\text{ m [E45°N]}$

**c)** The most direct route back to the starting point is [S45°W].

**57.** $\Delta d_{\text{total}} = 176\text{ m}$
$\Delta\vec{d} = 49\text{ m [E45°N]}$
$\Delta t = 0.15\text{ h}$
$$v = \frac{\Delta d_{\text{total}}}{\Delta t} = \frac{176\text{ m}}{0.15\text{ h}} \times 10^{-3}\text{ km/m}$$
$$v \cong 1.2\text{ km/h}$$
$$\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{49\text{ m [E45°N]}}{0.15\text{ h}} \times 10^{-3}\text{ km/m}$$
$$\vec{v} = 0.33\text{ km/h [E45°N]}$$

**58.** ${}_{\text{P}}\vec{v}_{\text{A}} = 120\text{ km/h [E]}$
${}_{\text{A}}\vec{v}_{\text{G}} = 40\text{ km/h [S]}$
${}_{\text{P}}\vec{v}_{\text{G}} = ?$

**a)** $|{}_{\text{P}}\vec{v}_{\text{G}}|^2 = |{}_{\text{P}}\vec{v}_{\text{A}}|^2 + |{}_{\text{A}}\vec{v}_{\text{G}}|^2$
$$|{}_{\text{P}}\vec{v}_{\text{G}}| = \sqrt{(120\text{ km/h})^2 + (40\text{ km/h})^2}$$
$$|{}_{\text{P}}\vec{v}_{\text{G}}| = 126\text{ km/h} \cong 130\text{ km/h}$$
$$\tan\theta = \frac{|{}_{\text{A}}\vec{v}_{\text{G}}|}{|{}_{\text{p}}\vec{v}_{\text{A}}|}$$
$$\theta = \tan^{-1}\frac{40\text{ km/h}}{120\text{ km/h}} = 18°$$

Therefore, ${}_{\text{P}}\vec{v}_{\text{G}} = 130\text{ km/h [E18°S]}$.

**b)** ${}_{\text{P}}\vec{v}_{\text{G}} = \dfrac{\Delta\vec{d}}{\Delta t}$
$$\Delta t = \frac{1000\text{ km [E18°S]}}{126\text{ km/h [E18°S]}}$$
(Significant figures carried for accuracy.)
$$\Delta t = 7.9\text{ h}$$

**59.** ${}_{\text{B}}\vec{v}_{\text{G}} = 15\text{ km/h [N29°W]}$
${}_{\text{W}}\vec{v}_{\text{G}} = 5\text{ km/h [S]}$
${}_{\text{B}}\vec{v}_{\text{W}} = ?$

**a)** cosine law
$$|{}_{\text{B}}\vec{v}_{\text{W}}|^2 = |{}_{\text{B}}\vec{v}_{\text{G}}|^2 + |{}_{\text{W}}\vec{v}_{\text{G}}|^2 - 2|{}_{\text{B}}\vec{v}_{\text{G}}||{}_{\text{W}}\vec{v}_{\text{G}}|\cos\theta$$
$$= (15\text{ km/h})^2 + (5\text{ km/h})^2 - 2(15\text{ km/h})(5\text{ km/h})\cos 151°$$
$$|{}_{\text{B}}\vec{v}_{\text{W}}| = 20\text{ km/h}$$

sine law
$$\frac{\sin\varphi}{|{}_{\text{B}}\vec{v}_{\text{G}}|} = \frac{\sin\theta}{|{}_{\text{B}}\vec{v}_{\text{W}}|}$$
$$\sin\varphi = \frac{|{}_{\text{B}}\vec{v}_{\text{G}}|\sin\theta}{|{}_{\text{B}}\vec{v}_{\text{W}}|} = \frac{15\text{ km/h}}{20\text{ km/h}}\sin 151°$$
$$\varphi = 21°$$

Therefore, ${}_{\text{B}}\vec{v}_{\text{G}} = 20\text{ km/h [N21°W]}$

**b)** $\Delta\vec{d} = 790\text{ m [N29°W]}$
$$\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$$
$$\Delta t = \frac{\Delta\vec{d}}{\vec{v}} = \frac{790\text{ m [N29°W]}}{15\text{ km/h [N29°W]}} \times 10^{-3}\text{ km/m}$$
$$\Delta t = 0.053\text{ h}$$
$$\Delta t = 3.2\text{ min}$$

**60.** ${}_{M}\vec{v}_{A} = 26$ km/h [?]

${}_{A}\vec{v}_{G} = 10$ km/h [S20°E]

${}_{M}\vec{v}_{G} = ?$ [E]

sine law

$$\frac{\sin\theta}{|{}_{A}\vec{v}_{G}|} = \frac{\sin\varphi}{|{}_{M}\vec{v}_{A}|}$$

$$\sin\theta = \frac{|{}_{A}\vec{v}_{G}|\sin\varphi}{|{}_{M}\vec{v}_{A}|}$$

$$= \frac{10 \text{ km/h}}{26 \text{ km/h}}\sin 70°$$

$$\theta = 21°$$

By geometry, we know angle $\beta$ is $180° - \theta - \varphi$.

$\beta = 180° - 21° - 70°$

$\beta = 89°$

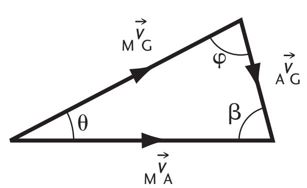
cosine law

$$|{}_{M}\vec{v}_{G}|^2 = |{}_{M}\vec{v}_{A}|^2 + |{}_{A}\vec{v}_{G}|^2 - 2|{}_{M}\vec{v}_{A}||{}_{A}\vec{v}_{G}|\cos\beta$$

$$= (26 \text{ km/h})^2 + (10 \text{ km/h})^2 - 2(26 \text{ km/h})(10 \text{ km/h})\cos 89°$$

$|{}_{M}\vec{v}_{G}| = 28$ km/h

Therefore, the heading is [E21°N]; the ground speed is 28 km/h.




**61.** ${}_{B}\vec{v}_{W} = 5$ m/s [N20°W]

${}_{W}\vec{v}_{G} = ?$ [E]

${}_{B}\vec{v}_{G} = 7.6$ m/s [N]

(Note: directions of ${}_{W}\vec{v}_{G}$, ${}_{B}\vec{v}_{G}$ were deduced from problem statement.)

$$\sin\theta = \frac{|{}_{W}\vec{v}_{G}|}{|{}_{B}\vec{v}_{W}|}$$

$$|{}_{W}\vec{v}_{G}| = |{}_{B}\vec{v}_{G}|\sin\theta$$

$$= (5 \text{ m/s})\sin 20°$$

$|{}_{W}\vec{v}_{G}| = 1.7$ m/s

Current flows eastward at ${}_{W}\vec{v}_{G} = 1.7$ m/s [E].

**62.** ${}_{P}\vec{v}_{G} = 380$ km/h [N30°E]

${}_{A}\vec{v}_{G} = 80$ km/h [S]

${}_{P}\vec{v}_{A} = ?$

$$|{}_{P}\vec{v}_{A}|^2 = |{}_{P}\vec{v}_{G}|^2 + |{}_{A}\vec{v}_{G}|^2 - 2|{}_{P}\vec{v}_{G}||{}_{A}\vec{v}_{G}|\cos\theta$$

$$= (380 \text{ km/h})^2 + (80 \text{ km/h})^2 - 2(380 \text{ km/h})(80 \text{ km/h})\cos 30°$$

$|{}_{P}\vec{v}_{A}| = 313$ km/h

$$\frac{\sin\varphi}{|{}_{A}\vec{v}_{G}|} = \frac{\sin\theta}{|{}_{P}\vec{v}_{G}|}$$

$$\sin\varphi = \frac{\sin\theta|{}_{A}\vec{v}_{G}|}{|{}_{P}\vec{v}_{G}|}$$

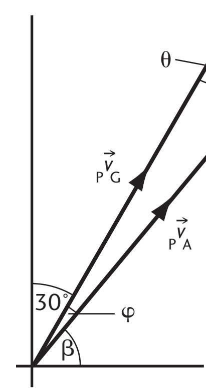
$$= \frac{\sin 30°(80 \text{ km/h})}{(380 \text{ km/h})}$$

$\varphi = 6°$

$\beta = 90° - 30° - 6°$

$= 54°$

Therefore, the plane's heading is [E54°N].




[Note: The answer in the student edition was arrived at using the component method.]

## Chapter 4

**19.** $m = 20$ kg

**a)** $\vec{F} = m\vec{a}$

When $a = 9.8$ m/s$^2$,

$F = (20 \text{ kg})(9.8 \text{ m/s}^2)$

$F = 196$ N

$\cong 200$ N

**b)** When $a = 0.28$ m/s$^2$,

$F = (20 \text{ kg})(0.28 \text{ m/s}^2)$

$= 5.6$ N

**c)** When $a = 5669$ km/h$^2$ $= 0.4397$ m/s$^2$,

$F = (20 \text{ kg})(0.4397 \text{ m/s}^2)$

$\cong 8.8$ N

**d)** When $a = 50$ km/h/s $= 13.89$ m/s$^2$,

$F = (20 \text{ kg})(13.89 \text{ m/s}^2)$

$= 277.8$ N

$\cong 280$ N

**20.** $\vec{F} = m\vec{a}$, $\vec{a} = \dfrac{\vec{F}}{m}$

$F = 50$ N

**a)** $a = \dfrac{50 \text{ N}}{40 \text{ kg}}$

$= 1.25$ m/s$^2$

**b)** When $m = 3$ g $= 0.003$ kg,

$a = \dfrac{50 \text{ N}}{0.003 \text{ kg}}$

$= 16\,666.67$ m/s$^2$

$\cong 2.0 \times 10^4$ m/s$^2$

**c)** When $m = 1.6 \times 10^8$ kg,

$a = \dfrac{50 \text{ N}}{1.6 \times 10^8 \text{ kg}}$

$\cong 3.0 \times 10^{-7}$ m/s$^2$

**d)** When $m = 2.2 \times 10^6$ g $= 2.2 \times 10^3$ kg,

$a = \dfrac{50 \text{ N}}{2.2 \times 10^3 \text{ kg}}$

$\cong 0.23$ m/s$^2$

**21.** $g = 9.8$ m/s$^2$

$a = 4.5\,g = 4.5(9.8 \text{ m/s}^2) = 44.1$ m/s$^2$

When $m = 65$ kg,

$F = ma$

$= (65 \text{ kg})(44.1 \text{ m/s}^2)$

$= 2866.5$ N

$\cong 2900$ N

**22. a)** $m = 5000$ kg

$a = 1.5$ m/s$^2$

$F = ma$

$= (5000 \text{ kg})(1.5 \text{ m/s}^2)$

$= 7500$ N

**b)** $F = 2.8 \times 10^7$ N

$m = 2.5 \times 10^6$ kg

$a = \dfrac{F}{m}$

$= \dfrac{2.8 \times 10^7 \text{ N}}{2.5 \times 10^6 \text{ kg}}$

$= 11.2$ m/s$^2$

$\cong 11$ m/s$^2$

**23.** $a = 9.80$ m/s$^2$, $F = 1000$ N

$m = \dfrac{F}{a}$

$= \dfrac{1000 \text{ N}}{9.8 \text{ m/s}^2}$

$= 102.04$ kg

$\cong 102$ kg

**24.** $a = 12.6$ m/s$^2$, $m = 60\,000$ g $= 60$ kg

$F = ma$

$= (60 \text{ kg})(12.6 \text{ m/s}^2)$

$= 756$ N

**25.** jet: 95 m/s in 50 s

$v_1 = 0$ m/s

$v_2 = 95$ m/s

$\Delta t = 50$ s

$a = \dfrac{v_2 - v_1}{\Delta t}$

$= \dfrac{95 \text{ m/s} - 0 \text{ m/s}}{50 \text{ s}}$

$= 1.9$ m/s$^2$

jet fighter: 60 m/s in 3.0 s

$v_1 = 0$ m/s

$v_2 = 60$ m/s

$\Delta t = 3.0$ s

$a = \dfrac{v_2 - v_1}{\Delta t}$

$= \dfrac{60 \text{ m/s} - 0 \text{ m/s}}{3.0 \text{ s}}$

$= 20$ m/s$^2$

Therefore, $F_{\text{jet}} = (8.0 \times 10^4 \text{ kg})(1.9 \text{ m/s}^2)$

$\cong 1.5 \times 10^5$ N

Therefore, $F_{\text{jet fighter}} = (8.0 \times 10^4 \text{ kg})(20 \text{ m/s}^2)$

$= 1.6 \times 10^6$ N

**26.** $m = 1.0 \times 10^8$ kg, $d = 3.5$ km $= 3500$ m
$v_1 = 0$ m/s, $v_2 = 4.1$ km/h $\cong 1.14$ m/s
$\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\vec{d}$
Since $v_1 = 0$ m/s,
$$a = \frac{v_2^2}{2d}$$
$$= \frac{(1.14 \text{ m/s})^2}{2(3500 \text{ m})}$$
$$\cong 1.86 \times 10^{-4} \text{ m/s}^2$$
$F = (1.0 \times 10^8 \text{ kg})(1.86 \times 10^{-4} \text{ m/s}^2)$
$= 1.86 \times 10^4$ N
$\cong 1.9 \times 10^4$ N

**27.** $v_1 = 0$ m/s, $\Delta t = 1.5$ s, $\Delta d = 1.6$ m,
$m = 65$ kg
from $\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
($v_1\Delta t = 0$ since $v_1 = 0$)
$\Delta d = \frac{1}{2}a\Delta t^2$
$$a = \frac{2\Delta d}{\Delta t^2}$$
$$= \frac{2(1.6 \text{ m})}{(1.5 \text{ s})^2}$$
$= 1.42$ m/s$^2$
$\cong 1.4$ m/s$^2$
Therefore, $F = (65 \text{ kg})(1.42 \text{ m/s}^2)$
$= 92.3$ N
$\cong 92$ N

**28.** $F_{net} = 200$ N, $v_1 = 30$ km/h $= 8.33$ m/s,
$v_2 = 20$ km/h $= 5.56$ m/s, $\Delta t = 2.3$ s
$v_2 - v_1 = a\Delta t$
$$a = \frac{v_2 - v_1}{\Delta t}$$
$$= \frac{5.56 \text{ m/s} - 8.33 \text{ m/s}}{2.3 \text{ s}}$$
$= -1.2$ m/s$^2$
$\vec{F} = m\vec{a}$
$$m = \frac{F}{a}$$
$$= \frac{200 \text{ N}}{1.2 \text{ m/s}^2}$$
$= 166.67$ kg
$\cong 170$ kg

**29.** $\vec{v}_1 = 20$ m/s [N], $\vec{v}_2 = 20$ m/s [S]
$= -20$ m/s, $\Delta t = 5.5$ s, $m = 1500$ kg
$$a = \frac{v_2 - v_1}{\Delta t}$$
$$= \frac{-20 \text{ m/s} - 20 \text{ m/s}}{5.5 \text{ s}} \qquad \text{N} = + \uparrow$$
$= -7.27$ m/s$^2$
$\vec{F} = m\vec{a}$
$= (1500 \text{ kg})(-7.27 \text{ m/s}^2)$
$= -10\,905$ N
$\cong -10\,900$ N or $10\,900$ N [S]

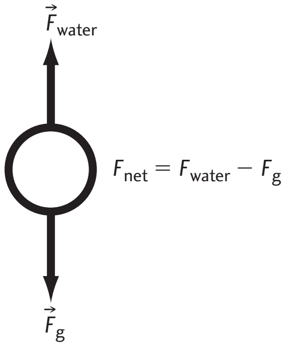
**30.** $m_1 = 14.6$ kg, $m_2 = 50$ kg, $F = 12$ N,
$\Delta t = 2.0$ s
$m_T = m_1 + m_2$
$= 14.6$ kg $+ 50$ kg
$= 64.6$ kg
$\vec{F} = m\vec{a}$
$$a = \frac{F}{m_T}$$
$$= \frac{12 \text{ N}}{64.6 \text{ kg}}$$
$= 0.19$ m/s$^2$
$v_2 = v_1 + a\Delta t$
$= 0 + (0.19 \text{ m/s}^2)(2.0 \text{ s})$
$= 0.38$ m/s$^2$

**31.** $m_{ball} = 140$ g $= 0.140$ kg, $\Delta t = 0.010$ s,
$v_1 = 0$ m/s, $v_2 = 60$ km/h $= 16.67$ m/s
$$a = \frac{v_2 - v_1}{\Delta t}$$
$$= \frac{16.67 \text{ m/s}}{0.010 \text{ s}}$$
$= 1667$ m/s$^2$
$F = ma$
$= (0.140 \text{ kg})(1667 \text{ m/s}^2)$
$= 233.28$ N
$\cong 233$ N

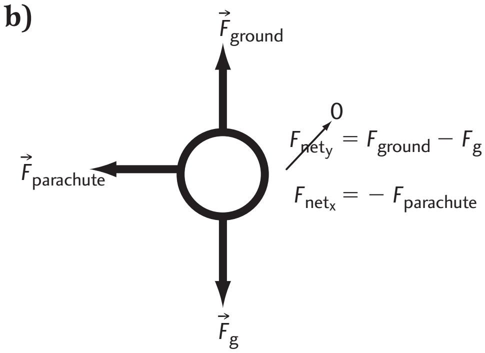
**32.** $m_{ball} = 0.140$ kg, $v_1 = 60$ km/h
$= 16.67$ m/s, $v_2 = -60$ km/h $= -16.67$ m/s,
$\Delta t = 0.010$ s
$$a = \frac{v_2 - v_1}{\Delta t}$$
$$= \frac{-16.67 \text{ m/s} - 16.67 \text{ m/s}}{0.010 \text{ s}}$$
$= -3334$ m/s$^2$

$$
\begin{aligned}
F &= ma \\
&= (0.140\text{ kg})(-3334\text{ m/s}^2) \\
&= -466.76\text{ N} \\
&\cong -467\text{ N}
\end{aligned}
$$

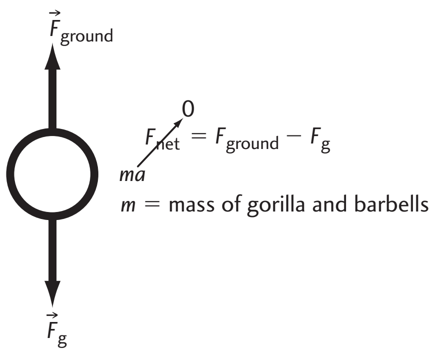
**33. a)**



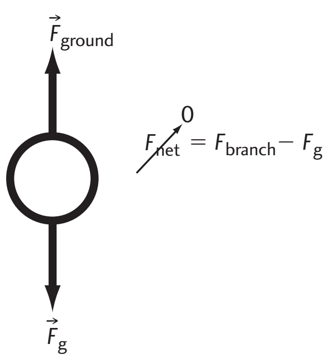

**b)**



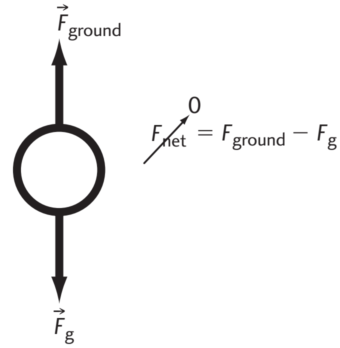

**c)**



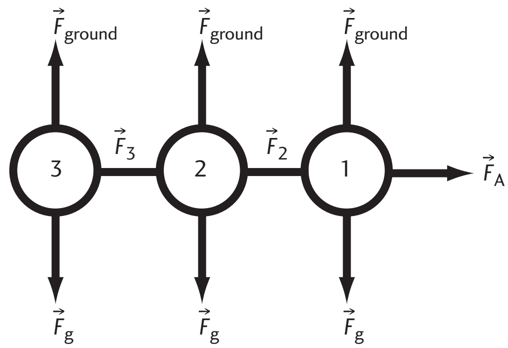

**d)**



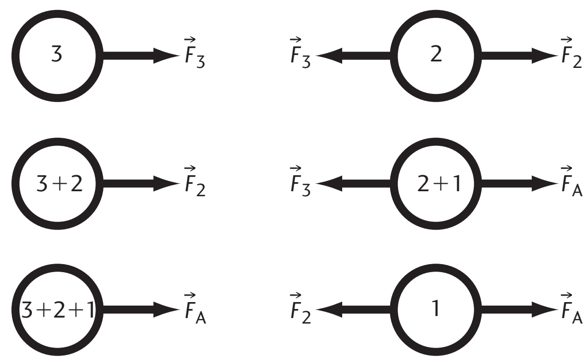

**e)**



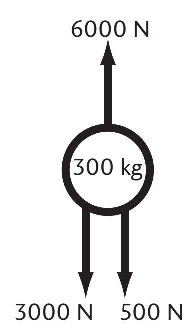

**34.**




We will ignore the $y$ direction, which is the same for all three, and $F_{net_y} = 0$

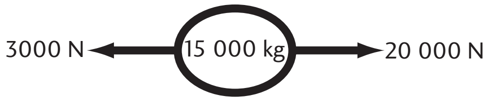



**35. a)**



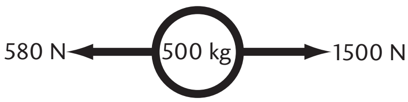

$$
\begin{aligned}
F_{net} &= 6000\text{ N} - 3500\text{ N} \\
ma &= 2500\text{ N} \\
a &= \frac{2500\text{ N}}{300\text{ kg}} \\
&= 8.33\text{ m/s}^2
\end{aligned}
$$

**b)**




$$F_{net} = 20\ 000\ \text{N} - 3000\ \text{N}$$
$$ma = 17\ 000\ \text{N}$$
$$a = \frac{17\ 000\ \text{N}}{15\ 000\ \text{kg}}$$
$$= 1.13\ \text{m/s}^2$$

**c)**




$$F_{net} = 1500\ \text{N} - 580\ \text{N}$$
$$ma = 920\ \text{N}$$
$$a = \frac{920\ \text{N}}{500\ \text{kg}}$$
$$= 1.84\ \text{m/s}^2$$

**36. a)** $F_{net} = 7.0\ \text{N} - 3.0\ \text{N}$
$$= 4.0\ \text{N}$$
$$a = \frac{4.0\ \text{N}}{1.0\ \text{kg}}$$
$$= 4.0\ \text{m/s}^2$$

**b)** $F_{net} = 3.0\ \text{N}$
$$m = \frac{F}{a}$$
$$= \frac{3.00\ \text{N}}{2.0\ \text{m/s}^2}$$
$$= 1.5\ \text{kg}$$

**c)** $F_{net} = 8.0\ \text{N} - 1.0\ \text{N} + F_1$

$a = 0$; therefore,
$$F_{net} = 0$$
$$F_1 = -7.0\ \text{N}$$

**d)** $F_{net} = 0$

$v$ is constant; therefore,
$$a = 0$$
$$F_{net} = 5\ \text{N} + F_1 - 30\ \text{N}$$
$$F_1 = 25\ \text{N}$$

**e)** $F_{net} = ma$
$$= (4.000\ \text{kg})(1.5\ \text{m/s}^2)$$
$$= 6.0\ \text{N}$$
$$6.0\ \text{N} = 10.0\ \text{N} - F_1 - F_2$$

Therefore, $F_1 = F_2 = 2.0\ \text{N}$

**f)** $F_{net} = ma$
$$= (5.0\ \text{kg})(0.5\ \text{m/s}^2)$$
$$= 2.5\ \text{N}$$
$$2.5\ \text{N} = F_1 - 6.0\ \text{N}$$
$$F_1 = 8.5\ \text{N}$$

**g)** $F_{net} = 23\ \text{N} - 20\ \text{N}$
$$= 3\ \text{N}$$
$$3\ \text{N} = m(5\ \text{m/s}^2)$$
$$m = 0.6\ \text{kg}$$

**h)** $a = 0$

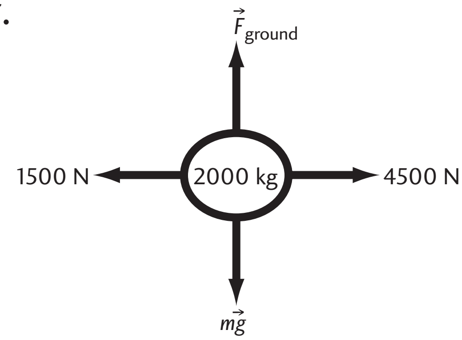
$v$ is constant; therefore,
$$F_{net} = 0$$
$$0 = F_1 - 10\ \text{N}$$
$$F_1 = 10\ \text{N}$$

(Mass can have any value.)

**i)** $F_{net} = F_1 - F_2$
$$= 2F_2 - F_2$$
$$1.8 \times 10^{-2}\ \text{N} = F_2$$

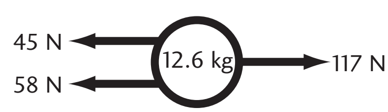
Therefore, $F_1 = 3.6 \times 10^{-2}\ \text{N}$

**37.**




$$F_{net_x} = 4500\ \text{N} - 1500\ \text{N}$$
$$= 3000\ \text{N}$$
$$m = 2000\ \text{kg}$$
$$a = \frac{F}{m}$$
$$= \frac{3000\ \text{N}}{2000\ \text{kg}}$$
$$= 1.5\ \text{m/s}^2$$

**38.** $F_{net} = 117\ \text{N} - 45\ \text{N} - 58\ \text{N} = 14\ \text{N}$
$$m = 12.6\ \text{kg}$$

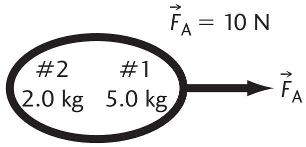



**a)** $a = \frac{F}{m}$
$$= \frac{14\ \text{N}}{12.6\ \text{kg}}$$
$$= 1.11\ \text{m/s}^2$$
$$\cong 1.1\ \text{m/s}^2$$

**b)** $v_1 = 0\ \text{m/s}$
$$\Delta t = 7.0\ \text{s}$$
$$v_2 = ?$$
$$a = 1.11\ \text{m/s}^2$$

$$v_2 = v_1 + a\Delta t$$
$$= 0 \text{ m/s} + (1.4 \text{ m/s}^2)(7.0 \text{ s})$$
$$= 7.77 \text{ m/s}$$
$$\cong 7.8 \text{ m/s}$$

**39. a)** $\vec{F} = m\vec{a}$




$$a = \frac{F}{m}$$
$$= \frac{10 \text{ N}}{7.0 \text{ kg}}$$
$$= 1.43 \text{ m/s}^2$$
$$\cong 1.4 \text{ m/s}^2$$

**b)** $\cancel{F_{\text{net}}} = F_T$

$ma$

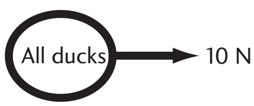

$$F_T = (2.0 \text{ kg})(1.43 \text{ m/s})$$
$$F_T = 2.86 \text{ N}$$
$$F_T \cong 2.9 \text{ N}$$

**40.** $m_{\text{ducks}} = 5.0 \text{ kg} + 2.0 \text{ kg} + 1.0 \text{ kg}$
$$= 8.0 \text{ kg}$$

$\cancel{F_{\text{net}}} = 10$ N

$ma$

**a)** $a = \dfrac{10 \text{ N}}{8.0 \text{ kg}}$

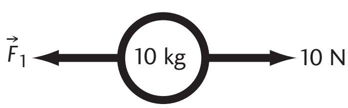



$$= 1.25 \text{ N/kg}$$
$$= 1.2 \text{ m/s}^2$$

**b)** $\cancel{F_{\text{net}}} = 10 \text{ N} - F_1$

$ma$

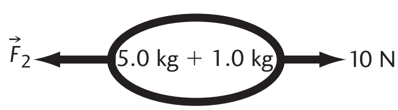
$$(1.0 \text{ kg})(1.25 \text{ m/s}^2) = 10 \text{ N} - F_1$$
$$F_1 = 8.8 \text{ N}$$



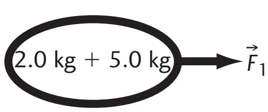

**c)** $\cancel{F_{\text{net}}} = 10 \text{ N} - F_2$

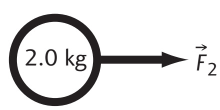
$ma$

$$(6.0 \text{ kg})(1.25 \text{ m/s}^2) = 10 \text{ N} - F_2$$
$$F_2 = 2.5 \text{ N}$$




**d)**




$\cancel{\vec{F}_{\text{net}}} = \vec{F}_1$

$m\vec{a}$

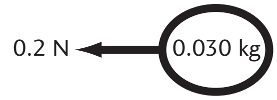
$$(7.0 \text{ kg})(1.25 \text{ m/s}^2) = F_1$$
$$F_1 = 8.8 \text{ N}$$

$\cancel{\vec{F}_{\text{net}}} = \vec{F}_2$

$m\vec{a}$

$$(2.0 \text{ kg})(1.25 \text{ m/s}^2) = F_2$$
$$F_2 = 2.5 \text{ N}$$

**41.**



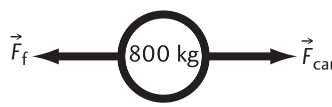

$$m = 30 \text{ g} = 0.030 \text{ kg}$$
$$F = -0.2 \text{ N}$$
$$v_1 = 10 \text{ km/h} = 2.78 \text{ m/s}$$
$$v_2 = 0 \text{ m/s}$$

**a)** $\vec{F} = m\vec{a}$

$$a = \frac{F}{m}$$
$$= \frac{-0.2 \text{ N}}{0.030 \text{ kg}}$$
$$= -6.67 \text{ m/s}^2$$
$$\cong -6.7 \text{ m/s}^2$$
$$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$$
$$\Delta t = \frac{\vec{v}_2 - \vec{v}_1}{\vec{a}}$$
$$= \frac{0 - 2.78 \text{ m/s}}{-6.67 \text{ m/s}^2}$$
$$\cong 0.42 \text{ s}$$

**b)** $\Delta d = v_1\Delta t + \frac{1}{2}a\Delta t^2$
$$= (2.78 \text{ m/s})(0.42 \text{ s}) + \tfrac{1}{2}(-6.67 \text{ m/s}^2)(0.42 \text{ s})^2$$
$$\cong 0.59 \text{ m}$$

**42.**



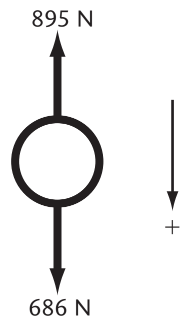

$$v_0 = 0 \text{ m/s}$$
$$v_1 = 350 \text{ km/h} = 97.22 \text{ m/s}$$
$$t = 6.2 \text{ s}$$
$$m = 800 \text{ kg}$$
$$F_{\text{net}} = 1600 \text{ N}$$
$$F_f = ?$$
$$a = \frac{v_1 - v_0}{t}$$
$$= \frac{97.22 \text{ m/s} - 0 \text{ m/s}}{6.2 \text{ s}}$$
$$\cong 15.68 \text{ m/s}^2$$
$$F_{\text{car}} = ma$$
$$= (800 \text{ kg})(15.68 \text{ m/s}^2)$$
$$= 12\,544.52 \text{ N}$$
$$F_{\text{net}} = F_{\text{car}} - F_f = 1600 \text{ N}$$
$$F_f = F_{\text{car}} - 1600 \text{ N}$$
$$= 12\,544 \text{ N} - 1600 \text{ N}$$
$$= 10\,944 \text{ N}$$
$$\cong 10\,900 \text{ N}$$

**43.** $m = 70$ kg, $F_r = 895$ N, $F_g = 686$ N, $v = 136$ km/h $= 37.78$ m/s

**a)** $F = ma$

$$-895\text{ N} + 686\text{ N} = (70\text{ kg})(a)$$

$$a = \frac{-209\text{ N}}{70\text{ kg}} = -2.99\text{ m/s}^2 \cong -3.0\text{ m/s}^2$$




**b)** down

**c)** $t = 5.0$ s, $\Delta d = ?$

$$\Delta d = v_1\Delta t + \tfrac{1}{2}a\Delta t^2$$
$$= (37.78\text{ m/s})(5.0\text{ s}) + \tfrac{1}{2}(-2.99\text{ m/s}^2)(5.0\text{ s})^2$$
$$= 188.9\text{ m} - 37.38\text{ m}$$
$$= 151.52\text{ m}$$
$$\cong 150\text{ m}$$

**44. a)** $F_{\text{net}_y} = 25\text{ N} - 40\text{ N} = -15\text{ N}$

$F_{\text{net}_x} = 50\text{ N} - 50\text{ N} = 0$

**b)** $F_{\text{net}_y} = 30\text{ N} + 50\text{ N} - 40\text{ N} = 40\text{ N}$

$F_{\text{net}_x} = 50\text{ N} - 10\text{ N} = 40\text{ N}$

**c)** $F_{\text{net}_y} = 2.0\text{ N} + 2.0\text{ N} - 0.5\text{ N} = 3.5\text{ N}$

$F_{\text{net}_x} = 2.0\text{ N} + 3.0\text{ N} - 6.0\text{ N} = -1.0\text{ N}$

**d)** $F_{\text{net}_y} = 10\text{ N} + 20\text{ N} + 5.0\text{ N} - 3.0\text{ N} - 2.0\text{ N} = 30\text{ N}$

$F_{\text{net}_x} = 21\text{ N} + 4\text{ N} - 20\text{ N} - 15\text{ N} = -10\text{ N}$

**45. a)** $F_{\text{net}} = \sqrt{(F_{\text{net}_x})^2 + (F_{\text{net}_y})^2}$

$$= \sqrt{(0\text{ N})^2 + (-15\text{ N})^2} = 15\text{ N}$$

($x$ direction is 0, $y$ direction is $-$)

$\vec{F}_{\text{net}} = 15$ N [S]

**b)** $F_{\text{net}} = \sqrt{(40\text{ N})^2 + (40\text{ N})^2} = 57\text{ N}$

$$\theta = \tan^{-1}\frac{F_{\text{net}_y}}{F_{\text{net}_x}} = \tan^{-1}\frac{40\text{ N}}{40\text{ N}}$$

$\theta = 45°$ ($x$ direction is $+$, $y$ direction is $+$)

Therefore, $\vec{F}_{\text{net}} = 57$ N [E45°N].

**c)** $F_{\text{net}} = \sqrt{(-1.0\text{ N})^2 + (3.5\text{ N})^2} = 3.6\text{ N}$

$$\theta = \tan^{-1}\frac{3.5\text{ N}}{1.0\text{ N}}$$

$= 74°$ ($x$ direction is $-$, $y$ direction is $+$)

Therefore, $\vec{F}_{\text{net}} = 3.6$ N [W74°N].

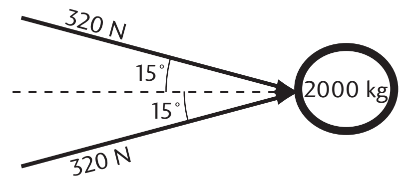
**d)** $F_{\text{net}} = \sqrt{(-10\text{ N})^2 + (30\text{ N})^2} = 32\text{ N}$

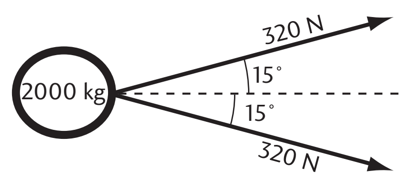
$$\theta = \tan^{-1}\frac{30\text{ N}}{10\text{ N}}$$

$= 72°$ ($x$ direction is $-$, $y$ direction is $+$)

Therefore, $\vec{F}_{\text{net}} = 32$ N [W72°N].

**46.** $m = 2000$ kg



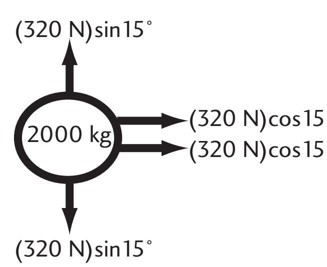

**Component Method**

**x**} $F_{\text{net}_x} = (320\text{ N})\cos 15° + (320\text{ N})\cos 15°$

$F_{\text{net}_x} = ma$

$ma = (320\text{ N})\cos 15° + (320\text{ N})\cos 15°$

$$a = \frac{2(320\text{ N}\cos 15°)}{2000\text{ kg}} = 0.309\text{ m/s}^2$$




Therefore, the acceleration of the car is approximately 0.31 m/s² [forward].

**Trigonometric Method**

Using sine law,

$$\frac{\sin A}{a} = \frac{\sin B}{b}$$

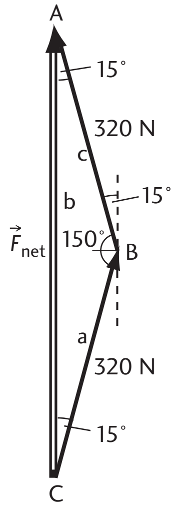
$$\frac{\sin 15°}{320\ \text{N}} = \frac{\sin 150°}{F_{\text{net}}}$$

$$F_{\text{net}} = \frac{(320\ \text{N})\sin 150°}{\sin 15°}$$

$$ma = \frac{175\ \text{N}}{\sin 15°}$$

$$a = \frac{175\ \text{N}}{2000\ \text{kg}(\sin 15°)}$$

$$= 0.309\ \text{m/s}^2$$




Therefore, the acceleration of the car is approximately 0.31 m/s$^2$ [forward].

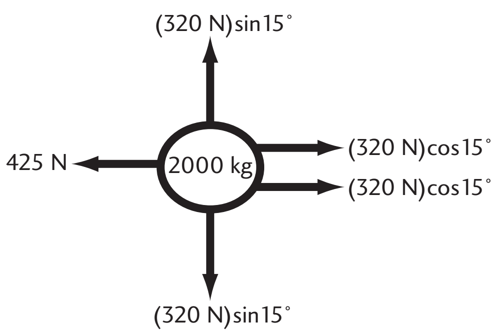
**47.** **x**} $F_{\text{net}_x} = 2(320\ \text{N} \cos 15°) - 425\ \text{N}$

$$F_{\text{net}_x} = ma$$

$$a(2000\ \text{kg}) = (640\ \text{N})\cos 15° - 425\ \text{N}$$

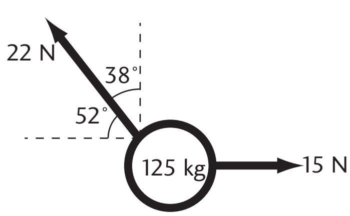
$$a = \frac{(640\ \text{N})\cos 15° - 425\ \text{N}}{2000\ \text{kg}}$$

$$= 0.097\ \text{m/s}^2$$




Therefore, the acceleration of the car is approximately 0.1 m/s$^2$ [forward].

**48.**




$m_c = 70\ \text{kg}$

$m_p = 55\ \text{kg}$

$\vec{F}_w = 15\ \text{N [E]}$

$\vec{F}_p = 22\ \text{N [N38°W]}$

$m_T = 70\ \text{kg} + 55\ \text{kg}$

$= 125\ \text{kg}$

**Component Method**

***x***} $F_{\text{net}_x} = 15\ \text{N} - (22\ \text{N})\cos 52°$

$= 1.455\ \text{N}$

***y***} $F_{\text{net}_y} = (22\ \text{N})\sin 52°$

$= 17.336\ \text{N}$

$$F_{\text{net}} = \sqrt{(17.3\ \text{N})^2 + (1.46\ \text{N})^2}$$

$$= 17.4\ \text{N}$$

$$\tan\theta = \frac{\text{opp}}{\text{adj}}$$

$$\tan\theta = \frac{17.3}{1.46}$$

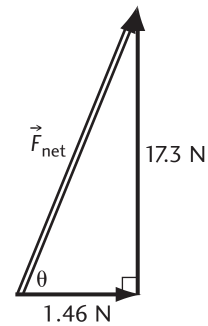
$$= 85.2°$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$a(125\ \text{kg}) = 17.4\ \text{N}$$

$$a = \frac{17.4\ \text{N}}{125\ \text{kg}}$$

$$= 0.139\ \text{m/s}^2$$




Therefore, the acceleration of the canoe and paddler is approximately 0.14 m/s$^2$ [E85°N].

**Trigonometric Method**

Using cosine law,

$b^2 = a^2 + c^2 - 2ac(\cos B)$

$(F_{\text{net}})^2 = (15\ \text{N})^2 + (22\ \text{N})^2 - 2(15\ \text{N})(22\ \text{N}) \cos 52°$

$(F_{\text{net}})^2 = (709\ \text{N})^2 - (660\ \text{N})^2 \cos 52°$

$F_{\text{net}} = 17.397\ \text{N}$

Using sine law,

$$\frac{\sin C}{c} = \frac{\sin B}{b}$$

$$\frac{\sin C}{22\ \text{N}} = \frac{\sin 52°}{17.4\ \text{N}}$$

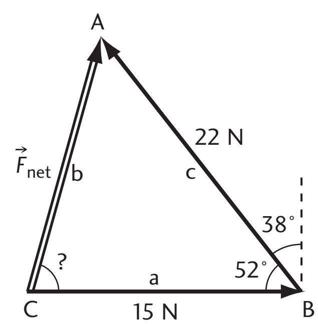
$$\sin C = \frac{(22\ \text{N})\sin 52°}{17.4\ \text{N}}$$

$$C = 85.2°$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$a = \frac{17.397\ \text{N}}{125\ \text{kg}}$$

$$= 0.139\ \text{m/s}^2$$



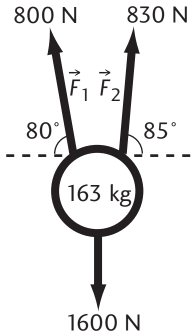

Therefore, the acceleration of the canoe and paddler is approximately 0.14 m/s$^2$ [E85°N].

**49. a)** $m = 163\ \text{kg}$

$\vec{F}_g = 1600\ \text{N}$

$\vec{F}_1 = 800\ \text{N [L80°U]}$

$\vec{F}_2 = 830\ \text{N [R85°U]}$




$x\}$ $F_{net_x} = (830 \text{ N})\cos 85° - (800 \text{ N})\cos 80°$
$= -66.58 \text{ N}$
$y\}$ $F_{net_y} = (830 \text{ N})\sin 85° + (800 \text{ N})\sin 80°$
$- 1600 \text{ N}$
$= 14.69 \text{ N}$

$F_{net} = \sqrt{(-66.58 \text{ N})^2 + (14.69 \text{ N})^2}$
$= 68.2 \text{ N}$

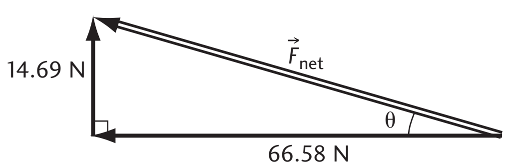
$\tan\theta = \dfrac{\text{opp}}{\text{adj}}$

$\tan\theta = \dfrac{14.69}{66.58}$

$\theta = 12.4°$

$\vec{F}_{net} = m\vec{a}$

$a = \dfrac{68.2 \text{ N}}{163 \text{ kg}}$
$= 0.418 \text{ m/s}^2$

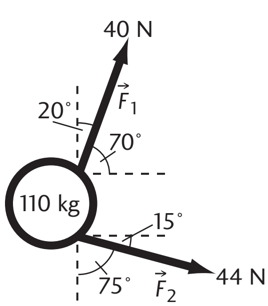



Therefore, the acceleration of the motor is approximately 0.42 m/s$^2$ [L12°U].

**b)** $\Delta t = 1.2$ s, $v_1 = 0$ m/s, $a = 0.42$ m/s$^2$
$\Delta d = v_1\Delta t + \frac{1}{2}a\Delta t^2$
$= (0 \text{ m/s})(1.2 \text{ s}) + \frac{1}{2}(0.42 \text{ m/s}^2)(1.2 \text{ s})^2$
$= 0.30$ m or 30 cm

Therefore, the people moved the motor 30 cm in 1.2 s.

**50.**

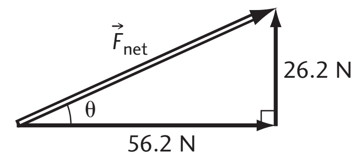



**a)** $m = 110$ kg
$\vec{F}_1 = 40$ N [U20°R]
$\vec{F}_2 = 44$ N [D75°R]
**x**$\}$ $F_{net_x} = (40 \text{ N})\cos 70° + (44 \text{ N})\cos 15°$
$= 56.2 \text{ N}$
**y**$\}$ $F_{net_y} = (40 \text{ N})\sin 70° - (44 \text{ N})\sin 15°$
$= 26.2 \text{ N}$
$F_{net} = \sqrt{(56.2 \text{ N})^2 + (26.2 \text{ N})^2}$
$= 61.99 \text{ N}$

$\tan\theta = \dfrac{\text{opp}}{\text{adj}}$

$= \dfrac{26.2}{56.2}$

$\theta = 25.0°$




$\vec{F}_{net} = m\vec{a}$

$a = \dfrac{61.99 \text{ N}}{110 \text{ kg}}$
$= 0.564 \text{ m/s}^2$

Therefore, the acceleration of the person is approximately 0.56 m/s$^2$ [R25°U].

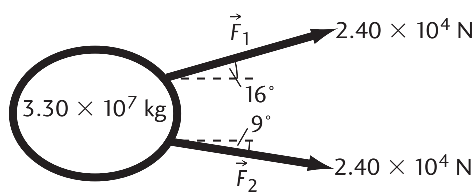
**b)** Let $x$ represent the extra force required to balance the weight of the sled.
$1078 \text{ N} + (44 \text{ N})\sin 15° = (40 \text{ N} + x)\sin 70°$

$40 \text{ N} + x = \dfrac{1078 \text{ N} + (44 \text{ N})\sin 15°}{\sin 70°}$

$x = 1159.3 \text{ N} - 40 \text{ N}$
$= 1119.3 \text{ N}$

Therefore, approximately 1100 N more lifting force is required.

**51. a)**




$m = 3.30 \times 10^7$ kg
$\vec{F}_1 = 2.40 \times 10^4$ N [R16°U]
$\vec{F}_2 = 2.40 \times 10^4$ N [R9°D]

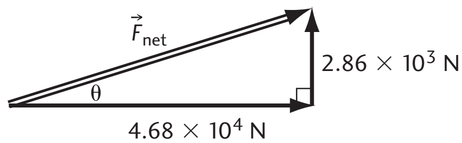
**Component Method**

**x**$\}$ $F_{net_x} = (2.40 \times 10^4 \text{ N})\cos 16° + (2.40 \times 10^4 \text{ N})\cos 9°$
$= 4.68 \times 10^4 \text{ N}$
**y**$\}$ $F_{net_y} = (2.40 \times 10^4 \text{ N})\sin 16° - (2.40 \times 10^4 \text{ N})\sin 9°$
$= 2.86 \times 10^3 \text{ N}$

$$F_{net} = \sqrt{(4.68 \times 10^4\,N)^2 + (2.86 \times 10^3\,N)^2}$$
$$= 4.69 \times 10^4\,N$$

$$\tan\theta = \frac{opp}{adj}$$
$$= \frac{2.86 \times 10^3}{4.68 \times 10^4}$$
$$\theta = 3.5°$$

$$\vec{F}_{net} = m\vec{a}$$
$$a = \frac{F_{net}}{m}$$
$$= \frac{4.69 \times 10^4\ N}{3.30 \times 10^7\ kg}$$
$$= 1.42 \times 10^{-3}\ m/s^2$$

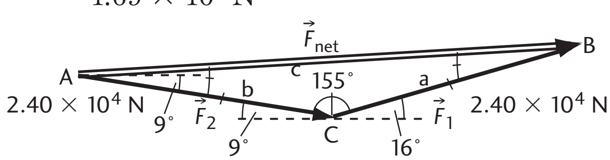



Therefore, the acceleration of the tanker is approximately $1.4 \times 10^{-3}\ m/s^2$ [R3.5°U].

**Trigonometric Method**

Using sine law,

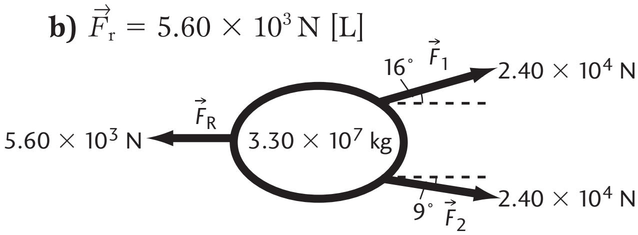
$$\frac{\sin A}{a} = \frac{\sin C}{c}$$
$$\frac{\sin 12.5°}{2.40 \times 10^4\ N} = \frac{\sin 155°}{F_{net}}$$
$$F_{net} = \frac{2.40 \times 10^4\ N(\sin 155°)}{\sin 12.5°}$$
$$= 4.69 \times 10^4\ N$$




$$\vec{F}_{net} = m\vec{a}$$
$$a = \frac{F_{net}}{m}$$
$$= \frac{4.69 \times 10^4\ N}{3.30 \times 10^7\ kg}$$
$$= 1.42 \times 10^{-3}\ m/s^2$$

Therefore, the acceleration of the tanker is approximately $1.4 \times 10^{-3}\ m/s^2$ [R3.5°U].

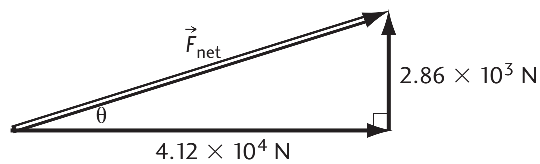
**b)** $\vec{F}_r = 5.60 \times 10^3\,N$ [L]




$$x\}\ F_{net_x} = (2.40 \times 10^4\,N)\cos 16° + (2.40 \times 10^4\,N)\cos 9° - 5.60 \times 10^3\,N$$
$$= 4.12 \times 10^4\,N$$
$$y\}\ F_{net_y} = (2.40 \times 10^4\ N)\sin 16° - (2.40 \times 10^4\ N)\sin 9°$$
$$= 2.86 \times 10^3\ N$$
$$F_{net} = \sqrt{(4.12 \times 10^4\ N)^2 + (2.86 \times 10^3\ N)^2}$$
$$= 4.13 \times 10^4\,N$$

$$\tan\theta = \frac{opp}{adj}$$
$$= \frac{2.86 \times 10^3}{4.12 \times 10^4}$$
$$\theta = 4.0°$$

$$\vec{F}_{net} = m\vec{a}$$
$$a = \frac{F_{net}}{m}$$
$$= \frac{4.13 \times 10^4\ N}{3.30 \times 10^7\ kg}$$
$$= 1.25 \times 10^{-3}\ m/s^2$$




Therefore, the acceleration of the tanker is approximately $1.2 \times 10^{-3}\,m/s^2$ [R4.0°U].

**c)** $\Delta t = 2.0$ min, $v_2 = ?$, $v_1 = 0$ m/s
$= 120$ s

**Case 1**

$a = 1.4 \times 10^{-3}\ m/s^2$
$$v_2 = v_1 + a\Delta t$$
$$= 0\ m/s + (1.4 \times 10^{-3}\ m/s^2)(120\ s)$$
$$= 0.17\ m/s$$
$$= 0.61\ km/h$$

Therefore, for case 1, the tanker would reach a speed of approximately 0.61 km/h in 2.0 minutes.

**Case 2**

$a = 1.2 \times 10^{-3}\ m/s^2$
$$v_2 = v_1 + a\Delta t$$
$$= 0\ m/s + (1.2 \times 10^{-3}\ m/s^2)(120\ s)$$
$$= 0.15\ m/s$$
$$= 0.54\ km/h$$

Therefore, for case 2, the tanker would reach a speed of approximately 0.54 km/h in 2.0 minutes.

**d)** $v_2 = 5.0$ km/h, $v_1 = 0$ m/s

$$= \frac{5000 \text{ m}}{3600 \text{ s}}$$

$$= 1.4 \text{ m/s}$$

**Case 1**

$a = 1.4 \times 10^{-3}$ m/s$^2$

$v_2^2 = v_1^2 + 2a\Delta d$

$$\Delta d = \frac{v_2^2 - v_1^2}{2a}$$

$$= \frac{(1.4 \text{ m/s})^2 - 0}{2(1.4 \times 10^{-3} \text{ m/s}^2)}$$

$$= 700 \text{ m}$$

Therefore, for case 1, a distance of approximately 700 m is required.

**Case 2**

$a = 1.2 \times 10^{-3}$ m/s$^2$

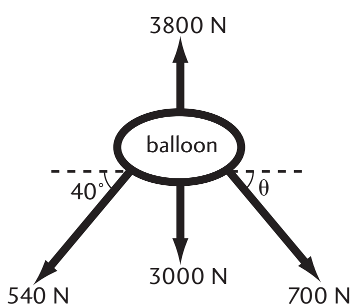
$$\Delta d = \frac{{v_2}^2 - {v_1}^2}{2a}$$

$$= \frac{(1.4 \text{ m/s})^2 - 0}{2(1.2 \times 10^{-3} \text{ m/s}^2)}$$

$$= 820 \text{ m}$$

Therefore, for case 2, a distance of approximately 820 m is required.

**52. a)**




$F_{\text{net}_y} = 3800 \text{ N} - 3000 \text{ N} - (700 \text{ N})\sin\theta - (540 \text{ N})\sin 40°$

$F_{\text{net}_y} = 0$

$(700 \text{ N})\sin\theta = 3800 \text{ N} - 3000 \text{ N} - (540 \text{ N})\sin 40°$

$$\sin\theta = \frac{800 \text{ N} - (540 \text{ N})\sin 40°}{700 \text{ N}}$$

$$\theta = 40°$$

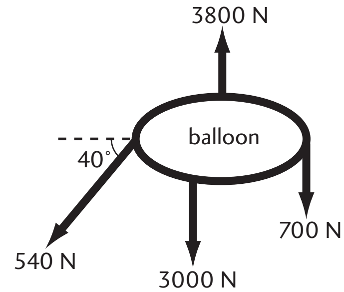
Therefore, the minimum angle required is approximately [R40°D].

**b)** $F_{\text{net}_x} = (700 \text{ N})\cos 40° - (540 \text{ N})\cos 40°$

$= 120$ N

The balloon accelerates to the right.

**c)**



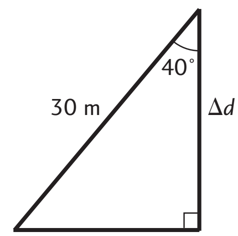

$F_{\text{net}_y} = 3800 \text{ N} - 3000 \text{ N} - 700 \text{ N} - (540 \text{ N})\sin 40°$

$= -247$ N

$$m = \frac{F}{g}$$

$$= \frac{3000 \text{ N}}{9.8 \text{ N/kg}}$$

$$= 306 \text{ kg}$$




$$\cos\theta = \frac{\text{adj}}{\text{hyp}}$$

$$\cos 40° = \frac{\Delta d}{30 \text{ m}}$$

$\Delta d = (30 \text{ m})\cos 40°$

$= 22.98$ m

$$a_y = \frac{F_{\text{net}_y}}{m}$$

$$= \frac{-247 \text{ N}}{306 \text{ kg}}$$

$$= -0.81 \text{ m/s}^2$$

$$\Delta\vec{d} = \vec{v}_1\Delta t + \tfrac{1}{2}\vec{a}\Delta t^2$$

$$\Delta t^2 = \frac{2\Delta d}{a}$$

$$\Delta t^2 = \frac{2(22.98 \text{ m})}{0.81 \text{ m/s}^2}$$

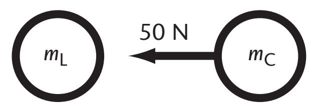
$\Delta t^2 = 56.7$ s

$\Delta t = 7.53$

$\cong 7.5$

Therefore, it will take approximately 7.5 s.

**53.** $m_L = 100$ kg, $m_C = 112$ kg




**a)** $F_{CL} = -F_{LC}$

$F_{CL}$ is the action force of magnitude 50 N (Canuck on Leaf).

$F_{LC}$ is the reaction force of 50 N but in the opposite direction as $F_{CL}$ (Leaf on Canuck).

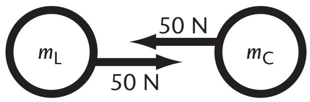
**b)** $\vec{F} = m\vec{a}$

$$a_L = \frac{F}{m_L} \qquad a_C = \frac{F}{m_C}$$

$$= \frac{-50\text{ N}}{100\text{ kg}} \qquad = \frac{50\text{ N}}{112\text{ kg}}$$

$$= -0.50\text{ m/s}^2 \qquad = 0.45\text{ m/s}^2$$

**54.** $m_L = 100\text{ kg}, m_C = 112\text{ kg}$




**a)** action–reaction pairs:

| Action | Reaction |
|---|---|
| Leaf pushes Canuck. | Canuck pushes Leaf because of Leaf push. |
| Canuck pushes Leaf. | Leaf pushes Canuck because of Canuck push. |

**b)** $F_{\cancel{net}} = -100\text{ N}$
$ma$

$$a_L = \frac{F}{m_L} \qquad a_C = \frac{F}{m_C}$$

$$= \frac{-100\text{ N}}{100\text{ kg}} \qquad = \frac{100\text{ N}}{112\text{ kg}}$$

$$= -1.0\text{ m/s}^2 \qquad = 0.89\text{ m/s}^2$$

**55.**


**b)** $F_{\cancel{net}} = -100\text{ N} + 5\text{ N} \quad F_{\cancel{net}} = 100\text{ N} - 5\text{ N}$
$ma \qquad ma$

$$a_L = \frac{F}{m_L} \qquad a_C = \frac{F}{m_C}$$

$$= \frac{-95\text{ N}}{100\text{ kg}} \qquad = \frac{95\text{ N}}{112\text{ kg}}$$

$$= -0.95\text{ m/s}^2 \qquad = 0.85\text{ m/s}^2$$

# Chapter 5

(Common constants: $m_{Earth} = 5.98 \times 10^{24}$ kg, $r_{Earth} = 6.38 \times 10^6$ m, $G = 6.67 \times 10^{-11}$ Nm$^2$/kg$^2$)

**20.** $F = \dfrac{Gm_1m_2}{r^2}$

**a)** $m_1 = 60$ kg, $m_2 = 80$ kg, $r = 1.4$ m

$$F = \frac{(6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2)(60\ \text{kg})(80\ \text{kg})}{(1.4\ \text{m})^2}$$

$= 1.60 \times 10^{-7}$ N

**b)** $m_1 = 60$ kg, $m_2 = 130$ t $= 130\ 000$ kg, $r = 10$ m

$$F = \frac{(6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2)(60\ \text{kg})(130\ 000\ \text{kg})}{(10\ \text{m})^2}$$

$= 5.2 \times 10^{-6}$ N

**c)** $m_1 = 60$ kg, $m_2 = 5.22 \times 10^9$ kg, $r = 1.0$ km $= 1000$ m

$$F = \frac{(6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2)(60\ \text{kg})(5.22 \times 10^9\ \text{kg})}{(1000\ \text{m})^2}$$

$= 2.1 \times 10^{-5}$ N

**d)** $m_1 = 60$ kg, $m_2 = 0.045$ kg, $r = 0.95$ m

$$F = \frac{(6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2)(60\ \text{kg})(0.045\ \text{kg})}{(0.95\ \text{m})^2}$$

$= 2.0 \times 10^{-10}$ N

**21.** $m_{Moon} = 7.34 \times 10^{22}$ kg, $m_{Earth} = 5.98 \times 10^{24}$ kg, $F = 2.00 \times 10^{20}$, $r = ?$

$$r = \frac{Gm_1m_2}{F}$$

$$= \sqrt{\frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(7.34 \times 10^{22}\ \text{kg})(5.98 \times 10^{24}\ \text{kg})}{2.00 \times 10^{20}\ \text{N}}}$$

$= \sqrt{1.46 \times 10^{17}\ \text{m}^2}$

$= 3.83 \times 10^8$ m

**22.** $m_1 = m_2$, $F = 3.5 \times 10^3$ N, $r = 85$ m

$$m_1m_2 = \frac{Fr^2}{G}$$

$$m = \frac{Fr^2}{G}$$

$$= \frac{(3.5 \times 10^3\ \text{N})(85\ \text{m})^2}{6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2}$$

$= 6.2 \times 10^8$ kg

**23. a)** $m = 68.0$ kg, $g = 9.83$ m/s$^2$

$F = mg$

$= (68.0\ \text{kg})(9.83\ \text{m/s}^2)$

$= 668$ N

**b)** $m = 5.98 \times 10^{24}$ kg,

$r = 6.38 \times 10^6$ m $+ 8848$ m $= 6\ 388\ 848$ m

$$g = \frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})}{(6\ 388\ 848\ \text{m})^2}$$

$= 9.77$ m/s$^2$

$F = mg$

$= (68.0\ \text{kg})(9.77\ \text{m/s}^2)$

$= 664$ N

**c)** $m_{Earth} = 5.98 \times 10^{24}$ kg,

$r = (2.5)(6.38 \times 10^6\ \text{m})$

$$g = \frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})}{[(2.5)(6.38 \times 10^6\ \text{m})]^2}$$

$= 1.57$ m/s$^2$

$F = mg$

$= (68.0)(1.57\ \text{m/s}^2)$

$= 107$ N

**24.** Mars: $r = 3.43 \times 10^6$ m, $m = 6.37 \times 10^{23}$ kg

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

$$= \frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(6.37 \times 10^{23}\ \text{kg})}{(3.43 \times 10^6\ \text{m})^2}$$

$= 3.61$ m/s$^2$

Therefore, $g_{Mars} = 3.61$ m/s$^2$

Jupiter: $r = 7.18 \times 10^7$ m, $m = 1.90 \times 10^{27}$ kg

$$g = \frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(1.90 \times 10^{27}\ \text{kg})}{(7.18 \times 10^7\ \text{m})^2}$$

$= 24.58$ m/s$^2$

Therefore, $g_{Jupiter} = 24.6$ m/s$^2$

Mercury: $r = 2.57 \times 10^6$ m, $m = 3.28 \times 10^{23}$ kg

$$g = \frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(3.28 \times 10^{23}\ \text{kg})}{(2.57 \times 10^6\ \text{m})^2}$$

$= 3.312$ m/s$^2$

Therefore, $g_{Mercury} = 3.31$ m/s$^2$

**25.** $m_1 = m_2 = 10$ t $= 10\ 000$ kg, $r = 20$ m

$$F = \frac{Gm_1m_2}{r^2}$$

$$F = \frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(10\ 000\ \text{kg})(10\ 000\text{kg})}{(20\ \text{m})^2}$$

$F = 1.67 \times 10^{-5}$ N

**26.** $g = 9.70\ \text{m/s}^2$, $m_E = 5.98 \times 10^{24}$ kg

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

$$r = \sqrt{\frac{Gm}{g}}$$

$$= \sqrt{\frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})}{9.70\ \text{m/s}^2}}$$

$$= 6\ 412\ 503.89\ \text{m}$$

$$h = 6\ 412\ 503.89\ \text{m} - 6.38 \times 10^6$$

$$= 32\ 503\ \text{m}$$

$$\cong 3.25 \times 10^4\ \text{m}$$

**27.** $g = 0.1\ \text{m/s}^2$, $m_E = 5.98 \times 10^{24}$ kg

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

$$r = \sqrt{\frac{Gm}{g}}$$

$$= \sqrt{\frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})}{0.1\ \text{m/s}^2}}$$

$$= 63\ 155\ 839\ \text{m}$$

$$h = 63\ 155\ 839\ \text{m} - 6.38 \times 10^6\ \text{m}$$

$$= 5.68 \times 10^7\ \text{m}$$

**28.** $F_1 = 980$ N

**a)** At $3r$,

$$F_2 = \frac{(F_1)(r_1)^2}{(3r_1)^2}$$

$$= \tfrac{1}{9}F_1$$

$$= \frac{980\ \text{N}}{9}$$

$$= 109\ \text{N}$$

**b)** At $7r$,

$$F_2 = \frac{(F_1)(r_1)^2}{(7r_1)^2}$$

$$= \tfrac{1}{49}F_1$$

$$= \frac{980\ \text{N}}{49}$$

$$= 20.0\ \text{N}$$

**c)** $\frac{128\ 000\ 000\ \text{m}}{6.38 \times 10^6\ \text{m}} = 20.1$ times the radius of Earth.

$$F_2 = \frac{(F_1)(r_1)^2}{(20.1r_1)^2}$$

$$= \frac{980\ \text{N}}{404.01}$$

$$= 2.43\ \text{N}$$

**d)** $$F_2 = \frac{(F_1)(r_1)^2}{(4.5r_1)^2}$$

$$= \frac{980\ \text{N}}{20.25}$$

$$= 48.4\ \text{N}$$

**e)** $\frac{745\ 500\ 000\ \text{m}}{6.38 \times 10^6\ \text{m}} = 116.85$ times the radius of Earth.

$$F_2 = \frac{(F_1)(r_1)^2}{(116.85r_1)^2}$$

$$= \frac{980}{(116.85)^2}$$

$$= 0.072\ \text{N}$$

**29. a)** $$F_2 = \frac{(F_1)(r_1)^2}{(\frac{1}{2}r_1)^2}$$

$$= 4F_1$$

$$= 4(500\ \text{N})$$

$$= 2000\ \text{N}$$

**b)** $$F_2 = \frac{(F_1)(r_1)^2}{(\frac{1}{8}r_1)^2}$$

$$= 64F_1$$

$$= 64(500\ \text{N})$$

$$= 32\ 000\ \text{N}$$

**c)** $$F_2 = \frac{(F_1)(r_1)^2}{(0.66r_1)^2}$$

$$= 2.30F_1$$

$$= 2.30(500\ \text{N})$$

$$= 1150\ \text{N}$$

**30.** $\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

Since $v_1 = 0$, $\Delta\vec{d} = \frac{1}{2}\vec{a}\Delta t^2$ and $\Delta t = \frac{2\Delta d}{a}$

$$t_{\text{Earth}} = \sqrt{\frac{2(553\ \text{m})}{9.83\ \text{m/s}^2}}$$

$$= 10.4\ \text{s}$$

$$t_{\text{Mars}} = \sqrt{\frac{2(553\ \text{m})}{3.61\ \text{m/s}^2}}$$

$$= 5.53\ \text{s}$$

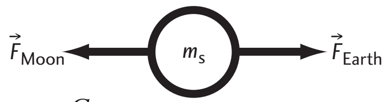
$$t_{\text{Jupiter}} = \sqrt{\frac{2(553\ \text{m})}{24.58\ \text{m/s}^2}}$$

$$= 6.71\ \text{s}$$

$$t_{\text{Mercury}} = \sqrt{\frac{2(553\ \text{m})}{3.31\ \text{m/s}^2}}$$

$$= 18.3\ \text{s}$$

**31.** $m_{\text{Moon}} = 7.34 \times 10^{22}$ kg, $m_{\text{Earth}} = 5.98 \times 10^{24}$ kg, $d = 3.83 \times 10^{8}$ m, $m_{\text{Satellite}} = 1200$ kg




**i)** $F_{\text{Earth}} = \dfrac{Gm_{\text{Earth}}m_{\text{Satellite}}}{(\frac{2}{3}d)^2}$

$= \dfrac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})m_{\text{Satellite}}}{[\frac{2}{3}(3.83 \times 10^{8}\ \text{m})]^2}$

$= (6.12 \times 10^{-3})m_{\text{Satellite}}$ N

$F_{\text{Moon}} = \dfrac{Gm_{\text{Earth}}m_{\text{Satellite}}}{(\frac{1}{3}d)^2}$

$= \dfrac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)(7.34 \times 10^{22}\ \text{kg})\ m_{\text{Satellite}}}{[\frac{1}{3}(3.83 \times 10^{8}\ \text{m})]^2}$

$= (3.00 \times 10^{-4})m_{\text{Satellite}}$ N

$F_{\text{net}} = F_{\text{Earth}} - F_{\text{Moon}} = (6.12 \times 10^{-3})m_{\text{Satellite}} - (3.00 \times 10^{-4})m_{\text{Satellite}}$
$= (5.82 \times 10^{-3})(1200\ \text{kg})$ N
$= 6.98$ N

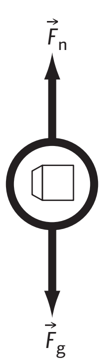
**ii)** $g = \dfrac{F}{m}$

$= \dfrac{5.82\ \text{N}}{1200\ \text{kg}}$

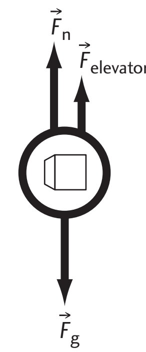
$= 4.85 \times 10^{-3}$ N/kg

**32.** $F_{\text{net}} = F_{\text{n}} - F_{\text{g}}$ and $F_{\text{g}} = mg$
$F_{\text{n}} = mg$
$= (40\ \text{kg})(9.8\ \text{m/s}^2)$
$= 392$ N

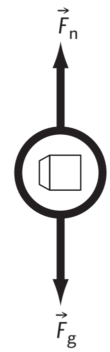

**33. a)** no change,
$F_{\text{n}} = mg\ (F_{\text{net}} = 0)$



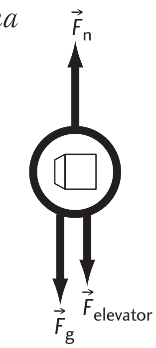

**b)** greater, $F_{\text{net}} = F_{\text{n}} - mg$
Therefore, $F_{\text{n}} = mg + ma$



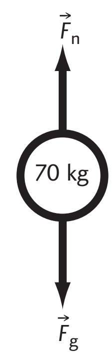

**c)** no change,
$F_{\text{n}} = mg\ (F_{\text{net}} = 0)$



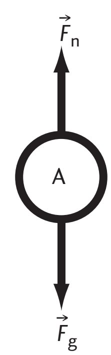

**d)** less, $F_{\text{n}} = mg - ma$




**34.** $m = 70$ kg, $F_{\text{n}} = 750$ N
weight $= F_{\text{g}} = (70\ \text{kg})(9.8\ \text{m/s}^2)$
$= 686$ N
$F_{\text{net}} = F_{\text{n}} - mg$
$a = \dfrac{750\ \text{N} - 686\ \text{N}}{70\ \text{kg}}$
$a = 0.91\ \text{m/s}^2$



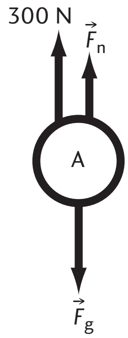

**35. a)** $m_{\text{T}} = 134$ kg
$F_{\text{net}} = F_{\text{n}} - F_{\text{g}} = 0$
$F_{\text{n}} = mg$
$= (134\ \text{kg})(9.8\ \text{m/s}^2)$
$= 1313$ N
$F_{\text{n}} \cong 1300$ N



**b)** $F_{net} = F_n + 300\text{ N} - mg = 0$

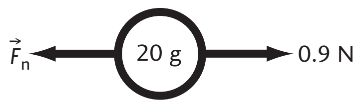
$F_n = (134\text{ kg})(9.8\text{ m/s}^2) - 300\text{ N}$

$= 1013\text{ N}$




**36.** $F_{net_x} = 0.9\text{ N} - F_n = 0$

The normal force ($F_n$) is 0.9 N.




**37.** $m = 1.4\text{ kg}$

$F_{net} = 21\text{ N} - F_n - mg = 0$

$F_n = 21\text{ N} - mg$

$= 21\text{ N} - (1.4\text{ kg})(9.8\text{ m/s}^2)$

$= 7.3\text{ N}$


**38.** $m_g = 26\text{ kg}$, $m_c = 18\text{ kg}$

$F_{net_y} = F_n + 10\text{ N} - 16\text{ N} - mg = 0$

$(26\text{ kg} + 18\text{ kg})(9.8\text{ m/s}^2) + 16\text{ N} - 10\text{ N} = F_n$

$F_n = 437\text{ N}$

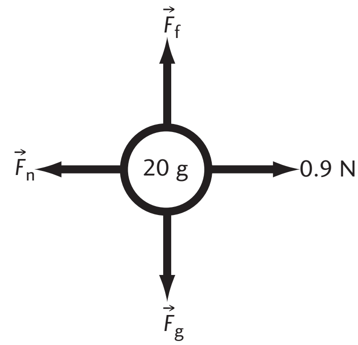

**39.** $\mu_k = 0.3$, $m = 20\text{ g} = 0.02\text{ kg}$

$F_n = 0.9\text{ N}$

**a)** $F_f = \mu F_n$

$= (0.3)(0.9)$

$= 0.27\text{ N}$




**b)** $F_g = mg$

$= (0.02\text{ kg})(9.8\text{ m/s}^2)$

$= 0.196\text{ N}$

$\cong 0.20\text{ N}$

**c)** $F_{net} = F_g - F_f$

$ma = 0.20\text{ N} - 0.27\text{ N}$

friction > weight

Therefore, the magnet does not move.

**40. a)** $F_f = \mu F_n$ where $F_n = 437.2\text{ N}$ and $\mu_k = 0.12$

$= (0.12)(437.2\text{ N})$

$= 52.46\text{ N}$

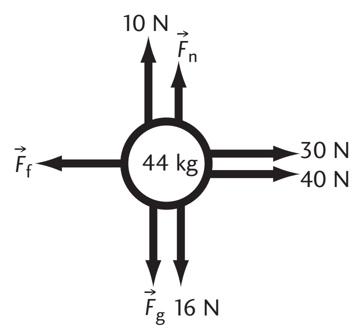
$\cong 52\text{ N}$

**b)** $F_{net} = F_{app} - F_f$

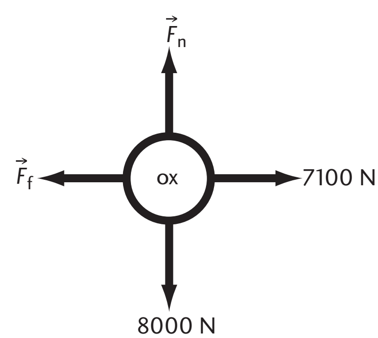
$a = \dfrac{F_{app} - F_f}{m}$

$= \dfrac{70\text{ N} - 52.46\text{ N}}{(26\text{ kg} + 18\text{ kg})}$

$= 0.40\text{ m/s}^2$



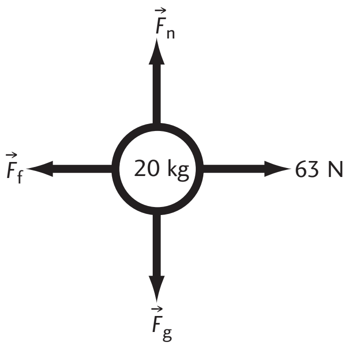

**41.** $a = 0$, $F_g = 8000\text{ N}$, $F_{app} = 7100\text{ N}$



$F_{net_y} = F_n - 8000 \text{ N} = 0$
so $F_n = 8000$ N
$F_f = \mu(8000 \text{ N})$
$F_{net_x} = 7100 \text{ N} - F_f = 0$
so $F_f = 7100$ N

$$\text{Therefore, } \mu = \frac{7100 \text{ N}}{8000 \text{ N}} = 0.89$$

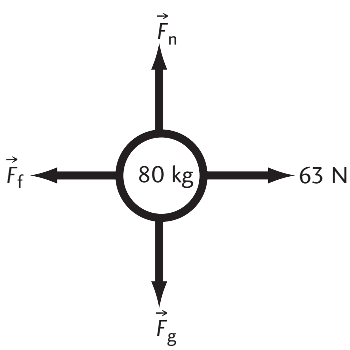
**42.** $m = 20$ kg, $F_{app} = 63$ N, $a = 0$




$F_{net_y} = F_n - F_g = 0$
$F_n = mg$
$F_f = \mu mg$
$F_{net} = F_{app} - F_f$
$ma = F_{app} - \mu mg$
$0 = 63 \text{ N} - \mu(20 \text{ kg})(9.8 \text{ m/s}^2)$

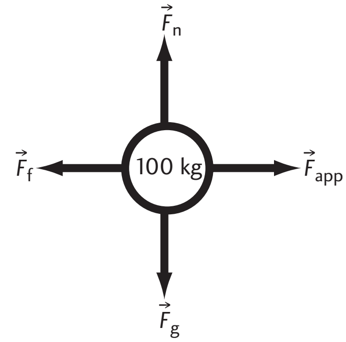
$$\mu = \frac{63 \text{ N}}{196 \text{ N}} = 0.32$$

**43.** $F_{app} = 63$ N, $m = 20 \text{ kg} + 60 \text{ kg} = 80$ kg




$F_f = \mu F_n$
$= \mu mg$
$= (0.32)(80 \text{ kg})(9.8 \text{ m/s}^2)$
$= 251$ N
$F_{net} = F_{app} - F_f$
$ma = 63 \text{ N} - 251 \text{ N}$
Therefore, the crate cannot move because the friction is too large.

**44.** $m = 100$ kg, $\mu_k = 0.4$




**Case 1**
$F_{net_y} = F_n - F_g = 0$
$F_n = \mu mg$
$F_{net_x} = F_{app} - F_f$
$ma = F_{app} > F_f$
$a \neq 0$, actually $a > 0$
Therefore, $F_{app} > \mu mg$
$F_{app} > (0.4)(100 \text{ kg})(9.8 \text{ m/s}^2)$
$F_{app} > 392$ N

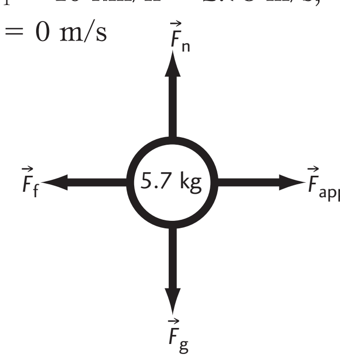
**Case 2**
$F_{net} = F_{app}$

$$a = \frac{F_{app}}{m}$$

Therefore, any applied force will start the fridge moving.

**45.** $m = 100$ kg, $\mu_s = 0.46$
$F_{net_y} = F_n - F_g = 0$
$F_n = F_g$
$= \mu_s(mg)$
$= (0.46)(100 \text{ kg})(9.8 \text{ m/s}^2)$
$= 450.8$ N
$\cong 451$ N
$F_{net} = F_{app} - F_f$ and $ma \neq 0$
$ma = F_{app} - F_f > 0$
$F_{app} > F_f$
$F_{app} > 451$ N

**46.** $m = 5.7$ kg, $v_1 = 10 \text{ km/h} = 2.78$ m/s, $\mu_k = 0.34$, $v_2 = 0$ m/s



**a)** $F_f = \mu_k F_n$

$= \mu_k mg$

$= (0.34)(5.7\text{ kg})(9.8\text{ m/s}^2)$

$= 18.99\text{ N}$

$\cong 19\text{ N}$

**b)** $F_{net} = -F_f$

$a = \dfrac{-19\text{ N}}{5.7\text{ kg}}$

$a = -3.33\text{ m/s}^2$

**c)** $\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d} = 0$

$\dfrac{-v_1{}^2}{2a} = \Delta d$

$\Delta d = \dfrac{-(2.78\text{ m/s})^2}{2(-3.33\text{ m/s}^2)}$

$= 1.16\text{ m}$

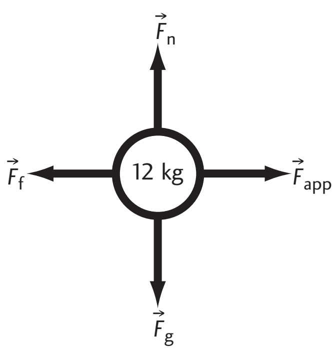
**d)** $\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$

$\dfrac{-v_1}{a} = \Delta t$

$\Delta t = \dfrac{-2.78\text{ m/s}}{-3.33\text{ m/s}^2}$

$= 0.83\text{ s}$

**47.** $m = 12\text{ kg}$, $v_1 = 0\text{ m/s}$,
$v_2 = 4.5\text{ km/h} = 1.25\text{ m/s}$,
$\Delta t = 3.0\text{ s}$, $\mu_k = 0.8$




**a)** $a = \dfrac{v_2 - v_1}{\Delta t}$

$= \dfrac{(1.25\text{ m/s} - 0\text{ m/s})}{3.0\text{ s}}$

$= 0.42\text{ m/s}^2$

$F_{net} = F_{app}$

$ma = (12\text{ kg})(0.42\text{ m/s}^2)$

$= 5.04\text{ N}$

**b)** $F_{net_y} = F_n - F_g = 0$

$F_n = F_g$

$F_f = \mu mg$

$F_{app} - F_f = ma = 5.04\text{ N}$

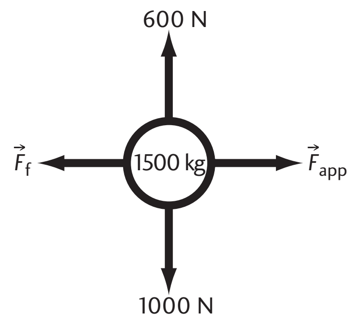
$F_{app} = F_f + 5.04\text{ N}$

$= \mu_k\,\text{mg} + 5.04\text{ N}$

$= (0.8)(12\text{ kg})(9.8\text{ m/s}^2) + 5.04\text{ N}$

$= 99\text{ N}$

**48.** $m = 1500\text{ kg}$, $a = 5.0\text{ m/s}^2$,
$F_L = 600\text{ N}$, $F_G = 1000\text{ N}$, $\mu_k = 1.0$




$F_{net_y} = mg + F_G - F_n + F_L = 0$

$F_n = mg + F_G - F_L$

$= (1500\text{ kg})(9.8\text{ m/s}^2) + 1000\text{ N} - 600\text{ N}$

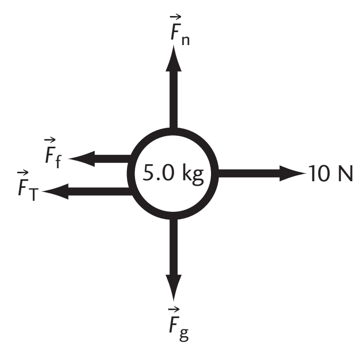
$= 15\ 100\text{ N}$

$F_f = \mu_k F_n = (1.0)(15\ 100\text{ N}) = 15\ 100\text{ N}$

$F_{net_x} = F_D - F_f$

Therefore, $F_D = ma + F_f = 2.26 \times 10^4\text{ N}$

**49.** $m_1 = 5.0\text{ kg}$, $m_2 = 2.0\text{ kg}$, $F_{app} = 10\text{ N}$




**a)** $F_{net_y} = F_n - F_g = 0$

Therefore, $F_n = mg$

$F_f = \mu_k F_n = (0.1)(5.0\text{ kg} + 2.0\text{ kg})(9.8\text{ m/s}^2)$

$= 6.86\text{ N}$

$F_{net_x} = F_{app} - F_f = ma$

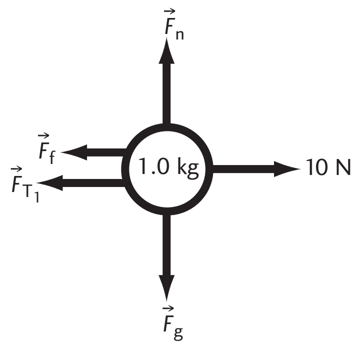
$a = \dfrac{F_{app} - F_f}{m_1 + m_2}$

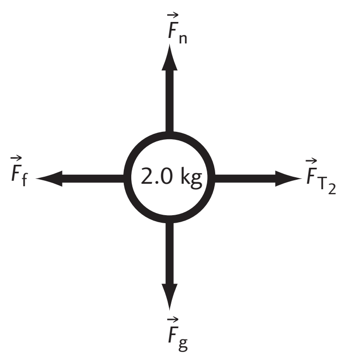
$= \dfrac{(10\text{ N} - 6.86\text{ N})}{7.0\text{ kg}}$

$= 0.45\text{ m/s}^2$

**b)** $F_{net_x} = F_T - F_f$
Therefore, $F_T = ma + F_f$ where
$F_f = \mu mg$
$F_T = (2\text{ kg})(0.45\text{ m/s}^2)$
$+ (0.1)(2\text{ kg})(9.8\text{ m/s}^2)$
$= 2.86\text{ N}$

**50.** $m_1 = 1.0\text{ kg}$, $m_2 = 5.0\text{ kg}$, $m_3 = 2.0\text{ kg}$, $F_{app} = 10\text{ N}$, $\mu_k = 0.1$




**i)** $F_{net_y} = F_n - F_g = 0$
Therefore, $F_n = F_g$
$F_f = \mu_k F_g$
$= \mu_k m_T g$
$= (0.1)(1.0\text{ kg} + 5.0\text{ kg} + 2.0\text{ kg})$
$(9.8\text{ m/s}^2)$
$= 7.84\text{ N}$
$F_{net_x} = F_{app} - F_f = ma$
$F_{app} - F_f = m_T a$
$$a = \frac{F_{app} - F_f}{m_T}$$
$$= \frac{10\text{ N} - 7.84\text{ N}}{8.0\text{ kg}}$$
$= 0.27\text{ m/s}^2$

**ii)** $F_f = \mu mg$
$= (0.1)(1.0\text{ kg})(9.8\text{ m/s}^2)$
$= 0.98\text{ N}$
$F_{net_x} = F_{app} - F_{T_1} - F_f = ma$
$F_{T_1} = F_{app} - F_f - ma$
$= 10\text{ N} - 0.98\text{ N} - (1.0\text{ kg})(0.27\text{ m/s}^2)$
$= 8.75\text{ N}$
$\cong 8.8\text{ N}$
$F_f = \mu mg$
$= (0.1)(2.0\text{ kg})(9.8\text{ m/s}^2)$
$= 1.96\text{ N}$
$F_{net_x} = F_{T_2} - F_f$
$F_{T_2} = ma + F_f$
$= (2.0\text{ kg})(0.27\text{ m/s}^2) + 1.96$
$= 2.5\text{ N}$

**51. a)** $k = \text{slope} = \dfrac{50\text{ N}}{0.8\text{ m}} = 62.5\text{ N/m}$
$\cong 62\text{ N/m}$

**b)** Area → Nm → Joules

**52.** $k = 58\text{ N/m}$

**a)** $x = 0.30\text{ m}$
$F = (58\text{ N/m})(0.30\text{ m}) = 17.4\text{ N} \cong 17\text{ N}$

**b)** $x = 56\text{ cm} = 0.56\text{ m}$
$F = (58\text{ N/m})(0.56\text{ m}) = 32.48\text{ N} \cong 32\text{ N}$

**c)** $x = 1023\text{ mm} = 1.023\text{ m}$
$F = (58\text{ N/m})(1.023\text{ m}) = 59.33\text{ N} \cong 59\text{ N}$

**53.** spring constant
$$k = \frac{F}{x} = \frac{365\text{ N}}{0.30\text{ m}} = 1216.67\text{ N/m}$$
**a)** $x = \dfrac{F}{k} = \dfrac{400\text{ N}}{1216.67\text{ N/m}} = 0.33\text{ m}$

**b)** $x = \dfrac{223\text{ N}}{1216.67\text{ N/m}} = 0.18\text{ m}$

**c)** $x = \dfrac{2.0\text{ N}}{1216.67\text{ N/m}} = 1.64 \times 10^{-3}\text{ m}$

**54.** $k = 25\text{ N/m}$, $x = 0.3\text{ m}$, $2.2\text{ lb} = 1\text{ kg}$
$F_g = kx$
$= (25\text{ N/m})(0.3\text{ m})$
$= 7.5\text{ N}$
$F_s = F_g = mg$
$$m = \frac{F}{g} = \frac{7.5\text{ N}}{9.8\text{ m/s}^2} = 0.77\text{ kg} = 1.68\text{ lb}$$

**55.** $m = 50$ kg, $k = 2200$ N/m, $x = 0.25$ m

$F_s = (2200 \text{ N/m})(0.25 \text{ m}) = 550 \text{ N}$

$F_s - mg = ma$

$$a = \frac{F_s - mg}{m}$$

$$= \frac{550 \text{ N} - (50 \text{ kg})(9.8 \text{ m/s}^2)}{50 \text{ kg}}$$

$$= 1.2 \text{ m/s}^2$$

**56.** $m = 50$ kg, $a = 0$, $x = 0.17$

$F_s - mg = 0$

$F_s = mg = (50 \text{ kg})(9.8 \text{ m/s}^2) = 490 \text{ N}$

$F_s = kx$

$$k = \frac{F_s}{x}$$

$$= \frac{490 \text{ N}}{0.17 \text{ m}} = 2882.35 \text{ N/m} \cong 2900 \text{ N/m}$$

**57.** $m = 670$ kg, $k = 900$ N/m, $x = 1.55$ m

$F_{net_y} = F_s + F_n - F_g = 0$ where $F_g = mg$

$F_n = mg - F_s$

$= (670 \text{ kg})(9.8 \text{ m/s}^2) - (900 \text{ N/m})(1.55 \text{ m})$

$= 6566 \text{ N} - 1395 \text{ N}$

$= 5171 \text{ N}$

$\cong 5200 \text{ N}$

**58.** $m = 12$ kg, $a = 3.0$ m/s$^2$, $k = 40$ N/m

$F_{net} = ma = (12 \text{ kg})(3.0 \text{ m/s}^2) = 36 \text{ N}$

$F_s = kx$, $ma = F_s$

Therefore, $36 \text{ N} = kx$

$$x = \frac{F}{k} = \frac{36 \text{ N}}{40 \text{ N/m}} = 0.9 \text{ m}$$

**59.** $m = 40$ kg, $k = 900$ N/m,

$\mu_k = 0.6$, $x = 0.4$ m

$F_{net_y} = F_n - F_g = 0$

$F_n = F_g$

So $F_f = \mu_k mg$

$= (40)(9.8 \text{ m/s}^2)(0.6)$

$= 235.2 \text{ N}$

$F_s = kx = (900 \text{ N/m})(0.4 \text{ m}) = 360 \text{ N}$

$F_{net_x} = F_s - F_f = ma$

$$a = \frac{F_s - F_f}{m}$$

$$= \frac{(360 \text{ N} - 235.2 \text{ N})}{40 \text{ kg}}$$

$$= 3.1 \text{ m/s}^2$$

# Chapter 6

**6.** Let $\theta$ be the angle of the inclined plane when the box starts to slide.

At this angle,

$F_s = \mu_s F_n$

$F_s = (0.35)(mg \cos \theta)$ (eq. 1)

$F_x = mg \sin \theta$ (eq. 2)

Set equation 1 equal to equation 2:

$(0.35)(mg \cos \theta) = mg \sin \theta$

$0.35 = \dfrac{\sin \theta}{\cos \theta}$

$\tan \theta = 0.35$

$\theta = \tan^{-1}(0.35)$

$\theta = 19°$

The minimum angle required is 19°.

**7.** **a)** The acceleration for child 1:

$F_{net} = F_x$

$m_1 a_1 = m_1 g \sin \theta$

$a_1 = g \sin \theta$

$a_1 = (9.8\ \text{m/s}^2) \sin 30°$

$a_1 = 4.9\ \text{m/s}^2$

The acceleration for child 2:

$F_{net} = F_x$

$m_2 a_2 = m_2 g \sin \theta$

$a_2 = g \sin \theta$

$a_2 = 4.9\ \text{m/s}^2$

Both children accelerate downhill at $4.9\ \text{m/s}^2$.

**b)** They reach the bottom at the same time.

**8.** **a)** $F_{net} = F_x - F_k$

$ma = mg \sin \theta - \mu_k F_n$

$ma = mg \sin \theta - \mu_k (mg \cos \theta)$

$a = g \sin \theta - \mu_k g \cos \theta$

$a = (9.8\ \text{m/s}^2) \sin 25° - (0.45)(9.8\ \text{m/s}^2) \cos 25°$

$a = 0.14\ \text{m/s}^2$

The acceleration of the box is $0.14\ \text{m/s}^2$.

**b)** $v_f^2 = v_i^2 + 2ad$

$v_f^2 = 2(0.14\ \text{m/s}^2)(200\ \text{m})$

$v_f = 7.6\ \text{m/s}$

The box reaches the bottom of the hill at $7.6\ \text{m/s}^2$.

**c)** $a = \dfrac{v_f - v_i}{t}$

$t = \dfrac{v_f}{a}$

$t = \dfrac{7.6\ \text{m/s}}{0.14\ \text{m/s}^2}$

$t = 53\ \text{s}$

It takes the box 53 s to reach the bottom of the hill.

**9.** Find his final speed, $v_f$, at the bottom of the ramp by first finding his acceleration:

$F_{net} = F_x$

$ma = mg \sin \theta$

$a = g \sin \theta$

$a = (9.8\ \text{m/s}^2) \sin 35°$

$a = 5.6\ \text{m/s}^2$

His final speed at the bottom of the ramp is:

$v_f^2 = v_i^2 + 2ad$

$v_f^2 = 2(5.6\ \text{m/s}^2)(50\ \text{m})$

$v_f = 23.6\ \text{m/s}$

$v_f$ will be the initial speed, $v_{i2}$, for the horizontal distance to the wall of snow.

Find the deceleration caused by the snow:

$F_{net} = F_k$

$ma = \mu_k F_n$

$ma = (0.50)(-9.8\ \text{m/s}^2)m$

$a = -4.9\ \text{m/s}^2$

Find the distance Boom-Boom will go into the wall of snow:

$v_f^2 = v_i^2 + 2ad$

$0 = v_i^2 + 2ad$

$-v_i^2 = 2ad$

$d = \dfrac{-v_i^2}{2a}$

$d = \dfrac{-(23.6\ \text{m/s})^2}{2(-4.9\ \text{m/s}^2)}$

$d = 57\ \text{m}$

Boom-Boom will go 57 m into the wall of snow.

**10.** Find the net force on Spot, then solve for the net acceleration:

$F_{net} = F_r - F_x$

$F_{net} = 2000\ \text{N} - mg \sin \theta$

$ma = 2000\ \text{N} - (250\ \text{kg})(9.8\ \text{m/s}^2)(\sin 20°)$

$ma = 2000\ \text{N} - 838\ \text{N}$

$ma = 1162\ \text{N}$

$a = \dfrac{1162\ \text{N}}{250\ \text{kg}}$

$a = 4.6\ \text{m/s}^2$

Find time, $t$:

$$d = v_i t + \frac{1}{2}at^2$$

$$d = \frac{1}{2}at^2$$

$$250\text{ m} = \frac{1}{2}(4.6\text{ m/s}^2)t^2$$

$$t^2 = 108\text{ s}^2$$

$$t = 10\text{ s}$$

**11. a) (a)** For $m_1$:

$$F_{net1} = T$$

$$T = m_1 a \qquad \text{(eq. 1)}$$

For $m_2$:

$$F_{net2} = F_g - T$$

$$m_2 a = m_2 g - T \qquad \text{(eq. 2)}$$

Substitute equation 1 into equation 2:

$$m_2 a = m_2 g - m_1 a$$

$$(m_1 + m_2)a = m_2 g$$

$$(40\text{ kg})a = (20\text{ kg})(9.8\text{ m/s}^2)$$

$$\vec{a} = 4.9\text{ m/s}^2\text{ [left]}$$

For tension $T$, substitute acceleration into equation 1:

$T = m_1 a$

$T = (20\text{ kg})(4.9\text{ m/s}^2)$

$T = 98\text{ N}$

**(b)** Assume the system moves towards $m_3$:

For $m_1$:

$$F_{net1} = T_1 - F_{1g}$$

$$m_1 a = T_1 - m_1 g \qquad \text{(eq. 1)}$$

For $m_2$:

$$F_{net2} = T_2 - T_1$$

$$m_2 a = T_2 - T_1 \qquad \text{(eq. 2)}$$

For $m_3$:

$$F_{net3} = F_{3g} - T_2$$

$$m_3 a = m_3 g - T_2 \qquad \text{(eq. 3)}$$

Add equations 1, 2, and 3:

$$m_1 a = T_1 - m_1 g \qquad \text{(eq. 1)}$$

$$m_2 a = T_2 - T_1 \qquad \text{(eq. 2)}$$

$$m_3 a = m_3 g - T_2 \qquad \text{(eq. 3)}$$

$$(m_1 + m_2 + m_3)a = m_3 g - m_1 g$$

$$(10\text{ kg} + 10\text{ kg} + 30\text{ kg})a = (30\text{ kg})(9.8\text{ m/s}^2) - (10\text{ kg})(9.8\text{ m/s}^2)$$

$$(50\text{ kg})a = 196\text{ N}$$

$$\vec{a} = 3.9\text{ m/s}^2\text{ [right]}$$

Find $T_1$:

$$m_1 a = T_1 - m_1 g \qquad \text{(eq. 1)}$$

$$T_1 = (10\text{ kg})(3.9\text{ m/s}^2) + (10\text{ kg})(9.8\text{ m/s}^2)$$

$$T_1 = 137\text{ N}$$

Find $T_2$:

$$m_3 a = m_3 g - T_2 \qquad \text{(eq. 3)}$$

$$T_2 = (30\text{ kg})(9.8\text{ m/s}^2) - (30\text{ kg})(3.9\text{ m/s}^2)$$

$$T_2 = 176\text{ N}$$

**(c)** For $m_1$:

$$F_{net1} = T - F_x$$

$$m_1 a = T - mg\sin\theta \qquad \text{(eq. 1)}$$

For $m_2$:

$$F_{net2} = F_{2g} - T$$

$$m_2 a = m_2 g - T \qquad \text{(eq. 2)}$$

Add equations 1 and 2:

$$m_1 a = T - mg\sin\theta \qquad \text{(eq. 1)}$$

$$m_2 a = m_2 g - T \qquad \text{(eq. 2)}$$

$$(m_1 + m_2)a = m_2 g - m_1 g\sin\theta$$

$$(25\text{ kg})a = (15\text{ kg})(9.8\text{ m/s}^2) - (10\text{ kg})(9.8\text{ m/s}^2)\sin 25°$$

$$\vec{a} = 4.2\text{ m/s}^2\text{ [right]}$$

For tension $T$, substitute acceleration into equation 2:

$$m_2 a = m_2 g - T$$

$$T = (15\text{ kg})(9.8\text{ m/s}^2) - (15\text{ kg})(4.2\text{ m/s}^2)$$

$$T = 84\text{ N}$$

**b) (a)** For $m_1$:

$$F_{net1} = T - F_k$$

$$m_1 a = T - \mu_k m_1 g \qquad \text{(eq. 1)}$$

For $m_2$:

$$F_{net2} = F_g - T$$

$$m_2 a = m_2 g - T \qquad \text{(eq. 2)}$$

Add equations 1 and 2:

$$m_1 a = T - \mu_k m_1 g \qquad \text{(eq. 1)}$$

$$m_2 a = m_2 g - T \qquad \text{(eq. 2)}$$

$$m_1 a + m_2 a = m_2 g - \mu_k m_1 g$$

$$a(m_1 + m_2) = g(m_2 - \mu_k m_1)$$

$$(20\text{ kg} + 20\text{ kg})a = 9.8\text{ m/s}^2[20\text{ kg} - 0.2(20\text{ kg})]$$

$$\vec{a} = 3.9\text{ m/s}^2\text{ [left]}$$

For tension $T$, substitute acceleration into equation 2:

$m_2a = m_2g - T$

$T = (20 \text{ kg})(9.8 \text{ m/s}^2) - (20 \text{ kg})(3.9 \text{ m/s}^2)$

$T = 118 \text{ N}$

**(b)** Assume the system moves towards $m_3$:

For $m_1$:

$$F_{\text{net1}} = T_1 - F_{1g}$$
$$m_1a = T_1 - m_1g \qquad \text{(eq. 1)}$$

For $m_2$:

$$F_{\text{net2}} = T_2 - T_1 - F_k$$
$$m_2a = T_2 - T_1 - \mu_k m_2 g \qquad \text{(eq. 2)}$$

For $m_3$:

$$F_{\text{net3}} = F_{3g} - T_2$$
$$m_3a = m_3g - T_2 \qquad \text{(eq. 3)}$$

Add equations 1, 2, and 3:

$$m_1a = T_1 - m_1g \qquad \text{(eq. 1)}$$
$$m_2a = T_2 - T_1 - \mu_k m_2 g \qquad \text{(eq. 2)}$$
$$m_3a = m_3g - T_2 \qquad \text{(eq. 3)}$$
$$(m_1 + m_2 + m_3)a = m_3g - \mu_k m_2 g - m_1 g$$

$$(10 \text{ kg} + 10 \text{ kg} + 30 \text{ kg})a = 9.8 \text{ m/s}^2[30 \text{ kg} - 0.2(10 \text{ kg}) - 10 \text{ kg}]$$
$$\vec{a} = 3.5 \text{ m/s}^2 \text{ [right]}$$

Find $T_1$:

$$m_1a = T_1 - m_1g \qquad \text{(eq. 1)}$$
$$T_1 = (10 \text{ kg})(3.5 \text{ m/s}^2) + (10 \text{ kg})(9.8 \text{ m/s}^2)$$
$$T_1 = 133 \text{ N}$$

Find $T_2$:

$$m_3a = m_3g - T_2 \qquad \text{(eq. 3)}$$
$$T_2 = (30 \text{ kg})(9.8 \text{ m/s}^2) - (30 \text{ kg})(3.5 \text{ m/s}^2)$$
$$T_2 = 188 \text{ N}$$

**(c)** For $m_1$:

$$F_{\text{net1}} = T - F_x - F_k$$
$$m_1a = T - m_1g \sin\theta - \mu_k m_1 g \cos\theta \qquad \text{(eq. 1)}$$

For $m_2$:

$$F_{\text{net2}} = F_{2g} - T$$
$$m_2a = m_2g - T \qquad \text{(eq. 2)}$$

Add equations 1 and 2:

$$m_1a = T - m_1g \sin\theta - \mu_k m_1 g \cos\theta \qquad \text{(eq. 1)}$$
$$m_2a = m_2g - T \qquad \text{(eq. 2)}$$
$$(m_1 + m_2)a = m_2g - m_1g \sin\theta - \mu_k m_1 g \cos\theta$$
$$(25 \text{ kg})a = (9.8 \text{ m/s}^2)[15 \text{ kg} - (10 \text{ kg}) \sin 25° - 0.2(10 \text{ kg}) \cos 25°]$$
$$\vec{a} = 3.5 \text{ m/s}^2 \text{ [right]}$$

For tension $T$, substitute acceleration into equation 2:

$$m_2a = m_2g - T$$
$$T = (15 \text{ kg})(9.8 \text{ m/s}^2) - (15 \text{ kg})(3.5 \text{ m/s}^2)$$
$$T = 94 \text{ N}$$

**12.** For $m_1$:

$$F_{\text{net1}} = T - F_{f1}$$
$$m_1a = T - \mu_k F_n$$
$$m_1a = T - \mu_k m_1 g \qquad \text{(eq. 1)}$$

For $m_2$:

$$F_{\text{net2}} = F_{2g} - T_1$$
$$m_2a = m_2g - T_1 \qquad \text{(eq. 2)}$$

Add equations 1 and 2:

$$m_1a = T - \mu_k m_1 g \qquad \text{(eq. 1)}$$
$$m_2a = m_2g - T \qquad \text{(eq. 2)}$$
$$(m_1 + m_2)a = m_2g - \mu_k m_1 g \qquad \text{(eq. 3)}$$
$$(9.0 \text{ kg})a = (4.0 \text{ kg})(9.8 \text{ m/s}^2) - (0.10)(5.0 \text{ kg})(9.8 \text{ m/s}^2)$$
$$\vec{a} = 3.8 \text{ m/s}^2 \text{ [right]}$$

**13.** For the system to be NOT moving, the acceleration of the whole system must be 0.

Using equation 3:

$$(m_1 + m_2)a = m_2g - \mu_k m_1 g \qquad \text{(eq. 3)}$$
$$0 = m_2g - \mu_k m_1 g$$
$$\mu_k m_1 g = m_2 g$$
$$\mu_k(5.0 \text{ kg}) = 4.0 \text{ kg}$$
$$\mu_k = 0.80$$

**14.** First find the system's acceleration:

For Tarzana:

$$F_{\text{netTA}} = T$$
$$m_{\text{TA}}a = T \qquad \text{(eq. 1)}$$

For Tarzan:

$$F_{\text{netTZ}} = F_{\text{TZg}} - T$$
$$m_{\text{TZ}}a = m_{\text{TZ}}g - T \qquad \text{(eq. 2)}$$

Add equations 1 and 2:

$$m_{TA}a = T \quad \text{(eq. 1)}$$
$$m_{TZ}a = m_{TZ}g - T \quad \text{(eq. 2)}$$
$$(m_{TA} + m_{TZ})a = m_{TZ}g$$
$$(65 \text{ kg} + 80 \text{ kg})a = (80 \text{ kg})(9.8 \text{ m/s}^2)$$
$$a = \frac{(80 \text{ kg})(9.8 \text{ m/s}^2)}{(65 \text{ kg} + 80 \text{ kg})}$$
$$a = 5.4 \text{ m/s}^2$$

To find time $t$:

$$d = v_i t + \frac{1}{2}at^2$$
$$15 \text{ m} = \frac{1}{2}at^2$$
$$\frac{30 \text{ m}}{a} = t^2$$
$$t = \sqrt{\frac{30 \text{ m}}{5.4 \text{ m/s}^2}}$$
$$t = 2.4 \text{ s}$$

**15.** $a_c = \dfrac{4\pi^2 r}{T^2}$ Assuming $a_c$ is a constant,

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

**a)** If the radius is doubled, the period increases by a factor of $\sqrt{2}$.

**b)** If the radius is halved, the period decreases by a factor of $\sqrt{2}$.

**16. a)** $a_c = \dfrac{4\pi^2 r}{T^2}$

$$a_c = \frac{4\pi^2(0.35 \text{ m})}{(0.42 \text{ s})^2}$$
$$a_c = 78 \text{ m/s}^2$$

**b)** The clothes do not fly towards the centre because the wall of the drum applies the normal force that provides the centripetal force. When the clothes are not in contact with the wall, there is no force acting on them. The clothes have inertia and would continue moving at a constant velocity tangential to the drum. The centripetal force acts to constantly change the direction of this velocity.

**17.** $a_c = \dfrac{4\pi^2 r}{T^2}$

$$T = 365 \text{ days} = 3.15 \times 10^4 \text{ s}$$
$$a_c = \frac{4\pi^2(1.5 \times 10^{11} \text{ m})}{(3.15 \times 10^7 \text{ s})}$$
$$a_c = 6.0 \times 10^{-3} \text{ m/s}^2$$

**18.** $F_c = F_f$

$$ma_c = \mu F_n$$
$$\frac{mv^2}{r} = \mu mg$$
$$v = \sqrt{\mu gr}$$
$$v = 21 \text{ m/s}$$

It is not necessary to know the mass.

**19.** Vertically: $F_n \cos\theta = ma_c$

$$F_n = \frac{mg}{\cos\theta}$$

Horizontally: $F_c = F_n \sin\theta$

$$ma_c = F_n \sin\theta$$
$$\left(\frac{mg}{\cos\theta}\right)\sin\theta = ma_c$$
$$g\tan\theta = \frac{v^2}{r}$$
$$v = \sqrt{rg\tan 25°}$$
$$v = 19 \text{ m/s}$$

**20.** $F_c = F_g$

$$ma_c = mg$$
$$g = \frac{v^2}{r}$$
$$v = \sqrt{gr}$$
$$v = 9.9 \text{ m/s}$$

**21. a)** $T = mg$

$$T = (0.5 \text{ kg})g$$
$$T = 4.9 \text{ N}$$

**b)** $T - mg = \dfrac{mv^2}{r}$

$$T = \frac{mv^2}{r} + mg$$
$$T = \frac{(0.5 \text{ kg})(2.4 \text{ m/s})^2}{(0.6 \text{ m})} + (0.5 \text{ kg})(9.8 \text{ m/s}^2)$$
$$T = 9.7 \text{ N}$$

**22.** Maximum tension occurs when the mass is at its lowest position. Tension acts upward, and gravity acts downward. The difference between these forces is the centripetal force:

$$T_{max} - mg = \frac{mv^2}{r}$$
$$T_{max} = \frac{mv^2}{r} + mg$$
$$T_{max} = \frac{(2.0 \text{ kg})(6.6 \text{ m/s})^2}{3.0 \text{ m}} + (2.0 \text{ kg})(9.8 \text{ m/s}^2)$$
$$T_{max} = 49 \text{ N}$$

The tension is minimized when the mass is at the top of its arc. Tension and gravity both act downward, and their sum is the centripetal force:

$$T_{min} + mg = \frac{mv^2}{r}$$

$$T_{min} = \frac{mv^2}{r} - mg$$

$$T_{min} = \frac{(2.0\text{ kg})(6.6\text{ m/s})^2}{3.0\text{ m}} - (2.0\text{ kg})(9.8\text{ m/s}^2)$$

$$T_{min} = 9.4\text{ N}$$

**23. a)**

$$F_{net} = ma$$

$$F_n - mg = m(9g)$$

$$F_n = 9mg + mg$$

$$F_n = 10mg$$

$$F_n = 5.9 \times 10^3\text{ N}$$

**b)**

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

$$9g = \frac{v^2}{r}$$

$$r = \frac{v^2}{9g}$$

$$r = \frac{(91.67\text{ m/s})^2}{9(9.8\text{ m/s}^2)}$$

$$r = 95\text{ m}$$

**24. a)** $G = 6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2$,
$T = 365\text{ days} = 3.15 \times 10^7\text{ s}$

$$\frac{Gm_Em_S}{r^2} = m_E\left(\frac{4\pi^2 r}{T^2}\right)$$

$$m_S = \frac{4\pi^2 r^3}{GT^2}$$

$$m_S = \frac{4\pi^2(1.5 \times 10^{11}\text{ m})^3}{(6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(3.15 \times 10^7\text{ s})^2}$$

$$m_S = 2.0 \times 10^{30}\text{ kg}$$

**b)**

$$\text{Density of the Sun} = \frac{m}{V} = \frac{2.0 \times 10^{30}\text{ kg}}{\frac{4}{3}\pi r^3} = 1.4 \times 10^3\text{ kg/m}^3$$

$$m_{Earth} = 5.98 \times 10^{24}\text{ kg}$$

$$\text{Density of Earth} = \frac{5.98 \times 10^{24}\text{ kg}}{\frac{4}{3}\pi r^3} = 5.5 \times 10^3\text{ kg/m}^3$$

The Sun is about $\frac{1}{4}$ as dense as Earth.

**25.** On mass 2:

$$F_c = m_2\left(\frac{4\pi^2 r}{T^2}\right)$$

$$T_2 = m_2\left(\frac{4\pi^2 r}{T^2}\right)$$

$$T_2 = m_2\left(\frac{4\pi^2(L_1 + L_2)}{T^2}\right)$$

On mass 1:

$$F_c = m_1\left(\frac{4\pi^2 r}{T^2}\right)$$

$$T_1 - T_2 = m_1\left(\frac{4\pi^2 r}{T^2}\right)$$

$$T_1 = m_1\left(\frac{4\pi^2 L_1}{T^2}\right) + m_2\left(\frac{4\pi^2(L_1 + L_2)}{T^2}\right)$$

$$T_1 = \left(\frac{4\pi^2}{T^2}\right)(m_1L_1 + m_2(L_1 + L_2))$$

**26.** $m_E = 5.98 \times 10^{24}\text{ kg}$, $r_E = 6.38 \times 10^6\text{ m}$,
$h = 400\text{ km} = 4.0 \times 10^5\text{ m}$

Orbital speed is given by:

$$v = \sqrt{\frac{GM}{r + h}}$$

$$v = \sqrt{\frac{(6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\text{ kg})}{6.38 \times 10^6\text{ m} + 4.0 \times 10^5\text{ m}}}$$

$$v = 7.67\text{ km/s}$$

The period of the orbit is the time required by the satellite to complete one rotation around Earth. Therefore, the distance travelled, $\Delta d$, is the circumference of the circular orbit. Therefore,

$$d = 2\pi(r + h)$$

$$d = 2(3.14)(6.38 \times 10^6\text{ m} + 4.0 \times 10^5\text{ m})$$

$$d = 42\,599\,996\text{ m}$$

Hence, speed is given by,

$$v = \frac{d}{T}$$

$$T = \frac{d}{v}$$

$$T = \frac{42\,599\,996\text{ m}}{7670\text{ m/s}}$$

$$T = 5552\text{ s}$$

The period of the orbit is 5552 s or 92.5 min.

**27.** $m_E = 5.98 \times 10^{24}\text{ kg}$, $r_E = 6.37 \times 10^6\text{ m}$

Since the orbit is geostationary, it has a period of 24 h = 86 400 s. Using Kepler's third law,

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$r = \left(\frac{GMT^2}{4\pi^2}\right)^{\frac{1}{3}}$$

$$r = \left(\frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})(86\ 400\ \text{s})^2}{4(3.14)^2}\right)^{\frac{1}{3}}$$

$r = 4.22 \times 10^7$ m

Subtracting Earth's radius,

$r = 4.22 \times 10^7\ \text{m} - 6.37 \times 10^6\ \text{m}$

$r = 3.59 \times 10^7$ m

The satellite has an altitude of $3.59 \times 10^4$ km.

**28. a)** The total energy of a satellite in an orbit is the sum of its kinetic and potential energies. In all cases, total energy remains constant. Therefore, when $r$ is increased, the gravitational potential energy increases as $E_p = \frac{-GMm}{r}$. As $r$ increases, the energy increases as it becomes less negative. Thus, when potential energy increases, kinetic energy decreases to maintain the total energy a constant. Since $E_k = \frac{1}{2}mv^2$, if kinetic energy decreases, $v$ also decreases and when $r$ increases, $v$ decreases.

**b)** In Kepler's third law equation $\frac{r^3}{T^2} = K$, $r$ is directly proportional to $T$. Therefore, as $r$ increases, $T$ also increases.

**29.** $m_{\text{Saturn}} = 5.7 \times 10^{26}$ kg, $r_{\text{Saturn}} = 6.0 \times 10^7$ m

Equating two equations for kinetic energy,

$$\frac{1}{2}mv^2 = \frac{GMm}{2r}$$

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

$$v = \sqrt{\frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.7 \times 10^{26}\ \text{kg})}{6 \times 10^7\ \text{m}}}$$

$v = 2.5 \times 10^4$ m/s

If an object is orbiting Saturn, it must have a minimum speed of $2.5 \times 10^4$ m/s.

**30.** $m_M = 7.35 \times 10^{22}$ kg,

$r = r_M + 100$ km

$r = 1.738 \times 10^6\ \text{m} + 1 \times 10^5\ \text{m}$

$r = 1.838 \times 10^6$ m

$$v_{\text{esc}} = \sqrt{\frac{2Gm_{\text{Moon}}}{r}}$$

$$v_{\text{esc}} = \sqrt{\frac{2(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(7.35 \times 10^{22}\ \text{kg})}{1.838 \times 10^6\ \text{m}}}$$

$v_{\text{esc}} = 2.31 \times 10^3$ m/s

The escape speed from the Moon at a height of 100 km is 2.31 km/s.

**31.** According to Kepler's third law,

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$T^2 = \frac{4\pi^2 r^3}{Gm_{\text{Moon}}}$$

$$T = \sqrt{\frac{4(3.14)^2(1.838 \times 10^6\ \text{m})^3}{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(7.35 \times 10^{22}\ \text{kg})}}$$

$T = 7071$ s

It would take the *Apollo* spacecraft 7071 s or 1 h 58 min to complete one orbit around the Moon.

**32.** $d_{\text{M-S}} = 2.28 \times 10^{11}$ m, $r_M = 3.43 \times 10^6$ m, $m_M = 6.37 \times 10^{23}$ kg, $m_S = 2.0 \times 10^{30}$ kg

**a)** Orbital speed is given by:

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

$$v = \sqrt{\frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(2.0 \times 10^{30}\ \text{kg})}{2.28 \times 10^{11}\ \text{m}}}$$

$v = 24.2$ km/s

**b)** $h = 80\ \text{km} = 8 \times 10^4$ m

$$v = \sqrt{\frac{Gm}{r + h}}$$

$$v = \sqrt{\frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(6.37 \times 10^{23}\ \text{kg})}{3.43 \times 10^6\ \text{m} + 8 \times 10^4\ \text{m}}}$$

$v = 3.48$ km/s

The speed required to orbit Mars at an altitude of 80 km is 3.48 km/s.

**33.** $m_M = 7.35 \times 10^{22}$ kg, $r_M = 1.738 \times 10^6$ m

Escape speed is given by:

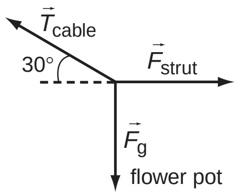
$$v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$$

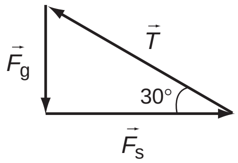
$$v_{\text{esc}} = \sqrt{\frac{2(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(7.35 \times 10^{22}\ \text{kg})}{1.738 \times 10^6\ \text{m}}}$$

$v_{\text{esc}} = 2.38$ km/s

# Chapter 7

**18.**




$$\sin 30° = \frac{F_g}{T}$$

$$T = \frac{F_g}{\sin 30°}$$

$$T = \frac{mg}{\sin 30°}$$

$$T = \frac{(10 \text{ kg})(9.8 \text{ N/kg})}{\sin 30°}$$

$$T = 196 \text{ N}$$

**19.** $\tan\theta = \dfrac{F_g}{F_s}$

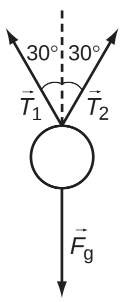
$$F_s = \frac{F_g}{\tan\theta}$$

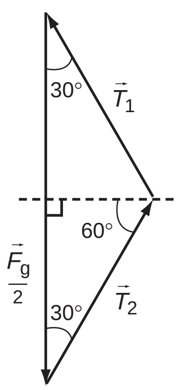
$$F_s = \frac{98 \text{ N}}{\tan 30°}$$

$$F_s = 169.7 \text{ N}$$

$$F_s = 170 \text{ N}$$

**20.**




$$\vec{T}_1 = \vec{T}_2 = \vec{T}$$

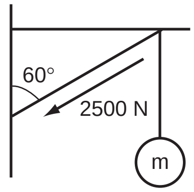
$$\cos 30° = \frac{\left(\frac{F_g}{2}\right)}{T}$$

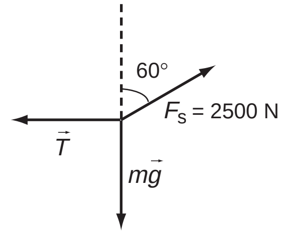
$$T = \frac{\left(\frac{F_g}{2}\right)}{(\cos 30°)}$$

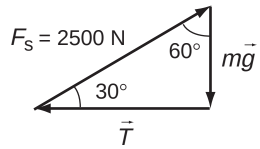
$$T = \frac{\left[\frac{(100 \text{ kg})(9.8 \text{ N/kg})}{2}\right]}{(\cos 30°)}$$

$$T = 566 \text{ N}$$

**21.**



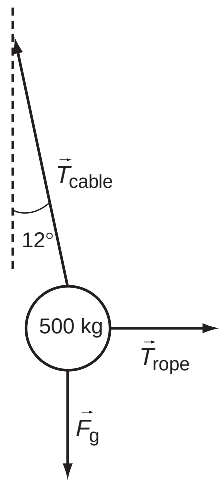

$$\sin 30° = \frac{mg}{F_s}$$

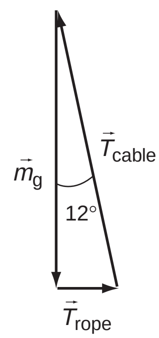
$$m = \frac{F_s \sin 30°}{g}$$

$$m = \frac{(2500 \text{ N}) \sin 30°}{9.8 \text{ N/kg}}$$

$$m = 128 \text{ kg}$$

**22.**




$$\cos 12° = \frac{mg}{T_{cable}}$$

$$T_{cable} = \frac{mg}{\cos 12°}$$

$$T_{cable} = \frac{(500 \text{ kg})(9.8 \text{ N/kg})}{\cos 12°}$$

$$T_{cable} = 5009.5 \text{ N}$$

$$T_{cable} = 5.01 \times 10^3 \text{ N}$$

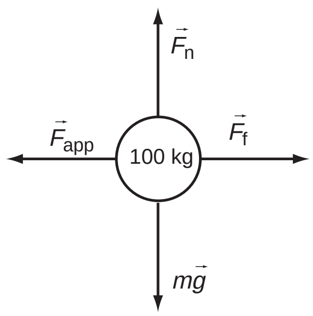
$$\tan 12° = \frac{F_{rope}}{mg}$$

$$F_{rope} = mg \tan 12°$$

$$F_{rope} = (500 \text{ kg})(9.8 \text{ N/kg}) \tan 12°$$

$$F_{rope} = 1.04 \times 10^3 \text{ N}$$

**23. a)**




$\mu = 0.63$

$F_{app} - F_f = 0$

$F_{app} = F_f$

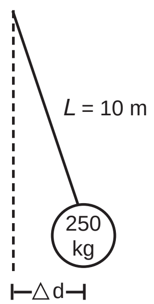
$F_{app} = \mu F_n$

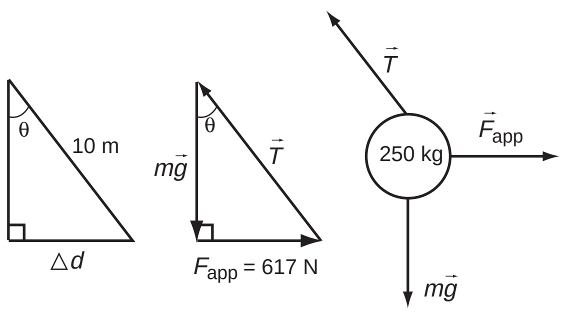
$F_{app} = \mu mg$

$F_{app} = 0.63(100\ \text{kg})(9.8\ \text{N/kg})$

$F_{app} = 617.4\ \text{N}$

**b)**




Using similar triangles, find $T$ first:

$T^2 = (mg)^2 + F_{app}{}^2$

$T = \sqrt{[(250\ \text{kg})(9.8\ \text{N/kg})]^2 + (617.4\ \text{N})^2}$

$T = 2526.6\ \text{N}$

$T = 2.53 \times 10^3\ \text{N}$

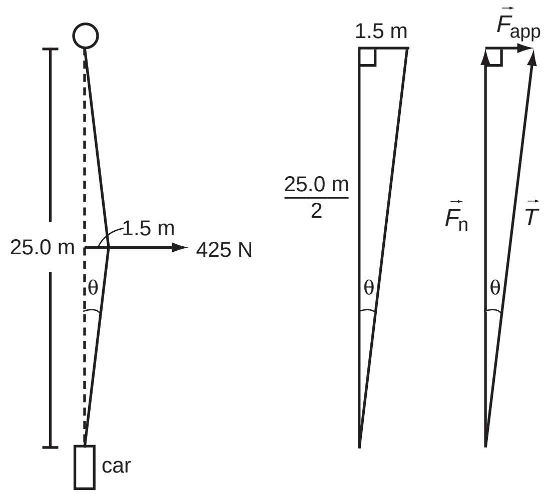
$$\frac{\Delta d}{L} = \frac{F_{app}}{T}$$

$$\Delta d = \frac{F_{app}L}{T}$$

$$\Delta d = \frac{(617.4\ \text{N})(10\ \text{m})}{2526.6\ \text{N}}$$

$\Delta d = 2.4\ \text{m}$

**24.**




$$\tan\theta = \frac{1.5\ \text{m}}{\left(\dfrac{25.0\ \text{m}}{2}\right)}$$

$\tan\theta = 0.12$

$\theta = 6.8°$

$$\sin\theta = \frac{F_{app}}{T}$$

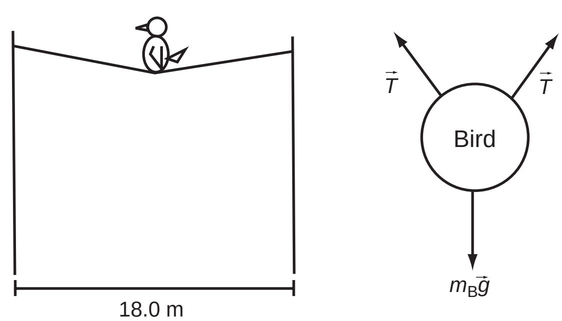
$$T = \frac{F_{app}}{\sin\theta}$$

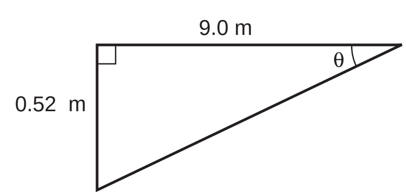
$$T = \frac{425\ \text{N}}{\sin 6.8°}$$

$T = 3.59 \times 10^3\ \text{N}$

The rope pulls with a force of $3.59 \times 10^3$ N.

**25.**

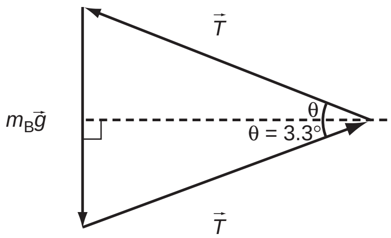



$$\tan\theta = \frac{0.52\ \text{m}}{9.0\ \text{m}}$$

$\tan\theta = 0.058$

$\theta = 3.3°$



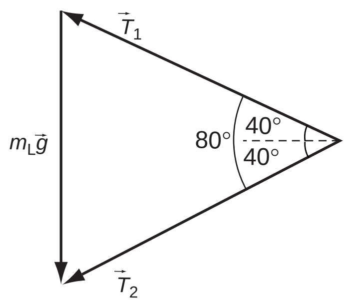

$$\sin\theta = \frac{\left(\frac{m_B g}{2}\right)}{T}$$

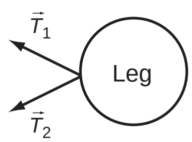
$$m_B = \frac{2T\sin\theta}{g}$$

$$m_B = \frac{2(90\text{ N})\sin 3.3°}{9.8\text{ N/kg}}$$

$$m_B = 1.1\text{ kg}$$

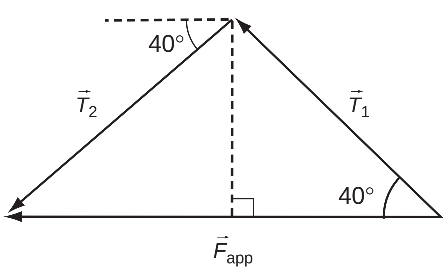
**26.**




$$T = (5.0\text{ kg})(9.8\text{ N/kg})$$

$$T = 49\text{ N}$$




$$\vec{F}_{app} = \vec{T}_1 + \vec{T}_2$$

$$\cos 40° = \frac{\left(\frac{F_{app}}{2}\right)}{T}$$

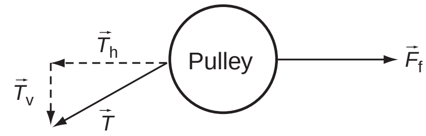
$$F_{app} = 2(T\cos 40°)$$

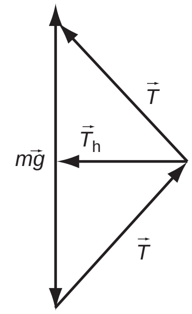
$$F_{app} = 2mg\cos 40°$$

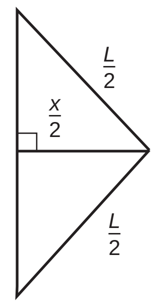
$$F_{app} = 2(5.0\text{ kg})(9.8\text{ N/kg})\cos 40°$$

$$F_{app} = 75\text{ N [left]}$$

**27.**




$$\vec{T}_h + \vec{F}_f = 0$$

With left taken to be the positive direction,

$$T_h - F_f = 0$$

$$T_h = F_f$$

$$T_h = \mu F_n$$

$$T_h = \frac{\mu mg}{2}$$

From Pythagoras' theorem:

$$T^2 = T_h^{\,2} + \left(\frac{mg}{2}\right)^2$$

$$T^2 = \mu^2\left(\frac{mg}{2}\right)^2 + \left(\frac{mg}{2}\right)^2$$

$$T^2 = \left(\frac{mg}{2}\right)^2(\mu^2 + 1)$$

$$T = \left(\frac{mg}{2}\right)\sqrt{(\mu^2 + 1)}$$

From similar triangles:

$$\frac{\left(\frac{x}{2}\right)}{\left(\frac{L}{2}\right)} = \frac{T_h}{T}$$

$$\frac{x}{L} = \frac{T_h}{T}$$

$$x = \frac{T_h L}{T}$$

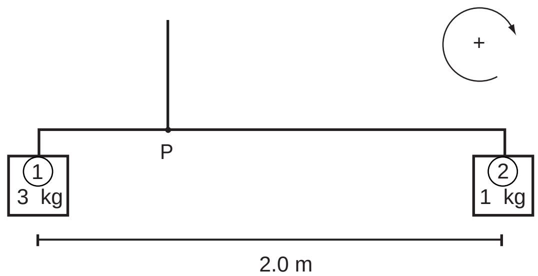
Substituting for $T_\text{h}$ and $T$,

$$x = \frac{\left(\dfrac{\mu mgL}{2}\right)}{\dfrac{mg}{2}\sqrt{\mu^2 + 1}}$$

$$x = \frac{\mu L}{\sqrt{\mu^2 + 1}}$$

$$x = \frac{\mu L}{\sqrt{\mu^2 + 1}}$$

**28. a)**




centre of mass = ?

$\vec{\tau}_\text{net} = 0$

With clockwise as the positive rotation,

$\tau_1 - \tau_2 = 0$

$\tau_1 = \tau_2$

$r_1 m_1 g \sin\theta = r_2 m_2 g \sin\theta$

$$r_1 = r_2\left(\frac{m_2 g}{m_1 g}\right)$$

$$r_1 = r_2\left(\frac{m_2}{m_1}\right)$$

$$r_1 = \frac{r_2}{3}$$

But $r_2 + r_1 = r_\text{T}$

$3r_1 = r_\text{T} - r_1$

$4r_1 = r_\text{T}$

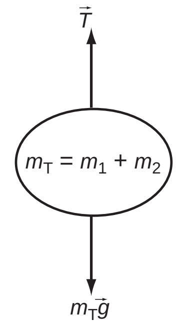
$$r_1 = \frac{r_\text{T}}{4}$$

$$r_1 = \frac{2.0\text{ m}}{4}$$

$r_1 = 0.5$ m

The centre of mass is 0.5 m from $m_1$ and 1.5 m from $m_2$.

**b)**




$\vec{T} = ?$

If up is positive,

$T = m_\text{T} g$

$T = (4.0\text{ kg})(9.8\text{ N/kg})$

$\vec{T} = 39.2$ N [up]

**29.** $\tau_\text{T} = 0$

The pivot is the left support.

$\tau_1 = 0$

$\vec{\tau}_2 + \vec{\tau}_\text{Board} + \vec{\tau}_\text{Duck} = 0$

$\tau_2 = -\tau_\text{B} - \tau_\text{D}$

$\tau_2 = -r_\text{B}F_\text{gB} - r_\text{D}F_\text{gD}$

$\tau_2 = -r_\text{B}m_\text{B}g - r_\text{D}m_\text{D}g$

$\tau_2 = -(2.0\text{ m})(50\text{ kg})(9.8\text{ N/kg}) - (4.0\text{ m})(8.5\text{ kg})(9.8\text{ N/kg})$

$\tau_2 = -1313.2$ N/m

$$F_2 = \frac{-\ 1313.2\text{ Nm}}{0.8\text{ m}}$$

$F_2 = -1641.5$ N

$\vec{F}_2 = 1.6 \times 10^3$ N [up]

For $F_1$:

$F_\text{T} = 0$

With down as positive,

$0 = -F_1 - F_2 + F_\text{B} + F_\text{D}$

$F_1 = F_\text{B} + F_\text{D} - F_2$

$F_1 = (m_\text{B}g) + (m_\text{D}g) - F_2$

$F_1 = (50\text{ kg})(9.8\text{ N/kg}) + (8.5\text{ kg})(9.8\text{ N/kg}) - 1.6 \times 10^3\text{ N}$

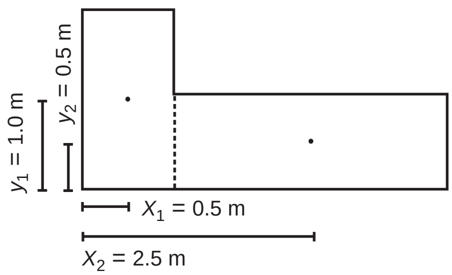
$F_1 = -1068.2$ N

$\vec{F}_1 = 1.1 \times 10^3$ N [down]

and

$\vec{F}_2 = 1.6 \times 10^3$ N [up]

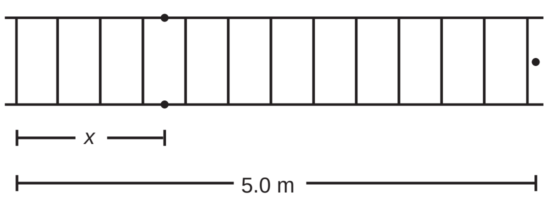
**30.**

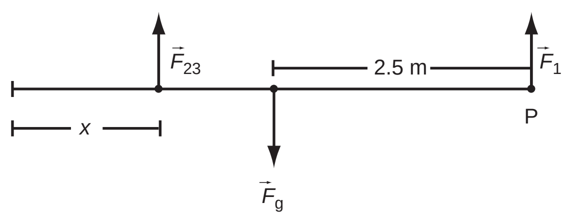



$$x_{cm} = \frac{x_1 + x_2}{2}$$
$$x_{cm} = \frac{0.5\text{ m} + 2.5\text{ m}}{2}$$
$$x_{cm} = 1.5\text{ m [right]}$$
$$y_{cm} = \frac{y_1 + y_2}{2}$$
$$y_{cm} = \frac{0.5\text{ m} + 1.0\text{ m}}{2}$$
$$y_{cm} = 0.75\text{ m [up]}$$

Centre of mass = 1.5 m [right], 0.75 m [up]

**31.**




Let $F_1$ be the pivot.

$$\tau_T = 0$$
$$\vec{\tau}_2 + \vec{\tau}_3 + \vec{\tau}_L = 0$$

With clockwise as positive,

$$2\tau_{23} - \tau_L = 0$$
$$r_{23}\left(\frac{2}{3}m\right)g = r_L mg$$
$$r_{23} = \frac{3r_L}{2}$$
$$r_{23} = \frac{3\left(\frac{5.0\text{ m}}{2}\right)}{2}$$
$$r_{23} = \frac{15.0\text{ m}}{4}$$
$$r_{23} = 3.75\text{ m}$$
$$x = 5.0\text{ m} - 3.75\text{ m}$$
$$x = 1.25\text{ m}$$

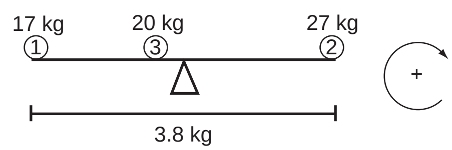
**32.** $\tau_T = 0$

$$\vec{\tau}_{man} + \vec{\tau}_{L(left)} + \vec{\tau}_{L(right)} + \vec{\tau}_{rock} = 0$$

With clockwise as the positive direction of rotation,

$$0 = -\tau_{man} - \tau_{L(left)} + \tau_{L(right)} + \tau_{rock}$$
$$\tau_{rock} = \tau_{man} + \tau_{L(left)} - \tau_{L(right)}$$
$$r_{rock}m_{rock}g\sin\theta = r_{man}m_{man}g\sin\theta + r_{L(left)}m_{L(left)}g\sin\theta - r_{L(right)}m_{L(right)}g\sin\theta$$
$$r_{rock}m_{rock} = [(1.90\text{ m})(86\text{ kg})] + \left[\left(\frac{1.90\text{ m}}{2}\right)\left((2.0\text{ kg})\frac{1.90\text{ m}}{2.40\text{ m}}\right)\right] - \left[\left(\frac{0.5\text{ m}}{2}\right)\left((2.0\text{ kg})\frac{0.50\text{ m}}{2.40\text{ m}}\right)\right]$$
$$r_{rock}m_{rock} = 163.4\text{ kg}\cdot\text{m} + 1.504\text{ kg}\cdot\text{m} - 0.104\text{ kg}\cdot\text{m}$$
$$r_{rock}m_{rock} = 164.8\text{ kg}\cdot\text{m}$$
$$m_{rock} = \frac{164.8\text{ kg}\cdot\text{m}}{0.50\text{ m}}$$
$$m_{rock} = 329.6\text{ kg}$$
$$m_{rock} = 3.3 \times 10^2\text{ kg}$$

**33. a)**




$$\tau_T = 0$$
$$\vec{\tau}_1 + \vec{\tau}_2 + \vec{\tau}_3 + \vec{\tau}_{TL} + \vec{\tau}_{TR} = 0$$

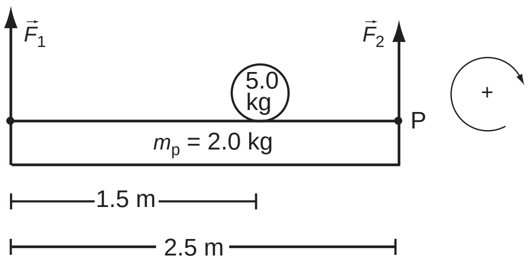
With clockwise as the positive rotation,

$$-\tau_1 + \tau_2 - \tau_3 - \tau_{TL} + \tau_{TR} = 0$$
$$\tau_3 = \tau_2 - \tau_1$$
$$r_3m_3g = r_2m_2g - r_1m_1g$$
$$r_3m_3 = \left[\left(\frac{3.8\text{ m}}{2}\right)(27\text{ kg})\right] - \left[\left(\frac{3.8\text{ m}}{2}\right)(17\text{ kg})\right]$$
$$r_3m_3 = 51.3\text{ kg}\cdot\text{m} - 32.3\text{ kg}\cdot\text{m}$$
$$r_3m_3 = 19\text{ kg}\cdot\text{m}$$
$$r_3 = \frac{19\text{ kg}\cdot\text{m}}{20\text{ kg}}$$
$$r_3 = 0.95\text{ m}$$

The third child of mass 20 kg must sit 0.95 m from the centre of the teeter-totter and on the same side as the 17.0-kg child.

**b)** No, the mass of the teeter-totter does not matter.

**34.**




Let $F_2$ be pivot.

$$\tau_{net} = 0$$
$$\vec{\tau}_1 + \vec{\tau}_B + \vec{\tau}_C = 0$$

With clockwise as the positive rotation,

$$\tau_1 - \tau_p - \tau_c = 0$$
$$\tau_1 = \tau_p + \tau_c$$
$$r_1F_1 = r_pF_{gp} + r_cF_{gc}$$
$$F_1 = \frac{r_pF_{gp} + r_cF_{gc}}{r_1}$$
$$F_1 = \frac{\left[\left(\frac{2.5\text{ m}}{2}\right)(2.0\text{ kg})(9.8\text{ N/kg})\right] + [(2.5\text{ m} - 1.5\text{ m})(5.0\text{ kg})(9.8\text{ N/kg})]}{2.5\text{ m}}$$
$$F_1 = 29.4\text{ N}$$

But $F_{net} = 0$

$$\vec{F}_1 + \vec{F}_{gB} + \vec{F}_{gC} + \vec{F}_2 = 0$$

With up as the positive direction,

$$0 = F_1 - F_{gB} - F_{gC} + F_2$$
$$F_2 = F_{gB} + F_{gC} - F_1$$
$$F_2 = m_Bg + m_Cg - F_1$$
$$F_2 = (2.0\text{ kg})(9.8\text{ N/kg}) + (5.0\text{ kg})(9.8\text{ N/kg}) - 29.4\text{ N}$$
$$F_2 = 39.2\text{ N}$$

The man farthest from the cement bag ($F_1$) lifts with 29.4 N and the second man lifts with 39.2 N of force.

**35.** Take front two and back two legs as single supports.

$\vec{\tau}_{net} = 0$ with front legs as pivot

$$\vec{\tau}_D + \vec{\tau}_{Back} = 0$$

Let clockwise be positive.

$$\tau_D - \tau_{Back} = 0$$
$$\tau_{Back} = \tau_D$$
$$r_BF_B = r_DF_{gD}$$
$$r_BF_B = r_Dm_Dg$$
$$r_BF_B = (0.30\text{ m})(30\text{ kg})(9.8\text{ N/kg})$$
$$r_BF_B = 88.2\text{ N}\cdot\text{m}$$
$$F_B = \frac{88.2\text{ N}\cdot\text{m}}{1.0\text{ m}}$$
$$F_B = 88.2\text{ N}$$
$$F_B = 8.8 \times 10^1\text{ N}$$

But $\vec{F}_{net} = 0$

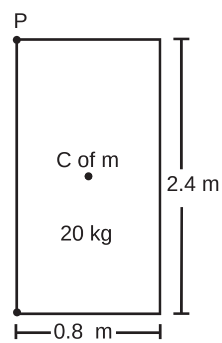
$$\vec{F}_F + \vec{F}_D + \vec{F}_B = 0$$

Let up be positive.

$$0 = F_F - F_D + F_B$$
$$F_F = F_D - F_B$$
$$F_F = m_Dg - F_B$$
$$F_F = (30\text{ kg})(9.8\text{ N/kg}) - 88.2\text{ N}$$
$$F_F = 205.8\text{ N}$$
$$F_F = 2.1 \times 10^2\text{ N}$$

Front legs: $1.05 \times 10^2$ N each; back legs: $4.4 \times 10^1$ N each (each divided by 2).

**36. a)**

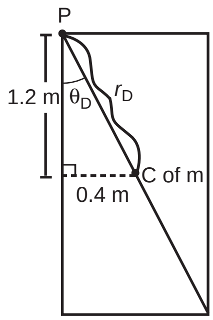



$$\vec{F}_{net} = 0$$
$$\vec{F}_T + \vec{F}_D = 0$$

Taking up to be positive,

$$0 = F_T - F_D$$
$$F_T = m_Dg$$
$$F_T = (20\text{ kg})(9.8\text{ N/kg})$$
$$\vec{F}_T = 196\text{ N [up]}$$

**b)**



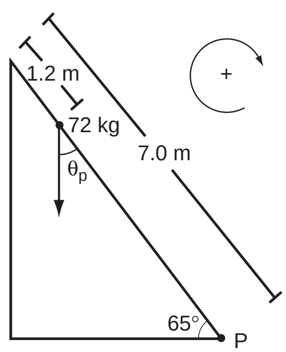

$$\theta = \tan^{-1}\left(\frac{0.4\text{ m}}{1.2\text{ m}}\right)$$

$\theta = 18.4°$

Assume the upper hinge is the pivot.

$$\vec{\tau}_B + \vec{\tau}_{door} = 0$$
$$-\tau_B + \tau_{door} = 0$$
$$\tau_B = \tau_{door}$$
$$r_B F_B \sin\theta_B = r_D m_D g \sin\theta_D$$
$$F_B = \frac{r_D m_D g \sin\theta_D}{r_B \sin\theta_B}$$
$$F_B = \frac{(1.26\text{ m})(20\text{ kg})(9.8\text{ N/kg})\sin 18.4°}{(2.4\text{ m})\sin(90° - 18.4°)}$$
$$\vec{F}_B = 34.2\text{ N [out horizontally]}$$

**37.**




$\theta_p = 90° - 65°$

$\theta_p = 25°$

Choose bottom as pivot.

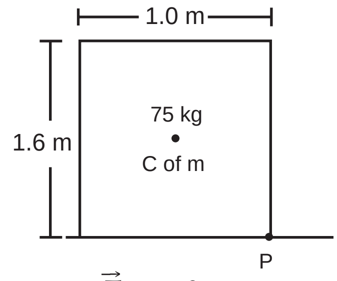
$$\vec{\tau}_{net} = 0$$
$$\vec{\tau}_{wall} + \vec{\tau}_p = 0$$

Taking right (horizontally) as positive,

$$\tau_{wall} - \tau_p = 0$$
$$\tau_{wall} = \tau_p$$
$$r_w F_w \sin\theta_w = r_p m_p g \sin\theta_p$$
$$F_w = \frac{r_p m_p g \sin\theta_p}{r_w \sin\theta_w}$$
$$F_w = \frac{[(7.0\text{ m} - 1.2\text{ m})(72\text{ kg})(9.8\text{ N/kg})(\sin 25°)]}{(7.0\text{ m})\sin 65°}$$
$$\vec{F}_w = 272.6\text{ N [horizontal]}$$
$$F_w = 2.7 \times 10^2\text{ N}$$

But $F_{h(bottom)} = -F_{h(top)}$ so $2.7 \times 10^2$ N is required to keep the ladder from sliding.

**38. a)**

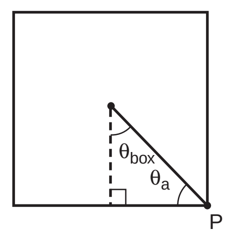



$$\vec{F}_{net} = 0$$
$$\vec{F}_{app\text{-}h} + \vec{F}_f = 0$$

Taking the direction of force application to be positive,

$$F_{app\text{-}h} = F_f$$
$$F_{app\text{-}h} = \mu F_n$$
$$F_{app\text{-}h} = \mu mg$$
$$F_{app\text{-}h} = 0.42(75\text{ kg})(9.8\text{ N/kg})$$
$$\vec{F}_{app\text{-}h} = 308.7\text{ N [horizontally]}$$
$$\vec{F}_{app\text{-}h} = 3.1 \times 10^2\text{ N [horizontally]}$$

**b)**




Just to the tip the box,

$$\vec{\tau}_{net} \geq 0$$
$$\vec{\tau}_a + \vec{\tau}_{box} \geq 0$$

Taking the direction of force application to be positive,

$$\tau_a - \tau_{box} \geq 0$$
$$\tau_a \geq \tau_{box}$$

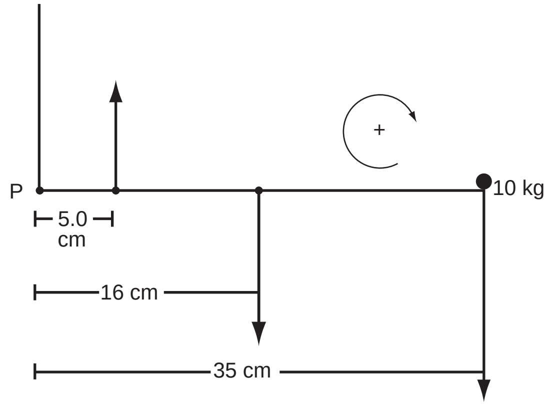
Take bottom corner as pivot.

$$\tan\theta_a = \frac{\left(\frac{1.6\text{ m}}{2}\right)}{\left(\frac{1.0\text{ m}}{2}\right)}$$
$$\theta_a = 58°$$
$$r_a F_a \sin\theta_a \geq r_{box} m_{box} g \sin\theta_{box}$$
$$r_a \geq \frac{r_{box} m_{box} g \sin\theta_{box}}{F_a \sin\theta_a}$$
$$r_a \geq \frac{\sqrt{(0.8\text{ m})^2 + (0.5\text{ m})^2}(75\text{ kg})(9.8\text{ N/kg})\sin(90° - 58°)}{(308.7\text{ N})\sin 58°}$$
$$r_a \geq 1.40\text{ m}$$

But:

$$h = r_a \sin 58°$$
$$h = 1.2\text{ m}$$

**39.**




$\vec{\tau}_{net} = 0$

$\vec{\tau}_{muscle} + \vec{\tau}_{arm} + \vec{\tau}_{water} = 0$

With clockwise as the direction of positive rotation,

$$-\tau_m + \tau_a + \tau_w = 0$$

$$\tau_m = \tau_a + \tau_w$$

$$r_m F_m \sin\theta = r_a m_a g \sin\theta + r_w m_w g \sin\theta$$

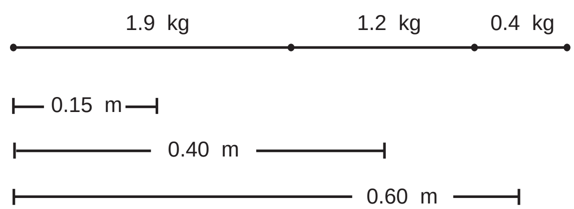
$$F_m = \frac{r_a m_a g + r_w m_w g}{r_m}$$

$$F_m = \frac{(0.16\text{ m})(3.0\text{ kg})(9.8\text{ N/kg}) + (0.35\text{ m})(10\text{ kg})(9.8\text{ N/kg})}{0.050\text{ m}}$$

$$F_m = 780.1\text{ N}$$

$$\vec{F}_m = 7.8 \times 10^2\text{ N [up]}$$

**40.**




The total of all three torques must be equivalent to the total torque through the centre of mass.

$$\vec{\tau}_{cm} = \vec{\tau}_{ua} + \vec{\tau}_{fa} + \vec{\tau}_{hand}$$

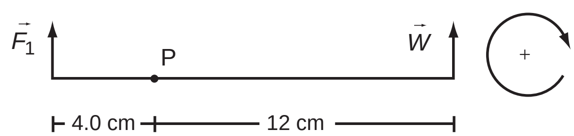
$$r_{cm} m_T g = r_{ua} m_{ua} g + r_{fa} m_{fa} g + r_{hand} m_{hand} g$$

$$r_{cm} = \frac{r_{ua} m_{ua} + r_{fa} m_{fa} + r_{hand} m_{hand}}{m_T}$$

$$r_{cm} = \frac{(0.15\text{ m})(1.9\text{ kg}) + (0.40\text{ m})(1.2\text{ kg}) + (0.60\text{ m})(0.4\text{ kg})}{3.5\text{ kg}}$$

$r_{cm} = 0.29$ m from shoulder

**41.**




Let the contact point of $F_2$ be the pivot $P$.

$\vec{\tau}_1 + \vec{\tau}_w = 0$

With clockwise being the positive torque direction,

$$\tau_1 - \tau_w = 0$$

$$\tau_1 = \tau_w$$

$$r_1 F_1 = r_w m g$$

$$F_1 = \frac{r_w m g}{r_1}$$

$$F_1 = \frac{(0.12\text{ m})(65\text{ kg})(9.8\text{ N/kg})}{0.04\text{ m}}$$

$$F_1 = 1911\text{ N}$$

$$\vec{F}_1 = 1.9 \times 10^3\text{ N [up]}$$

$$\vec{F}_{net} = 0$$

$$\vec{F}_1 + \vec{F}_2 + \vec{F}_g = 0$$

With up taken to be the positive direction,

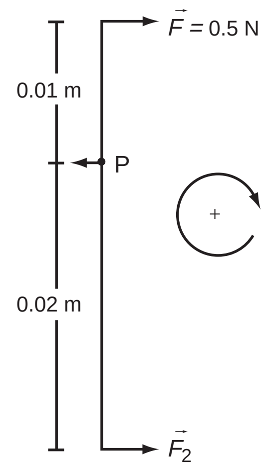
$F_2 = -F_1 - F_g$

$F_2 = -1911\text{ N} - (65.0\text{ kg})(9.8\text{ N/kg})$

$F_2 = -2548\text{ N}$

$\vec{F}_2 = 2.5 \times 10^3\text{ N [down]}$

**42.**




Use pivot $P$ as the point of contact of $F_1$.

$$\vec{\tau}_{net} = 0$$

$$\vec{\tau}_{F2} + \vec{\tau}_F = 0$$

With clockwise taken to be the positive torque direction,

$$\tau_{F2} - \tau_F = 0$$

$$\tau_{F2} = \tau_F$$

$$r_{F2} F_2 = r_F F$$

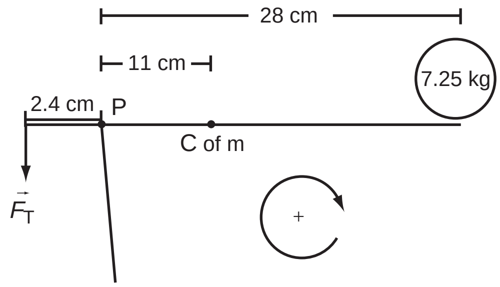
$$F_2 = \frac{r_F F}{r_{F2}}$$

$$F_2 = \frac{(0.01\text{ m})(0.5\text{ N})}{0.02\text{ m}}$$

$$F_2 = 0.25\text{ N}$$

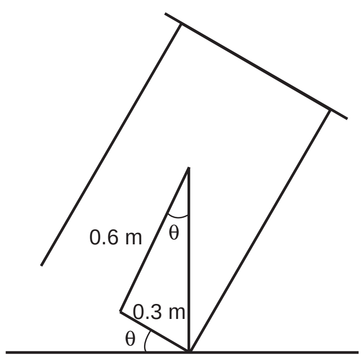
$$\vec{F}_{net} = 0$$
$$\vec{F} + \vec{F}_1 + \vec{F}_2 = 0$$
With right taken to be the positive direction,
$$F_1 = F + F_2$$
$$F_1 = 0.5\text{ N} + 0.25\text{ N}$$
$$F_1 = 0.75\text{ N}$$
$\vec{F}_1 = 0.75$ N [left], and $\vec{F}_2 = 0.25$ N [right]

**43.**



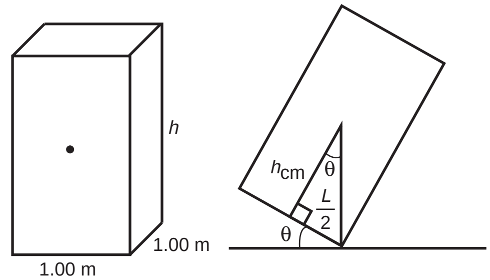

Set $P$ at elbow joint.
$$\vec{\tau}_{net} = 0$$
$$\vec{\tau}_T + \vec{\tau}_{arm} + \vec{\tau}_{sp} = 0$$
With clockwise taken to be the positive torque direction,
$$-\tau_T + \tau_{arm} + \tau_{sp} = 0$$
$$\tau_T = \tau_{arm} + \tau_{sp}$$
$$r_T F_T = r_{arm} F_{g(arm)} + r_{sp} F_{g(sp)}$$
$$F_T = \frac{r_{arm} m_{arm} g + r_{sp} m_{sp} g}{r_T}$$
$$F_T = \frac{(0.11\text{ m})(2.7\text{ kg})(9.8\text{ N/kg}) + (0.280\text{ m})(7.25\text{ kg})(9.8\text{ N/kg})}{0.024\text{ m}}$$
$$F_T = 9.5 \times 10^2\text{ N}$$

**44.**



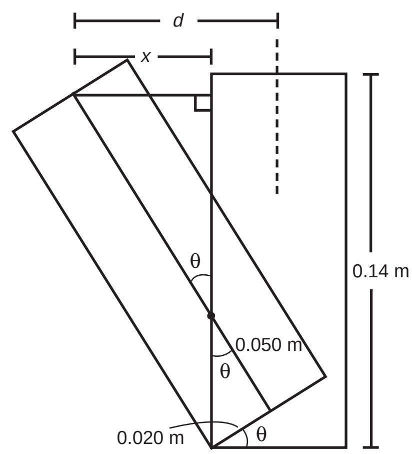

$$\tan\theta = \frac{0.3\text{ m}}{0.6\text{ m}}$$
$$\theta = 26°$$
The tipping angle is 26° from the horizontal.

**45.**



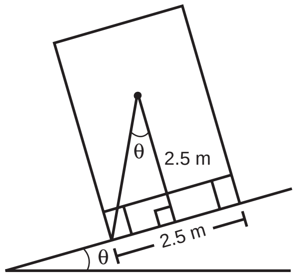

$$\tan\theta = \frac{\left(\frac{L}{2}\right)}{h_{cm}}$$
$$h_{cm} = \frac{\left(\frac{L}{2}\right)}{\tan\theta}$$
$$h_{cm} = \frac{\left(\frac{1.00\text{ m}}{2}\right)}{\tan 30°}$$
$$h_{cm} = 0.8660\text{ m}$$
But:
$$h = 2h_{cm}$$
$$h = 2(0.8660\text{ m})$$
$$h = 1.73\text{ m}$$
NOTE: The solution to problem 46 is based on the pivot point of the glass being at the corner of the base.

**46.**




$$\tan\theta = \frac{0.020\text{ m}}{0.050\text{ m}}$$
$$\theta = 21.8°$$
$$\sin\theta = \frac{x}{h - 0.050\text{ m}}$$
$$x = (0.14\text{ m} - 0.050\text{ m})\sin 21.8°$$
$$x = 0.033\text{ m}$$
$$d = x + r$$
$$d = 0.033\text{ m} + 0.020\text{ m}$$
$$d = 0.053\text{ m}$$

**47.**




$$\tan\theta = \frac{\left(\dfrac{base}{2}\right)}{h_{\text{cm}}}$$

$$\tan\theta = \frac{\left(\dfrac{2.5\text{ m}}{2}\right)}{2.5\text{ m}}$$

$$\theta = 26.6°$$

# Chapter 8

**28.** $\vec{p} = m\vec{v}$

**a)** $m = 120$ kg, $v = 4.0$ m/s

$p = (120 \text{ kg})(4.0 \text{ m/s})$

$= 480 \text{ kg} \cdot \text{m/s}$

**b)** $m = 2.04 \times 10^5$ kg, $v = 0.2$ m/s

$p = (2.04 \times 10^5 \text{ kg})(0.2 \text{ m/s})$

$= 40\ 800 \text{ kg} \cdot \text{m/s}$

**c)** $m = 0.060$ kg, $v = 140$ km/h $= 38.89$ m/s

$p = (0.060 \text{ kg})(38.89 \text{ m/s})$

$= 2.3 \text{ kg} \cdot \text{m/s}$

**d)** $m = 130\ 000$ kg, $v = 20$ km/h $= 5.56$ m/s

$p = (130\ 000 \text{ kg})(5.56 \text{ m/s})$

$= 722\ 800 \text{ kg} \cdot \text{m/s}$

**e)** $m = 9.00 \times 10^{-4}$ kg,

$v = 29$ km/h $= 8.06$ m/s

$p = (9.00 \times 10^{-4} \text{ kg})(8.06 \text{ m/s})$

$= 7.25 \times 10^{-3} \text{ kg} \cdot \text{m/s}$

**29.** $p = mv$

$p = (7500 \text{ kg})(120 \text{ m/s})$

$p = 9.0 \times 10^5 \text{ kg} \cdot \text{m/s}$

**30.** $p = mv$

$p = (0.025 \text{ kg})(3 \text{ m/s})$

$p = 0.075 \text{ kg} \cdot \text{m/s}$

**31.** 90 km/h = 25 m/s, $m = 25$ g $= 0.025$ kg

$p = mv$

$p = (0.025 \text{ kg})(25 \text{ m/s})$

$p = 0.63 \text{ kg} \cdot \text{m/s}$

**32.** $v = 500$ km/h $= 138.89$ m/s,

$p = 23\ 000 \text{ kg} \cdot \text{m/s}$

$$m = \frac{p}{v}$$

$$m = \frac{23\ 000 \text{ kg} \cdot \text{m/s}}{138.89 \text{ m/s}}$$

$m = 165.6$ kg

**33.** $$v = \frac{p}{m}$$

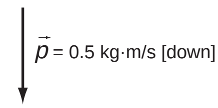
$$v = \frac{1.00 \text{ kg} \cdot \text{m/s}}{1.6726 \times 10^{-27} \text{ kg}}$$

$v = 6.00 \times 10^{26}$ m/s, which is much greater than the speed of light.

**34.** $\vec{p} = m\vec{v}$

$\vec{p} = (0.050 \text{ g})(10 \text{ m/s [down]})$

$\vec{p} = 0.5 \text{ kg} \cdot \text{m/s [down]}$



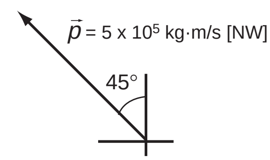

**35.** $$v = (300 \text{ km/h})\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)$$

$= 83.3$ m/s

$\vec{p} = m\vec{v}$

$\vec{p} = (6000 \text{ kg})(83.3 \text{ m/s [NW]})$

$\vec{p} = 5 \times 10^5 \text{ kg} \cdot \text{m/s [NW]}$




**36.** $F = 2200$ N, $\Delta t = 1.30 \times 10^{-3}$ s

**a)** $J = F\Delta t$

$= (2200 \text{ N})(1.30 \times 10^{-3} \text{ s})$

$= 2.86 \text{ kg} \cdot \text{m/s}$

**b)** $\Delta p = J$

$= 2.86 \text{ kg} \cdot \text{m/s}$

**37.** $v_1 = 22$ m/s, $v_2 = 26$ m/s, $m = 1750$ kg

**a)** $\Delta p = p_2 - p_1$

$= m(v_2 - v_1)$

$= (1750 \text{ kg})(26 \text{ m/s} - 22 \text{ m/s})$

$= 7000 \text{ kg} \cdot \text{m/s}$

**b)** $J = \Delta p = 7000 \text{ kg} \cdot \text{m/s}$

**38.** $v_1 = 22$ m/s, $v_2 = -26$ m/s, $m = 1750$ kg

**a)** $\Delta p = p_2 - p_1$

$= m(v_2 - v_1)$

$= (1750 \text{ kg})(-26 \text{ m/s} - 22 \text{ m/s})$

$= 84\ 000 \text{ kg} \cdot \text{m/s}$

**b)** $J = \Delta p, = 84\ 000 \text{ kg} \cdot \text{m/s}$

**39.** $m = 50$ kg, $\vec{F} = 250$ N [forward],

$\Delta t = 3.0$ s, $\vec{v}_1 = 0$

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

$$(250 \text{ N [forward]})(3.0 \text{ s}) = (50 \text{ kg})(\vec{v}_2 - \vec{v}_1)$$

$$\frac{740 \text{ N [forward]}}{50 \text{ kg}} = \vec{v}_2$$

$$\vec{v}_2 = 15 \text{ m/s [forward]}$$

**40.** $m = 150$ kg, $v_1 = 0$, $a = 2.0$ m/s$^2$,

$\Delta t = 4.0$ s

**a)** $v_2 = v_1 + a\Delta t$

$v_2 = 0 + (2.0 \text{ m/s}^2)(4.0 \text{ s})$

$v_2 = 8.0$ m/s

$p = mv$

$p = (150 \text{ kg})(8.0 \text{ m/s})$

$p = 1200 \text{ kg·m/s}$

**b)** $J = \Delta p$

$J = m_2v_2 - m_1v_1$

$J = (150 \text{ kg})(8.0 \text{ m/s}) - (150 \text{ kg})(0)$

$J = 1200 \text{ kg·m/s}$

**41.** $m = 1.5$ kg, $\Delta h = -17$ m, $v_1 = 0$, $a = -9.8$ N/kg

**a)** $$\Delta h = v_1\Delta t + \frac{1}{2}a\Delta t^2$$

$$-17 \text{ m} = 0 + \frac{1}{2}(-9.8 \text{ m/s}^2)\Delta t^2$$

$$\Delta t = 1.86 \text{ s}$$

**b)** $F = ma$

$F = (1.5 \text{ kg})(-9.8 \text{ N/kg})$

$F = -14.7 \text{ N}$

**c)** $J = F\Delta t$

$J = (-14.7 \text{ N})(1.86 \text{ s})$

$J = -27.3 \text{ kg·m/s}$

**42.** $F = 700$ N, $\Delta t = 0.095$ s

**a)** $J = F\Delta t$

$J = (700 \text{ N})(0.095 \text{ s})$

$J = 66.5 \text{ kg·m/s}$

**b)** $J = \Delta p$

$\Delta p = 66.5 \text{ kg·m/s}$

**43.** $m = 0.20$ kg, $v_1 = -25$ m/s, $v_2 = 20$ m/s

$\Delta p = m_2v_2 - m_1v_1$

$\Delta p = (0.2 \text{ kg})(20 \text{ m/s}) - (0.2 \text{ kg})(-25 \text{ m/s})$

$\Delta p = 9.0 \text{ kg·m/s}$

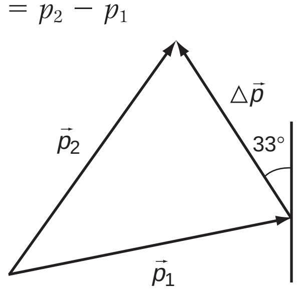
**44.** $$F\Delta t = m\Delta v$$

$$(\text{N})(\text{s}) = (\text{kg})(\text{m/s})$$

$$(\text{kg·m/s}^2)(\text{s}) = (\text{kg})(\text{m/s})$$

$$\text{kg·m/s} = \text{kg·m/s}$$

**45.** $\Delta\vec{p} = \vec{p}_2 - \vec{p}_1$




**46.** $v_1 = 0$, $v_2 = 250$ m/s, $m = 3.0$ kg, $F = 2.0 \times 10^4$ N

**a)** $J = \Delta p$

$J = m_2v_2 - m_1v_1$

$J = (3.0 \text{ kg})(250 \text{ m/s}) - 0$

$J = 750 \text{ kg·m/s}$

**b)** $J = F\Delta t$

$$\Delta t = \frac{J}{F}$$

$$\Delta t = \frac{750 \text{ kg·m/s}}{2 \times 10^4 \text{ N}}$$

$\Delta t = 0.038 \text{ s}$

**47.** $m = 7000$ kg, $v_1 = 110$ km/h $= 30.56$ m/s, $\Delta t = 0.40$ s, $v_2 = 0$

**a)** $$F = \frac{\Delta p}{\Delta t}$$

$$F = \frac{m_2v_2 - m_1v_1}{\Delta t}$$

$$F = \frac{0 - (7000 \text{ kg})(30.56 \text{ m/s})}{0.40 \text{ s}}$$

$F = -5.3 \times 10^5 \text{ N}$

**b)** $$F = \frac{\Delta p}{\Delta t}$$

$$F = \frac{m_2v_2 - m_1v_1}{\Delta t}$$

$$F = \frac{0 - (7000 \text{ kg})(30.56 \text{ m/s})}{8.0 \text{ s}}$$

$F = -2.7 \times 10^4 \text{ N}$

**48.** $m = 30 \text{ g} = 0.03$ kg, $v_1 = 360$ m/s, $\Delta d = 5 \text{ cm} = 0.05$ m

**a)** $p = mv$

$p = (0.03 \text{ kg})(360 \text{ m/s})$

$p = 11 \text{ kg·m/s}$

**b)** $v_2^2 = v_1^2 + 2a\Delta d$

$0^2 = (360 \text{ m/s})^2 + 2a(0.05 \text{ m})$

$a = -1.3 \times 10^6 \text{ m/s}^2$

**c)** $F = ma$

$F = (0.03 \text{ kg})(-1.3 \times 10^6 \text{ m/s}^2)$

$F = -3.9 \times 10^4 \text{ N}$

**d)** $$a = \frac{v_2 - v_1}{\Delta t}$$

$$\Delta t = \frac{v_2 - v_1}{a}$$

$$\Delta t = \frac{0 - 360 \text{ m/s}}{-1.3 \times 10^6 \text{ m/s}^2}$$

$\Delta t = 2.8 \times 10^{-4} \text{ s}$

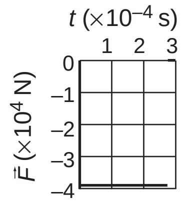
**e)** $J = \Delta p$

$J = m_2v_2 - m_1v_1$

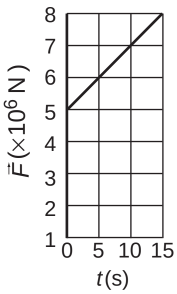
$J = (0.03 \text{ kg})(0) - (0.03 \text{ kg})(360 \text{ m/s})$

$J = -11 \text{ kg·m/s}$

**f)**




**49. a)**




**b)** Area $= \frac{1}{2}h(a + b)$

$$J = \frac{1}{2}(15\ \text{s})(5 \times 10^6\ \text{N} + 8 \times 10^6\ \text{N})$$

$$J = 9.8 \times 10^7\ \text{N}\cdot\text{s}$$

**50. a)** area is a trapezoid

$$\text{area} = \left(\frac{20\ \text{s} + 15\ \text{s}}{2}\right)(100\ \text{N}) = 1750\ \text{N}\cdot\text{s}$$

**b)** area is a triangle

$$\text{area} = \tfrac{1}{2}(4 \times 10^{-2}\ \text{s})(15\ \text{N}) = 0.3\ \text{N}\cdot\text{s}$$

**c)** area is a trapezoid

$$\text{area} = \left(\frac{12.5\ \text{s} + 27.5\ \text{s}}{2}\right)(-10\ \text{N}) = -200\ \text{N}\cdot\text{s}$$

**51.** $J$ = area under the curve

$$J = \frac{1}{2}(-90\ \text{N})(0.3\ \text{s}) + (120\ \text{N})(0.2\ \text{s}) + \frac{1}{2}(75\ \text{N})(0.4\ \text{s})$$

$$J = (-13.5\ \text{N}\cdot\text{s}) + (24\ \text{N}\cdot\text{s}) + (15\ \text{N}\cdot\text{s})$$

$$J = 25.5\ \text{N}\cdot\text{s}$$

**52.** $J$ = area under the graph

Counting roughly 56 squares,

$$J = 56(0.5 \times 10^3\ \text{N})(0.05\ \text{s})$$

$$J = 1.4 \times 10^3\ \text{N}\cdot\text{s}$$

**53.**

$$J = \Delta p$$

$$J = mv_2 - mv_1, \text{ where } v_1 = 0,$$

$$1.4 \times 10^3\ \text{N}\cdot\text{s} = (0.250\ \text{kg})(v_2)$$

$$v_2 = 5.6 \times 10^3\ \text{m/s}$$

**54.** $\vec{v}_1 = 50.0\ \text{km/h [W]} = -13.9\ \text{m/s}$,

$m = 2200\ \text{kg}$

from graph, $\vec{F}\Delta t = \frac{1}{2}(0.6\ \text{s})(9600\ \text{N})$

$= 2880\ \text{N}\cdot\text{s}$

$$\vec{F}\Delta t = \Delta\vec{p}$$

$$= m(\vec{v}_2 - \vec{v}_1)$$

$$\vec{v}_2 = \frac{\vec{F}\Delta t}{m} + v_1$$

$$= \frac{2880\ \text{N}\cdot\text{s}}{2200\ \text{kg}} + (-13.9\ \text{m/s})$$

$$= -12.6\ \text{m/s}\ (45.3\ \text{km/h [W]})$$

**55.** $m = 0.045\ \text{kg}$, $v_1 = 0$, $\Delta p = 2.86\ \text{kg}\cdot\text{m/s}$

$$\Delta\vec{p} = \vec{p}_2 - \vec{p}_1 = m(\vec{v}_2 - \vec{v}_1)$$

$$\frac{\Delta\vec{p}}{m} = \vec{v}_2$$

$$v_2 = \frac{2.86\ \text{kg}\cdot\text{m/s}}{0.045\ \text{kg}}$$

$$= 63.56\ \text{m/s}$$

$$\cong 63.6\ \text{m/s}$$

**56.** $a = 125\ \text{m/s}^2$, $\Delta t = 0.20\ \text{s}$, $m = 60\ \text{kg}$

**a)** $J = F\Delta t = ma\Delta t$

$$= (60\ \text{kg})(125\ \text{m/s}^2)(0.20\ \text{s})$$

$$= 1500\ \text{kg}\cdot\text{m/s}$$

**b)** $\vec{J} = \Delta\vec{p} = m\Delta\vec{v}$

$$\Delta v = \frac{J}{m}$$

$$= \frac{(1500\ \text{kg}\cdot\text{m/s})}{(60\ \text{kg})}$$

$$= 25\ \text{m/s}$$

**57.** $m_g = 0.045\ \text{kg}$, $m_p = 0.004\ \text{kg}$,

$v_p = 8.1 \times 10^3\ \text{m/s}$

$$p_g = p_p$$

$$m_g v_g = m_p v_p$$

$$v_g = \frac{m_p v_p}{m_g}$$

$$= \frac{(0.004\ \text{kg})(8.2 \times 10^3\ \text{m/s})}{0.045\ \text{kg}}$$

$$= 729\ \text{m/s}$$

$$= 2624\ \text{km/h}$$

**58.** $m_c = 2000$ kg, $m_o = 0.91$ kg,
$v_o = 7242$ m/s

$$m_c v_c = m_o v_o$$

$$v_c = \frac{m_o v_o}{m_c} = \frac{(0.91 \text{ kg})(7242 \text{ m/s})}{2000 \text{ kg}} = 3.3 \text{ m/s}$$

**59.** $m = 0.142$ kg, $v = 160$ km/h $= 44.44$ m/s

**a)** $\Delta t = 0.02$ s

$$\vec{J} = \vec{F}\Delta t = \vec{p} = m\vec{v}$$

$$F = \frac{mv}{\Delta t} = \frac{(0.142 \text{ kg})(44.44 \text{ m/s})}{0.02 \text{ s}} \cong 320 \text{ N}$$

**b)** $\Delta t = 0.20$ s

$$F = \frac{(0.142 \text{ kg})(44.44 \text{ m/s})}{0.20 \text{ s}} = 32 \text{ N}$$

**60. a)** $m = 80$ kg, $v_1 = 27.78$ m/s,
$v_2 = 9.17$ m/s, $\Delta t = 4.0$ s

$$\Delta p = m(v_2 - v_1) = (80 \text{ kg})(9.17 \text{ m/s} - 27.78 \text{ m/s}) = -1488.8 \text{ kg}\cdot\text{m/s}$$

$$\vec{J} = \vec{F}\Delta t = \Delta\vec{p}$$

$$F = \frac{\Delta p}{\Delta t} = \frac{-1488.8 \text{ kg}\cdot\text{m/s}}{4.0 \text{ s}} \cong -370 \text{ N}$$

**b)** $m = 80$ kg, $v_2 = 0$ m/s,
$v_1 = 9.17$ m/s, $\Delta t = 0.500$ s

$$\Delta p = m(v_2 - v_1) = (80 \text{ kg})(0 \text{ m/s} - 9.17 \text{ m/s}) = -733 \text{ kg}\cdot\text{m/s}$$

$$\vec{J} = \vec{F}\Delta t = \Delta\vec{p}$$

$$F = \frac{\Delta p}{\Delta t} = \frac{-733.6 \text{ kg}\cdot\text{m/s}}{0.5 \text{ s}} \cong -1470 \text{ N}$$

**c)** $m = 80$ kg, $v_2 = 0$ m/s,
$v_1 = 9.17$ m/s, $\Delta t = 0.0150$ s

$$\Delta p = m(v_2 - v_1) = (80 \text{ kg})(0 \text{ m/s} - 9.17 \text{ m/s}) = -733 \text{ kg}\cdot\text{m/s}$$

$$\vec{J} = \vec{F}\Delta t = \Delta\vec{p}$$

$$F = \frac{\Delta p}{\Delta t} = \frac{-733.6 \text{ kg}\cdot\text{m/s}}{0.015 \text{ s}} \cong -48\,900 \text{ N}$$

**61.** $m = 0.0600$ kg, $v_1 = 330$ m/s,
$v_2 = 0$ m/s, $\Delta d = 0.15$ m

**a)** $\Delta\vec{d} = \frac{1}{2}(\vec{v}_1 + \vec{v}_2)\Delta t$

$$\Delta t = \frac{2\Delta d}{(v_1 + v_2)} = \frac{2(0.15 \text{ m})}{330 \text{ m/s}} = 9.09 \times 10^{-4} \text{ s}$$

$$\vec{J} = \vec{F}\Delta t = \Delta\vec{p} = m(\vec{v}_2 - \vec{v}_1)$$

$$F = \frac{m(v_2 - v_1)}{\Delta t} = \frac{(0.0600 \text{ kg})(-330 \text{ m/s})}{9.09 \times 10^{-4} \text{ s}} = -21\,782.18 \text{ N} \cong -21\,800 \text{ N}$$

**b)** $J = F\Delta t = (-21\,782.18 \text{ N})(9.09 \times 10^{-4} \text{ s}) = -19.8 \text{ kg}\cdot\text{m/s}$

**c)** $\Delta p = m(v_2 - v_1) = (0.0600 \text{ kg})(-330 \text{ m/s}) = -19.8 \text{ kg m/s}$

**62.** $m = 0.06$ kg, $v_1 = 30$ m/s,
$v_2 = -40$ m/s, $\Delta t = 0.025$ s

**a)** $\vec{J} = \vec{F}\Delta t = \Delta\vec{p} = m(\vec{v}_2 - \vec{v}_1)$

$$F = \frac{m(v_2 - v_1)}{\Delta t} = \frac{(0.06 \text{ kg})(-40 \text{ m/s} - 30 \text{ m/s})}{0.025 \text{ s}} = -168 \text{ N}$$

**b)** $\vec{F} = m\vec{a}$

$$a = \frac{F}{m} = \frac{-168 \text{ N}}{0.06 \text{ kg}} = -2800 \text{ m/s}^2$$

**63.** $m = 120$ kg
$v_1 = 15$ km/h
$v_2 = 0$ m/s
$\Delta t = 1.10$ s

**a)** $\Delta\vec{p} = m(\vec{v}_2 - \vec{v}_1)$

$$\Delta p = (120 \text{ kg})(0 \text{ m/s} - 4.17 \text{ m/s})$$

$$\Delta p = -500 \text{ kg}\cdot\text{m/s}$$

**b)** $J = \Delta p = -500 \text{ kg}\cdot\text{m/s}$

**c)** $\vec{J} = \vec{F}\Delta t$

$$\vec{F} = \frac{\vec{J}}{\Delta t}$$

$$F = \frac{-500 \text{ kg}\cdot\text{m/s}}{1.10 \text{ s}}$$

$$F = -455 \text{ N}$$

**d)** $\Delta d = \frac{1}{2}(v_1 + v_2)\Delta t$

$$\Delta d = \tfrac{1}{2}(4.17 \text{ m/s} + 0 \text{ m/s})(1.10 \text{ s})$$

$$\Delta d = 2.29 \text{ m}$$

**64.** $m = 0.165 \text{ kg} = m_1 = m_2$
$v_{1_i} = 8.2 \text{ m/s}$
$v_{2_i} = 0 \text{ m/s}$
$v_{1_f} = 3.0 \text{ m/s}$
$m\vec{v}_{1_f} + m\vec{v}_{2_f} = m\vec{v}_{1_i} + m\vec{v}_{1_f}$
$\vec{v}_{1_f} + \vec{v}_{2_f} = \vec{v}_{1_i} + \vec{v}_{1_f}$
$\vec{v}_{2_f} = \vec{v}_{1_i} + \vec{v}_{2_i} - \vec{v}_{1_f}$
$v_{2_f} = 8.2 \text{ m/s} + 0 \text{ m/s} - 3.0 \text{ m/s}$
$v_{2_f} = 5.2 \text{ m/s}$

**65.** $v_{1_i} = 8.2 \text{ m/s}$
$v_{1_f} = -1.2 \text{ m/s}$
$v_{2_i} = 0 \text{ m/s}$
$\vec{v}_{2_f} = \vec{v}_{1_i} + \vec{v}_{2_i} - \vec{v}_{1_f}$
$\vec{v}_{2_f} = 8.2 \text{ m/s} + 0 \text{ m/s} - (-1.2 \text{ m/s})$
$v_{2_f} = 9.4 \text{ m/s}$

**66.** $v_{1_i} = 8.2 \text{ m/s}$
$v_{1_f} = 8.0 \text{ m/s}$
$v_{2_i} = 2.0 \text{ m/s}$
$\vec{v}_{2_f} = \vec{v}_{1_i} + \vec{v}_{2_i} - \vec{v}_{1_f}$
$v_{2_f} = 8.2 \text{ m/s} + 2.0 \text{ m/s} - 3.0 \text{ m/s}$
$v_{2_f} = 7.2 \text{ m/s}$

**67.** $v_{1_f} = 0.8 \text{ m/s}$
$v_{2_i} = 2.2 \text{ m/s}$
$v_{2_f} = 4.5 \text{ m/s}$
$\vec{v}_{1_i} = \vec{v}_{1_f} + \vec{v}_{2_f} - \vec{v}_{2_i}$
$v_{1_i} = 0.8 \text{ m/s} + 4.5 \text{ m/s} - 2.2 \text{ m/s}$
$v_{1_i} = 3.1 \text{ m/s}$

**68.** $v_{1_i} = 7.6 \text{ m/s}$
$v_{2_i} = -4.5 \text{ m/s}$
$v_{2_f} = 2.5 \text{ m/s}$
$m_1\vec{v}_{1_i} + m_2\vec{v}_{2_i} = m_1\vec{v}_{1_f} + m_2\vec{v}_{2_f}$
$\vec{v}_{1_f} = \vec{v}_{1_i} + \vec{v}_{2_f} - \vec{v}_{2_i}$
$v_{1_f} = 7.6 \text{ m/s} - 4.5 \text{ m/s} - 2.5 \text{ m/s}$
$v_{1_f} = 0.6 \text{ m/s}$

**69.** $m_1 = 40 \text{ g} = 0.04 \text{ kg}$
$m_2 = 50 \text{ g} = 0.05 \text{ kg}$
$v_{1_i} = 25 \text{ cm/s} = 0.25 \text{ m/s}$
$v_{2_i} = 0 \text{ m/s}$
$m_1\vec{v}_{1_i} + m_2\vec{v}_{2_i} = (m_1 + m_2)\vec{v}_f$

$$\vec{v}_f = \frac{m_1\vec{v}_{1_i} + m_2\vec{v}_{2_i}}{m_1 + m_2}$$

$$v_f = \frac{(0.04 \text{ kg})(0.25 \text{ m/s}) + (0.05 \text{ kg})(0 \text{ m/s})}{0.04 \text{ kg} + 0.05 \text{ kg}}$$

$v_f = 0.11 \text{ m/s}$

**70.** $m_1 = 2200 \text{ kg}$
$m_2 = 1800 \text{ kg}$
$v_{1_i} = 40 \text{ km/h} = 11.11 \text{ m/s}$
$v_{2_i} = 20 \text{ km/h} = 5.56 \text{ m/s}$

$$v_f = \frac{m_1 v_{1_i} + m_2 v_{2_i}}{m_1 + m_2}$$

$$v_f = \frac{(2200 \text{ kg})(11.11 \text{ m/s}) + (1800 \text{ kg})(5.56 \text{ m/s})}{2200 \text{ kg} + 1800 \text{ kg}}$$

$v_f = 8.6 \text{ m/s}$

**71. a)** $m_M = 5.5 \times 10^{10} \text{ kg}$
$m_E = 5.98 \times 10^{24} \text{ kg}$
$v_{M_i} = 70\,000 \text{ km/h} = 19\,444.44 \text{ m/s}$
$v_{E_i} = 0 \text{ m/s}$

$$\vec{v}_{E_f} = \frac{m_M\vec{v}_{E_i} + m_E\vec{v}_{E_i}}{m_1 + m_2}$$

$$v_{E_f} = \frac{(5.5 \times 10^{10} \text{ kg})(19\,444.44 \text{ m/s}) + (5.98 \times 10^{24} \text{ kg})(0 \text{ m/s})}{(5.5 \times 10^{10} \text{ kg} + 5.98 \times 10^{24} \text{ kg})}$$

$v_{E_f} = 1.79 \times 10^{-10} \text{ m/s}$

$$\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$$

$$v = \frac{2\pi(1.49 \times 10^{11} \text{ m})}{365 \times 24 \times 60 \times 60}$$

$v = 29\,686.54 \text{ m/s}$
$\cong 29\,700 \text{ m/s}$

**b)** $(5.5 \times 10^{10} \text{ kg})(19\,444 \text{ m/s})$
$+ (5.98 \times 10^{24} \text{ kg})(29\,700 \text{ m/s})$
$= 0 + (5.98 \times 10^{24} \text{ kg})v_{E_f}$
$v_{E_f} = 29\,700 \text{ m/s}$

Therefore, $\vec{v}_{E_f}$ does not change appreciably.

**72.** $m_T = 300 \text{ g} = 0.3 \text{ kg}$
$m_1 = 120 \text{ g} = 0.12 \text{ kg}$
$v_{1_f} = 220 \text{ m/s}$
$m_2 = 300 \text{ g} - 120 \text{ g} = 180 \text{ g} = 0.18 \text{ kg}$
$m_1\vec{v}_{1_i} + m_2\vec{v}_{2_i} = m_1\vec{v}_{1_f} + m_2\vec{v}_{2_f}$
$(m_1 + m_2)\vec{v}_i = m_1\vec{v}_{1_f} + m_2\vec{v}_{2_f}$
$0 = m_1\vec{v}_{1_f} + m_2\vec{v}_{2_f}$

$$\vec{v}_{2_f} = -\left(\frac{m_1}{m_2}\right)\vec{v}_{1_f}$$

$$v_{2_f} = \frac{-0.12 \text{ kg}}{0.18 \text{ kg}} \times 220 \text{ m/s}$$

$v_{2_f} = -145 \text{ m/s}$

**73.** $m_1 = 250 \text{ g} = 0.25 \text{ kg}$
$m_2 = 1.2 \text{ kg}$
$v_{1_i} = 330 \text{ m/s}$
$v_{1_f} = 120 \text{ m/s}$
$v_{2_i} = 0 \text{ m/s}$

$d = 0.30$ m

**a)** $\vec{v}_{2f} = \dfrac{(m_1\vec{v}_{1_i} + m_2\vec{v}_{2_i} - m_1\vec{v}_{1_f})}{m_2}$

$v_{2f} = \frac{(0.25 \text{ kg})(330 \text{ m/s}) + (1.2 \text{ kg})(0 \text{ m/s}) - (0.25 \text{ kg})(120 \text{ m/s})}{1.2 \text{ kg}}$

$v_{2f} = 43.75$ m/s

$v_{2f} \cong 44$ m/s

**b)** $\vec{J} = \Delta\vec{p} = (m_1\vec{v}_{1_f} - m_1\vec{v}_{1_i})$

$\Delta p = (1.2 \text{ kg})(43.75 \text{ m/s}) - 0$

$\Delta p = 52 \text{ kg}\cdot\text{m/s}$

**c)** $\vec{J} = \Delta\vec{p} = (m_1\vec{v}_{1_f} - m_1\vec{v}_{1_i})$

$\Delta p = (0.25 \text{ kg})(120 \text{ m/s})$
$\quad - (0.25 \text{ kg})(330 \text{ m/s})$

$\Delta p = -52 \text{ kg}\cdot\text{m/s}$

Newton's third law → action–reaction

**d)** $\Delta d = \frac{1}{2}(v_{1_i} + v_{1_f})\, \Delta t$

$\Delta t = \dfrac{2(0.30 \text{ m})}{(330 \text{ m/s} + 120 \text{ m/s})}$

$\Delta t = 1.3 \times 10^{-3}$ s

**e)** $\vec{J} = \vec{F}\Delta t$

$\vec{F} = \dfrac{\vec{J}}{\Delta t}$

$F = \dfrac{-52.5 \text{ kg}\cdot\text{m/s}}{1.33 \times 10^{-3} \text{ s}}$

$F = -3.95 \times 10^4$ N

$\cong -4.0 \times 10^4$ N

**f)** $\vec{F} = m\vec{a}$

$\vec{a} = \dfrac{\vec{F}}{m}$

$a = \dfrac{-3.95 \times 10^4 \text{ N}}{0.25 \text{ kg}}$

$a = -158\,000 \text{ m/s}^2$

$a \cong -1.6 \times 10^5 \text{ m/s}^2$

**74.** $m_T = 10\,000$ kg

$v_{T_i} = 30$ km/h $= 8.33$ m/s

$v_{T_f} = 0$ m/s

**a)** $\Delta\vec{p} = m_T(\vec{v}_{T_f} - \vec{v}_{T_i})$

$\Delta p = (10\,000 \text{ kg})(-8.33 \text{ m/s})$

$\Delta p = -8.33 \times 10^4 \text{ kg}\cdot\text{m/s}$

**b)** $J = \Delta p = -83\,300 \text{ kg}\cdot\text{m/s}$

**c)** $F_f = \mu F_n$

$F_f = (1.4)(100 \text{ kg})(9.8 \text{ m/s}^2)$

$F_f = 1372$ N

**d)** $J = F_f\Delta t$

$\Delta t = \dfrac{J}{F_f}$

$\Delta t = \dfrac{83\,300 \text{ kg}\cdot\text{m/s}}{1372 \text{ N}}$

$\Delta t = 61$ s

**e)** $\Delta d = \frac{1}{2}(v_{1_i} + v_{1_f})\Delta t$

$\Delta d = \frac{1}{2}(8.33 \text{ m/s})(61 \text{ s})$

$\Delta d = 250$ m

**75.** $\vec{p}_{To} = \vec{p}_{Tf}$

$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = (m_1 + m_2)\vec{v}_f$,
where $\vec{v}_{2o} = 0$

$(5000 \text{ kg})(5 \text{ m/s [S]}) = (10\,000 \text{ kg})(\vec{v}_f)$

$\vec{v}_f = 2.5$ m/s [S]

**76.** $\vec{p}_{To} = \vec{p}_{Tf}$

$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = (m_1 + m_2)\vec{v}_f$, where $\vec{v}_{2o} = 0$

$(45 \text{ kg})(5 \text{ m/s}) = (47 \text{ kg})(\vec{v}_f)$

$\vec{v}_f = 4.8$ m/s [in the same direction as $\vec{v}_{1o}$]

**77.** $\vec{p}_{To} = \vec{p}_{Tf}$

$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$

$(65 \text{ kg})(15 \text{ m/s}) + (100 \text{ kg})(-5 \text{ m/s})$

$= (65 \text{ kg})\left(\dfrac{1}{3}\right)(15 \text{ m/s}) + (100 \text{ kg})(v_{2f})$

$(975 - 500 - 325) \text{ kg}\cdot\text{m/s} = (100 \text{ kg})(v_{2f})$

$v_{2f} = 1.5$ m/s

**78.** $\vec{p}_{To} = \vec{p}_{Tf}$

$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = (m_1 + m_2)\vec{v}_f$,
where $v_{2o} = 0$

$(0.5 \text{ kg})(20 \text{ m/s}) + 0 = (30.5 \text{ kg})(v_f)$

$v_f = 0.33$ m/s

**79.** $\vec{p}_{To} = \vec{p}_{Tf}$

$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$

$(0.2 \text{ kg})(3 \text{ m/s}) + (0.2 \text{ kg})(-1 \text{ m/s})$

$= (0.2 \text{ kg})(2 \text{ m/s}) + (0.2 \text{ kg})(v_{2f})$

$0.4 \text{ kg}\cdot\text{m/s} = 0.4 \text{ kg}\cdot\text{m/s} + (0.2 \text{ kg})(v_{2f})$

$v_{2f} = 0$

**80.** $v_{1o} = 90$ km/h $= 25$ m/s,

$v_f = 80$ km/h $= 22.2$ m/s

$p_{To} = p_{Tf}$

$m_1v_{1o} + m_2v_{2o} = (m_1 + m_2)v_f$,
where $v_{2o} = 0$

$m_1(25 \text{ m/s}) + 0 = (m_1 + 6000 \text{ kg})(22.2 \text{ m/s})$

$m_1(25 \text{ m/s}) = m_1(22.2 \text{ m/s}) + 133\,333.3 \text{ kg}\cdot\text{m/s}$

$m_1(25 \text{ m/s} - 22.2 \text{ m/s}) = 133\,333.3 \text{ kg}\cdot\text{m/s}$

$$m_1 = \frac{133\ 333.3\ \text{kg}\cdot\text{m/s}}{2.8\ \text{m/s}}$$

$$m_1 = 4.8 \times 10^4\ \text{kg}$$

**81.**
$$F_1 = -F_2$$
$$ma_1 = -ma_2$$
$$m\left(\frac{v_{1f} - v_{1o}}{\Delta t}\right) = -m\left(\frac{v_{2f} - v_{2o}}{\Delta t}\right)$$
$$m(v_{1f} - v_{1o}) = -m(v_{2f} - v_{2o})$$
$$mv_{1f} - mv_{1o} = -mv_{2f} + mv_{2o}$$
$$mv_{1f} + mv_{2f} = mv_{1o} + mv_{2o}$$
$$p_{Tf} = p_{To}$$
$$p_{Tf} - p_{To} = 0$$
$$\Delta p = 0$$

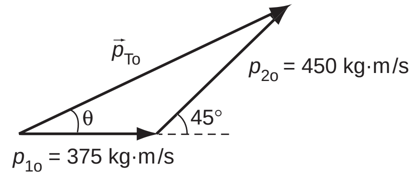
**82.** $m_1 = 1.67 \times 10^{-27}$ kg, $m_2 = 4m_1$,
$$v_1 = 2.2 \times 10^7\ \text{m/s}$$
$$p_{To} = p_{Tf}$$
$$m_1v_{1o} + m_2v_{2o} = (m_1 + m_2)v_f,$$
where $v_{2o} = 0$
$$m_1(2.2 \times 10^7\ \text{m/s}) = (5m_1)v_f$$
$$v_f = \frac{2.2 \times 10^7\ \text{m/s}}{5}$$
$$v_f = 4.4 \times 10^6\ \text{m/s}$$

**83.** $m_1 = 3m$, $m_2 = 4m$, $v_{1o} = v$
$$p_{To} = p_{Tf}$$
$$m_1v_{1o} + m_2v_{2o} = (m_1 + m_2)v_f, \text{ where } v_{2o} = 0$$
$$(3m)v = (7m)v_f$$
$$v_f = \frac{3}{7}v$$

**84.** $m_1 = 99.5$ kg, $m_2 = 0.5$ kg, $v_{1f} = ?$,
$v_{2f} = -20$ m/s
$$p_{To} = p_{Tf}$$
$$0 = (99.5\ \text{kg})(v_{1f}) + (0.5\ \text{kg})(-20\ \text{m/s})$$
$$v_{1f} = \frac{10\ \text{kg}\cdot\text{m/s}}{99.5\ \text{kg}}$$
$$v_{1f} = 0.1\ \text{m/s}$$
$$\Delta t = \frac{\Delta d}{v}$$
$$\Delta t = \frac{200\ \text{m}}{0.1\ \text{m/s}}$$
$$\Delta t = 2 \times 10^3\ \text{s}$$

**85.** $\vec{p}_{1o} = 375$ kg·m/s [E],
$\vec{p}_{2o} = 450$ kg·m/s [N45°E]

**a)** $\vec{p}_{To} = \vec{p}_{1o} + \vec{p}_{2o}$



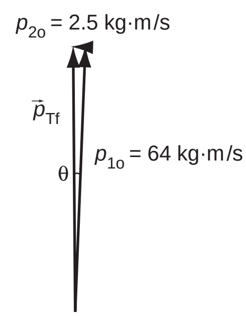

**b)** $\vec{p}_{Tf} = \vec{p}_{To}$

Using the cosine and sine laws,
$$|\vec{p}_{To}|^2 = (375\ \text{kg}\cdot\text{m/s})^2 + (450\ \text{kg}\cdot\text{m/s})^2 - 2(375\ \text{kg}\cdot\text{m/s})(450\ \text{kg}\cdot\text{m/s})\cos 135°$$
$$|\vec{p}_{To}| = 762.7\ \text{kg}\cdot\text{m/s}$$
$$|\vec{p}_{Tf}| = 762.7\ \text{kg}\cdot\text{m/s}$$
$$\frac{\sin\theta}{450\ \text{kg}\cdot\text{m/s}} = \frac{\sin 135°}{762.7\ \text{kg}\cdot\text{m/s}}$$
$$\theta = 24.7°$$

Therefore, $\vec{p}_{Tf} = 763$ kg·m/s [E24.7°N]

**86.** $m_1 = 3.2$ kg, $\vec{v}_{1o} = 20$ m/s [N],
$\vec{p}_{1o} = 64$ kg·m/s [N], $m_2 = 0.5$ kg,
$\vec{v}_{2o} = 5$ m/s [W], $\vec{p}_{2o} = 2.5$ kg·m/s [W]
$$\vec{p}_{To} = \vec{p}_{Tf}$$
$$\vec{p}_{1o} + \vec{p}_{2o} = \vec{p}_{Tf}$$
$$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = (m_1 + m_2)\vec{v}_f$$

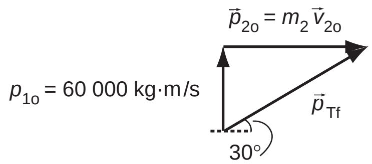
Using the diagram and Pythagoras' theorem,




$$|\vec{p}_{Tf}| = \sqrt{(2.5\ \text{kg}\cdot\text{m/s})^2 + (64\ \text{kg}\cdot\text{m/s})^2}$$
$$|\vec{p}_{Tf}| = 64.05\ \text{kg}\cdot\text{m/s}$$
$$\tan\theta = \frac{2.5\ \text{kg}\cdot\text{m/s}}{64\ \text{kg}\cdot\text{m/s}}$$
$$\theta = 2.2°$$
$$\vec{p}_T = (m_1 + m_2)\vec{v}_f$$
$$64.05\ \text{kg}\cdot\text{m/s [N2.2°W]} = (3.7\ \text{kg})\vec{v}_f$$
$$\vec{v}_f = 17\ \text{m/s [N2.2°W]}$$

**87.** $m_1 = 3000$ kg, $\vec{v}_{1o} = 20$ m/s [N],
$\vec{p}_{1o} = 60\ 000$ kg·m/s [N], $m_2 = 5000$ kg,
$\vec{v}_{2o} = ?$ [E], $\vec{p}_{2o} = ?$ [E], $\vec{v}_f = ?$ [E30°N],
$\vec{p}_f = ?$ [E30°N]
$$\vec{p}_{To} = \vec{p}_{Tf}$$
$$\vec{p}_{1o} + \vec{p}_{2o} = \vec{p}_{Tf}$$

Using the following momentum diagram,




$$\tan 60° = \frac{p_{2o}}{60\ 000\ \text{kg}\cdot\text{m/s}}$$

$$p_{2o} = (60\ 000\ \text{kg}\cdot\text{m/s})(\tan 60°)$$

$$p_{2o} = 103\ 923\ \text{kg}\cdot\text{m/s}$$

$$m_2v_{2o} = 103\ 923\ \text{kg}\cdot\text{m/s}$$

$$v_{2o} = \frac{103\ 923\ \text{kg}\cdot\text{m/s}}{5000\ \text{kg}}$$

$$\vec{v}_{2o} = 20.8\ \text{m/s [E]}$$

**88.** $m_o = 1.2 \times 10^{-24}$ kg, $\vec{v}_o = 0$, $\vec{p}_o = 0$,
$m_1 = 3.0 \times 10^{-25}$ kg, $\vec{v}_1 = 2.0 \times 10^7$ m/s [E],
$\vec{p}_1 = 6 \times 10^{-18}$ kg·m/s [E],
$m_2 = 2.3 \times 10^{-25}$ kg, $\vec{v}_2 = 4.2 \times 10^7$ m/s [N],
$\vec{p}_2 = 9.66 \times 10^{-18}$ kg·m/s [N]

$$m_3 = 1.2 \times 10^{-24}\ \text{kg} - 3.0 \times 10^{-25}\ \text{kg} - 2.3 \times 10^{-25}\ \text{kg}$$

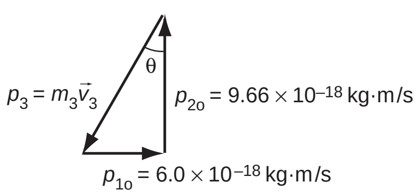
$$m_3 = 6.7 \times 10^{-25}\ \text{kg}$$

$$\vec{p}_{To} = 0$$

$$\vec{p}_{To} = \vec{p}_{Tf}$$

$$0 = \vec{p}_1 + \vec{p}_2 + \vec{p}_3$$

Drawing a momentum vector diagram and using Pythagoras' theorem,




$$|\vec{p}_3|^2 = (9.66 \times 10^{-18}\ \text{kg}\cdot\text{m/s})^2 + (6 \times 10^{-18}\ \text{kg}\cdot\text{m/s})^2$$

$$|\vec{p}_3| = 1.1372 \times 10^{-17}\ \text{kg}\cdot\text{m/s}$$

$$|\vec{v}_3| = \frac{|\vec{p}_3|}{m_3}$$

$$|\vec{v}_3| = \frac{1.1372 \times 10^{-17}\ \text{kg}\cdot\text{m/s}}{6.7 \times 10^{-25}\ \text{kg}}$$

$$|\vec{v}_3| = 1.7 \times 10^7\ \text{m/s}$$

$$\tan\theta = \frac{6 \times 10^{-18}\ \text{kg}\cdot\text{m/s}}{9.66 \times 10^{-18}\ \text{kg}\cdot\text{m/s}}$$

$$\theta = 31.8°$$

Therefore, $\vec{v}_3 = 1.7 \times 10^7$ m/s [S32°W]

**89.** $m_1 = m_2 = m$, $\vec{v}_{1o} = \dfrac{60\ \text{m}}{4.8\ \text{s}} = 12.5$ m/s [R], $\vec{v}_{2o} = 0$, $\vec{v}_{2f} = 1.5$ m/s [R25°U]

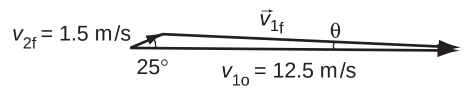
$$\vec{p}_{To} = \vec{p}_{Tf}$$

$$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

Since $m_1 = m_2$ and $\vec{v}_{2o} = 0$,

$$\vec{v}_{1o} = \vec{v}_{1f} + \vec{v}_{2f}$$

Drawing a vector diagram and using trigonometry,




$$|\vec{v}_{1f}|^2 = (1.5\ \text{m/s})^2 + (12.5\ \text{m/s})^2 - 2(1.5\ \text{m/s})(12.5\ \text{m/s})\cos 25°$$

$$|\vec{v}_{1f}| = 11.16\ \text{m/s}$$

$$\frac{\sin\theta}{1.5\ \text{m/s}} = \frac{\sin 25°}{11.6\ \text{m/s}}$$

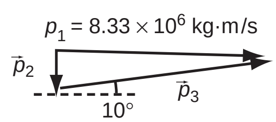
$$\theta = 3.3°$$

Therefore, the first stone is deflected 3.3° or [R3.3°D].

**90.** $m_1 = 10\ 000$ kg,
$\vec{v}_1 = 3000$ km/h [E] $= 833.3$ m/s [E],
$\vec{p}_1 = 8.333 \times 10^6$ kg·m/s [E], $m_2 = ?$,
$\vec{v}_2 = 5000$ km/h [S] $= 1388.9$ m/s [S],
$\vec{p}_2 = m_2(1388.9$ m/s) [S],
$m_3 = 10\ 000$ kg $- m_2$, $\vec{v}_3 = ?$ [E10°N],
$\vec{p}_3 = (10\ 000$ kg $- m_2)(v_3)$ [E10°N]

$$\vec{p}_1 = \vec{p}_2 + \vec{p}_3$$

Drawing a momentum diagram and using trigonometry,




$$\tan 10° = \frac{\vec{p}_2}{\vec{p}_1}$$

$$|\vec{p}_2| = (8.33 \times 10^6\ \text{kg}\cdot\text{m/s})(\tan 10°)$$

$$|\vec{p}_2| = 1.47 \times 10^6\ \text{kg}\cdot\text{m/s}$$

$$\vec{p}_2 = m_2(1388.9\ \text{m/s})\ [\text{S}]$$

$$m_2 = \frac{1.47 \times 10^6\ \text{kg}\cdot\text{m/s}}{1388.8\ \text{m/s}}$$

$$m_2 = 1057.6\ \text{kg}$$

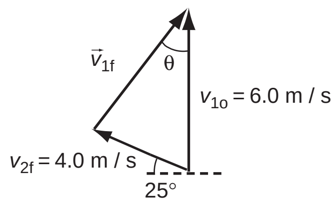
The mass of the ejected object is $1.058 \times 10^3$ kg.

**91.** $m_1 = m_2 = m$, $\vec{v}_{1o} = 6.0$ m/s [U], $\vec{v}_{2o} = 0$,
$\vec{v}_{2f} = 4$ m/s [L25°U], $\vec{v}_{1f} = ?$

$$\vec{p}_{To} = \vec{p}_{Tf}$$
$$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

Since $m_1 = m_2$ and $\vec{v}_{2o} = 0$,
$\vec{v}_{1o} = \vec{v}_{1f} + \vec{v}_{2f}$

Using the vector diagram and trigonometry,



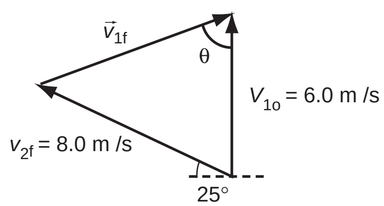

$$|\vec{v}_{1f}|^2 = (6.0 \text{ m/s})^2 + (4.0 \text{ m/s})^2 - 2(6.0 \text{ m/s})(4.0 \text{ m/s}) \cos 65°$$
$$|\vec{v}_{1f}| = 5.63 \text{ m/s}$$
$$\frac{\sin\theta}{4.0 \text{ m/s}} = \frac{\sin 65°}{5.63 \text{ m/s}}$$
$$\theta = 40°$$

Therefore $\vec{v}_{1f} = 5.63$ m/s [U40°R]

**92.** $2m_1 = m_2$, $\vec{v}_{1o} = 6.0$ m/s [U], $\vec{v}_{2o} = 0$,
$\vec{v}_{2f} = 4$ m/s [L25°U], $\vec{v}_{1f} = ?$

$$\vec{p}_{To} = \vec{p}_{Tf}$$
$$m_1\vec{v}_{1o} + m_2\vec{v}_{2o} = m_1 v_{1f} + m_2 v_{2f},$$
since $2m_1 = m_2$ and $\vec{v}_{2o} = 0$
$$\vec{v}_{1o} = \vec{v}_{1f} + 2\vec{v}_{2f}$$

Using the vector diagram and trigonometry,




$$|\vec{v}_{1f}|^2 = (6.0 \text{ m/s})^2 + (8.0 \text{ m/s})^2 - 2(6.0 \text{ m/s})(8.0 \text{ m/s}) \cos 65°$$
$$|\vec{v}_{1f}| = 7.7 \text{ m/s}$$
$$\frac{\sin\theta}{8.0 \text{ m/s}} = \frac{\sin 65°}{7.7 \text{ m/s}}$$
$$\theta = 70°$$

Therefore, $\vec{v}_{1f} = 7.7$ m/s [R20°U]

**93.** Counting ten dots for a one-second interval and measuring the distance with a ruler and the angle with a protractor gives:

**a)** $|\vec{v}_{1o}| = \dfrac{33 \text{ mm}}{1 \text{ s}}$

$|\vec{v}_{1o}| = 0.033$ m/s

$|\vec{v}_{2o}| = 0$

$|\vec{v}_{1f}| = \dfrac{33 \text{ mm}}{1 \text{ s}}$

$|\vec{v}_{1f}| = 0.033$ m/s

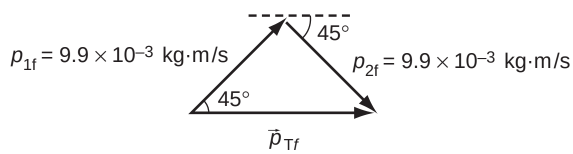
$|\vec{v}_{2f}| = \dfrac{33 \text{ mm}}{1 \text{ s}}$

$|\vec{v}_{2f}| = 0.033$ m/s

**b)** $\vec{v}_{1o} = 0.033$ m/s [E]
$\vec{v}_{2o} = 0$
$\vec{v}_{1f} = 0.033$ m/s [E45°S]
$\vec{v}_{2f} = 0.033$ m/s [E45°N]

**c)** $\vec{p}_{1o} = (0.3 \text{ kg})(0.033 \text{ m/s [E]})$
$\vec{p}_{1o} = 9.9 \times 10^{-3}$ kg·m/s [E]
$\vec{p}_{2o} = (0.3 \text{ kg})(0) = 0$
$\vec{p}_{To} = 9.9 \times 10^{-3}$ kg·m/s [E]
$\vec{p}_{1f} = (0.3 \text{ kg})(0.033 \text{ m/s [E45°S]})$
$\vec{p}_{1f} = 9.9 \times 10^{-3}$ kg·m/s [E45°S]
$\vec{p}_{2f} = (0.3 \text{ kg})(0.033 \text{ m/s [E45°N]})$
$\vec{p}_{2f} = 9.9 \times 10^{-3}$ kg·m/s [E45°N]

The vector diagram for the final situation is shown below.




Using Pythagoras' theorem,

$$|\vec{p}_{Tf}|^2 = (9.9 \times 10^{-3} \text{ kg·m/s})^2 + (9.9 \times 10^{-3} \text{ kg·m/s})^2$$
$$\vec{p}_{Tf} = 1.4 \times 10^{-2} \text{ kg·m/s [E]}$$

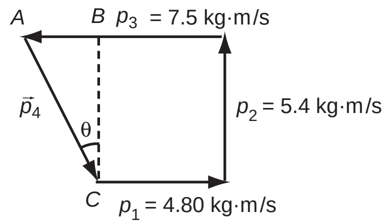
**d)** $p_{1oh} = +\,9.9 \times 10^{-3}$ kg·m/s
$p_{1ov} = 0$
$p_{2oh} = 0$
$p_{2ov} = 0$
$p_{1fh} = +(9.9 \times 10^{-3} \text{ kg·m/s})(\cos 45°)$
$p_{1fh} = 7.0 \times 10^{-3}$ kg·m/s
$p_{1fv} = -(9.9 \times 10^{-3} \text{ kg·m/s})(\sin 45°)$
$p_{1fv} = -7.0 \times 10^{-3}$ kg·m/s
$p_{2fh} = +(9.9 \times 10^{-3} \text{ kg·m/s})(\cos 45°)$
$p_{2fh} = 7.0 \times 10^{-3}$ kg·m/s
$p_{2fv} = +(9.9 \times 10^{-3} \text{ kg·m/s})(\sin\ 45°)$
$p_{2fv} = 7.0 \times 10^{-3}$ kg·m/s

**e)** Momentum is not conserved in this collision. The total final momentum is about 1.4 times the initial momentum.

**94.** $m_1 = 0.2$ kg, $\vec{v}_1 = 24$ m/s [E],
$\vec{p}_1 = 4.8$ kg·m/s [E], $m_2 = 0.3$ kg,
$\vec{v}_2 = 18$ m/s [N], $\vec{p}_2 = 5.4$ kg·m/s [N],
$m_3 = 0.25$ kg, $\vec{v}_3 = 30$ m/s [W],
$\vec{p}_3 = 7.5$ kg·m/s [W], $m_4 = 0.25$ kg,
$\vec{v}_4 = ?$, $\vec{p}_4 = ?$

$$\vec{p}_{To} = 0$$
$$\vec{p}_1 + \vec{p}_2 + \vec{p}_3 + \vec{p}_4 = 0$$

Drawing a vector diagram and using trigonometry,




Using triangle ABC,

$$\tan\theta = \frac{2.7\ \text{kg}\cdot\text{m/s}}{5.4\ \text{kg}\cdot\text{m/s}}$$
$$\theta = 26.6°$$
$$|\vec{p}_4|^2 = (2.7\ \text{kg}\cdot\text{m/s})^2 + (5.4\ \text{kg}\cdot\text{m/s})^2$$
$$|\vec{p}_4| = 6.037\ \text{kg}\cdot\text{m/s}$$
$$|\vec{v}_4| = \frac{6.037\ \text{kg}\cdot\text{m/s}}{0.25\ \text{kg}}$$
$$|\vec{v}_4| = 24.1\ \text{m/s}$$

Therefore, $\vec{v}_4 = 24.1$ m/s [S26.6°E]

## Chapter 9

**21.** $d = 2.5$ m
$F = 25.0$ N
$W = ?$
$W = F \cdot d$
$= (25.0 \text{ N})(2.5 \text{ m})$
$= 62.5$ J

**22.** $F = 12.0$ N
$d = 200.0$ m
$\theta = 90°$
$W = ?$
$W = F \cdot d \cos \theta$
$= (12.0 \text{ N})(200.0 \text{ m}) \cos 90°$
$= (12.0 \text{ N})(200.0 \text{ m})(0)$
$= 0$ J
No work is done on the briefcase by the woman.
No work is done by the businesswoman because the force applied is at right angles to the displacement of the briefcase.

**23.** $F = 6000$ N
$d = 0$ m
$W = ?$
$W = F \cdot d$
$= (6000 \text{ N})(0 \text{ m})$
$= 0$ J
No work is done by the teachers because there was no displacement, despite the force applied.

**24.** $W = 4050$ J
$d = 3.4$ m
$F = ?$
$W = F \cdot d$
Therefore, $F = \dfrac{W}{d}$
$$F = \frac{W}{d}$$
$$= \frac{4050 \text{ J}}{3.4 \text{ m}}$$
$= 1191.1 \text{ N} \cong 1.2 \times 10^3$ N
The snow plow applied $1.2 \times 10^3$ N of force to the snow.

**25.** $W = 1020$ J
$F = 2525$ N
$d = ?$
$W = F \cdot d$
Therefore, $d = \dfrac{W}{F}$
$$d = \frac{1020 \text{ J}}{2525 \text{ N}}$$
$= 0.404$ m
The arrow would have been drawn 0.404 m horizontally.

**26.** $W = F \cdot d$
$W = (25.0 \text{ N})(2.5 \text{ m})$
$= 62$ J
Therefore, friction has no effect.

**27.** **a)** $W = F_{app} \cdot d$
$= (500 \text{ N})(22 \text{ m})$
$= 1.1 \times 10^4$ J

**b)** $W = F_{app} \cdot d$ (The force applied is still 500 N.)
$= (500 \text{ N})(22 \text{ m})$
$= 1.1 \times 10^4$ J

**c)** With an unbalanced force of 500 N: In case a), the toboggan will accelerate. In case b), the applied force is balanced by friction, resulting in constant speed.

**28.** $m = 750$ kg
$d = 8.2$ m
$F = ?$
$F = ma$
$= (750 \text{ kg})(9.8 \text{ m/s}^2)$
$= 7.35 \times 10^3$ J
Therefore, $W = F \cdot d$
$= (7.35 \times 10^3 \text{ N})(8.2 \text{ m})$
$= 6.0 \times 10^4$ J

**29.** $W = 2000$ J
$d = 8.2$ m
$F = ?$
$W = F \cdot d$
Therefore, $F = \dfrac{W}{d}$

$$= \frac{2000\ J}{8.2\ m}$$
$$= 2.4 \times 10^2\ N$$
$F = ma$

Therefore, $m = \frac{F}{a}$

$$m = \frac{2.4 \times 10^2\ N}{9.8\ m/s^2}$$
$$\cong 25\ kg$$

**30.** $v = 0.75$ m/s

$v = \frac{d}{t}$

Therefore, $d = vt$

$$d = (0.75\ m/s)(1\ h)\left(\frac{60\ min}{1\ h}\right)\left(\frac{60\ s}{1\ min}\right)$$
$$= 2.7 \times 10^3\ m$$

Therefore, $W = F \cdot d$
$$= (75\ N)(2.7 \times 10^3\ m)$$
$$\cong 2.0 \times 10^5\ J$$

**31.** $W = Fd \cos \theta$
$$= (200\ N)(20\ m)(\cos 45°)$$
$$= 2.83 \times 10^3\ J$$

**32. a)** $W = F\Delta d$

$W = (4000\ N)(5.0\ m)$

$W = 2.0 \times 10^4\ J$

**b)** $W = (570\ N)(0.08\ m)$

$W = 46\ J$

**c)** $W = \Delta E_k$

$W = E_{k2} - E_{k1}$

$W = \frac{1}{2}mv^2 - 0$

$W = \frac{1}{2}(9.1 \times 10^{-31}\ kg)(1.6 \times 10^8\ m/s)^2$

$W = 1.2 \times 10^{-14}\ J$

**33. a)** $W = F\Delta d$

$W = (500\ N)(5.3\ m)$

$W = 2.7 \times 10^3\ J$

**b)** $W = F\Delta d \cos \theta$

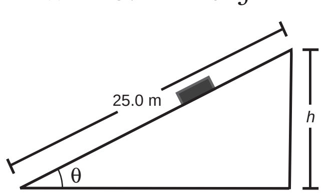
$W = (500\ N)(5.3\ m) \cos 20°$

$W = 2.5 \times 10^3\ J$

**c)** $W = (500\ N)(5.3\ m) \cos 70°$

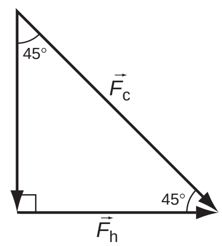
$W = 9.1 \times 10^2\ J$

**34.**




$$W = \Delta E_g$$
$$F\Delta d = mg\Delta h$$
$$(350\ N)(25.0\ m) = (50.0\ kg)(9.8\ N/kg)h$$
$$h = 18\ m$$
$$\sin \theta = \frac{h}{25.0\ m}$$
$$\sin \theta = \frac{18\ m}{25.0\ m}$$
$$\theta = 46°$$

**35.** The two campers must overcome 84 N of friction, or 42 N each in the horizontal direction since both are at the same 45° angle.




The horizontal component of $F_c$, called $F_h$, must be equal to 42 N.

$W = F_h\Delta d$

$W = (42\ N)(50\ m)$

$W = 2.1 \times 10^3\ N \cdot m$

Each camper must do $2.1 \times 10^3$ J of work to overcome friction.

**36.** $W = F\Delta d$ ,where $\Delta d$ for each revolution is zero. Therefore, $W = 0$ J.

**37.** −350 J indicates that the force and the displacement are in the opposite direction. An example would be a car slowing down because of friction. Negative work represents a flow or transfer of energy out of an object or system.

**38.** $\Delta d_{ramp} = 5$ m

$m = 35$ kg

$\Delta d_{height} = 1.7$ m

**a)** $F = ma$

$F = (35\ kg)(9.8\ N/kg)$

$F = 343\ N$

$F = 3.4 \times 10^2\ N$

**b)** $W = F\Delta d$

$W = (3.4 \times 10^2\ N)(1.7\ m)$

$W = 583.1\ J$

$W = 5.8 \times 10^2\ N$

**c)** $W = F\Delta d_{ramp}$

$583.1\ J = F(5\ m)$

$$F = 116.62 \text{ N}$$
$$F = 1.2 \times 10^2 \text{ N}$$

**39.** $W$ = Area under the graph

$$W = \frac{(20 \text{ m})(200 \text{ N})}{2} + (10 \text{ m})(200 \text{ N}) + \frac{(20 \text{ m})(600 \text{ N})}{2} + (20 \text{ m})(200 \text{ N}) + (10 \text{ m})(800 \text{ N}) + \frac{(20 \text{ m})(400 \text{ N})}{2} + (20 \text{ m})(800 \text{ N}) + (10 \text{ m})(1200 \text{ N})$$

$$W = 5.4 \times 10^4 \text{ J}$$

**40. a)** $W$ = area under the graph

$$W = \frac{(1 \text{ m})(100 \text{ N})}{2} + \frac{(1 \text{ m})(200 \text{ N})}{2} + (1 \text{ m})(100 \text{ N}) + (2 \text{ m})(300 \text{ N})$$

$$W = 8.5 \times 10^2 \text{ J}$$

**b)** The wagon now has kinetic energy (and may also have gained gravitational potential energy).

**c)**
$$W = E_k$$
$$E_k = \frac{1}{2}mv^2$$
$$850 \text{ J} = \frac{1}{2}(120 \text{ kg})v^2$$
$$v = 3.8 \text{ m/s}$$

**41.**
$$P = \frac{W}{t} = \frac{3000 \text{ J}}{2 \text{ s}} = 1500 \text{ W}$$

(Discuss the number of significant digits to quote here with the students due to the "two seconds" given in the question.)

**42.**
$$W = P \cdot t$$
$$= (100 \text{ W})(8.0 \text{ h})\left(\frac{60 \text{ min}}{1 \text{ h}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right)$$
$$= 2.9 \times 10^6 \text{ J}$$

**43.**
$$P = \frac{W}{t}$$
$$= \left(\frac{1.8 \times 10^6 \text{ J}}{0.600 \text{ h}}\right)\left(\frac{1 \text{ h}}{60 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$
$$= 8.3 \times 10^2 \text{ W}$$

**44.** $W = P \cdot t$

Therefore, $t = \frac{W}{P}$

$$t = \frac{750 \text{ J}}{1000 \text{ W}}$$
$$= 0.750 \text{ s}$$

**45.**
$$P = \frac{W}{t} = \frac{F_g \cdot d}{t} = F_g \cdot v$$

Therefore, $v = \frac{P}{F_g}$

$$v = \frac{P}{mg} = \frac{950 \text{ W}}{(613.0 \text{ kg})(9.8 \text{ m/s}^2)} = 0.158 \text{ m/s}$$

**46.** $P = \frac{W}{t} = \frac{mgd}{t}$

Recall that 1 L of water has a mass of 1 kg, so 75 L/s = 75 kg/s.

$$= \left(\frac{75 \text{ kg}}{1 \text{ s}}\right)(9.8 \text{ m/s}^2)(92.0 \text{ m})$$
$$= 67\,620 \text{ kg}\cdot\text{m}^2/\text{s}^3$$
$$\cong 6.8 \times 10^4 \text{ W}$$

**47.**
$$E_k = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(0.0600 \text{ kg})(10.0 \text{ m/s})^2 = 3.00 \text{ J}$$

**b)**
$$E_k = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(0.0600 \text{ kg})(25.0 \text{ m/s})^2 \cong 18.8 \text{ J}$$

**48.** $E_k = \tfrac{1}{2}mv^2$

Therefore, $m = \frac{2E_k}{v^2}$

$$m = \frac{2(370 \text{ J})}{(10.0 \text{ m/s})^2} = 7.40 \text{ kg}$$

**49.**
$$E_k = \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(0.0370 \text{ kg})\left[\left(\frac{234.0 \text{ km}}{1 \text{ h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\right]^2$$
$$\cong 78.2 \text{ J}$$

**50.**
$$E_k = \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(2000 \text{ kg})\left[\left(\frac{80 \text{ km}}{1 \text{ h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\right]^2$$
$$= 4.9 \times 10^5 \text{ J}$$

**51.** $E_k = \tfrac{1}{2}mv^2$

Therefore, $v = \sqrt{\frac{2E_k}{m}}$

$$v = \sqrt{\frac{2(246\,913.6 \text{ J})}{2000 \text{ kg}}}$$

$$= \left(\frac{15\text{ m}}{1\text{ s}}\right)\left(\frac{1\text{ km}}{1000\text{ m}}\right)\left(\frac{60\text{ s}}{1\text{ min}}\right)\left(\frac{60\text{ min}}{1\text{ h}}\right)$$
$$= 54\text{ km/h}$$

**52.** $W = \Delta E_k$
$= \frac{1}{2}(105\text{ kg})(10.0\text{ m/s})^2 - \frac{1}{2}(105\text{ kg})(5.0\text{ m/s})^2$
$= 3.9 \times 10^3\text{ J}$

**53. a)** $E_k = \frac{1}{2}mv^2$

Therefore, $v = \sqrt{\frac{2E_k}{m}}$

$$v = \sqrt{\frac{2(2.8 \times 10^4\text{ J})}{250.0\text{ kg}}}$$
$= 15\text{ m/s}$

**b)** $E_k = \frac{1}{2}mv^2$

Therefore, $v = \sqrt{\frac{2E_k}{m}}$

$$v = \sqrt{\frac{2(1.12 \times 10^5\text{ J})}{250.0\text{ kg}}}$$
$= 30\text{ m/s}$

**54. a)** $E_k = \frac{1}{2}mv^2$

$E_k = \frac{1}{2}(45\text{ kg})(10\text{ m/s})^2$

$E_k = 2.3 \times 10^3\text{ J}$

**b)** $v = \frac{2\pi r}{\Delta t}$

$v = \frac{2\pi(0.1\text{ m})}{1\text{ s}}$

$v = 0.628\text{ m/s}$

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

$E_k = \frac{1}{2}(0.002\text{ kg})(0.628\text{ m/s})^2$

$E_k = 3.9 \times 10^{-4}\text{ J}$

**c)** $v = \frac{100\text{ km}}{1\text{ h}} \times \frac{1\text{ h}}{3600\text{ s}} \times \frac{1000\text{ m}}{1\text{ km}}$

$v = 27.7778\text{ m/s}$

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

$E_k = \frac{1}{2}(15\ 000\text{ kg})(27.7778\text{ m/s})^2$

$E_k = 5.8 \times 10^6\text{ J}$

**55.** $v = \frac{\Delta d}{\Delta t}$

$v = \frac{5.0\text{ m}}{2.0\text{ s}}$

$v = 2.5\text{ m/s}$

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

$450\text{ J} = \frac{1}{2}m(2.5\text{ m/s})^2$

$m = 1.4 \times 10^2\text{ kg}$

**56.** $E_k = \frac{1}{2}mv^2$

$5.5 \times 10^8\text{ J} = \frac{1}{2}(1.2\text{ kg})v^2$

$v = \sqrt{\frac{2(5.5 \times 10^8\text{ J})}{1.2\text{ kg}}}$

$v = 3.0 \times 10^4\text{ m/s}$

**57.** $E_{\text{k-gained}} = \Delta E_g$
$E_{\text{k-gained}} = mgh_2 - mgh_1$
$E_{\text{k-gained}} = mg(h_2 - h_1)$
$E_{\text{k-gained}} = (15\text{ kg})(9.8\text{ N/kg})(200\text{ m} - 1\text{ m})$
$E_{\text{k-gained}} = 2.9 \times 10^4\text{ J}$

**58.** $p = \sqrt{2mE_k}$
$\text{kg}\cdot\text{m/s} = \sqrt{(\text{kg})(\text{J})}$
$\text{kg}\cdot\text{m/s} = \sqrt{(\text{kg})(\text{N}\cdot\text{m})}$
$\text{kg}\cdot\text{m/s} = \sqrt{\text{kg}(\text{kg}\cdot\text{m/s}^2)\text{m}}$
$\text{kg}\cdot\text{m/s} = \sqrt{\text{kg}^2\cdot\text{m}^2/\text{s}^2}$
$\text{kg}\cdot\text{m/s} = \text{kg}\cdot\text{m/s}$

**59.** $5\text{ keV} \times \frac{1000\text{ eV}}{1\text{ keV}} \times \frac{1.6 \times 10^{-19}\text{ J}}{1\text{ eV}}$
$= 8 \times 10^{-16}\text{ J}$

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

$8 \times 10^{-16}\text{ J} = \frac{1}{2}(9.1 \times 10^{-31}\text{ kg})v^2$

$v = 4.2 \times 10^7\text{ m/s}$

As a percentage of the speed of light:

$\frac{4.2 \times 10^7\text{ m/s}}{3 \times 10^8\text{ m/s}} \times 100 = 14\%$

**60. a)** $a = \frac{(v_2{}^2 - v_1{}^2)}{2d}$

$a = \frac{0 - (350\text{ m/s})^2}{2(0.0033\text{ m})}$

$a = -1.86 \times 10^7\text{ m/s}^2$

$F = ma$

$F = (0.015\text{ kg})(-1.86 \times 10^7\text{ m/s}^2)$

$F = -2.8 \times 10^5\text{ N}$

**b)** $F = -\text{force of bullet}$

$F = 2.8 \times 10^5\text{ N}$

**61.** For 1 m:

$W = (50\text{ N})(1\text{ m})$

$W = 50\text{ J}$

$W = E_k$

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

$50\text{ J} = \frac{1}{2}(1.5\text{ kg})v^2$

$v = 8\text{ m/s}$

For 2 m:

$W = 50\text{ J} + (50\text{ N})(1\text{ m}) + \frac{1}{2}(250\text{ N})(1\text{ m})$

$W = 225\text{ J}$

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

$225\text{ J} = \frac{1}{2}(1.5\text{ kg})v^2$

$v = 17.3\text{ m/s}$

For 3 m:

$W = 225\text{ J} + \frac{1}{2}(50\text{ N})\left(\frac{1}{6}\text{ m}\right) +$

$(300\text{ N})\left(\frac{1}{6}\text{ m}\right) + \frac{1}{2}(350\text{ N})\left(\frac{5}{6}\text{ m}\right)$

$W = 425\text{ J}$

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

$425\text{ J} = \frac{1}{2}(1.5\text{ kg})v^2$

$v = 23.8\text{ m/s}$

**62.** $p = \sqrt{2mE_k}$

$p = \sqrt{2(5\text{ kg})(3.0 \times 10^2\text{ J})}$

$p = 55\text{ N}\cdot\text{s}$

**63.** $m_1 = 0.2\text{ kg}$

$m_2 = 1\text{ kg}$

$v_{1o} = 125\text{ m/s}$

$v_{1f} = 100\text{ m/s}$

$v_{2o} = 0$

$v_{2f} = ?$

$\Delta d_2 = 3\text{ m}$

**a)**
$$\begin{aligned} p_{To} &= p_{Tf} \\ m_1v_{1o} + m_2v_{2o} &= m_1v_{1f} + m_2v_{2f} \\ (0.2\text{ kg})(125\text{ m/s}) + 0 &= (0.2\text{ kg})(100\text{ m/s}) + \\ &\quad (1\text{ kg})v_{2f} \\ v_{2f} &= 5\text{ m/s} \end{aligned}$$

**b)** $E_k = \frac{1}{2}mv^2$

$E_k = \frac{1}{2}(1\text{ kg})(5\text{ m/s})^2$

$E_k = 12.5\text{ J}$

**c)** This collision is not elastic since some kinetic energy is not conserved. Some energy may be lost due to the deformation of the apple.

**d)** $v_2^2 = v_1^2 + 2a\Delta d$

$0 = (5\text{ m/s})^2 + 2a(3.0\text{ m})$

$a = -4.1667\text{ m/s}^2$

$F = ma$

$F = (1.0\text{ kg})(-4.1667\text{ m/s}^2)$

$F = -4.2\text{ N}$

**64. a)** $E_p = mg\Delta h$

$= \left[(275.0\text{ g})\left(\frac{1\text{ kg}}{1000\text{ g}}\right)\right](9.8\text{ m/s}^2)(2.60\text{ m})$

$= 7.0\text{ J}$

**b)** $E_p = mg\Delta h$

$= \left[(275.0\text{ g})\left(\frac{1\text{ kg}}{1000\text{ g}}\right)\right](9.8\text{ m/s}^2)(1.8\text{ m})$

$= 4.85\text{ J}$

**c)** $E_p = mg\Delta h$

$= \left[(275.0\text{ g})\left(\frac{1\text{ kg}}{1000\text{ g}}\right)\right](9.8\text{ m/s}^2)(0.30\text{ m})$

$= 0.81\text{ J}$

**65. a)** $E_p = mg\Delta h$

The fifth floor is four floors up, so $\Delta h = 4(3.8\text{ m}) = 15.2\text{ m}$.

$E_p = (0.2750\text{ kg})(9.8\text{ m/s}^2)(15.2\text{ m})$

$E_p = 41\text{ J}$ (A floor height of 3.8 m means the answer requires only two significant figures.)

**b)** $E_p = mg\Delta h$

The tenth floor is nine floors up, so $\Delta h = 9(3.8\text{ m}) = 34.2\text{ m}$.

$E_p = (0.275\text{ kg})(9.8\text{ m/s}^2)(34.2\text{ m})$

$E_p = 92\text{ J}$ (A floor height of 3.8 m means the answer requires only two significant figures.)

**c)** $E_p = mg\Delta h$

The first basement level is 3.8 m below the ground floor.

$E_p = (0.275\text{ kg})(9.8\text{ m/s}^2)(-3.8\text{ m})$

$E_p \cong -10\text{ J}$

**66.** Percentage remaining $= \dfrac{E_{p2}}{E_{p1}} \times 100\,\%$

$$= \frac{mg\Delta h_2}{mg\Delta h_1} \times 100\,\%$$

$$= \frac{\Delta h_2}{\Delta h_1} \times 100\,\%$$

$$= \frac{0.76 \text{ m}}{3.0 \text{ m}} \times 100\,\%$$

$$= 25\,\% \text{ remaining}$$

Therefore, percentage lost is $100\,\% - 25\,\%$ $= 75\,\%$

**67. a)** With respect to the water's surface,

$E_p = mg\Delta h$

$= (70.0 \text{ kg})(9.8 \text{ m/s}^2)(19.6 \text{ m})$

$= 1.34 \times 10^4 \text{ J}$

**b)** With respect to the bottom,

$E_p = mg\Delta h$

$= (70.0 \text{ kg})(9.8 \text{ m/s}^2)(19.6 \text{ m} + 5.34 \text{ m})$

$= 1.71 \times 10^4 \text{ J}$

**68.** $\Delta E_p = mg\Delta h$

$= (1.00 \text{ kg})(9.8 \text{ m/s}^2)(0.75 \text{ m})$

$\cong 7.4 \text{ J}$

**69. a)** $E_g = mg\Delta h$

$E_g = (2.0 \text{ kg})(9.8 \text{ N/kg})(1.3 \text{ m})$

$E_g = 25 \text{ J}$

**b)** $E_g = mg\Delta h$

$E_g = (0.05 \text{ kg})(9.8 \text{ N/kg})(3.0 \text{ m})$

$E_g = 1.5 \text{ J}$

**c)** $E_g = mg\Delta h$

$E_g = (200 \text{ kg})(9.8 \text{ N/kg})(469 \text{ m})$

$E_g = 9.2 \times 10^5 \text{ J}$

**d)** $E_g = mg\Delta h$

$E_g = (5000 \text{ kg})(9.8 \text{ N/kg})(0)$

$E_g = 0 \text{ J}$

**70. a)** $m = \dfrac{F}{a}$

$m = \dfrac{4410 \text{ N}}{9.8 \text{ N/kg}}$

$m = 4.5 \times 10^2 \text{ kg}$

**b)** $W = F\Delta d$

$W = (4410 \text{ N})(3.5 \text{ m})$

$W = 1.5 \times 10^4 \text{ J}$

**71.** Using conservation of energy:

$$E_{To} = E_{Tf}$$

$$mgh + \frac{1}{2}mv_o^2 = \frac{1}{2}mv_f^2$$

$$(9.8 \text{ m/s}^2)(1.8 \text{ m}) + \frac{1}{2}(4.7 \text{ m/s})^2 = \frac{1}{2}v^2$$

$$17.64 \text{ m}^2/\text{s}^2 + 11.045 \text{ m}^2/\text{s}^2 = \frac{1}{2}v^2$$

$$v = 7.6 \text{ m/s}$$

**72.**

$$E_e = E_g$$

$$\frac{1}{2}kx^2 = mg\Delta h$$

$$\frac{1}{2}(1200 \text{ N/m})x^2 = (3.0 \text{ kg})(9.8 \text{ N/kg})(0.80 \text{ m})$$

$$x = 0.2 \text{ m}$$

$$x = 20 \text{ cm}$$

**73.** $m = 0.005 \text{ kg}$

$h = 2.0 \text{ m}$

Initial:

$E = mg\Delta h$

$E = (0.005 \text{ kg})(9.8 \text{ N/kg})(2.0 \text{ m})$

$E = 0.098 \text{ J}$

At half the height:

$E = (0.005 \text{ kg})(9.8 \text{ N/kg})(1.0 \text{ m})$

$E = 0.049 \text{ J}$

After the first bounce:

$E = (0.80)(0.098 \text{ J})$

$E = 0.0784 \text{ J}$

After the second bounce:

$E = (0.80)(0.0784 \text{ J})$

$E = 0.062\ 72 \text{ J}$

After the third bounce:

$E = (0.80)(0.062\ 72 \text{ J})$

$E = 0.050\ 176 \text{ J}$

After the fourth bounce:

$E = (0.80)(0.050\ 176 \text{ J})$

$E = 0.040\ 140\ 9 \text{ J}$

Therefore, after the fourth bounce, the ball loses over half of its original height.

**74. a)** The greatest potential energy is at point A (highest point) and point F represents the lowest amount of potential energy (lowest point).

**b)** Maximum speed occurs at F when most of the potential energy has been converted to kinetic energy.

$$E_{g\text{-lost}} = E_{k\text{-gained}}$$

$$mg\Delta h = \frac{1}{2}mv^2$$

$$(1000 \text{ kg})(9.8 \text{ N/kg})(75 \text{ m}) = \frac{1}{2}(1000 \text{ kg})v^2$$

$v = 38 \text{ m/s}$

**c)** At point E, 18 m of $E_p$ is converted to $E_k$.

$$mg\Delta h = \frac{1}{2}mv^2$$

$$(1000 \text{ kg})(9.8 \text{ N/kg})(18 \text{ m}) = \frac{1}{2}(1000 \text{ kg})v^2$$

$$v = 19 \text{ m/s}$$

**d)** Find the acceleration, then use $F = ma$.

$v_2^2 = v_1^2 + 2a\Delta d$

$0 = (38 \text{ m/s})^2 + 2a(5 \text{ m})$

$a = -144.4 \text{ m/s}^2$

$F = ma$

$F = (1000 \text{ kg})(144.4 \text{ m/s}^2)$

$F = 1.4 \times 10^5 \text{ N}$

**75.** $E_e = E_k$

$$\frac{1}{2}kx^2 = \frac{1}{2}m\Delta v^2$$

$$(890 \text{ N/m})x^2 = (10\ 005 \text{ kg})(5 \text{ m/s})^2$$

$x = 16.8 \text{ m}$

$x = 17 \text{ m}$

**76.** $\Delta d_h = \dfrac{v_1^2 \sin 2\theta}{g}$

$$15 \text{ m} = \frac{v_1^2 \sin 90°}{9.8 \text{ m/s}^2}$$

$v_1 = 12.1 \text{ m/s}$

$E_k = E_e$

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

$$(0.008 \text{ kg})(12.1 \text{ m/s}) = (350 \text{ N/m})x^2$$

$x = 0.058 \text{ m}$

$x = 5.8 \text{ cm}$

**77.** 85% of the original energy is left after the first bounce, therefore,

$(0.85)mg\Delta h_{tree} = mg\Delta h_{bounce}$

$(0.85)(2 \text{ m}) = \Delta h_{bounce}$

$\Delta h = 1.7 \text{ m}$

**78.** $E_e = E_k$

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

$$(35\ 000 \text{ N/m})(4.5 \text{ m})^2 = (65 \text{ kg})v^2$$

$v = 104.4 \text{ m/s}$

$$\Delta d_h = \frac{v_1^2 \sin 2\theta}{g}$$

$$\Delta d_h = \frac{(104.4 \text{ m/s})^2 \sin 90°}{9.8 \text{ m/s}^2}$$

$\Delta d_h = 1.1 \times 10^3 \text{ m}$

**79.** $k = \text{slope}$

$$k = \frac{\text{rise}}{\text{run}}$$

$$k = \frac{F}{x}$$

$$k = \frac{120 \text{ N}}{0.225 \text{ m}}$$

$k = 5.3 \times 10^2 \text{ N/m}$

**80.** $W$ = area under the graph

**a)** $W = \frac{1}{2}(0.05 \text{ m})(2 \times 10^3 \text{ N})$

$W = 50 \text{ J}$

**b)** $W = 50 \text{ J} + (0.02 \text{ m})(2 \times 10^3 \text{ N}) + \frac{1}{2}(0.02 \text{ m})(4.5 \times 10^3 \text{ N})$

$W = 135 \text{ J}$

$W = 1.4 \times 10^2 \text{ J}$

**81.** $E_k = E_e$

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

$$(0.05 \text{ kg})v^2 = (400 \text{ N/m})(0.03 \text{ m})^2$$

$v = 2.7 \text{ m/s}$

**82.** $E_k = E_e$

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

$$(2.5 \times 10^3 \text{ kg})(95 \text{ m/s})^2 = k(35 \text{ m})^2$$

$k = 1.8 \times 10^4 \text{ N/m}$

**83.** $E_e \geq E_k$

$$\frac{1}{2}kx^2 \geq \frac{1}{2}mv^2$$

$$(5 \times 10^7 \text{ N/m})(0.15 \text{ m})^2 \geq (1000 \text{ kg})v^2$$

$v \leq 34 \text{ m/s}$

**84. a)** $E_k = E_e$

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

$$(3 \text{ kg})v^2 = (125 \text{ N/m})(0.12 \text{ m})^2$$

$v = 0.77 \text{ m/s}$

**b)** $F_f = \mu F_n$

$F_f = (0.1)(3 \text{ kg})(-9.8 \text{ N/kg})$

$F_f = -2.94 \text{ N}$

$F = ma$

$$a = \frac{F}{m}$$

$$a = \frac{-2.94 \text{ N}}{3 \text{ kg}}$$

$a = -0.98 \text{ m/s}^2$

$$v_2{}^2 = v_1{}^2 + 2a\Delta d$$
$$0 = (0.77\text{ m/s})^2 + 2(-0.98\text{ m/s}^2)\Delta d$$
$$\Delta d = 0.3\text{ m}$$
$$\Delta d = 30\text{ cm}$$

**85.** $E_k = E_e$
$$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$$
$$(3.0\text{ kg})v^2 = (350\text{ N/m})(0.1\text{ m})^2$$
$$v = 1.1\text{ m/s}$$

**86.** $F = kx$
$$F = (4000\text{ N/m})(0.15\text{ m})$$
$$F = 600\text{ N}$$

**87.** $F = ma$
$$F = (100\text{ kg})(9.8\text{ N/kg})$$
$$F = 980\text{ N}$$
Divided into 20 springs:
$$F = \frac{980\text{ N}}{20}$$
$F = 49$ N per spring
$$F = kx$$
$$49\text{ N} = k(0.035\text{ m})$$
$$k = 1.4 \times 10^3\text{ N/m}$$

**88.** $F = kx$
$$mg = kx$$
$$(10\text{ kg})(9.8\text{ N/kg}) = k(1.3\text{ m})$$
$$k = 75.3846\text{ N/m}$$
$$E_e = \frac{1}{2}kx^2$$
$$2 \times 10^6\text{ J} = \frac{1}{2}(75.3846\text{ N/m})x^2$$
$$x = 2.3 \times 10^2\text{ m}$$

**89.** $E_i = E_f$
$$E_{k_1} + E_{p_1} = E_{k_2} + E_{p_2}$$
$$\tfrac{1}{2}mv_1^2 + mgh_1 = \tfrac{1}{2}mv_2^2 + mgh_2$$
(The masses divide out.)
$$\tfrac{1}{2}v_1^2 + gh_1 = \tfrac{1}{2}v_2^2 + gh_2$$
$$\tfrac{1}{2}(0)^2 + (9.8\text{ m/s}^2)(92.0\text{ m}) = \tfrac{1}{2}v_2^2 + (9.8\text{ m/s}^2)(40.0\text{ m})$$
$$v_2 = \sqrt{2[(9.8\text{ m/s}^2)(92.0\text{ m}) - (9.8\text{ m/s}^2)(40.0\text{ m})]}$$
$$= 31.9\text{ m/s}$$
Therefore, $E_k = \tfrac{1}{2}mv^2$
$$= \tfrac{1}{2}(5.0\text{ kg})(31.9\text{ m/s})^2$$
$$= 2544\text{ J}$$
$$\cong 2.5 \times 10^3\text{ J}$$
Therefore, $E_p = mgh$
$$= (5.0\text{ kg})(9.8\text{ m/s}^2)(40.0\text{ m})$$
$$= 1960\text{ J}$$
$$\cong 2.0 \times 10^3\text{ J}$$

**90.** $E_1 = E_2$
$$E_{k_1} + E_{p_1} = E_{k_2} + E_{p_2}$$
$$\tfrac{1}{2}mv_1^2 + E_{p_1} = \tfrac{1}{2}mv_2^2 + mgh_2$$
$$\tfrac{1}{2}(0.240\text{ kg})(20.0\text{ m/s})^2 + 70\text{ J} = \tfrac{1}{2}(0.240\text{ kg})v_2^2 + 0.240\text{ kg }(9.8\text{ m/s}^2)(0\text{ m})$$
$$v_2 = \sqrt{\left(\frac{\tfrac{1}{2}(0.240\text{ kg})(20.0\text{ m/s})^2 + 70\text{ J}}{\tfrac{1}{2}(0.240\text{ kg})}\right)}$$
$$= 31.4\text{ m/s}$$

**91.** $E_{p-\text{rim}} = E_{p_2} + 0.15\,E_{p+\text{rim}}$
$$mg\Delta h_1 = mg\Delta h_2 + 0.15(mg\Delta h_1)$$
$$\Delta h_1 = \Delta h_2 + 0.15(\Delta h_1)$$
$$\Delta h_2 = (3.05\text{ m}) - (0.15)(3.05\text{ m})$$
$$= 2.6\text{ m}$$
*OR*
$$E_{g_2} = (0.85)E_{g_1}$$
$$mgh_2 = (0.85)mgh_1$$
$$h_2 = (0.85)h_1$$
$$= (0.85)(3.05\text{ m})$$
$$= 2.6\text{ m}$$

**92.** $\tfrac{1}{2}mv_{\text{bot}}{}^2 = mgh_{\text{top}}$
$$\tfrac{1}{2}v_{\text{bot}}{}^2 = gh_{\text{top}}$$
$$v_{\text{bot}} = \sqrt{2gh_{\text{top}}}$$
$$= \sqrt{2(9.8\text{ m/s}^2)(30.0\text{ m})}$$
$$= 24.2\text{ m/s}$$

**93.** Using the conservation of momentum:
$$m_1v_{1o} + m_2v_{2o} = m_1v_{1f} + m_2v_{2f}$$
$$m_1v_{1o} = m_1v_{1f} + m_2v_{2f}$$
$$m_1(v_{1o} - v_{1f}) = m_2v_{2f} \qquad \text{(eq. 1)}$$
Using the conservation of kinetic energy:
$$m_1(v_{1o}{}^2 - v_{1f}{}^2) = m_2v_{2f}{}^2 \qquad \text{(eq. 2)}$$
Dividing equation 2 by equation 1:
$$\frac{m_1(v_{1o}{}^2 - v_{1f}{}^2)}{m_1(v_{1o} - v_{1f})} = \frac{m_2v_{2f}{}^2}{m_2v_{2f}}$$
$$v_{1o} + v_{1f} = v_{2f}$$
$$v_{1f} = v_{2f} - v_{1o} \qquad \text{(eq. 3)}$$
Substituting equation 3 into equation 1:
$$m_1(v_{1o} - v_{1f}) = m_2v_{2f}$$
$$m_1(v_{1o} - v_{2f} + v_{1o}) = m_2v_{2f}$$
$$m_1(2v_{1o} - v_{2f}) = m_2(v_{2f})$$
$$v_{1o}(2m_1) = v_{2f}(m_1 + m_2)$$
$$v_{2f} = \frac{2m_1v_{1o}}{m_1 + m_2}$$

**94. a)** $v_{1f} = v_{1o}\dfrac{m_1 - m_2}{m_1 + m_2}$

$v_{1f} = (3\ \text{m/s})\dfrac{15\ \text{kg} - 3\ \text{kg}}{15\ \text{kg} + 3\ \text{kg}}$

$v_{1f} = 2\ \text{m/s}$

$v_{2f} = v_{1o}\dfrac{2m_1}{m_1 + m_2}$

$v_{2f} = (3\ \text{m/s})\dfrac{2(15\ \text{kg})}{15\ \text{kg} + 3\ \text{kg}}$

$v_{2f} = 5\ \text{m/s}$

**b)** $E_k = \dfrac{1}{2}mv^2$

$E_k = \dfrac{1}{2}(3\ \text{kg})(5\ \text{m/s})^2$

$E_k = 37.5\ \text{J}$

$E_k = 38\ \text{J}$

**95.** $p_{Tf} = p_{To}$

$(m_1 + m_2)v_f = m_1v_{1o} + m_2v_{2o}$

$(0.037\ \text{kg})v_f = (0.035\ \text{kg})(8\ \text{m/s}) + (0.002\ \text{kg})(-12\ \text{m/s})$

$v_f = 6.9\ \text{m/s}$

**96. a)** $p_{To} = m_1v_{1o}+m_2v_{2o}$

$p_{To} = (3.2\ \text{kg})(2.2\ \text{m/s}) + (3.2\ \text{kg})(0)$

$p_{To} = 7.0\ \text{kg}\cdot\text{m/s}$

$E_{k\text{-}To} = \dfrac{1}{2}mv^2$

$E_{k\text{-}To} = \dfrac{1}{2}(3.2\ \text{kg})(2.2\ \text{m/s})^2$

$E_{k\text{-}To} = 7.7\ \text{J}$

**b)** Using the conservation of momentum and $m_1 = m_2$:

$m_1v_{1o} + m_2v_{2o} = m_1v_{1f} + m_2v_{2f}$

$2.2\ \text{m/s} + 0 = 1.1\ \text{m/s} + v_{2f}$

$v_{2f} = 1.1\ \text{m/s}$

**c)** $E_{k\text{-}Tf} = \dfrac{1}{2}mv_{1f}{}^2 + \dfrac{1}{2}mv_{2f}{}^2$

$E_{k\text{-}Tf} = \dfrac{1}{2}(3.2\ \text{kg})(1.1\ \text{m/s})^2 + \dfrac{1}{2}(3.2\ \text{kg})(1.1\ \text{m/s})^2$

$E_{k\text{-}Tf} = 3.8\ \text{J}$

**d)** The collision is not elastic since there was a loss of kinetic energy from 7.7 J to 3.8 J.

**97.** $p_{To} = p_{Tf}$

$m_1v_{1o} + m_2v_{2o} = m_1v_{1f} + m_2v_{2f}$

$(0.015\ \text{kg})(375\ \text{m/s}) + 0 = (0.015\ \text{kg})(300\ \text{m/s}) + (2.5\ \text{kg})v_{2f}$

$v_{2f} = 0.45\ \text{m/s}$

**98.** $m_1 = 6m$

$v_{1o} = 5\ \text{m/s}$

$m_2 = 10m$

$v_{2o} = -3\ \text{m/s}$

Changing the frame of reference so that $v_{2f} = 0$:

$v_{1o} = 8\ \text{m/s}$

$v_{1f} = v_{1o}\dfrac{m_1 - m_2}{m_1 + m_2}$

$v_{1f} = (8\ \text{m/s})\dfrac{6m - 10m}{6m + 10m}$

$v_{1f} = -2\ \text{m/s}$

$v_{2f} = v_{1o}\dfrac{2m_1}{m_1 + m_2}$

$v_{2f} = (8\ \text{m/s})\dfrac{2(6m)}{6m + 10m}$

$v_{2f} = 6\ \text{m/s}$

Returning to our original frame of reference (subtract 3 m/s):

$v_{1f} = -2\ \text{m/s} - 3\ \text{m/s} = -5\ \text{m/s}$,

$v_{2f} = 6\ \text{m/s} - 3\ \text{m/s} = 3\ \text{m/s}$

**99. a)** $v_{1f} = v_{1o}\dfrac{m_1 - m_2}{m_1 + m_2}$

$v_{1f} = (5\ \text{m/s})\dfrac{3m_2 - m_2}{3m_2 + m_2}$

$v_{1f} = 2.5\ \text{m/s}$

**b)** $v_{2f} = v_{1o}\dfrac{2m_1}{m_1 + m_2}$

$v_{2f} = (5\ \text{m/s})\dfrac{2(3m_2)}{3m_2 + m_2}$

$v_{2f} = 7.5\ \text{m/s}$

**100.** $m_w = 0.750\ \text{kg}$

$k = 300\ \text{N/m}$

$m_b = 0.03\ \text{kg}$

$x = 0.102\ \text{m}$

**a)** $E_{e\text{-gained}} = E_{k\text{-lost}}$

$\dfrac{1}{2}kx^2 = \dfrac{1}{2}mv^2$

$(300\ \text{N/m})(0.102\ \text{m})^2 = (0.78\ \text{kg})v^2$

$v = 2\ \text{m/s}$

Using the conservation of momentum:

$p_{To} = p_{Tf}$

$m_b v_{bo} + m_w v_{wo} = m_{(b+w)} v_f$

$(0.03 \text{ kg}) v_{bo} + 0 = (0.78 \text{ kg})(2.0 \text{ m/s})$

$v_{bo} = 52 \text{ m/s}$

**b)** The collision is inelastic since:

$E_{ko} = \frac{1}{2}(0.03 \text{ kg})(52 \text{ m/s})^2$

$E_{ko} = 40.56 \text{ J}$

and

$E_{kf} = 0$

The kinetic energy is not conserved.

**101. a)** $mgh = \frac{1}{2}mv^2$

$(2.05 \text{ kg})(-9.8 \text{ m/s})(0.15 \text{ m}) = \frac{1}{2}(2.05 \text{ kg})v^2$

$v = 1.7 \text{ m/s}$

**b)** $m_1 v_1 = v_2(m_1 + m_2)$

$(0.05 \text{ kg})v_1 = (1.71 \text{ m/s})(2.05 \text{ kg})$

$v_1 = 70 \text{ m/s}$

**102.** Using the conservation of momentum and $m_1 = m_2 = m$:

$p_{To} = p_{Tf}$

$mv_{1o} + mv_{2o} = mv_{1f} + mv_{2f}$

$v_{1o} + 0 = v_{1f} + v_{1f}$ (eq. 1)

Using the conservation of kinetic energy:

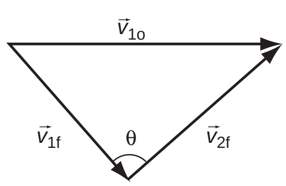
$E_{k-To} = E_{k-Tf}$

$\frac{1}{2}mv_{1o}{}^2 + \frac{1}{2}mv_{2o}{}^2 = \frac{1}{2}mv_{1f}{}^2 + \frac{1}{2}mv_{2f}{}^2$

$v_{1o}{}^2 + 0 = v_{1f}{}^2 + v_{2f}{}^2$

$v_{1o}{}^2 = v_{1f}{}^2 + v_{2f}{}^2$ (eq. 2)

Equation 1 can be represented by the vector diagram:




The angle θ is the angle between the final velocity of the eight ball and the cue ball after the collision.

Using the cosine law and equation 2:

$v_{1o}{}^2 = v_{1f}{}^2 + v_{2f}{}^2 - 2(v_{1f})(v_{2f}) \cos\theta$

$v_{1o}{}^2 = v_{1o}{}^2 - 2(v_{1f})(v_{2f}) \cos\theta$

$0 = -2(v_{1f})(v_{2f}) \cos\theta$

$0 = \cos\theta$

$\theta = 90°$

Therefore, the angle between the two balls after collision is 90°.

**103.** Three waves pass in every 12 s, with 2.4 m between wave crests.

$f = \frac{\text{number of waves}}{\text{time}}$

$f = \frac{3}{12 \text{ s}}$

$f = 0.25 \text{ Hz}$

**104.** $k = 12 \text{ N/m}$, $m = 230 \text{ g} = 0.23 \text{ kg}$, $A = 26 \text{ cm} = 0.26 \text{ m}$

At the maximum distance, i.e., $A$, $v = 0$, therefore the total energy is:

$E = \frac{1}{2}kA^2$

Also, at the equilibrium point, the displacement is zero, therefore the total energy is the kinetic energy:

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

Hence,

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

$v = \sqrt{\frac{kA^2}{m}}$

$v = \sqrt{\frac{(12 \text{ N/m})(0.26 \text{ m})^2}{0.23 \text{ m}}}$

$v = 1.88 \text{ m/s}$

The speed of the mass at the equilibrium point is 1.88 m/s.

**105.** $m = 2.0 \text{ kg}$, $x = 0.3 \text{ m}$, $k = 65 \text{ N/m}$

**a)** $E = \frac{1}{2}kx^2$

$E = \frac{1}{2}(65 \text{ N/m})(0.3 \text{ m})^2$

$E = 2.925 \text{ J}$

Initial potential energy of the spring is 2.925 J.

**b)** Maximum speed is achieved when the total energy is equal to kinetic energy only.

Therefore,

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

$$2.925\text{ J} = \frac{1}{2}(2.0\text{ kg})v^2$$

$$v = \sqrt{2.925}$$

$$v = 1.71\text{ m/s}$$

The mass reaches a maximum speed of 1.71 m/s.

**c)** $x = 0.20$ m

Total energy of the mass at this location is given by:

$$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$

$$2.925\text{ J} = \frac{1}{2}(2.0\text{ kg})v^2 + \frac{1}{2}(65\text{ N/m})(0.2\text{ m})^2$$

$$v = \sqrt{1.625}$$

$$v = 1.275\text{ m/s}$$

The speed of the mass when the displacement is 0.20 m is 1.275 m/s.

**106.** Given the information in problem 105,

**a)** Maximum acceleration is achieved when the displacement is maximum since $F = kx$ and $F = ma$

Therefore, maximum displacement is $x = 0.30$ m

Hence,

$$ma = kx$$

$$a = \frac{kx}{m}$$

$$a = \frac{(65\text{ N/m})(0.30\text{ m})}{(2.0\text{ kg})}$$

$$a = 9.75\text{ m/s}^2$$

The mass' maximum acceleration is 9.75 m/s$^2$.

**b)** $x = 0.2$ m

$$a = \frac{kx}{m}$$

$$a = \frac{(65\text{ N/m})(0.2\text{ m})}{2.0\text{ kg}}$$

$$a = 6.5\text{ m/s}^2$$

The mass' acceleration when the displacement is 0.2 m is 6.5 m/s$^2$.

**107.** $d_{\text{tide}} = 15$ m, $m_{\text{floats}} = m$, $span_{\text{floats}} = 10$ km, $T_{\text{tide}} = 12$ h 32 min $= 45\ 120$ s

**a)** Finding the work done by the upward movement of the floats,

$$W_{\text{up}} = F_g d$$

$$W_{\text{up}} = m(9.8\text{ m/s}^2)(15\text{ m})$$

$$W_{\text{up}} = 147m\text{ J}$$

Since there is a downward movement as well,

$$W_{\text{up, down}} = 2W_{\text{up}}$$

$$W_{\text{up, down}} = 294m\text{ J}$$

Since the linkages are only 29% efficient,

$$W_{\text{actual}} = 0.29(294m\text{ J})$$

$$W_{\text{actual}} = 85.26m\text{ J}$$

To find power:

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

$$P = \frac{85.26m\text{ J}}{45\ 120\text{ s}}$$

$$P = 1.89 \times 10^{-3}m\text{ W}$$

$$P = 1.89m\text{ mW}$$

The power produced would be 1.89$m$ mW.

**b)** 1.89$m$ mW from the hydroelectric linkages is not even comparable to 900 MW from a reactor at Darlington Nuclear Power Station. In order for the linkages to produce the same power, the total mass of the floats would have to be $4.76 \times 10^{11}$ kg, or 476 million tonnes.

**108.** $m = 100$ kg, $d = 12$ m, $x = 0.64$ cm $= 0.0064$ m

First, we must find the speed at which the mass first makes contact with the spring. Using kinematics,

$$v^2 = v_o^2 + 2ad$$

$$v = \sqrt{v_o^2 + 2ad}$$

$$v = \sqrt{0 + 2(9.8\text{ m/s}^2)(12\text{ m})}$$

$$v = 15.34\text{ m/s}$$

Finding the maximum kinetic energy of the mass (instant before compression of spring),

$$E_{\text{kmax}} = \frac{1}{2}mv^2$$

$$E_{\text{kmax}} = \frac{1}{2}(100\text{ kg})(15.34\text{ m/s})^2$$

$E_{kmax} = 11\ 760$ J

Since kinetic energy is fully converted to elastic potential energy when the spring is fully compressed,

$$E_{pmax} = \frac{1}{2}kx^2$$

$$k = \frac{2E_{pmax}}{x^2}$$

$$k = \frac{2(11\ 760\ \text{J})}{(0.0064\ \text{m})^2}$$

$$k = 5.7 \times 10^8\ \text{N/m}$$

The spring constant is $5.7 \times 10^8$ N/m.

**109.** $k = 16$ N/m, $A = 3.7$ cm

Since total energy is equal to maximum potential energy, maximum amplitude = $x$ at the point of maximum potential energy:

$$E_p = E_{total}$$

$$E_p = \frac{1}{2}kx^2$$

$$E_p = \frac{1}{2}(16\ \text{N/m})(0.037\ \text{m})^2$$

$$E_p = 0.011\ \text{J}$$

The total energy of the system is 0.011 J.

**110.** $m_{bullet} = 5$ g $= 0.005$ kg, $m_{mass} = 10$ kg, $k = 150$ N/m, $v_{o\ bullet} = 350$ m/s

To find the final velocity, use the law of conservation of linear momentum:

$$p_o = p_f$$

$$(0.005\ \text{kg})(350\ \text{m/s}) + 0 = (10.005\ \text{kg})v$$

$$v = 0.175\ \text{m/s}$$

Therefore, the mass and bullet's kinetic energy is:

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

$$E_k = \frac{1}{2}(10.005\ \text{kg})(0.175\ \text{m/s})^2$$

$$E_k = 0.153\ \text{J}$$

Since all of this energy is transferred to elastic potential energy,

$$E_p = E_k$$

$$\frac{1}{2}kx^2 = 0.153\ \text{J}$$

$$x = \sqrt{\frac{2(0.153\ \text{J})}{150\ \text{N/m}}}$$

$$x = 0.045\ \text{m}$$

**111.** $P = 750$ W

$h = 37.0$ m

rate $= 1.48$ kg/s

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

$$= \left(\frac{1.48\ \text{kg}}{1\ \text{s}}\right)(9.8\ \text{m/s}^2)(37.0\ \text{m})$$

$$= 537\ \text{W}$$

$$\text{percentage efficiency} = \frac{\text{useful output energy}}{\text{total input energy}}$$

$$= \frac{537\ \text{W}}{750\ \text{W}} \times 100\,\%$$

$$= 71.6\ \%$$

**112.** $E_k = (0.25)\ 35.0$ J

$= 8.75$ J

$$E_k = \tfrac{1}{2}mv^2$$

$$v = \sqrt{\frac{2E_k}{m}}$$

$$= \sqrt{\frac{2(8.75\ \text{J})}{70.0\ \text{kg}}}$$

$$= 0.50\ \text{m/s}$$

**113. a)** $W = \vec{F} \cdot \vec{d}$

$= mgd$

$= (170.0\ \text{kg})(9.8\ \text{N/kg})(2.20\ \text{m})$

$= 3.66 \times 10^3$ J

**b)** $W = \vec{F} \cdot \vec{d}$

$= (1.72 \times 10^3\ \text{N})(2.20\ \text{m})$

$= 3\ 784$ J

$= 3.78 \times 10^3$ J

**c)** $$\text{percentage efficiency} = \frac{3.66 \times 10^3\ \text{J}}{3.78 \times 10^3\ \text{J}}$$

$= 96.8\ \%$

**d)** Some of the energy they exert is transferred to heat and sound energy of the pulley system because of friction and noise instead of being used to just lift the engine.

# Chapter 10

**29. a)** $\lambda = 4$ m

**b)** amplitude = 7 cm

**c)** $T = 8$ s

**d)** $f = \frac{1}{T}$

$f = \frac{1}{8\text{ s}}$

$f = 0.125\text{ s}^{-1} \cong 0.1\text{ s}^{-1}$

**e)** $v = \lambda \cdot f$

$v = 4\text{ m} \times 0.125\text{ Hz}$

$v = 0.5$ m/s

**30. a)** $\lambda = 8$ m

amplitude = 7 cm

$T = 16$ s

$f = \frac{1}{16\text{ s}}$

$f = 0.0625\text{ s}^{-1}$

$f \cong 0.06\text{ s}^{-1}$

$v = \lambda \cdot f$

$v = 8\text{ m} \times 0.0625\text{ s}^{-1}$

$v = 0.5$ m/s

**b)** $\lambda = 2$ m

amplitude = 7 cm

$T = 4$ s

$f = \frac{1}{4\text{ s}}$

$f = 0.25\text{ s}^{-1} \cong 0.2\text{ s}^{-1}$

$v = \lambda \cdot f$

$v = 0.5$ m/s

**31.** $T = \frac{\text{time}}{\text{oscillations}}$

$T = \frac{3.2\text{ s}}{10}$

$T = 0.32$ s

$f = \frac{1}{T}$

$f = 3.125\text{ s}^{-1}$

$f \cong 3.1\text{ s}^{-1}$

**32.** $T = \frac{\text{time}}{\text{beats}}$

$T = \frac{60\text{ s}}{72}$

$T = 0.83$ s

$f = \frac{1}{T}$

$f = 1.2$ s

**33.** $T = \frac{1}{f}$

$T = 0.0167$ s

$T \cong 0.017$ s

**34. a)** $f = 150$ rpm

$f = 2.5$ rps

**b)** $T = \frac{1}{f}$

$T = 0.4$ s

**35. i)** $f = 78$ rpm

$f = 1.3$ Hz

$T = \frac{1}{f}$

R = 0.77 s

**ii)** $f = 45$ rpm

$f = 0.75$ Hz

$T = \frac{1}{f}$

$T = 1.3$ s

**iii)** $f = 33.3$ rpm

$f = 0.555$ Hz

$T = \frac{1}{f}$

$T = 1.80$ s

**36. i)** number of turns = $t \cdot f$

number of turns = 3732 s × 1.3 Hz

number of turns = 4851.6

number of turns ≅ 4800

**ii)** number of turns = 3732 s × 0.75 Hz

number of turns = 2799

number of turns ≅ 2800

**iii)** number of turns = 3732 s × 0.555 Hz

number of turns = 2071.26

number of turns ≅ 2100

**37. a)** $c = f \cdot \lambda$

$f = \frac{c}{\lambda}$

$f_{\text{red}} = \frac{3.0 \times 10^8\text{ m/s}}{6.50 \times 10^{-9}\text{ m}}$

$f_{\text{red}} = 4.62 \times 10^{16}$ Hz

**b)** $f_{\text{orange}} = 5.00 \times 10^{16}$ Hz

**c)** $f_{\text{yellow}} = 5.17 \times 10^{16}$ Hz

**d)** $f_{\text{green}} = 5.77 \times 10^{16}$ Hz

**e)** $f_{\text{blue}} = 6.32 \times 10^{16}$ Hz

**f)** $f_{\text{violet}} = 7.5 \times 10^{16}$ Hz

**38. a)** $t = \dfrac{d}{v}$

$t = \dfrac{1.49 \times 10^{11}\ \text{m}}{3.0 \times 10^{8}\ \text{m/s}}$

$t = 497\ \text{s}$

$t = 8.28\ \text{min}$

$t = 0.138\ \text{h}$

**b)** $t = 1.27\ \text{s}$

$t = 0.0211\ \text{min}$

$t = 3.53 \times 10^{-4}\ \text{h}$

**c)** $t = 1.93 \times 10^{4}\ \text{s}$

$t = 322\ \text{min}$

$t = 5.36\ \text{h}$

**d)** $t = 303\ \text{s}$

$t = 5.05\ \text{min}$

$t = 0.0842\ \text{h}$

**39. a) i)** $t = \dfrac{d}{v}$

$t = 1.79 \times 10^{9}\ \text{s}$

**ii)** $t = 4.56 \times 10^{6}\ \text{s}$

**iii)** $t = 6.96 \times 10^{10}\ \text{s}$

**iv)** $t = 1.092 \times 10^{9}\ \text{s}$

**b) i)** $t = \dfrac{d}{v}$

$t = 1.79 \times 10^{7}\ \text{s}$

**ii)** $t = 4.56 \times 10^{4}\ \text{s}$

**iii)** $t = 6.96 \times 10^{8}\ \text{s}$

**iv)** $t = 1.092 \times 10^{7}\ \text{s}$

**40.** $d = v \cdot t$

$d = (3.0 \times 10^{8}\ \text{m/s})(31\ 536\ 000\ \text{s})$

$d = 9.4608 \times 10^{15}\ \text{m}$

**41.** $t = \dfrac{d}{v}$

$t = 100$ years

**42.** $t = \dfrac{d}{v}$

$t = \dfrac{(160\ \text{m})}{(3.0 \times 10^{8}\ \text{m/s})}$

$t = 5.33 \times 10^{-7}\ \text{s}$

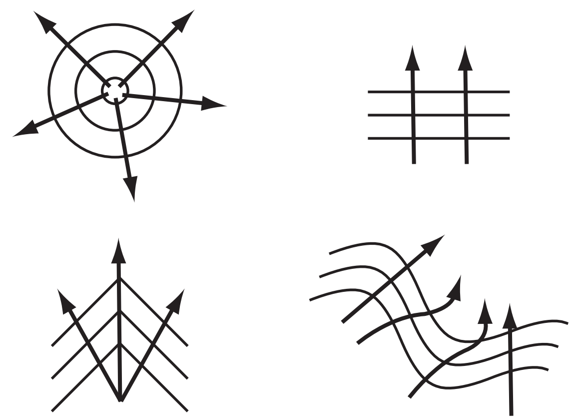
**43.** $t = \dfrac{d}{v}$

$t_{\text{light}} = 0.013\ \text{s}$

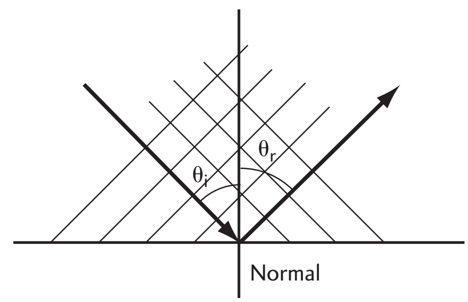
Therefore, number of times faster

$= \dfrac{t_{\text{car}}}{t_{\text{light}}} = \dfrac{180\ 000\ \text{s}}{0.013\ \text{s}} = 1.38 \times 10^{7}.$

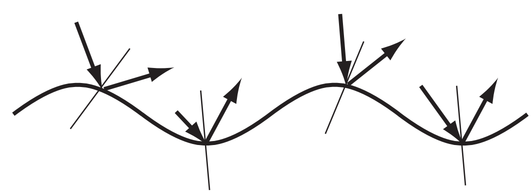
**44.**



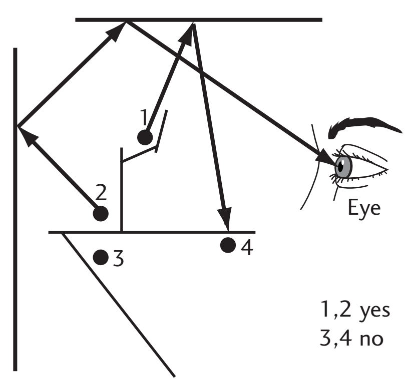
**45.**




**46.**



**47.**



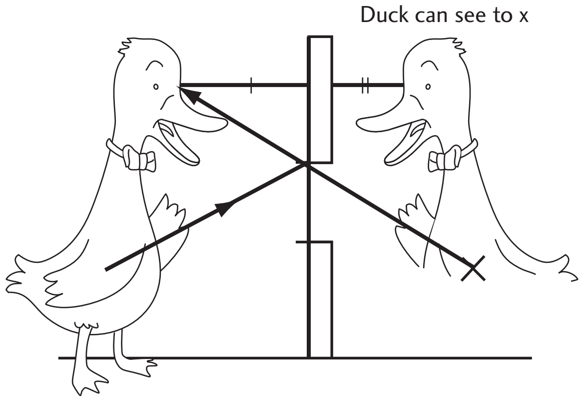

**48.** $2\theta = 46°$

$\theta = 23°$

**49.** $\theta = 90° - 40°$

$\theta = 50°$

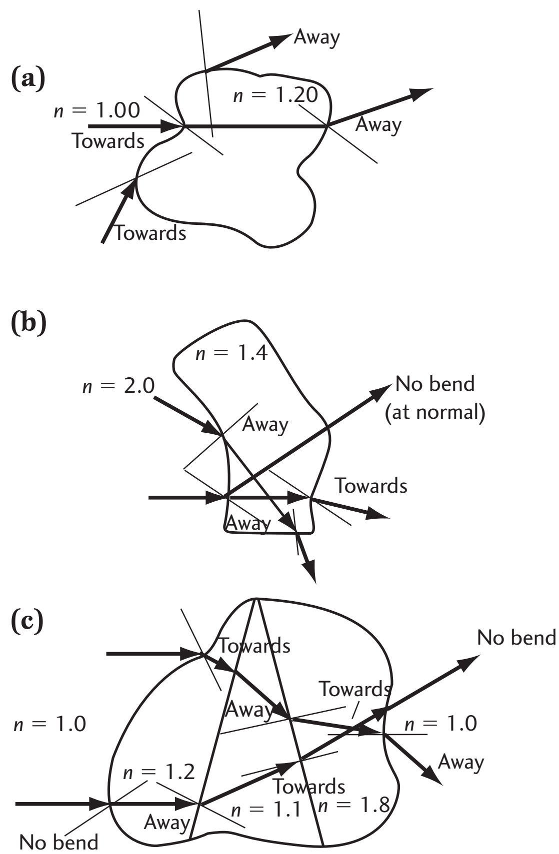
**50.**




**51.** For a flat mirror, $d_i = d_o$. Therefore, the $d_i$ for the friend is 2.5 m. The distance from me to the friend's image is 2.5 m + 2.0 m = 4.5 m.

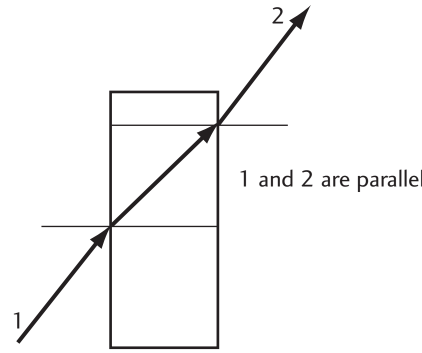
**52.** $\frac{d_{\text{eyes to feet}}}{2} = \frac{1.7\text{ m}}{2} = 0.85$ m. Since the mirror is 1.5 m tall, she can see her feet.

**53.**




**54.** Reverse the direction of the refraction. Towards the normal becomes away from the normal and vice versa.

**55.**




**56.** Same as problem 55 except the refraction angles are greater. The refracted ray still comes out parallel to the incident ray.

**57. a)** $v = \frac{c}{n}$

$v = 1.24 \times 10^8$ m/s

**b)** $v = 1.97 \times 10^8$ m/s

**c)** $v = 2.26 \times 10^8$ m/s

**d)** $v = 2.31 \times 10^8$ m/s

**58. a)** $n_r = \frac{n_2}{n_1}$

$n_r = \frac{1.00}{2.42}$

$n_r = 0.413$

**b)** $n_r = \frac{1.00}{1.52}$

$n_r = 0.658$

**c)** $n_r = \frac{1.00}{1.33}$

$n_r = 0.752$

**d)** $n_r = \frac{1.00}{1.30}$

$n_r = 0.769$

**59. a)** $n = \frac{c}{v}$

$n = \frac{3.0 \times 10^8\text{ m/s}}{1.58 \times 10^8\text{ m/s}}$

$n = 1.90$

**b)** $n = 1.46$

**c)** $n = 1.50$

**d)** $n = 0.79$

**60.** $v = \frac{c}{n}$

$v = 2.26 \times 10^8$ m/s

$\Delta t = \frac{\Delta d}{v}$

$\Delta t = 5.31 \times 10^{-5}$ s

**61. a)** $v = \dfrac{\Delta d}{\Delta t}$

$v = 1.25 \times 10^{8}$ m/s

**b)** $n = \dfrac{c}{v}$

$n = 2.4$

**c)** diamond

**62. a)** $\sin 30° = 0.5$

**b)** $\sin 60° = 0.87$

**c)** $\sin 45° = 0.71$

**d)** $\sin 12.6° = 0.218$

**e)** $\sin 74.4° = 0.96$

**f)** $\sin 0° = 0.0$

**g)** $\sin 90° = 1.0$

**63. a)** $\sin^{-1}(0.342) = 20°$

**b)** $\sin^{-1}(0.643) = 40°$

**c)** $\sin^{-1}(0.700) = 44.4°$

**d)** $\sin^{-1}(0.333) = 19.4°$

**e)** $\sin^{-1}(1.00) = 90°$

**64. a)** $n_1 \sin \theta_1 = n_2 \sin \theta_2$

$\theta_2 = \sin^{-1}\left(\dfrac{n_1}{n_2} \times \sin \theta_1\right)$

$\theta_2 = 22.1°$

**b)** $\theta_2 = 11.9°$

**c)** $\theta_2 = 21.6°$

**d)** $\theta_2 = 15.3°$

**65. a)** $\theta_2 = 29.2°$

**b)** $\theta_2 = 15.6°$

**c)** $\theta_2 = 28.6°$

**d)** $\theta_2 = 20°$

**66. a)** $n_1 \sin \theta_1 = n_2 \sin \theta_2$

$\theta_1 = \sin^{-1}\left[\left(\dfrac{n_2}{n_1}\right) \sin \theta_2\right]$

$\theta_1 = 4.11°$

**b)** $\theta_1 = 24.8°$

**c)** $\theta_1 = 13.4°$

**d)** $\theta_1 = 18.4°$

**67. a)** $n_1 \sin \theta_1 = n_2 \sin \theta_2$

$n_2 = n_1 \times \dfrac{\sin \theta_1}{\sin \theta_2}$

$n_2 = 1.28$

**b)** $n_2 = 2.40$

**c)** $n_2 = 1.27$

**68. a)** $n_2 = 1.71$

**b)** $n_2 = 3.20$

**c)** $n_2 = 1.69$

**69.** Air → Glass: $\theta_2 = \sin^{-1}\left(\dfrac{n_1}{n_2} \times \sin \theta_1\right)$

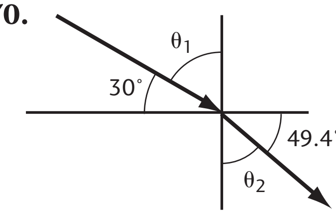
$\theta_2 = 13.0°$

Glass → Water: $\theta_2 = 14.9°$

Water → Glass: $\theta_2 = 13.0°$

Glass → Air: $\theta_2 = 20°$

**70.**




$n_1 \sin \theta_1 = n_2 \sin \theta_2$

$n_2 = \dfrac{n_1 \sin \theta_1}{\sin \theta_2}$

$n_2 = \dfrac{(1.00) \sin 60°}{\sin 40.6°}$

$n_2 = 1.33$

$\theta_1 = 90° - 30° = 60°$

$\theta_2 = 90° - 49.4° = 40.6°$

**71.** $d_2 = d_1 \times \dfrac{n_2}{n_1}$

$= 3.0 \text{ m} \times \dfrac{1.00}{1.33} = 2.256 \text{ m} \cong 2.3 \text{ m}$

**72.** $d_1 = d_2 \times \dfrac{n_1}{n_2}$

$= (1.50 \text{ m}) \times \dfrac{1.33}{1.00} = 1.995 \text{ m} \cong 2.0 \text{ m}$

**73.** $h_2 = h_1 \times \dfrac{n_2}{n_1}$

$h_2 = (170 \text{ cm} + 70 \text{ cm}) \times \dfrac{1.33}{1.00}$

$h_2 = 319$ cm

**74. a)** $n_1 \sin \theta_1 = n_2 \sin \theta_2$

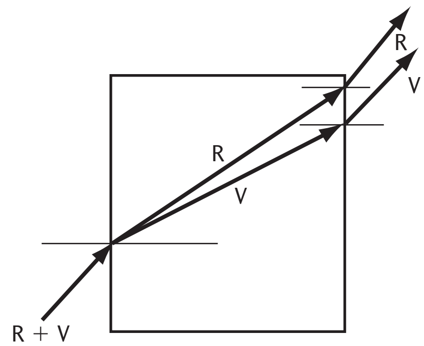
$\theta_2 = \sin^{-1}\left(\dfrac{n_1}{n_2} \times \sin \theta_1\right)$

Red: $\theta_2 = 19.2°$

Violet: $\theta_2 = 18.9°$

**b)** same calculation: $\theta_2 = 29.99°$ for red and 29.92° for violet

**75.**




**76.** Small differences in temperature change the $n$ of the air, causing light to bend in an arc as it travels to the observer. Since the light seems to come from the clouds, this is where the image appears.

**77.** $n_1 \sin \theta_c = n_2 \sin \theta_2$

$\theta_2 = 90°$, $\sin \theta_2 = 1$

$n_1 \sin \theta_c = n_2(1)$

$$\sin \theta_c = \frac{n_2}{n_1}$$

**78.** $\sin \theta_c = \frac{n_2}{n_1}$, $\frac{n_2}{n_1} < 1$ by definition of the sine function. Therefore, $n_2 < n_1$.

**79. a)** $\sin \theta_c = \frac{n_2}{n_1}$

$\theta_c = 24.4°$

**b)** $\theta_c = 48.8°$

**c)** $\theta_c = 41.8°$

**d)** $\theta_c = 33.3°$

**80. a)** $\sin \theta_c = \frac{n_2}{n_1}$

$$n_1 = \frac{n_2}{\sin \theta_c}$$

$n_1 = 2.00$

**b)** $n_1 = 2.66$

**81.** Glass → Water: $\theta_c = 61.0°$

Glass → Air: $\theta_c = 41.1°$

**82.** Diamond → Zircon: $\theta_c = 51.7°$

Diamond → Ice: $\theta_c = 32.5°$

Zircon → Ice: $\theta_c = 43.2°$

**83.** $f_2 = f_1\left(1 - \frac{v_r}{c}\right)$

$$f_2 = 7.0 \times 10^{14}\ \text{s}^{-1}\left(1 - \frac{1.5 \times 10^7\ \text{m/s}}{3.0 \times 10^8\ \text{m/s}}\right)$$

$f_2 = 6.65 \times 10^{14}\ \text{s}^{-1}$

**84.** $f_2 = f_1\left(1 - \frac{v_r}{c}\right)$ and $f = \frac{c}{\lambda}$

$$f_2 = \frac{c}{\lambda_1} \times \left(1 - \frac{v_r}{c}\right)$$

$$= \left(\frac{3.0 \times 10^8\ \text{m/s}}{5.0 \times 10^{-7}\ \text{m}}\right)\left(1 - \frac{2.5 \times 10^7\ \text{m/s}}{3.0 \times 10^8\ \text{m/s}}\right)$$

$= 5.5 \times 10^{14}\ \text{s}^{-1}$

**85. i)** $f_2 = f_1\left(1 + \frac{v_a}{c}\right)$

$$f_2 = (7.0 \times 10^{14})\left(1 + \frac{1.5 \times 10^7\ \text{m/s}}{3.0 \times 10^8\ \text{m/s}}\right)$$

$f_2 = 7.35 \times 10^{14}\ \text{s}^{-1}$

**ii)** $f_2 = \frac{c}{\lambda}\left(1 + \frac{v_a}{c}\right)$

$$f_2 = \frac{3.0 \times 10^8\ \text{m/s}}{5.0 \times 10^{-7}\ \text{m}}\left(1 + \frac{2.5 \times 10^7\ \text{m/s}}{3.0 \times 10^8\ \text{m/s}}\right)$$

$f_2 = 6.5 \times 10^{14}\ \text{s}^{-1}$

**86. a)** The galaxy is moving away from us because the light is red shifted.

**b)** $v_r = \frac{\Delta\lambda}{\lambda} \times c$

$$v_r = \frac{4.0 \times 10^{-9}\ \text{m}}{6.0 \times 10^{-7}\ \text{m}} \times 3.0 \times 10^8\ \text{m/s}$$

$v_r = 2.0 \times 10^6\ \text{m/s}$

**c)** $\Delta\lambda = \frac{v_a \times \lambda_1}{c}$

$$\Delta\lambda = \frac{(-2.00 \times 10^6\ \text{m/s})(7.0 \times 10^{-7}\ \text{m})}{3.0 \times 10^8\ \text{m/s}}$$

$\Delta\lambda = -4.0 \times 10^{-9}$ m or $-4$ nm

Therefore, the wavelength is 600 nm − 4 nm = 596 nm.

**87.** $f_2 = f_1\left(1 + \frac{v_r}{c}\right)$

$$v_r = \left(\frac{\Delta f}{2 f_i}\right)c$$

$$v_r = \left[\frac{2000\ \text{Hz}}{(2)(7.8 \times 10^9\ \text{Hz})}\right] \times 3.0 \times 10^8\ \text{m/s}$$

$v_r = 38.5$ m/s

$v_r = 138$ km/h

**88. a)** $v_r = |v_{car} - v_{cop}|$

$v_{car} = 188$ km/h

**b)** $v_r = |v_{car} - v_{cop}|$

$v_r = 88$ km/h

**89.** $v_r = \left(\frac{\Delta f}{2f_i}\right)c$

$f_1 = \left(\frac{\Delta f}{2v_r}\right)c$ where $v_r = 160$ km/h $- 80$ km/h

$= 80$ km/h $= 22.2$ m/s

$f_1 = \left(\frac{3000\ \text{Hz}}{2 \times 22.2\ \text{m/s}}\right) \times 3.0 \times 10^8$ m/s

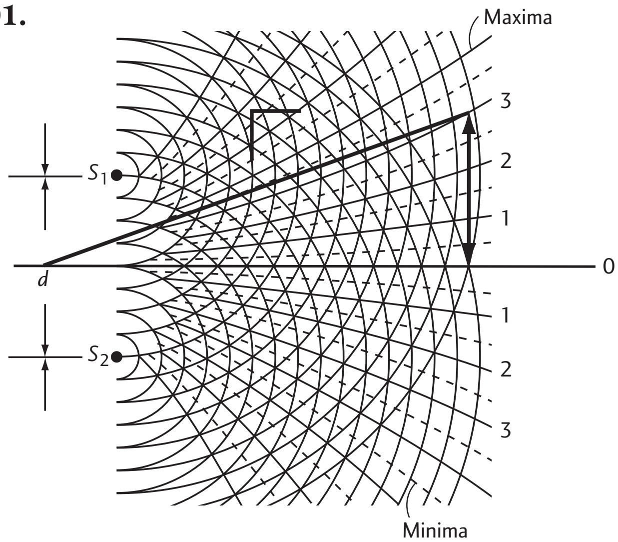
$f_1 = 2.03 \times 10^{10}\ \text{s}^{-1}$

**90. a)** $\frac{\lambda}{2}$

**b)** $\frac{3\lambda}{4}$

**c)** $\frac{\lambda}{4}$

**91.**




Example of how to calculate λ

$n\lambda = \frac{d\,x_n}{L}$

$n = 3$

$d = 2.5$ cm

$L = 6.5$ cm

$x_3 = 2.0$ cm

$\lambda = \frac{(2.5\ \text{cm})(2.0\ \text{cm})}{(3)(6.5\ \text{cm})}$

$\lambda = 0.26$ cm

**92. a)** $n\lambda = d \sin \theta_n$

$\sin \theta_1 = \frac{5.5 \times 10^{-7}\ \text{m}}{4.0 \times 10^{-6}\ \text{m}}$

$\theta_1 = 7.9°$

**b)** $(n - \frac{1}{2})\,\lambda = d \sin \theta_1,\ n = 3$

$\sin \theta_n = \frac{5.1 \times 10^{-7}\ \text{m}}{(2)(4.0 \times 10^{-6}\ \text{m})}$

$\theta_1 = 3.94° \cong 4°$

**c)** $n\lambda = d \sin \theta_n,\ n = 3$

$\theta_1 = 24.4°$

**d)** $(n - \frac{1}{2})\,\lambda = d \sin \theta_1,\ n = 3$

$\theta_2 = 20.1° = 20°$

**93.** $n\lambda = d \sin \theta_n$

$d = \frac{2(6.0 \times 10^{-7}\ \text{nm})}{\sin 22°}$

$d = 3.2 \times 10^{-6}$ m

**94.** $\theta_2 = \tan^{-1}\left(\frac{0.078}{1.1}\right)$

$\theta_2 = 4.1° \cong 4°$

$n\lambda = d \sin \theta_n$

$\lambda = \frac{0.000015 \times \sin 4.1°}{2}$

$\lambda = 5.36 \times 10^{-7}$ m

**95.** $\lambda = 580$ nm

$\lambda = 5.80 \times 10^{-7}$ m

$L = 1.3$ m

$x_9 = 3.0$ cm $= 3.0 \times 10^{-2}$ m

$d = ?$

$\frac{dx_n}{L} = (n - \frac{1}{2})\,\lambda$

$d = \frac{L(n - \frac{1}{2})\,\lambda}{x_n}$

$d = \frac{1.3\ \text{m}(9 - \frac{1}{2})(5.80 \times 10^{-7}\ \text{m})}{3.0 \times 10^{-2}\ \text{m}}$

$d = 2.14 \times 10^{-4}$ m

**96.** $d = \frac{1.0\ \text{m}}{10^6\ \text{slits}}$

$d = 10^{-6}$ m

$d = 5.40 \times 10^{-7}$ m, $n = 1$

$n\lambda = d \sin \theta_n$

$\theta_1 = \sin^{-1} \frac{5.40 \times 10^{-7}\ \text{m}}{10^{-6}\ \text{m}}$

$\theta_1 = 33°$

**97.** $d = \frac{0.01\ \text{m}}{2000\ \text{slits}}$

$d = 5.0 \times 10^{-6}$ m

$\lambda = 6.50 \times 10^{-7}$ m

$n\lambda = d \sin \theta_n$

$n = \frac{d \sin \theta_n}{\lambda}$

$n = \frac{(5.0 \times 10^{-6}\ \text{m})(\sin 11.25°)}{6.50 \times 10^{-7}\ \text{m}}$

$n = 1.5$

**98.** $d = \dfrac{1.0 \times 10^{-3}\text{ m}}{2.0 \times 10^{4}\text{ slits}}$

$d = 5.0 \times 10^{-8}$ m

$\lambda = 6.00 \times 10^{-7}$ m

$L = 0.9$ m

$\dfrac{dx_n}{L} = n\lambda$

$x_2 = \dfrac{(n\lambda)L}{d}$

$x_2 = \dfrac{2(6.00 \times 10^{-7}\text{ m})(0.9)}{5.0 \times 10^{-8}\text{ m}}$

$x_2 = 21.6\text{ m} \rightarrow$ (effectively not seen)

**99. a)** $\lambda = 6.50 \times 10^{-7}$ m

set $n = 0$ and $\sin\theta = 1$ $(90° = \theta)$

$(n + \frac{1}{2})\lambda = d\sin\theta_n$

so $\dfrac{\lambda}{2} = d$

$d = 3.25 \times 10^{-7}$ m

**b)** $\dfrac{3.25 \times 10^{-7}\text{ m}}{6.50 \times 10^{-7}\text{ m}}$

$= 0.5 = \frac{1}{2}$

**100. a)** $n\lambda = w\sin\theta_n$

$n = 2$, $w = 1.0 \times 10^{-5}$ m, $\lambda = 6.40 \times 10^{-7}$ m

$\theta_2 = \sin^{-1}\dfrac{2(6.40 \times 10^{-7}\text{ m})}{1.0 \times 10^{-5}\text{ m}}$

$\theta_2 = 7.4°$

**b)** $(n - \frac{1}{2})\lambda = w\sin\theta_n$

$\theta_2 = \sin^{-1}\dfrac{(1.5)(6.40 \times 10^{-7}\text{ m})}{1.0 \times 10^{-5}\text{ m}}$

$\theta_2 = 5.5°$

**101.** $w = 1.2 \times 10^{-2}\text{ mm} = 1.2 \times 10^{-5}$ m

$n = 1$, $\theta_1 = 4°$

$\lambda = ?$

$n\lambda = w\sin\theta_n$

$\lambda = \dfrac{(1.2 \times 10^{-5}\text{ m})(\sin 4°)}{1}$

$\lambda = 8.37 \times 10^{-7}$ m

**102.** $w = ?$, $\lambda = 4.00 \times 10^{-7}$ m

The total width is 6.8°. Therefore, the width to the first minimum is $\frac{6.8°}{2} = 3.4°$.

$n\lambda = w\sin\theta_n$, $n = 1$

$w = \dfrac{\lambda}{\sin\theta_n}$

$w = \dfrac{4.00 \times 10^{-7}\text{ m}}{\sin 3.4°}$

$w = 6.74 \times 10^{-6}$ m

**103.** $\lambda = 5.95 \times 10^{-7}$ m

$w = 1.23 \times 10^{-5}$ m

$L = 1.2$ m

$n = 3$

**a)** $n\lambda = \dfrac{wx_n}{L}$

$x_n = \dfrac{L\lambda n}{w}$

$x_3 = \dfrac{(1.2\text{ m})(5.95 \times 10^{-7}\text{ m})(3)}{1.23 \times 10^{-5}\text{ m}}$

$x_3 = 1.74 \times 10^{-1}$ m

$x_3 = 17.4$ cm

**b)** $(n + \frac{1}{2})\lambda = \dfrac{wx_n}{L}$

$x_2 = \dfrac{(1.2\text{ m})(5.95 \times 10^{-7}\text{ m})(2.5)}{1.23 \times 10^{-5}\text{ m}}$

$x_2 = 1.45 \times 10^{-1}$ m

$x_2 = 14.5$ cm

**104.** The width of the central maximum is twice the distance from the first nodal line.

$n\lambda = w\sin\theta_n$, $n = 1$

$\theta_1 = \sin^{-1}\left(\dfrac{\lambda}{w}\right)$

$\theta_1 = \sin^{-1}\left(\dfrac{4.70 \times 10^{-7}\text{ m}}{1.00 \times 10^{-5}\text{ m}}\right)$

$\theta_1 = 2.69°$

Therefore, the width is two times $\theta_1$, or 5.39°.

**105. a)** The width of the central maximum is twice the distance from the first nodal line.

Therefore, the width is $2 \times 3.1$ mm, or 6.2 mm.

**b)** $x_1 = 3.1 \times 10^{-3}$ m

$\theta = \sin^{-1}\dfrac{3.1 \times 10^{-3}\text{ m}}{3.5\text{ m}}$

$\theta = 0.057°$

Therefore, the total width $= 2 \times 0.051°$ $= 0.10°$.

**106.** $n\lambda = w\sin\theta_n$

$\sin\theta_n = \dfrac{\lambda}{w}$

**a)** $\dfrac{\lambda}{w} < 1$. Therefore, $\lambda < w$.

**b)** 1

## Chapter 11

**23.** $\Delta t = 2.0$ s

$N = 250$

**a)** $f = \dfrac{N}{\Delta t}$

$f = \dfrac{250 \text{ cycles}}{2.0 \text{ s}}$

$f = 125$ Hz

**b)** $T = \dfrac{1}{f}$

$T = \dfrac{1}{125 \text{ Hz}}$

$T = 0.008$ s

**24. a)** 4 m

**b)** 8 s

**c)** 7 cm

**d)** 14 cm

**e)** $f = \dfrac{1}{T} = \dfrac{1}{8 \text{ s}}$

$f = 0.125$ Hz

**25.** $\Delta t = 6.5$ h

$N = 6$

**a)** $f = \dfrac{N}{\Delta t}$

$f = \dfrac{6}{6.5 \text{ h}}$

$f = 0.92$ Hz

**b)** $T = \dfrac{1}{f}$

$T = \dfrac{1}{0.92 \text{ Hz}}$

$T = 1.08$ s

**26. a)** $f = 440$ Hz

$v = 332$ m/s

$v = \lambda f$

$\lambda = \dfrac{v}{f}$

$\lambda = \dfrac{332 \text{ m/s}}{440 \text{ s}^{-1}}$

$\lambda = 0.75$ m

**b)** $f = 440$ Hz

$v = 350$ m/s

$\lambda = \dfrac{v}{f}$

$\lambda = \dfrac{350 \text{ m/s}}{440 \text{ s}^{-1}}$

$\lambda = 0.80$ m

**c)** $f = 440$ Hz

$v = 1225$ km/h

$v = 340.28$ m/s

$\lambda = \dfrac{v}{f}$

$\lambda = \dfrac{340.28 \text{ m/s}}{440 \text{ s}^{-1}}$

$\lambda = 0.77$ m

**27. a)** $f = 1000$ Hz

$\lambda = 35$ cm

$v = \lambda f$

$v = 0.35 \text{ m} \times 1000 \text{ s}^{-1}$

$v = 350$ m/s

**b)** 350 m/s = 1260 km/h

**28.** $v = 3.0 \times 10^8$ m/s

$f = 1600$ Hz

football field = 250 m

$\lambda = \dfrac{v}{f}$

$\lambda = \dfrac{3.0 \times 10^8 \text{ m/s}}{1600 \text{ s}^{-1}}$

$\lambda = 187\,500$ m

$\lambda = 750$ football fields

**29.** $\dfrac{\lambda}{4} = 0.85$ m

$\lambda = 3.4$ m

**a)** $f = 125$ Hz

**b)** $T = \dfrac{1}{125 \text{ Hz}}$

$T = 0.008$ s

**c)** $v = \lambda f$

$v = 3.4 \text{ m} \times 125 \text{ Hz}$

$v = 425$ m/s

**30. a)** $\lambda = 0.50$ m

$f = 0.30$ Hz

$v = \lambda f$

$v = 0.15$ m/s

**b)** $v = 200$ m/s

**c)** $v = 15$ m/s

**d)** $v = 2500$ m/s

**e)** $v = 5.1 \times 10^7$ m/s

**31. a)** $\lambda = 75$ cm $= 0.75$ m

$T = 0.020$ s

$f = \dfrac{1}{T}$

$f = 50 \text{ Hz} = 50 \text{ s}^{-1}$

$v = \lambda f$

$v = 0.75 \text{ m} \times 50 \text{ s}^{-1}$

$v = 37.5 \text{ m/s}$

**b)** $v = 50 \text{ m/s}$

**c)** $v = 0.0063 \text{ m/s}$

**d)** $v = 3.5 \times 10^{-4} \text{ m/s}$

**32.** $f = 440 \text{ Hz} = 440 \text{ s}^{-1}$

$v = 344 \text{ m/s}$

$\Delta d = 300 \text{ m}$

$\lambda = \frac{v}{f}$

$\lambda = \frac{344 \text{ m/s}}{440 \text{ s}^{-1}}$

$\lambda = 0.782 \text{ m}$

number of wavelengths $= 300 \text{ m} \times \frac{1 \text{ wavelength}}{0.782 \text{ m}}$

number of wavelengths $= 383.63 = 384$

**33. a)** $v = 972 \text{ m/s}$

$\Delta d = 2000 \text{ m}$

$\Delta t = \frac{\Delta d}{v}$

$\Delta t = \frac{2000 \text{ m}}{972 \text{ m/s}}$

$\Delta t = 2.06 \text{ s}$

**b)** $\Delta t = 1.38 \text{ s}$

**c)** $\Delta t = 0.39 \text{ s}$

**d)** $\Delta t = 4.26 \text{ s}$

**34. a)** $f = 1000 \text{ s}^{-1}$

$v = 1230 \text{ m/s}$

$\lambda = \frac{v}{f}$

$\lambda = \frac{1230 \text{ m/s}}{1000 \text{ s}^{-1}}$

$\lambda = 1.23 \text{ m}$

**b)** $\lambda = 1.267 \text{ m}$

**c)** $\lambda = 0.1119 \text{ m}$

**d)** $\lambda = 0.3428 \text{ m}$

**35. a)** $T = 0°\text{C}$

$v = 332 \text{ m/s} + 0.6T$

$v = 332 \text{ m/s}$

**b)** $v = 347 \text{ m/s}$

**c)** $v = 350 \text{ m/s}$

**d)** $v = 323 \text{ m/s}$

**36.** $f = 90 \text{ kHz}$

$f = 90\,000 \text{ Hz}$

$T = 22°\text{C}$

$v = 332 \text{ m/s} + 0.6T$

$v = 345.2 \text{ m/s}$

$\lambda = \frac{v}{f}$

$\lambda = \frac{345.2 \text{ m/s}}{90\,000 \text{ Hz}}$

$\lambda = 3.84 \times 10^{-3} \text{ m}$

**37.** $\Delta t = 7.0 \text{ s}$

$T = 31°\text{C}$

$v = ?$

$\Delta d = ?$

$v = 332 \text{ m/s} + 0.6(31) = 350.6 \text{ m/s}$

$\Delta d = v\Delta t = 350.6 \text{ m/s} \times 7.0 \text{ s}$

$= 2454 \text{ m}$

**38.** $\Delta t = 435 \text{ ms}$

$\Delta t = 0.435 \text{ s}$

$v = 5300 \text{ km/h}$

$v = 1472.2 \text{ m/s}$

$\Delta d = v\Delta t$

$\Delta d = 1472.2 \text{ m/s} \times 0.435 \text{ s}$

$\Delta d = 640.4 \text{ m}$

**39.** $\Delta t = 0.8 \text{ s}$

$\Delta d = 272 \text{ m}$

$v = \frac{\Delta d}{\Delta t}$

$v = \frac{272 \text{ m}}{0.8 \text{ s}}$

$v = 340 \text{ m/s}$

$v = 332 + 0.6T$

$T = \frac{v - 332}{0.6}$

$T = \frac{340 - 332}{0.6}$

$T = 13.3°\text{C}$

**40.** $\Delta t = 2.0 \text{ s}$

$T = 21°\text{C}$

$v = 332 + 0.6T$

$v = 344.6 \text{ m/s}$

$\Delta d = \Delta t \times v$

$\Delta d = 2.0 \text{ s} \times 344.6 \text{ m/s}$

$\Delta d = 689.2 \text{ m}$

$\Delta d = 690 \text{ m}$

**41.** For you, in water: $\Delta t = 3.5 \text{ s}$

$v = 1450 \text{ m/s}$

$\Delta d = \Delta t \times v$

$\Delta d = 5075 \text{ m}$

For friend, on dock: $\Delta d = 5075$ m

$T = 20°C$

$v = 332 + 0.6T$

$v = 344$ m/s

$$\Delta t = \frac{\Delta d}{v}$$

$$\Delta t = \frac{5075 \text{ m}}{344 \text{ m/s}}$$

$\Delta t = 14.75 \text{ s} = 14.8 \text{ s}$

**42.** For you: $T = 32°C$

$\Delta d = 350$ m

$v = 332 + 0.6T$

$v = 351.2$ m/s

$$\Delta t = \frac{\Delta d}{v}$$

$\Delta t = 1.00$ s

For friend: $\Delta d = 30\,000 \text{ km} = 3.0 \times 10^7$ m

$v = 3.0 \times 10^8$ m/s

$$\Delta t = \frac{\Delta d}{v}$$

$\Delta t = 0.10$

Therefore, the friend hears it first.

**43.** Air: $T = 10°C$

$f = 500$ Hz

$v = 332 + 0.6T$

$v = 338$ m/s

$$\lambda = \frac{v}{f}$$

$\lambda = 0.676$ m

Water: $f = 500$ Hz

$v = 5220$ km/h

$v = 1450$ m/s

$$\lambda = \frac{v}{f}$$

$\lambda = 2.90$ m

number of times more wavelengths in air than in water $= \frac{2.9 \text{ m}}{0.676 \text{ m}} = 4.3$

**44. a)** $v_{sound} = 332$ m/s

$v = 664$ m/s

$$\text{Mach} = \frac{v}{v_{sound}}$$

Mach = 2

Since Mach > 1 → supersonic

**b)** Mach = 0.92 → subsonic

**c)** Mach = 0.12 → subsonic

**d)** Mach = 6.0 → supersonic

**45. a)** $v = 332$ m/s

$T = 30°C$

$v_{sound} = 332 + 0.6T$

$v_{sound} = 350$ m/s

$$\text{Mach} = \frac{v}{v_{sound}}$$

Mach = 0.95

**b)** $v_{sound} = 326$ m/s

Mach = 1.04

**c)** $v = 6000$ km/h

$v = 1666.67$ m/s

$v_{sound} = 339.8$ m/s

Mach = 4.90

**d)** $v = 6000$ km/h

$v = 1666.67$ m/s

$v_{sound} = 324.2$ m/s

Mach = 5.14

**46.** Mach = 2.2

$T = 15°C$

$v_{sound} = 332 + 0.6T$

$v_{sound} = 341$ m/s

$v_{plane} = \text{Mach} \times v_{sound}$

$v_{plane} = 2.2 \times 341$ m/s

$v_{plane} = 750.2 \text{ m/s} = 750$ m/s

$$v = \frac{\Delta d}{\Delta t}$$

$\Delta d = v\Delta t$

$\Delta d = 750 \text{ m/s} \times 3.4$ s

$\Delta d = 2550$ m

**47.** Earth: Mach = 20

$T = 5°C$

$v_{sound} = 332 + 0.6T$

$v_{sound} = 335$ m/s

$v_{spacecraft} = v_{sound} \times \text{Mach}$

$v_{spacecraft} = 6700$ m/s

Other planet: $v_{spacecraft} = 6700$ m/s

$v_{sound} = 1267$ m/s

$$\text{Mach} = \frac{v_{spacecraft}}{v_{sound}}$$

Mach = 5.29

**48. i)** $\Delta t = 1.495$ h

$\Delta t = 5382$ s

$r = 6.73 \times 10^6$ m

$\Delta d = 2\pi r$

$\Delta d = 4.23 \times 10^7$ m

$v_{shuttle} = \dfrac{\Delta d}{\Delta t}$

$v_{shuttle} = \dfrac{4.23 \times 10^7\ \text{m}}{5382\ \text{s}}$

$v_{shuttle} = 7.86 \times 10^3\ \text{m/s}$

**ii)** $v_{sound} = 332 + 0.6T$

$T = -30°\text{C}$

$v_{sound} = 314\ \text{m/s}$

$\text{Mach} = \dfrac{v_{shuttle}}{v_{sound}}$

$\text{Mach} = \dfrac{7.86 \times 10^3\ \text{m/s}}{314\ \text{m/s}}$

$\text{Mach} = 25$

**49. a)** $I_1 = 6.0 \times 10^{-6}\ \text{W/m}^2$

$r_2 = 2r_1$

$\dfrac{I_1}{I_2} = \dfrac{(r_2)^2}{(r_1)^2}$

$I_2 = \dfrac{(1)^2}{(2)^2} \times I_1$

$I_2 = \frac{1}{4} \times 6.0 \times 10^{-6}\ \text{W/m}^2$

$I_2 = 1.5 \times 10^{-6}\ \text{W/m}^2$

**b)** $I_2 = 3.75 \times 10^{-7}\ \text{W/m}^2$

**c)** $I_2 = 2.4 \times 10^{-5}\ \text{W/m}^2$

**d)** $I_2 = 5.4 \times 10^{-5}\ \text{W/m}^2$

**50.** $I_1 = 1.2 \times 10^{-11}\ \text{W/m}^2$

$I_2 = 1.0 \times 10^{-12}\ \text{W/m}^2$

$\dfrac{I_1}{I_2} = \dfrac{(r_2)^2}{(r_1)^2}$

$\dfrac{(r_2)^2}{(r_1)^2} = \dfrac{1.2 \times 10^{-11}\ \text{W/m}^2}{1.0 \times 10^{-12}\ \text{W/m}^2}$

$\dfrac{(r_2)^2}{(r_1)^2} = 12$

$\left(\dfrac{r_2}{r_1}\right)^2 = 12$

The sound is at the threshold of hearing at 3.5 m away.

**51.** $A = 5.5\ \text{m}^2$

$P = 3.0 \times 10^{-3}\ \text{W}$

$I = \dfrac{P}{A}$

$I = 5.45 \times 10^{-4}\ \text{W/m}^2$

**52. a)** $I = 4.8 \times 10^{-5}\ \text{W/m}^2$

$P = 3.0 \times 10^{-3}\ \text{W}$

$A = \dfrac{P}{I}$

$A = 62.5\ \text{m}^2$

**b)** $I_1 = 5.45 \times 10^{-4}\ \text{W/m}^2$

$I_2 = 4.8 \times 10^{-5}\ \text{W/m}^2$

$\dfrac{I_1}{I_2} = 11.35$

$\dfrac{I_1}{I_2} = 11.4$

**c)** $x = 3.37$

**53. a)** $\log 100 = 2$

**b)** $\log 1000 = 3$

**c)** $\log 0.01 = -2$

**d)** $\log 3.5 \times 10^{-4} = -3.46$

**e)** $\log 5.67 \times 10^6 = 6.75$

**f)** $\log 1 = 0$

**g)** log 0 does not exist

**54. a)** $2 = \log 100$

**b)** $6 = \log 1\,000\,000$

**c)** $-2 = \log 0.01$

**d)** $-6 = \log 0.000\,001$

**e)** $3.5 = \log 3162.28$

**f)** $0.35 = \log 2.24$

**55. a)** $I = 10 \log\left(\dfrac{I_2}{I_1}\right)$

$0.1 = \log\left(\dfrac{I_2}{I_1}\right)$

$\dfrac{I_2}{I_1} = 1.26$

$I_2$ is 1.26 times larger than $I_1$.

**b)** $4 = 10 \log\left(\dfrac{I_2}{I_1}\right)$

$0.4 = \log\left(\dfrac{I_2}{I_1}\right)$

$\dfrac{I_2}{I_1} = 2.51$

**c)** $-1 = 10 \log\left(\dfrac{I_2}{I_1}\right)$

$-0.1 = \log\left(\dfrac{I_2}{I_1}\right)$

$\dfrac{I_2}{I_1} = 0.79$

**d)** $-3 = 10 \log\left(\dfrac{I_2}{I_1}\right)$

$-0.3 = \log\left(\dfrac{I_2}{I_1}\right)$

$\dfrac{I_2}{I_1} = 0.50$

**e)** $2.5 = 10 \log\left(\frac{I_2}{I_1}\right)$

$0.25 = \log\left(\frac{I_2}{I_1}\right)$

$\frac{I_2}{I_1} = 1.78$

**f)** $0.5 = 10 \log\left(\frac{I_2}{I_1}\right)$

$0.05 = \log\left(\frac{I_2}{I_1}\right)$

$\frac{I_2}{I_1} = 1.12$

**56. a)** $\beta = 120$ dB
$\beta = 60$ dB
$\Delta\beta = 60$ dB

$60 \text{ dB} = 10 \log\left(\frac{I_2}{I_1}\right)$

$6 = \log\left(\frac{I_2}{I_1}\right)$

$\frac{I_2}{I_1} = 10^6$

The threshold of pain is 1 000 000 times greater in intensity than a normal conversation.

**b)** $\beta_2 = 120$ dB
$\beta_1 = 20$ dB
$\Delta\beta = 110$ dB

$100 \text{ dB} = 10 \log\left(\frac{I_2}{I_1}\right)$

$10 = \log\left(\frac{I_2}{I_1}\right)$

$\frac{I_2}{I_1} = 10^{10}$

**c)** $\beta = 120$ dB
$\beta = 110$ dB
$\Delta\beta = 10$ dB

$10 \text{ dB} = 10 \log\left(\frac{I_2}{I_1}\right)$

$1 = \log\left(\frac{I_2}{I_1}\right)$

$\frac{I_2}{I_1} = 10$

**d)** $\beta_2 = 120$ dB
$\beta_1 = 75$ dB
$\Delta\beta = 45$ dB

$45 \text{ dB} = 10 \log\left(\frac{I_2}{I_1}\right)$

$4.5 = \log\left(\frac{I_2}{I_1}\right)$

$\frac{I_2}{I_1} = 3.2 \times 10^4$

**57. a)** $I_1 = 3.5 \times 10^{-6}$ W/m$^2$

$\frac{r_2}{r_1} = \frac{2}{1}$

$\frac{I_1}{I_2} = \frac{(r_2)^2}{(r_1)^2}$

$I_2 = \frac{(r_2)^2}{(r_1)^2} \times I_1$

$\text{I}_2 = 8.75 \times 10^{-7}$ W/m$^2$

**b)** $I_1 = 1.0 \times 10^{-12}$ W/m$^2$
$I_2 = 3.6 \times 10^{-6}$ W/m$^2$

$\beta_1 = 10 \log\left(\frac{I_2}{I_1}\right)$

$\beta_1 = 65.4$ dB
$I_1 = 1.0 \times 10^{-12}$ W/m$^2$
$I_2 = 8.75 \times 10^{-7}$ W/m$^2$

$\beta_2 = 10 \log\left(\frac{I_2}{I_1}\right)$

$\beta_2 = 59.4$ dB
$\Delta\beta = 65.4 \text{ dB} - 59.4 \text{ dB}$
$\Delta B = 6$ dB

**58. a)** $\Delta\beta = 30$ dB

$\Delta\beta = 10 \log\left(\frac{I_2}{I_1}\right)$

$30 = 10 \log\left(\frac{I_2}{I_1}\right)$

$3 = \log\left(\frac{I_2}{I_1}\right)$

$\frac{I_2}{I_1} = 1000$

Therefore, the intensity of sound increases by 1000 times.

**b)** $\Delta\beta = 22$ dB

$$\beta = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$22 = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$2.2 = \log\left(\frac{I_2}{I_1}\right)$$

$$\frac{I_2}{I_1} = 158.5$$

**c)** $\Delta\beta = 18.9$ dB

$$\beta = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$18.9 = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$1.89 = \log\left(\frac{I_2}{I_1}\right)$$

$$\frac{I_2}{I_1} = 77.6$$

**59.** $P = 25$ W

$\beta = 110$ dB

$$110 \text{ dB} = 10 \log\left(\frac{I_2}{10^{-12} \text{ W/m}^2}\right)$$

$$11 = \log\left(\frac{I_2}{10^{-12} \text{ W/m}^2}\right)$$

$$10^{11} = \frac{I_2}{10^{-12} \text{ W/m}^2}$$

$I_2 = 0.1$ W

The number of jack hammers $= \dfrac{25 \text{ W}}{0.1 \text{ W}} = 250$

**60.** $r_1 = 2$

$\beta_1 = 120$ dB

$\beta_2 = 100$ dB

$\Delta\beta = -20$ dB

$$-20 \text{ dB} = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$-2 = \log\left(\frac{I_2}{I_1}\right)$$

$$\frac{I_2}{I_1} = \frac{1}{100}$$

$$\frac{I_1}{I_2} = \frac{(r_2)^2}{(r_1)^2}$$

$$(r_2)^2 = \left(\frac{100}{1}\right) \times (2)^2$$

$(r_2)^2 = 400$

$r_2 = 20$

Therefore, you should be 20 m back.

**61.** $\beta_1 = 5$ dB

$\beta_2 = 25$ dB

$\Delta\beta = 20$ dB

$$\beta = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$20 = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$2 = \log\left(\frac{I_2}{I_1}\right)$$

$$\frac{I_2}{I_1} = 100$$

**62.** $\beta_1 = 50$ dB

$\beta_2 = 60$ dB

$\Delta\beta = 10$ dB

$$\beta = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$1 = \log\left(\frac{I_2}{I_1}\right)$$

$$\frac{I_2}{I_1} = 10$$

Therefore, the 60 dB stereo system is better by a factor of 10.

**63.** $\beta_1 = 65$ dB

$\beta_2 = 120$ dB

$\Delta\beta = 55$ dB

$$55 = 10 \log\left(\frac{I_2}{I_1}\right)$$

$$5.5 = \log\left(\frac{I_2}{I_1}\right)$$

$$\frac{I_2}{I_1} = 316\,227.8$$

Therefore, you would need to add about 316 228 two-people conversation intensities.

**64. a)** $v_s = 332$ m/s

$v_o = 25.0$ m/s (toward)

$f_1 = 1700$ Hz

$$f_2 = \left(\frac{f_1 v_s}{v_s - v_o}\right)$$

$f_2 = 1838$ Hz

$f_2 \cong 1840$ Hz

**b)** $v_s = 332$ m/s

$v_o = 25.0$ m/s (away from)

$f_1 = 1700$ Hz

$$f_2 = \left(\frac{f_1 v_s}{v_s + v_o}\right)$$

$f_2 = 1580$ Hz

**c)** $v_s = 332$ m/s
$v_o = 140$ km/h
$v_o = 38.9$ m/s (toward)
$f_1 = 1700$ Hz
$f_2 = \left(\frac{f_1 v_s}{v_s - v_o}\right)$
$f_2 = 1926$ Hz
$f_2 = 1930$ Hz

**65. a)** $T = 30°C$
$v_o = 25.0$ m/s (toward)
$f_1 = 1700$ Hz
$v_s = 332 \text{ m/s} + 0.6T$
$v_s = 350$ m/s
$f_2 = \left(\frac{f_1 v_s}{v_s - v_o}\right)$
$f_2 = 1830$ Hz

**b)** $T = 30°C$
$v_o = 25.0$ m/s (away from)
$f_1 = 1700$ Hz
$v_s = 332 \text{ m/s} + 0.6T$
$v_s = 350$ m/s
$f_2 = \left(\frac{f_1 v_s}{v_s + v_o}\right)$
$f_2 = 1586.7$ Hz
$f_2 = 1590$ Hz

**c)** $T = 30°C$
$v_o = 140$ km/h
$v_o = 38.9$ m/s (toward)
$f_1 = 1700$ Hz
$v_s = 332 \text{ m/s} + 0.6T$
$v_s = 350$ m/s
$f_2 = \left(\frac{f_1 v_s}{v_s - v_o}\right)$
$f_2 = 1912.6$ Hz
$f_2 = 1910$ Hz

**66.** $f_1 = 900$ Hz
$f_2 = 875$ Hz
$v_s = 332$ m/s
Since the frequency drops, it is moving away.
$f_2 = \left(\frac{f_1 v_s}{v_s + v_o}\right)$
$v_o = \left(\frac{f_1 \cdot v_s}{f_2}\right) - v_s$
$v_o = 9.49$ m/s

**67.** Let $f_1 = 1.0$ Hz
Therefore, $f_2 = 1.2$ Hz.
$v_s = 345$ m/s (toward)
$f_2 = \left(\frac{f_1 v_s}{v_s - v_o}\right)$
$v_o = -\left[\left(\frac{f_1}{f_2}\right) \times v_s\right] + v_s$
$v_o = 57.5$ m/s
$v_o = 58$ m/s

**68.** Let $f_1 = 1.0$ Hz.
Therefore, $f_2 = 0.8$ Hz
$T = 22°C$
$v_s = 332 \text{ m/s} + 0.6T$
$v_s = 345.2$ m/s
$v_o = \left[\left(\frac{f_1}{f_2}\right) \times v_s\right] - v_s$
$v_o = 86.3$ m/s
$v_o = 86$ m/s

**69.** For person in front (ambulance coming toward him):
$f_1 = 1700$ Hz
$v_s = 333$ m/s
$v_o = 120$ km/h
$v_o = 33.3$ m/s
$f_2 = \left(\frac{f_1 v_s}{v_s - v_o}\right)$
$f_2 = 1888.9$ Hz
For person behind (ambulance moving away from him):
$f_1 = 1700$ Hz
$v_s = 333$ m/s
$v_o = 33.3$ m/s
$f_2 = f_1\left(\frac{v_s}{v_s + v_o}\right)$
$f_2 = 1545.3$ Hz
Therefore, the difference in frequencies between the two people = 1888.9 Hz − 1543.3 Hz = 345.6 Hz = 346 Hz.

**70. a)** $v_o = 30$ m/s
$v_s = 332$ m/s (toward)
$f_1 = 1800$ Hz
$f_2 = f_1\left(1 + \frac{v_o}{v_s}\right)$
$f_2 = 1960$ Hz

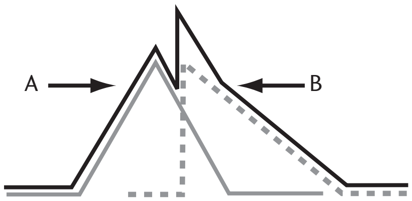
**b)** $v_o = 30$ m/s
$v_s = 332$ m/s (away from)
$f_1 = 1800$ Hz
$f_2 = f_1\left(1 - \frac{v_o}{v_s}\right)$
$f_2 = 1640$ Hz

**71. a)** $v_o = 30$ m/s
$v_s = 332$ m/s (toward)
$f_1 = 1800$ Hz
$f_2 = \frac{f_1 v_s}{v_s - v_o}$
$f_2 = 1978.8$ Hz
$f_2 = 1980$ Hz

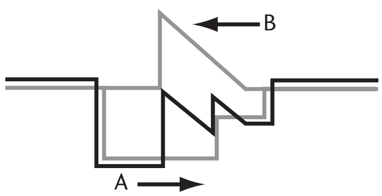
**b)** $v_o = 30$ m/s
$v_s = 332$ m/s (away from)
$f_1 = 1800$ Hz
$f_2 = \frac{f_1 v_s}{v_s + v_o}$
$f_2 = 1650.8$ Hz
$f_2 = 1650$ Hz

## Chapter 12

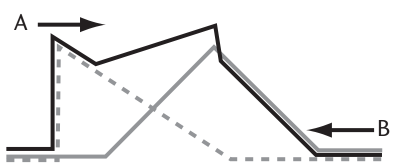
**10.** The resultant pulse of each example is shown in each diagram as a black line.



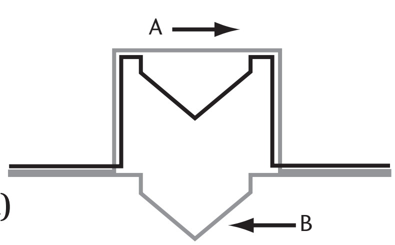

**(a)**




**(b)**



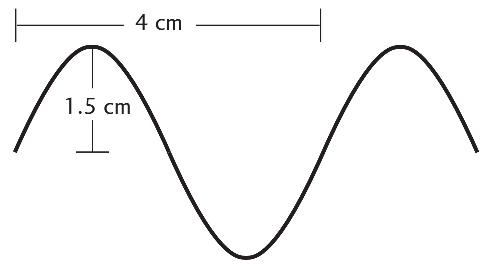

**(c)**



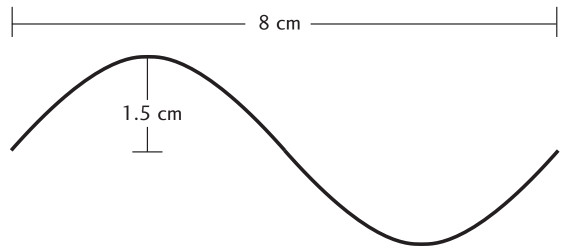

**(d)**

**11.** An oscilloscope is an electronic device that can display a transverse wave structure of a sound wave. It is able to sample and graphically display the electrical voltage signal that represents the music coming from the speakers. This signal (that an oscilloscope can read) is the electrical signal that creates the compressions and rarefactions of the sound waves heard.

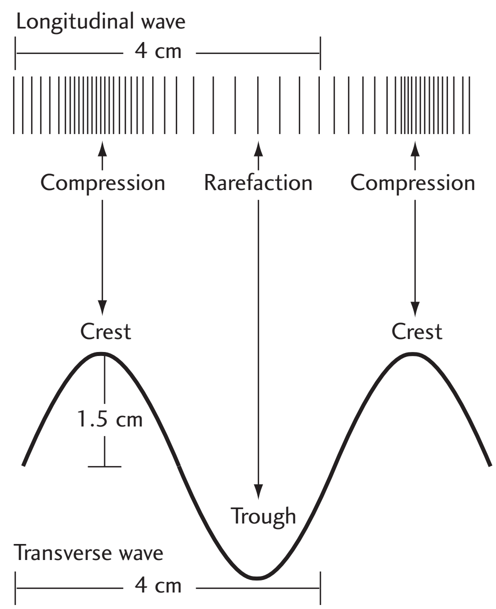
**12. (a)**




**(b)**




**(c)**




**13.** $\dfrac{\lambda_1}{\lambda_2} = \dfrac{v_1}{v_2}$

$$\lambda_2 = \frac{\lambda_1 v_2}{v_1}$$

$$= \frac{(0.33 \text{ m})(335 \text{ m/s})}{341 \text{ m/s}}$$

$$= 0.32 \text{ m}$$

**14.** $f_1 = \dfrac{v_1}{\lambda_1} = \dfrac{341 \text{ m/s}}{0.33 \text{ m}} = 1.0 \times 10^3 \text{ Hz}$

$$\frac{f_2}{f_1} = \frac{\frac{v_2}{\lambda_2}}{\frac{v_1}{\lambda_1}}$$

$$f_2 = f_1\left(\frac{\frac{v_2}{\lambda_2}}{\frac{v_1}{\lambda_1}}\right)$$

$$f_2 = 1.0 \times 10^3 \text{ Hz}\left(\frac{\frac{335 \text{ m/s}}{0.32 \text{ m}}}{\frac{341 \text{ m/s}}{0.33 \text{ m}}}\right)$$

$$f_2 = 1.0 \times 10^3 \text{ Hz}$$

The frequency of each wave does not change for the audience. The change in the speed of sound is compensated for by the change in wavelength. The slower the speed, the smaller the wavelength, so the frequency remains the same.

**15.** resonance at $\dfrac{n\lambda}{2} = \dfrac{5\lambda}{2}$

Therefore, $\dfrac{5\lambda}{2} = 0.200 \text{ m}$

$\lambda = 0.080 \text{ m}$

Therefore, $v = 332 \text{ m} + 0.6T$

$= 332 \text{ m/s} + 0.6(22.0°\text{C})$

$= 345.2 \text{ m/s}$

Therefore, $f = \dfrac{v}{\lambda}$

$= \dfrac{345.2 \text{ m/s}}{0.080 \text{ m}}$

$= 4.32 \times 10^3 \text{ Hz}$

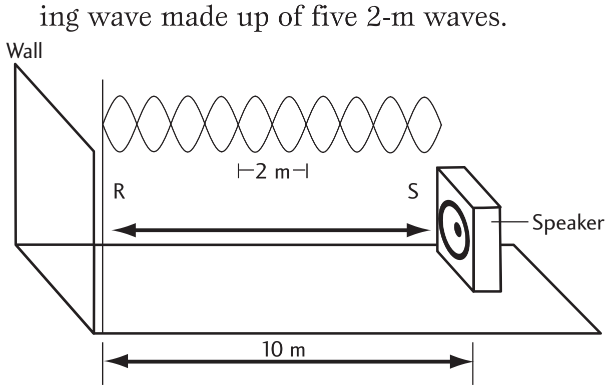
**16.** If $t = 30°\text{C}$ and $f = 175$ Hz then:

$v = 332 + 0.6T = 332 + 0.6(30°\text{C}) = 350 \text{ m/s}$

Therefore,

$\lambda = \dfrac{v}{f} = \dfrac{350 \text{ m/s}}{175 \text{ Hz}} = 2.00 \text{ m}$

In a distance of 10 m, there would be a standing wave made up of five 2-m waves.




**17.** If pendulum 1 was set in motion, only pendulum 3 would be set in motion. The principle is that of mechanical resonance. The similar lengths of the two strings give each pendulum the same natural frequency. When one starts in motion, only the other of the same frequency will resonate with the periodic force being sent along the flexible cord.

**18.** A gravel truck causes your windows to vibrate because of mechanical resonance. It is producing the same frequency as that of the window. The window begins to vibrate at the same frequency as that of the rumbling truck.

**19.** $\frac{1}{2}\lambda = 0.24 \text{ m}$

$\lambda = 0.48 \text{ m}$

If the tube was closed at one end, only $\frac{1}{4}\lambda$ would fit in the same tube instead of the previous $\frac{1}{2}\lambda$.

$\frac{1}{4}\lambda = 0.24 \text{ m}$

$\lambda = 0.96 \text{ m}$

The resulting sound would have an increased wavelength of 0.96 m, leaving a lower fundamental frequency.

**20. a)** $\frac{1}{4}\lambda = 0.08 \text{ m}$

$\lambda = 0.32 \text{ m}$

The wavelength of the first sound heard in the tube is 0.32 m.

**b)** $L = 1.25\lambda$

$L = 1.25(0.32 \text{ m})$

$= 0.40 \text{ m}$

The third resonant length for this note would be 0.40 m.

**21. a)** $v = 332 \text{ m/s} + 0.6T$

$= 332 \text{ m/s} + 0.6(25.0°\text{C})$

$= 347 \text{ m/s}$

**b)** $\lambda = \dfrac{347 \text{ m/s}}{950 \text{ Hz}}$

$= 0.365 \text{ m}$

**c)** $L = \frac{1}{2}\lambda$

$= \frac{1}{2}(0 .365 \text{ m})$

$\cong 0.183 \text{ m}$

$= 18.3 \text{ cm}$

**22.** $v = 332 \text{ m/s} + 0.6T$

$= 332 \text{ m/s} + 0.6(30.0°\text{C})$

$= 350 \text{ m/s}$

$\lambda = \dfrac{350 \text{ m/s}}{1024 \text{ Hz}}$

$= 0.342 \text{ m}$

$$L = \tfrac{1}{4}\lambda$$
$$= \tfrac{1}{4}(0.342 \text{ m})$$
$$= 0.0855$$
$$= 8.55 \text{ cm}$$

**23. a)** $L = \tfrac{1}{4}\lambda$

$$\lambda = 4L$$
$$= 4(23.0 \text{ cm})$$
$$= 92 \text{ cm}$$
$$L = \tfrac{1}{4}\lambda$$
$$= 4L$$
$$= 4(30.0 \text{ cm})$$
$$= 120 \text{ cm}$$

**b)** $f = \dfrac{v}{\lambda}$

$$= \frac{341 \text{ m/s}}{0.920 \text{ m}}$$
$$= 371 \text{ Hz}$$
$$f = \frac{v}{\lambda}$$
$$= \frac{341 \text{ m/s}}{1.20 \text{ m}}$$
$$= 284 \text{ Hz}$$

**c)** $v = 332 \text{ m/s} + 0.6T$

$$t = \frac{v - 332 \text{ m/s}}{0.6}$$
$$t = \frac{341 \text{ m/s} - 332 \text{ m/s}}{0.6}$$
$$= 15°\text{C}$$

**24. a)** $L = \tfrac{1}{2}\lambda$

$$\lambda = 2L$$
$$= 2(10 \text{ cm})$$
$$= 20 \text{ cm}$$

**b)** $v = 332 \text{ m/s} + 0.6T$

$$v = 332 \text{ m/s} + 0.6(20.0°\text{C})$$
$$= 344 \text{ m/s}$$

Therefore, $f = \dfrac{v}{\lambda}$

$$= \frac{344 \text{ m/s}}{0.20 \text{ m}}$$
$$= 1720 \text{ Hz}$$
$$= 1.7 \times 10^3 \text{ Hz}$$

**25.** $3(\tfrac{1}{2})\lambda = 90.0 \text{ cm}$

$$\lambda = 60.0 \text{ cm}$$

Therefore, $v = 332 \text{ m/s} + 0.6T$

$$v = 332 \text{ m/s} + 0.6(25.0°\text{C})$$
$$= 347 \text{ m/s}$$

Therefore, $f = \dfrac{v}{\lambda}$

$$= \frac{347 \text{ m/s}}{0.600 \text{ m}}$$
$$= 578 \text{ Hz}$$

**26. a)** $v = 332 \text{ m/s} + 0.6(25.0°\text{C})$

$$= 347 \text{ m/s}$$

**b)** $\tfrac{3}{2}\lambda = L$

$$\lambda = \tfrac{2}{3}(2.5 \text{ m})$$
$$\cong 1.7 \text{ m}$$

**c)** $f = \dfrac{v}{\lambda}$

$$= \frac{347 \text{ m/s}}{1.7 \text{ m}}$$
$$= 204.1 \text{ Hz}$$
$$= 2.0 \times 10^2 \text{ Hz}$$

**27.** $f_1 = 2048 \text{ Hz}$

$$L_2 = 2L_1$$
$$t_2 = 2t_1$$
$$f_2 = ?$$
$$\frac{f_1}{f_2} = \left(\frac{L_1}{L_2}\right)$$
$$f_2 = \frac{f_1}{2}$$
$$= \frac{2048}{2}$$
$$= 1024 \text{ Hz}$$

Therefore, $\dfrac{f_1}{f_2} = \dfrac{\sqrt{t_1}}{\sqrt{t_2}}$

$$f_2 = \frac{f_1}{\sqrt{2}}$$
$$= 1448 \text{ Hz}$$
$$= 1.448 \times 10^3 \text{ Hz}$$

**28. a)** $f_2 = f_1\left(\dfrac{L_1}{L_2}\right)$

$$= 1000 \text{ Hz}\left(\frac{90.0 \text{ cm}}{100.0 \text{ cm}}\right)$$
$$= 900 \text{ Hz}$$

**b)** $f_2 = f_1\left(\dfrac{\sqrt{t_2}}{\sqrt{t_1}}\right)$

$$= 1000 \text{ Hz}\left(\frac{\sqrt{80}}{\sqrt{60}}\right)$$
$$= 1.15 \times 10^3 \text{ Hz}$$

**c)** $f_2 = f_1\left(\dfrac{d_1}{d_2}\right)$

$= 1000\text{ Hz}\left(\dfrac{0.75\text{ mm}}{0.77\text{ mm}}\right)$

$= 970\text{ Hz}$

**d)** $f_2 = f_1\left(\dfrac{L_1}{L_2}\right)\left(\dfrac{\sqrt{t_2}}{\sqrt{t_1}}\right)$

$= 1000\text{ Hz}\left(\dfrac{90.0\text{ cm}}{100\text{ cm}}\right)\left(\dfrac{\sqrt{80}}{\sqrt{60}}\right)$

$= 1035\text{ Hz}$

$= 1.0 \times 10^3\text{ Hz}$

**29. a)** first $= \frac{1}{2}\lambda$

$= 2f$

$= 2 \times 550\text{ Hz}$

$= 1100\text{ Hz}$

$= 1.10 \times 10^3\text{ Hz}$

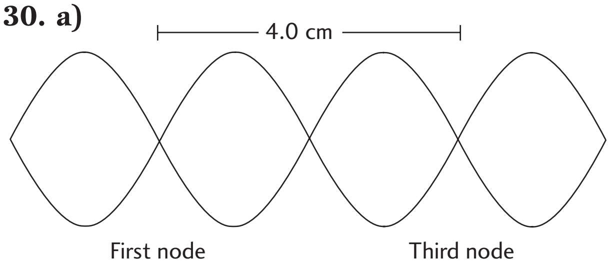
**b)** $f_2 = f_1\left(\dfrac{\sqrt{t_2}}{\sqrt{t_1}}\right)$

$= f_1\sqrt{2}\left(\dfrac{\sqrt{t_1}}{\sqrt{t_1}}\right)$

$= \sqrt{2}(550\text{ Hz})$

$\cong 778\text{ Hz}$

**30. a)**




**b)** $2d_n = 4.0\text{ cm}$

$d_n = 2.0\text{ cm}$

$\frac{1}{2}\lambda = d_n$

$\lambda = 2d_n$

$= 2(2.0\text{ cm})$

$= 4.0\text{ cm}$

**c)** $f = \dfrac{v}{\lambda}$

$= \dfrac{345\text{ m/s}}{0.04\text{ m}}$

$= 8625\text{ Hz}$

$= 8.6 \times 10^3\text{ Hz}$

**31.** $\dfrac{f_1}{f_2} = \dfrac{\sqrt{t_1}}{\sqrt{t_2}}$

$f_2 = \dfrac{f_1\sqrt{t_2}}{\sqrt{t_1}}$

$= \dfrac{300\text{ Hz}(\sqrt{340\text{ N}})}{\sqrt{170\text{ N}}}$

$= 424\text{ Hz}$

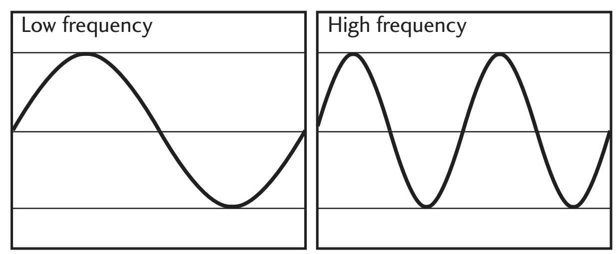
**32.** $\dfrac{f_1}{f_2} = \dfrac{L_2}{L_1}$

$f_2 = \dfrac{f_1 L_1}{L_2}$

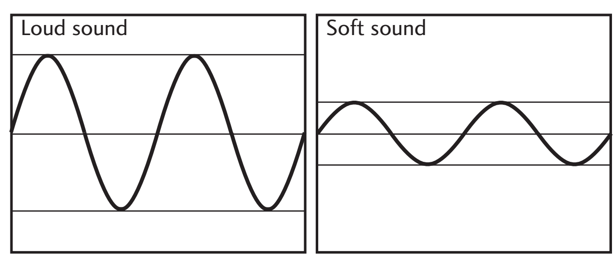
$= \dfrac{250\text{ Hz}(0.75\text{ m})}{0.95\text{ m}}$

$= 197\text{ Hz}$

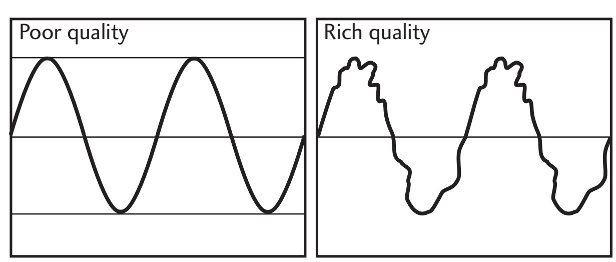
**33.**




A high-frequency wave has the same shape and amplitude as a low-frequency wave, but there are more waves in the same amount of time.




A softer sound has the same frequency (and therefore the same number of waves in the same amount time) than a loud sound, but a lower amplitude.




A rich-quality sound has the same frequency as a poor-quality sound, i.e., the same number of waves in the same amount of time, but it is more complex.

**34.** Harmonics relates to the sounding of more than one related frequency simultaneously. These frequencies are usually fractional multiples of a base frequency because the harmonic wavelengths differ by the addition of $\frac{1}{2}\lambda$ each time. For example, a base frequency of 512 Hz sounded at 0°C would have a wavelength of 0.648 m.

$v = 332 \text{ m/s} + 0.6 \text{ m/s°C } (0°\text{C}) = 332 \text{ m/s}$

$$\lambda = \frac{v}{f} = \frac{332 \text{ m/s}}{512 \text{ Hz}} = 0.648 \text{ m}$$

Adding $\frac{1}{2}\lambda$ or 0.324 m would give a frequency of:

$$f = \frac{v}{\lambda} = \frac{332 \text{ m/s}}{0.973 \text{ m}} = 341 \text{ Hz}$$

The resulting higher frequency, 341 Hz, is called the first harmonic frequency. This second frequency, sounded with a lower amplitude and at the same time as the base frequency, results in a more rich-quality overall sound. The addition of even higher-order harmonics improves the quality of the sound even more.

**35.** Xylophone bars are removable, especially for those used by small children, so they can concentrate on only a few notes in their composition. The bars cannot be interchanged because each of them must rest on the instrument at a node of vibration. The nodes are the only place on the bar that will not vibrate. The bar rests on the nodes so that it can vibrate to make a sound but will stay secure on the instrument without jumping around. A xylophone is tapered from wide to narrow to accommodate the different inter-nodal distances.

**36. i)** $\text{second} = 3f = 3(512 \text{ Hz}) = 1536 \text{ Hz} = 1.54 \times 10^3 \text{ Hz}$

**ii)** $\text{fourth} = 5f = 5(512 \text{ Hz}) = 2560 \text{ Hz} = 2.56 \times 10^3 \text{ Hz}$

**iii)** $\text{fifth} = 6f = 6(512 \text{ Hz}) = 3072 \text{ Hz} = 3.07 \times 10^3 \text{ Hz}$

**37. a)** $f_B = |f_2 - f_1| = |300 \text{ Hz} - 312 \text{ Hz}| = 12 \text{ Hz}$

**b)** $f_B = |f_2 - f_1| = |857 \text{ Hz} - 852 \text{ Hz}| = 5 \text{ Hz}$

**c)** $f_B = |f_2 - f_1| = |1000 \text{ Hz} - 1024 \text{ Hz}| = 24 \text{ Hz}$

**38.** Yes, more information is needed.

$f_B = |f_2 - f_1|$

$4 \text{ Hz} = |f_2 - 440 \text{ Hz}|$

$f_2 = 440 \pm 4$

$f_2 = 444 \text{ and } 436 \text{ Hz}$

When the frequency is 444 Hz, Ms. Boyd should reduce the string tension and for 436 Hz, she should increase the tension.

**39.** $f_B = |f_2 - f_1|$

$3 \text{ Hz} = |f_2 - 512 \text{ Hz}|$

$f_2 = 512 \pm 3 \text{ Hz}$

$f_2 = 515 \text{ Hz and } 509 \text{ Hz}$

The two possible frequencies are 515 Hz and 509 Hz.

## Chapter 13

**33.** Positive signs: protons
Negative signs: electrons

**34.** **a)** No charge
**b)** Negative
**c)** Positive
**d)** No charge
**e)** Positive

**35.** **a)** Negative
**b)** Positive
**c)** Negative
**d)** Positive

**36.** **a)** Negative
**b)** Electrons

**37.** **a)** Glass: positive; silk: negative
**b)** Since they have opposite charges, they will be attracted

**38.** **a)** Insulator (non-metallic)
**b)** Conductor (conducts lightning to ground)
**c)** Insulator (non-metallic)
**d)** Insulator (non-metallic)
**e)** Insulator (non-metallic)
**f)** Insulator (non-metallic)

**39.** Dog hair is positive since a silk shirt rubbed with wool socks would have a negative charge.

**40.** **a)** The electroscope becomes positive because it gives up some electrons to the glass rod to reduce the rod's deficit of electrons. This is called charging by contact.
**b)** The leaves become positively charged as well. In charging by contact, the charged object receives the same charge as the charging rod.
**c)** Negative charges will enter the leaves if the system is grounded.

**41.** $1 \text{ C} = 6.25 \times 10^{18}\ e^-$, $q = 15 \text{ C}$
$q = (15 \text{ C})(6.25 \times 10^{18}\ e^-/\text{C})$
$q = 9.38 \times 10^{19}\ e^-$

**42.** $q = 1.1\ \mu\text{C}$
$q = 1.1 \times 10^{-6} \text{ C}$
$q = (1.1 \times 10^{-6} \text{ C})(6.25 \times 10^{18}\ e^-/\text{C})$
$q = 6.9 \times 10^{12}\ e^-$

**43.** The electroscope has an overall positive charge:
$q = -4.0 \times 10^{11}\ e^-$
$q = (-4.0 \times 10^{11}\ e^-)(-1.602 \times 10^{-19} \text{ C}/e^-)$
$q = +6.4 \times 10^{-8} \text{ C}$

**44.** $q = \dfrac{1}{2}(+5.4 \times 10^{8}\ e^-)$
$q = \dfrac{1}{2}(+5.4 \times 10^{8}\ e^-)(-1.602 \times 10^{-19} \text{ C}/e^-)$
$q = -4.3 \times 10^{-11} \text{ C}$

**45.** $q_n = +2.4 \times 10^{-12} \text{ C}$
$(2.4 \times 10^{-12} \text{ C})(6.25 \times 10^{18}\ e/\text{C})$
$= 1.5 \times 10^{7}$ elementary charges
This means that there are $1.5 \times 10^7$ protons in the nucleus, so the neutral atom must have an equal number of electrons: $1.5 \times 10^7$.

**46.** $F_e = \dfrac{kqq}{r^2}$

**a)** $F_{e1} = \dfrac{kqq}{(4r)^2}$
$F_{e1} = \dfrac{kqq}{16r^2}$
$F_{e1} = \dfrac{1}{16}F_e$

**b)** $F_{e2} = \dfrac{k(2q)(2q)}{r^2}$
$F_{e2} = \dfrac{4kqq}{r^2}$
$F_{e2} = 4F_e$

**c)** $F_{e3} = \dfrac{4}{16}F_e$
$F_{e2} = \dfrac{1}{4}F_e$

**47.** Each sphere loses half of its charge to balance with its identical neutral sphere.
$q_1' = \dfrac{1}{2}q_1,\ q_2' = \dfrac{1}{2}q_2$
$F_{e1} = \dfrac{kq_1q_2}{r_1^2}$
$F_{e2} = \dfrac{kq'_1q'_2}{r_2^2}$
$F_{e2} = \dfrac{k\left(\frac{1}{2}q_1\right)\left(\frac{1}{2}q_2\right)}{r_2^2}$
$F_{e2} = \dfrac{kq_1q_2}{4r_2^2}$

But $F_{e2} = F_{e1}$

$$\frac{kq_1q_2}{4r_2^2} = \frac{kq_1q_2}{r_1^2}$$

$$\frac{1}{4r_2^2} = \frac{1}{r_1^2}$$

$$r_2^2 = \frac{r_1^2}{4}$$

Therefore, $r_2 = \frac{1}{2}r_1$

The spheres should be placed one-half their original distance apart to regain their original repulsion.

**48.** $r = 100 \text{ pm} = 100 \times 10^{-12} \text{ m} = 1.00 \times 10^{-10} \text{ m}$,
$q_1 = q_2 = 1.602 \times 10^{-19} \text{ C}$

$$F_e = \frac{kq_1q_2}{r^2}$$

$$F_e = \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(1.602 \times 10^{-19} \text{ C})^2}{(1.00 \times 10^{-10} \text{ m})^2}$$

$$F_e = 2.3 \times 10^{-8} \text{ N}$$

**49.** $r = 25.0 \text{ cm} = 0.250 \text{ m}$, $F_e = 1.29 \times 10^{-4} \text{ N}$,
$q_1 = q_2 = q = \frac{2}{3}q_o$

**a)** $F_e = \frac{kqq}{r^2}$

$$q = \sqrt{\frac{F_e r^2}{k}}$$

$$q = \sqrt{\frac{(1.29 \times 10^{-4} \text{ N})(0.25 \text{ m})^2}{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)}}$$

$$q = 3.00 \times 10^{-8} \text{ C}$$

**b)** $q$ is $\frac{2}{3}$ the original charge on each sphere.

$$q_o = \frac{3}{2}q$$

$$q_o = \frac{3}{2}(3.00 \times 10^{-8} \text{ C})$$

$$q_o = 4.5 \times 10^{-8} \text{ C}$$

The type of charge, positive or negative, does not matter as long as they are both the same. (Like charges repel.)

**50.** $q_1 = +q$, $q_2 = -3q$
$q_T = q + (-3q) = -2q$

So $q_1' = q_2' = \frac{-2q}{2} = -q$

$$\frac{F_{e2}}{F_{e1}} = \frac{\left(\frac{kq'_1q'_2}{r^2}\right)}{\left(\frac{kq_1q_2}{r^2}\right)}$$

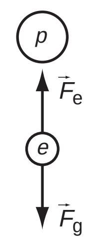
$$\frac{F_{e2}}{F_{e1}} = \frac{(-q)(-q)}{(+q)(-3q)}$$

$$\frac{F_{e2}}{F_{e1}} = \frac{q^2}{-3q^2}$$

$$\frac{F_{e2}}{F_{e1}} = -\frac{1}{3}$$

The magnitude of $F_{e2}$ is $\frac{1}{3}F_{e1}$, and in the opposite direction of $F_{e1}$.

**51. a)**




**b)** $q_1 = -1.602 \times 10^{-19} \text{ C}$,
$q_2 = +1.602 \times 10^{-19} \text{ C}$,
$m = 9.1 \times 10^{-31} \text{ kg}$, $g = -9.8 \text{ m/s}^2$

$$F_g = F_e$$

$$mg = \frac{kq_1q_2}{r^2}$$

$$r = \sqrt{\frac{kq_1q_2}{mg}}$$

$$r = \sqrt{\frac{-(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(1.602 \times 10^{-19} \text{ C})^2}{(9.1 \times 10^{-31} \text{ kg})(-9.8 \text{ m/s}^2)}}$$

$$r = 5.1 \text{ m}$$

**52.** $q_1 = -2.0 \times 10^{-6} \text{ C}$, $q_2 = +3.8 \times 10^{-6} \text{ C}$,
$q_3 = +2.3 \times 10^{-6} \text{ C}$

**a)** $r_1 = 0.10 \text{ m}$, $r_2 = 0.30 \text{ m}$

$${}_1F_{e3} = \frac{kq_1q_3}{r_1^2}$$

$${}_1F_{e3} = \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(-2.0 \times 10^{-6} \text{ C})(2.3 \times 10^{-6} \text{ C})}{(0.10 \text{ m})^2}$$

$${}_1F_{e3} = -4.14 \text{ N (attraction)}$$

$${}_1\vec{F}_{e3} = 4.14 \text{ N [right]}$$

$${}_2F_{e3} = \frac{kq_2q_3}{r_2^2}$$

$${}_2F_{e3} = \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(3.8 \times 10^{-6} \text{ C})(2.3 \times 10^{-6} \text{ C})}{(0.30 \text{ m})^2}$$

$${}_2F_{e3} = +0.87 \text{ N (repulsion)}$$

$${}_2\vec{F}_{e3} = 0.87 \text{ N [left]}$$

$\vec{F}_{eT} = 4.14 \text{ N [right]} + 0.87 \text{ N [left]}$
$\vec{F}_{eT} = 3.3 \text{ N [right]}$

**b)** $r_1 = 0.30 \text{ m}, r_2 = 0.10 \text{ m}$

$${}_1F_{e3} = \frac{kq_1q_3}{r_1^2}$$

$${}_1F_{e3} = \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(-2.0 \times 10^{-6} \text{ C})(2.3 \times 10^{-6} \text{ C})}{(0.30 \text{ m})^2}$$

${}_1F_{e3} = -0.46 \text{ N (attraction)}$
${}_1\vec{F}_{e3} = 0.46 \text{ N [left]}$

$${}_2F_{e3} = \frac{kq_2q_3}{r_2^2}$$

$${}_2F_{e3} = \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(3.8 \times 10^{-6} \text{ C})(2.3 \times 10^{-6} \text{ C})}{(0.10 \text{ m})^2}$$

${}_2F_{e3} = +\ 7.86 \text{ N (repulsion)}$
${}_2\vec{F}_{e3} = 7.86 \text{ N [right]}$
$\vec{F}_{eT} = 0.46 \text{ N [left]} + 7.86 \text{ N [right]}$
$\vec{F}_{eT} = 7.4 \text{ N [right]}$

**c)** ${}_1F_{e3} = -4.14 \text{ N (attraction)}$
${}_1\vec{F}_{e3} = 4.14 \text{ N [left]}$
${}_2F_{e3} = 7.86 \text{ N (repulsion)}$
${}_2\vec{F}_{e3} = 7.86 \text{ N [left]}$
$\vec{F}_{eT} = 4.14 \text{ N [left]} + 7.86 \text{ N [left]}$
$\vec{F}_{eT} = 12 \text{ N [left]}$

**d)** The third charge could only be placed to the left or to the right of the two basic charges for the forces to balance and give a force of 0.

For the charge to be placed a distance of $r_x$ metres to the left of the first charge:

$$-{}_1F_{e3} = {}_2F_{e3}$$

$$-\frac{kq_1q_3}{r_x^2} = \frac{kq_2q_3}{(0.20 \text{ m} + r_x)^2}$$

$$-\frac{(-2.0 \times 10^{-6} \text{ C})}{r_x^2} = \frac{(3.8 \times 10^{-6} \text{ C})}{(2.0 \times 10^{-1} \text{ m} + r_x)^2}$$

$$(3.8 \times 10^{-6})r_x{}^2 = (2.0 \times 10^{-6})(4.0 \times 10^{-2} + 4.0 \times 10^{-1}r_x + r_x{}^2)$$

$$(3.8 \times 10^{-6})r_x{}^2 = 8.0 \times 10^{-8} + 8.0 \times 10^{-7}r_x + 2.0 \times 10^{-6}r_x{}^2$$

Rearranging:
$1.8 \times 10^{-6}r_x{}^2 - 8.0 \times 10^{-7}r_x - 8.0 \times 10^{-8} = 0$

Solve for $r_x$ using the quadratic formula.

$$r_x = \frac{-(-8.0 \times 10^{-7}) \pm \sqrt{(-8.0 \times 10^{-7})^2 - 4(1.8 \times 10^{-6})(-8.0 \times 10^{-8})}}{2(1.8 \times 10^{-6})}$$

So $r_x = 0.53$ m or $-0.084$ m.

Therefore, the charge must be placed 0.53 m to the left of the first charge. The other answer, $-0.084$ m, would place the charge between the two base charges and therefore is an inappropriate answer. For a charge placement to the right of the two charges, two inappropriate answers are calculated, meaning that the only possible placement for the charge is at 0.53 m to the left of the first charge.

**53.** The forces on the test charge from the repulsion by the other two charges must equal one another for the test charge to come to rest there. The force of charge 1 on the test charge (${}_1F_{qt}$) must equal the force of charge 2 on the test charge (${}_2F_{qt}$).

$${}_1F_{qt} = {}_2F_{qt}$$

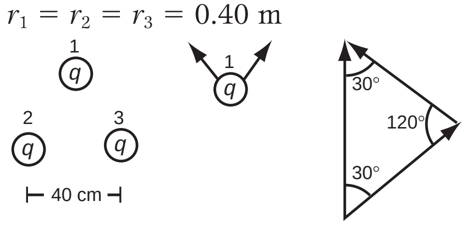
$$\frac{kqq_t}{\left(\frac{1}{3}r\right)^2} = \frac{k4qq_t}{\left(\frac{2}{3}r\right)^2}$$

$$\frac{r^2}{9} = \frac{4r^2}{4(9)}$$

$$r^2 = r^2$$

Therefore, the net force on the charge would be 0 if it was placed $\frac{1}{3}$ of the distance between the two charges.

**54.** $q_2 = q_1 = q_3 = +1.0 \times 10^{-4} \text{ C}$,
$r_1 = r_2 = r_3 = 0.40 \text{ m}$




For $q_1$: The force is the vector sum of two forces, ${}_2\vec{F}_{e1}$ and ${}_3\vec{F}_{e1}$. These two magnitudes must have the same value.

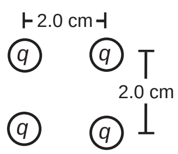
$${}_2F_{e1} = \frac{kqq}{r^2}$$

$${}_2F_{e1} = \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(1.0 \times 10^{-4} \text{ C})^2}{(0.40 \text{ m})^2}$$

${}_2F_{e1} = 5.6 \times 10^2 \text{ N} = {}_3F_{e1}$
$F_{eT}^2 = {}_2F_{e1}^2 + {}_3F_{e1}^2 - 2({}_2F_{e1})({}_2F_{e1})(\cos 120°)$
$F_{eT} = \sqrt{2(5.6 \times 10^2 \text{ C})^2 - 2(5.6 \times 10^2 \text{ C})^2(\cos 120°)}$
$F_{eT} = 9.7 \times 10^2 \text{ N}$

From the isosceles triangle with angles of 30°, the total angle is 30° + 60° = 90°.
$\vec{F}_{eT1} = 9.7 \times 10^2$ N [up]
$\vec{F}_{eT2} = 9.7 \times 10^2$ N [left 30° down]
$\vec{F}_{eT3} = 9.7 \times 10^2$ N [right 30° down]
Each force is $9.7 \times 10^2$ N [at 90° from the line connecting the other two charges].

**55. a)** $l = 2.0 \times 10^{-2}$ m,
$q_1 = q_2 = q_3 = q_4 = -1.0 \times 10^{-6}$ C




$${}_2F_{e1} = \frac{kqq}{r_2^2}$$

$${}_2F_{e1} = \frac{(9.0 \times 10^9\ \mathrm{N\cdot m^2/C^2})(-1.0 \times 10^{-6}\ \mathrm{C})^2}{(2.0 \times 10^{-2}\ \mathrm{m})^2}$$

${}_2\vec{F}_{e1} = 22.5$ N [left]
${}_4\vec{F}_{e1} = 22.5$ N [up]

$${}_3F_{e1} = \frac{kqq}{r_3^2}$$

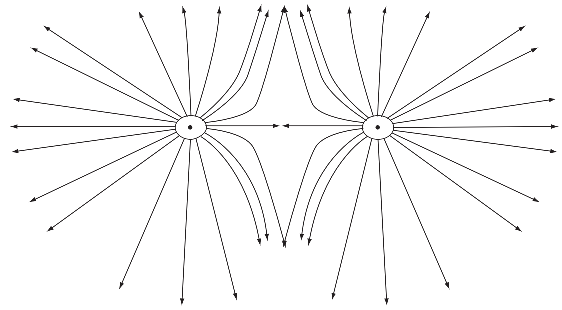
$${}_3F_{e1} = \frac{(9.0 \times 10^9\ \mathrm{N\cdot m^2/C^2})(-1.0 \times 10^{-6}\ \mathrm{C})^2}{\sqrt{2(2.0 \times 10^{-2}\ \mathrm{m})^2}}$$

${}_3\vec{F}_{e1} = 11.25$ N [left 45° up]
From Pythagoras' theorem:
${}_2F_{e1} + {}_4F_{e1} = \sqrt{2(22.5\ \mathrm{N})^2}$
${}_2\vec{F}_{e1} + {}_4\vec{F}_{e1} = 31.82$ N [left 45° up]
Therefore,
$\vec{F}_{eT1} = (31.82\ \mathrm{N} + 11.25\ \mathrm{N})$ [left 45° up]
$\vec{F}_{eT1} = 43.1$ N [left 45° up]
$\vec{F}_{eT2} = 43.1$ N [right 45° up]
$\vec{F}_{eT3} = 43.1$ N [right 45° down]
$\vec{F}_{eT4} = 43.1$ N [left 45° down]
Each force is 43.1 N [symmetrically outward from the centre of the square].

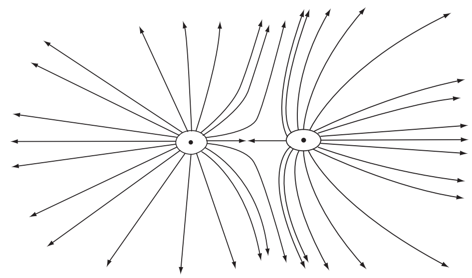
**b)** The force on the fifth charge is 0 N because the forces from each charge are balanced.

**c)** Sign has no effect. If the new fifth charge were either positive or negative, the attractive/repulsive forces would still balance one another.

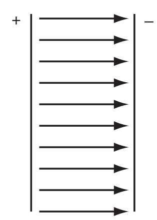
**56.**

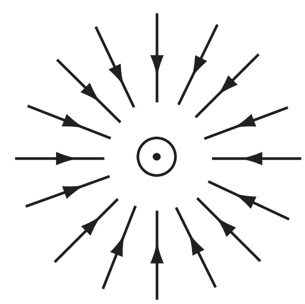


**57.** The field is similar to the one above, but is now asymmetrical and has its inflection points pushed farther to the right.



**58.** Parallel plates: Coaxial cable:



**59.** $q = +2.2 \times 10^{-6}$ C, $F_e = 0.40$ N

$$\varepsilon = \frac{F_e}{q}$$

$$\varepsilon = \frac{0.40\ \mathrm{N}}{2.2 \times 10^{-6}\ \mathrm{C}}$$

$\varepsilon = 1.8 \times 10^5$ N/C

**60.** $F_e = 3.71$ N, $\varepsilon = 170$ N/C

$$q = \frac{F_e}{\varepsilon}$$

$$q = \frac{3.71\ \mathrm{N}}{170\ \mathrm{N/C}}$$

$q = 2.2 \times 10^{-2}$ C

**61.** $q_1 = +4.0 \times 10^{-6}$ C, $q_2 = +8.0 \times 10^{-6}$ C, $r = 2.0$ m

$$\varepsilon = \frac{kq_2}{\left(\frac{1}{2}r\right)^2} - \frac{kq_1}{\left(\frac{1}{2}r\right)^2}$$

$$\varepsilon = \frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(8.0 \times 10^{-6}\ \mathrm{C})}{\left(\frac{2.0\ \mathrm{m}}{2}\right)^2} - \frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(4.0 \times 10^{-6}\ \mathrm{C})}{\left(\frac{2.0\ \mathrm{m}}{2}\right)^2}$$

$\varepsilon = 3.6 \times 10^4$ N/C

Therefore, the field strength is $3.6 \times 10^4$ N/C towards the smaller charge.

**62. a)** $q = 2.0 \times 10^{-6}$ C, $\vec{F}_e = 7.5$ N [left]

$$\vec{\varepsilon} = \frac{\vec{F}_e}{q}$$

$$\vec{\varepsilon} = \frac{7.5\ \mathrm{N\ [left]}}{2.0 \times 10^{-6}\ \mathrm{C}}$$

$\vec{\varepsilon} = 3.8 \times 10^6$ N/C [left]

**b)** $q_2 = -4.9 \times 10^{-5}$ C

Take right to be positive.

$\vec{F}_e = q\vec{\varepsilon}$

$F_e = (-4.9 \times 10^{-5}\ \mathrm{C})(3.8 \times 10^6\ \mathrm{N/C})$

$F_e = -1.86 \times 10^2$ N

The force would be $1.86 \times 10^2$ N [left].

**63.** $r = 0.5$ m, $q = 1.0 \times 10^{-2}$ C

$$\varepsilon = \frac{kq}{r^2}$$

$$\varepsilon = \frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(1.0 \times 10^{-2}\ \mathrm{C})}{(0.5\ \mathrm{m})^2}$$

$\vec{\varepsilon} = 3.6 \times 10^8$ N/C [left]

**64.** $q_1 = 4.0 \times 10^{-6}$ C, $q_2 = -1.0 \times 10^{-6}$ C

Take right to be positive.

$\vec{\varepsilon} = \vec{\varepsilon}_2 + \vec{\varepsilon}_1$

$$\varepsilon = \frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(4.0 \times 10^{-6}\ \mathrm{C})}{(0.40\ \mathrm{m})^2} + \left(-\frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(-1.0 \times 10^{-6}\ \mathrm{C})}{(0.30\ \mathrm{m})^2}\right)$$

$\vec{\varepsilon} = 3.25 \times 10^5$ N/C [right]

**65.** $r = 5.3 \times 10^{-11}$ m, $q = 1.602 \times 10^{-19}$ C

$$\varepsilon = \frac{kq}{r^2}$$

$$\varepsilon = \frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(1.602 \times 10^{-19}\ \mathrm{C})}{(5.3 \times 10^{-11}\ \mathrm{m})^2}$$

$\varepsilon = 5.1 \times 10^{11}$ N/C

**66.** $r_T = 0.20$ m, $q_1 = +1.5 \times 10^{-6}$ C, $q_2 = +3.0 \times 10^{-6}$ C

$r_2{}^2 = (0.20 - r_1)^2$

$$\varepsilon_1 = \varepsilon_2$$

$$\frac{kq_1}{r_1^2} = \frac{kq_2}{r_2^2}$$

$$\frac{1.5 \times 10^{-6}\ \mathrm{C}}{r_1^2} = \frac{3.0 \times 10^{-6}\ \mathrm{C}}{r_2^2}$$

$$r_2^2 = 2r_1^2$$

Substitute for $r_2{}^2$ and rearrange:

$0 = r_1{}^2 + 0.4r_1 - 4.0 \times 10^{-2}$

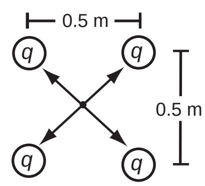
$$r_1 = \frac{-0.4 \pm \sqrt{(0.4)^2 - 4(-4.0 \times 10^{-2})}}{2}$$

$r_1 = 8.3 \times 10^{-2}$ m, therefore,

$r_2 = 1.17 \times 10^{-1}$ m $= 1.2 \times 10^{-1}$ m

$\varepsilon = 0$ at $1.2 \times 10^{-1}$ m from the larger charge, or $8.3 \times 10^{-2}$ m from the smaller charge.

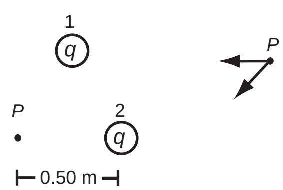
**67.** $q_1 = q_2 = q_3 = q_4 = +1.0 \times 10^{-6}$ C, $r = 0.5$ m




Since the magnitudes of all four forces are equal, and they are paired with forces in the opposite direction ($\vec{F}_{e2} = -\vec{F}_{e4}$ and $\vec{F}_{e1} = -\vec{F}_{e3}$), there is no net force. Therefore, there is no net field strength.

$\varepsilon = 0$ N/C

**68.** $q_1 = q_2 = +2.0 \times 10^{-5}$ C, $r = 0.50$ m




$$\varepsilon_1 = \frac{kq}{r^2}$$

$$\varepsilon_1 = \frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(2.0 \times 10^{-5}\ \mathrm{C})}{(0.50\ \mathrm{m})^2}$$

$\varepsilon_1 = 7.2 \times 10^5$ N/C

$\varepsilon_1 = \varepsilon_2$ and $\vec{\varepsilon}_T = \vec{\varepsilon}_1 + \vec{\varepsilon}_2$

Therefore, $\varepsilon_T = \sqrt{2(\varepsilon_1)^2 - 2(\varepsilon_1)^2(\cos 120°)}$

$\vec{\varepsilon}_T = 1.2 \times 10^6$ N/C [at 90° from the line connecting the other two charges]

**69.** $q = 0.50\text{ C}, \Delta V = 12\text{ V}$

$W = q\Delta V$

$W = (0.50\text{ C})(12\text{ V})$

$W = 6.0\text{ J}$

**70.** $W = 7.0 \times 10^2\text{ J}, \Delta V = 6.0\text{ V}$

$$q = \frac{W}{\Delta V}$$

$$q = \frac{7.0 \times 10^2\text{ J}}{6.0\text{ V}}$$

$q = 1.2 \times 10^2\text{ C}$

**71.** $q = 1.5 \times 10^{-2}\text{ C}, F_e = 7.5 \times 10^3\text{ N},$

$\Delta d = 4.50\text{ cm} = 4.50 \times 10^{-2}\text{ m}$

$$\Delta V = \frac{W}{q}$$

$$\Delta V = \frac{F_e\Delta d}{q}$$

$$\Delta V = \frac{(7.5 \times 10^3\text{ N})(4.5 \times 10^{-2}\text{ m})}{1.5 \times 10^{-2}\text{ C}}$$

$\Delta V = 2.3 \times 10^4\text{ V}$

**72.** $\varepsilon = 130\text{ N/C}, F_e = 65\text{ N}, \Delta V = 450\text{ V}$

$$W = \frac{\Delta V}{q}$$

$$W = \frac{\Delta V F_e}{\varepsilon}$$

$$W = \frac{(450\text{ V})(65\text{ N})}{(130\text{ N/C})}$$

$W = 2.3 \times 10^2\text{ J}$

**73.** $d = 0.30\text{ m}, q = +6.4 \times 10^{-6}\text{ C}$

$$V = \frac{kq}{\Delta d}$$

$$V = \frac{(9.0 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(6.4 \times 10^{-6}\text{ C})}{0.30\text{ m}}$$

$V = 1.9 \times 10^5\text{ V}$

**74. a)** $q_1 = -1.0 \times 10^{-6}\text{ C}, q_2 = -5.0 \times 10^{-6}\text{ C},$

$r = 0.25\text{ m}$

$$E_e = \frac{kq_1q_2}{r}$$

$$E_e = \frac{(9.0 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(-1.0 \times 10^{-6}\text{ C})(-5.0 \times 10^{-6}\text{ C})}{0.25\text{ m}}$$

$E_e = 0.18\text{ J}$ (repulsion)

**b)** $$E_{e1} = \frac{kq_1q_2}{r}$$

$$E_{e1} = \frac{(9.0 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(-1.0 \times 10^{-6}\text{ C})(-5.0 \times 10^{-6}\text{ C})}{1.00\text{ m}}$$

$E_{e1} = 0.045\text{ J}$ (repulsion)

$W = \Delta E_e$

$W = E_{e2} - E_{e1}$

$W = 0.18\text{ J} - 0.045\text{ J}$

$W = 0.14\text{ J}$

**75.** Position in the field has no bearing on the field strength.

$\varepsilon = 5.0 \times 10^3\text{ N/C}, d = 5.0\text{ cm} = 5.0 \times 10^{-2}\text{ m}$

$V = d\varepsilon$

$V = (5.0 \times 10^{-2}\text{ m})(5.0 \times 10^3\text{ N/C})$

$V = 2.5 \times 10^2\text{ V}$

**76. a)** $q = 1 \times 10^{-5}\text{ C}, \varepsilon = 50\text{ N/C}$

$F_e = q\varepsilon$

$F_e = (1 \times 10^{-5}\text{ C})(50\text{ N/C})$

$F_e = 5.0 \times 10^{-4}\text{ N}$

**b)** $\Delta d = 1.0\text{ m}$

$\Delta E_k = W$

$\Delta E_k = F_e\Delta d$

$\Delta E_k = (5.0 \times 10^{-4}\text{ N})(1.0\text{ m})$

$\Delta E_k = 5.0 \times 10^{-4}\text{ J}$

**c)** $v = 2.5 \times 10^4\text{ m/s}$

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

$$m = \frac{2E_k}{v^2}$$

$$m = \frac{2(5.0 \times 10^{-4}\text{ J})}{(2.5 \times 10^4\text{ m/s})^2}$$

$m = 1.6 \times 10^{-12}\text{ kg}$

**77.** $d_1 = 1.0 \times 10^{-9}\text{ m}, d_2 = 1.0 \times 10^{-8}\text{ m},$

$q_1 = q_2 = -1.602 \times 10^{-19}\text{ C},$

$m_1 = m_2 = 9.11 \times 10^{-31}\text{ kg}$

$\Delta E_e = E_2 - E_1$

$$\Delta E_e = \frac{kq_1q_2}{d_2} - \frac{kq_1q_2}{d_1}$$

$$\Delta E_e = kq_1q_2\left(\frac{1}{d_2} - \frac{1}{d_1}\right)$$

$\Delta E_e = -2.08 \times 10^{-19}\text{ J}$

Therefore, the electric potential energy was reduced by $2.08 \times 10^{-19}$ J, which was transferred to kinetic energy. The energy is spread over both electrons, so the energy for each electron is $1.04 \times 10^{-19}$ J.

For one electron:

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

$$v = \sqrt{\frac{2E_k}{m}}$$

$$v = \sqrt{\frac{2(1.04 \times 10^{-19}\ \text{J})}{9.11 \times 10^{-31}\ \text{kg}}}$$

$$v = 4.78 \times 10^5\ \text{m/s}$$

**78.** $V_2 = 2V_1$ and $E_k = \Delta E_e = qV$

With the same charge on each electron, the kinetic energy is also doubled, i.e., $E_{k2} = 2E_{k1}$

$$\frac{E_{k2}}{E_{k1}} = \frac{2E_{k1}}{E_{k1}}$$

$$\frac{\frac{1}{2}mv_2^2}{\frac{1}{2}mv_1^2} = 2$$

$$v_2^2 = 2v_1^2$$

$$v_2 = \sqrt{2}v_1$$

Therefore, the speed is 1.41 times greater.

**79. a)** $V = 15\ \text{kV} = 1.5 \times 10^4\ \text{V}$, $P = 27\ \text{W}$,

$1\ \text{C} = 6.25 \times 10^{18}\ e$

$$\text{number of electrons}/s = \frac{P(6.25 \times 10^{18}\ e/\text{C})}{\text{V}}$$

$$\text{number of electrons}/s = (27\ \text{J/s})\left(\frac{1\ \text{C}}{1.5 \times 10^4\ \text{J}}\right)(6.25 \times 10^{18}\ e/\text{C})$$

$$\text{number of electrons}/s = 1.1 \times 10^{16}$$

**b)** $q = 1.602 \times 10^{-19}\ \text{C}$, $m = 9.11 \times 10^{-31}\ \text{kg}$

Accelerating each electron from rest,

$$E_k = \Delta E_e$$

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

$$v = \sqrt{\frac{2Vq}{m}}$$

$$v = \sqrt{\frac{2(1.5 \times 10^4\ \text{V})(1.602 \times 10^{-19}\ \text{C})}{9.11 \times 10^{-31}\ \text{kg}}}$$

$$v = 7.3 \times 10^7\ \text{m/s}$$

**80. a)** $d = 1.2\ \text{m}$, $V = 7.5 \times 10^3\ \text{V}$,

$m = 3.3 \times 10^{-26}\ \text{kg}$

$$F_e = q\varepsilon$$

$$ma = \frac{qV}{d}$$

$$a = \frac{qV}{md}$$

$$a = \frac{(1.602 \times 10^{-19}\ \text{C})(7.5 \times 10^3\ \text{V})}{(3.3 \times 10^{-26}\ \text{kg})(1.2\ \text{m})}$$

$$a = 3.0 \times 10^{10}\ \text{m/s}^2$$

**b)** $E = Vq$

$$E = (1.602 \times 10^{-19}\ \text{C})(7.5 \times 10^3\ \text{V})$$

$$E = 1.202 \times 10^{-15}\ \text{J}$$

**c)** At this speed and energy, relativistic effects may be witnessed. Although the speed may not be what is predicted by simple mechanics, the total energy should be the same but may be partly contributing to a mass increase of the ion.

**81.** $q_1 = q_2 = +1.602 \times 10^{-19}\ \text{C}$,

$m_1 = m_2 = 1.67 \times 10^{-27}\ \text{kg}$,

$v_1 = v_2 = 2.7 \times 10^6\ \text{m/s}$

$\Delta E_k = \Delta E_e$

The total energy for both ions is:

$$(2)\frac{1}{2}mv^2 = \frac{kq_1q_2}{r}$$

$$r = \frac{kq_1q_2}{mv^2}$$

$$r = \frac{(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(1.602 \times 10^{-19}\ \text{C})^2}{(1.67 \times 10^{-27}\ \text{kg})(2.7 \times 10^6\ \text{m/s})^2}$$

$$r = 1.9 \times 10^{-14}\ \text{m}$$

**82. a)** $q_\alpha = +2e$, $m_\alpha = 6.696 \times 10^{-27}\ \text{kg}$,

$v_{1v} = 0\ \text{m/s}$, $v_{1h} = 6.0 \times 10^6\ \text{m/s}$,

$V = 500\ \text{V}$, $d_v = 0.03\ \text{m}$, $d_h = 0.15\ \text{m}$

Acceleration is toward the negative plate:

$$a = \frac{F_e}{m}$$

$$a = \frac{q\varepsilon}{m}$$

$$a = \frac{qV}{md_v}$$

$$a = \frac{2(1.602 \times 10^{-19}\ \text{C})(500\ \text{V})}{(6.696 \times 10^{-27}\ \text{kg})(3.0 \times 10^{-2}\ \text{m})}$$

$$a = 7.97 \times 10^{11}\ \text{m/s}^2$$

Time between the plates is:

$t = \frac{d_h}{v_h}$

$t = \frac{0.15 \text{ m}}{6.0 \times 10^6 \text{ m/s}}$

$t = 2.5 \times 10^{-8}$ s

Therefore,

$\Delta d_h = \frac{1}{2}at^2$

$\Delta d_h = \frac{1}{2}(7.97 \times 10^{11} \text{ m/s}^2)(2.5 \times 10^{-8} \text{ s})^2$

$\Delta d_h = 2.5 \times 10^{-4}$ m

$\Delta d_h = 0.025$ cm

The alpha particle is 3.0 cm − 0.025 cm = 2.975 cm from the negative plate if it enters at the positive plate or 1.475 cm from the negative plate if it enters directly between the two plates.

**b)** $v_{2v} = v_{1v} + at$

$v_{2v} = 0 + (7.97 \times 10^{11} \text{ m/s}^2)(2.5 \times 10^{-8} \text{ s})$

$v_{2v} = 2.0 \times 10^4$ m/s

From Pythagoras' theorem,

$v_2 = \sqrt{(6.0 \times 10^6 \text{ m/s})^2 + (2.0 \times 10^4 \text{ m/s})^2}$

$v_2 = 6.0 \times 10^6$ m/s

**83.** $d = 0.050$ m, $V = 39.0$ V

$\varepsilon = \frac{V}{d}$

$\varepsilon = \frac{39.0 \text{ V}}{0.050 \text{ m}}$

$\varepsilon = 7.80 \times 10^2$ N/C

**84.** $\varepsilon = 2.85 \times 10^4$ N/C,

$d = 6.35 \text{ cm} = 6.35 \times 10^{-2}$ m

$V = d\varepsilon$

$V = (6.35 \times 10^{-2} \text{ m})(2.85 \times 10^4 \text{ N/C})$

$V = 1.81 \times 10^3$ V

**85. a)** $m = 2m_p + 2m_n = 4(1.67 \times 10^{-27} \text{ kg})$,

$g = 9.80$ N/kg, $q = +2e$

$F_e = F_g$

$\varepsilon = \frac{mg}{q}$

$\varepsilon = \frac{4(1.67 \times 10^{-27} \text{ kg})(9.80 \text{ N/kg})}{2(1.602 \times 10^{-19} \text{ C})}$

$\varepsilon = 2.04 \times 10^{-7}$ N/C

**b)** $d = 3.0 \text{ cm} = 3.0 \times 10^{-2}$ m

$V = d\varepsilon$

$V = (3.0 \times 10^{-2} \text{ m})(2.04 \times 10^{-7} \text{ N/C})$

$V = 6.1 \times 10^{-9}$ V

**86.** $d = 0.12$ m, $V = 92$ V

$\varepsilon = \frac{V}{d}$

$\varepsilon = \frac{92 \text{ V}}{0.12 \text{ m}}$

$\varepsilon = 7.7 \times 10^2$ N/C

**87.** $\varepsilon = 3 \times 10^6$ N/C, $d = 1.0 \times 10^{-3}$ m

$V = d\varepsilon$

$V = (1.0 \times 10^{-3} \text{ m})(3 \times 10^6 \text{ N/C})$

$V = 3 \times 10^3$ V

Therefore, $3.0 \times 10^3$ V is the maximum potential difference that can be applied. Exceeding it would cause a spark to occur between the plates.

**88.** $V = 50$ V, $\varepsilon = 1 \times 10^4$ N/C

$d = \frac{V}{\varepsilon}$

$d = \frac{50 \text{ V}}{1 \times 10^4 \text{ N/C}}$

$d = 5.0 \times 10^{-3}$ m

**89.** $V = 120$ V, $\varepsilon = 450$ N/C

$d = \frac{V}{\varepsilon}$

$d = \frac{120 \text{ V}}{450 \text{ N/C}}$

$d = 2.67 \times 10^{-1}$ m

**90. a)** $m = 2.2 \times 10^{-15}$ kg, $d = 5.5 \times 10^{-3}$ m,

$V = 280$ V, $g = 9.80$ N/kg

$F_e = F_g$

$q\varepsilon = mg$

$\frac{qV}{d} = mg$

$q = \frac{mgd}{V}$

$q = \frac{(2.2 \times 10^{-15} \text{ kg})(9.80 \text{ N/kg})(5.5 \times 10^{-3} \text{ m})}{280 \text{ V}}$

$q = 4.2 \times 10^{-19}$ C

**b)** $N = \frac{4.2 \times 10^{-19} \text{ C}}{1.602 \times 10^{-19} \text{ } e\text{/C}}$

$N = 2.63\, e \approx 3\, e$

The droplet has three excess electrons.

**91.** $V = 450$ V, $m_e = 9.11 \times 10^{-31}$ kg,
$e = 1.602 \times 10^{-19}$ C

**a)** $\Delta E_e = qV$

$\Delta E_e = (1.602 \times 10^{-19}\text{ C})(450\text{ V})$

$\Delta E_e = 7.21 \times 10^{-17}$ J

Therefore,

$$E_k = \Delta E_e$$

$$\frac{1}{2}mv^2 = \Delta E_e$$

$$v = \sqrt{\frac{2\Delta E_e}{m}}$$

$$v = \sqrt{\frac{2(7.21 \times 10^{-17}\text{ J})}{9.11 \times 10^{-31}\text{ kg}}}$$

$$v = 1.26 \times 10^7\text{ m/s}$$

**b)** $\frac{1}{2}mv^2 = \frac{1}{3}\Delta E_e$

$$v = \sqrt{\frac{2\Delta E_e}{3m}}$$

$$v = \sqrt{\frac{2(7.21 \times 10^{-17}\text{ J})}{3(9.11 \times 10^{-31}\text{ kg})}}$$

$$v = 7.26 \times 10^6\text{ m/s}$$

**92.** $k = 6.0 \times 10^{-3}$ N/m, $d = 0.10$ m, $V = 450$ V,
$x = 0.01$ m

**a)** $\varepsilon = \frac{V}{d}$

$$\varepsilon = \frac{450\text{ V}}{0.10\text{ m}}$$

$$\varepsilon = 4.5 \times 10^3\text{ N/C}$$

**b)** The force to deform one spring is:

$F = kx$

$F = (6.0 \times 10^{-3}\text{ N/m})(0.01\text{ m})$

$F = 6.0 \times 10^{-5}$ N

The force to deform both springs is:

$2(6.0 \times 10^{-5}\text{ N}) = 1.2 \times 10^{-4}$ N

**c)** The force on the pith ball must also be $1.2 \times 10^{-4}$ N

**d)** $F_{spring} = F_e$

$F_{spring} = q\varepsilon$

$$q = \frac{F_{spring}}{\varepsilon}$$

$$q = \frac{1.2 \times 10^{-4}\text{ N}}{4.5 \times 10^3\text{ N/C}}$$

$$q = 2.7 \times 10^{-8}\text{ C}$$

## Chapter 14

**9.** $I = 9.3\ \text{mA}\left(\dfrac{1\ \text{A}}{1000\ \text{mA}}\right) = 9.3 \times 10^{-3}\ \text{A}$

$Q = 12\ \text{C}$

$t = \dfrac{Q}{I} = \dfrac{12\ \text{C}}{9.3 \times 10^{-3}\ \text{A}} = 1.3 \times 10^{3}\ \text{s}$

It would take $1.3 \times 10^3$ s to transfer the charge.

**10.** $19\ \text{min}\left(\dfrac{60\ \text{s}}{1\ \text{min}}\right) = 1.14 \times 10^{3}\ \text{s}$

$Q = It = (0.8\ \text{A})(1.14 \times 10^{3}\ \text{s})$

$Q = 9.1 \times 10^{2}\ \text{C}$

**11.** $V = \dfrac{E}{Q} = \dfrac{2.0 \times 10^{3}\ \text{J}}{1\ \text{C}} = 2.0 \times 10^{3}\ \text{V}$

**12.** $V = \dfrac{E}{Q} = \dfrac{2.5 \times 10^{2}\ \text{J}}{65\ \text{C}} = 3.8\ \text{V}$

**13.** $V = \dfrac{E}{Q}$

$E = VQ = (5.00 \times 10^{5}\ \text{V})(1.602 \times 10^{-19}\ \text{C})$

$E = 8.01 \times 10^{-14}\ \text{J}$

**14.** $t = 1.5\ \text{min}\left(\dfrac{60\ \text{s}}{1\ \text{min}}\right) = 90\ \text{s}$

$E = VIt$
$= (115\ \text{V})(0.40\ \text{A})(90\ \text{s})$
$= 4140\ \text{J}$
$= 4.1 \times 10^{3}\ \text{J}$

**15.** $E = VIt$

$V = \dfrac{E}{It}$
$= \dfrac{9360\ \text{J}}{(2.5\ \text{A})(32\ \text{s})}$
$= 117\ \text{V}$
$\cong 1.2 \times 10^{2}\ \text{V}$

**16.** $t = 2.5\ \text{min}\left(\dfrac{60\ \text{s}}{1\ \text{min}}\right) = 90\ \text{s}$

$E = VIt$
$= (80\ \text{V})(5.0\ \text{A})(150\ \text{s})$
$= 6.0 \times 10^{4}\ \text{J}$

**17.** $E = VIt$

$I = \dfrac{E}{Vt}$
$= \dfrac{50\,000\ \text{J}}{(120\ \text{V})(60\ \text{s})}$
$= 6.94\ \text{A}$
$\cong 6.9\ \text{A}$

**18.** $E = VIt$
$= (120\ \text{V})(9.5\ \text{A})(40\ \text{s})$
$= 4.56 \times 10^{4}\ \text{J}$
$\cong 4.6 \times 10^{4}\ \text{J}$

**19.** $E = VIt$

$V = \dfrac{E}{It}$
$= \dfrac{2.30 \times 10^{4}\ \text{J}}{(3.2\ \text{A})(30\ \text{s})}$
$= 2.4 \times 10^{2}\ \text{V}$

**20. a)** $I = \dfrac{Q}{t}$
$= \dfrac{45\ \text{C}}{3.0 \times 10^{-2}\ \text{s}}$
$= 1500\ \text{A}$
$= 1.5 \times 10^{3}\ \text{A}$

**b)** $E = VQ$
$= (1 \times 10^{8}\ \text{V})(45\ \text{C})$
$= 4.5 \times 10^{9}\ \text{J}$

**21.** $Q = Ne$
$= 1\ e(1.602 \times 10^{-19}\ \text{C}/e)$
$= 1.602 \times 10^{-19}\ \text{C}$

$E = VQ$
$= (2.5 \times 10^{4}\ \text{V})(1.602 \times 10^{-19}\ \text{C})$
$= 4.0 \times 10^{-15}\ \text{J}$

**22.** $t = 10\ \text{min}\left(\dfrac{60\ \text{s}}{1\ \text{min}}\right) = 600\ \text{s}$

$E = VIt$
$= (117\ \text{V})(13\ \text{A})(600\ \text{s})$
$= 9.126 \times 10^{5}\ \text{J}$
$\cong 9.1 \times 10^{5}\ \text{J}$

**23.** $R = \dfrac{V}{I}$
$= \dfrac{120\ \text{V}}{6.0\ \text{A}}$
$= 20\ \Omega$

**24.** $I = \dfrac{V}{R}$
$= \dfrac{3.0\ \text{V}}{9.2\ \Omega}$
$= 0.33\ \text{A}$

**25.** $V = IR$
$= (2.2\ \text{A})(50\ \Omega)$
$= 110\ \text{V}$
$= 1.1 \times 10^{2}\ \text{V}$

**26.** $\dfrac{R_1}{R_2} = \dfrac{L_1}{L_2}$

$$R_2 = \frac{R_1 L_2}{L_1}$$
$$= 100\ \Omega\left(\frac{2L_1}{L_1}\right)$$
$$= 200\ \Omega$$

**27.** $\dfrac{R_1}{R_2} = \dfrac{A_1}{A_2}$

$$R_2 = R_1\left(\frac{\pi r_1^2}{\pi r_2^2}\right)$$
$$= R_1\,\frac{r_1^2}{r_2^2}$$
$$= R_1\,\frac{r_1^2}{(\frac{1}{2}r_1)^2}$$
$$= (500\ \Omega)(4)$$
$$= 2000\ \Omega$$

**28.** $\rho = \dfrac{RA}{L}$

$$R = \frac{\rho L}{A}$$
$$= \frac{\rho L}{\pi(\frac{d}{2})^2} = \frac{4\rho L}{\pi d^2}$$
$$= \frac{4(1.7 \times 10^{-8}\ \Omega \cdot \text{m})(100\ \text{m})}{\pi(1.0 \times 10^{-3}\ \text{m})^2}$$
$$= 2.1645\ \Omega$$
$$\cong 2.2\ \Omega$$

**29. a)** $R_T = \dfrac{V_T}{I_T}$

$$= \frac{120\ \text{V}}{3.8\ \text{A}}$$
$$= 31.6\ \Omega$$
$$= 3.2 \times 10^1\ \Omega$$

**b)** $R_T = nR_B$

$$= \frac{31.6\ \Omega}{25}$$
$$= 1.26\ \Omega$$
$$= 1.3\ \Omega$$

**c)** $V_B = I_B R_B$

$$= (3.8\ \text{A})(1.26\ \Omega)$$
$$\cong 4.8\ \text{V}$$

**30. a)** $R = \dfrac{V}{I}$

$$= \frac{117\ \text{V}}{5.0\ \text{A}}$$
$$= 23.4\ \Omega$$
$$= 2.3 \times 10^1\ \Omega$$

**b)** $R_T = \dfrac{117\ \text{V}}{15.0\ \text{A}} = 7.8\ \Omega$

but $\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

Therefore,

$$\text{R}_2 = \left(\frac{1}{R_T} - \frac{1}{R_1}\right)^{-1}$$
$$= \left(\frac{1}{R_T} - \frac{1}{R_1}\right)^{-1}$$
$$= \left(\frac{1}{7.8\ \Omega} - \frac{1}{2.3 \times 10^1}\right)^{-1}$$
$$= 11.7\ \Omega$$
$$\cong 12\ \Omega$$

**31. a)** $R_T = R_1 + R_2 + R_3$

$$= 20\ \Omega + 30\ \Omega + 60\ \Omega$$
$$= 110\ \Omega$$

**b)** $\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

$$\frac{1}{R_T} = \frac{1}{8\ \Omega} + \frac{1}{6\ \Omega} + \frac{1}{48\ \Omega}$$
$$\frac{1}{R_T} = 0.3125\ \Omega$$

Therefore, $R_T = 3.2\ \Omega$

**c)** $R_T = \left(\dfrac{1}{4\ \Omega} + \dfrac{1}{9\ \Omega}\right)^{-1} + \left(\dfrac{1}{4\ \Omega} + \dfrac{1}{12\ \Omega}\right)^{-1}$

$$= 2.769\ \Omega + 3.0\ \Omega$$
$$= 5.77\ \Omega$$
$$\cong 5.8\ \Omega$$

**32.** $R_T = \dfrac{V}{I}$

$$= \frac{120\ \text{V}}{10.0\ \text{A}}$$
$$= 12.0\ \Omega$$
$$\frac{1}{R_T} = \frac{n}{R}$$
$$n = \frac{R}{R_T}$$
$$= \frac{60\ \Omega}{12.0\ \Omega} = 5$$

**33.** $R = \dfrac{V}{I}$

$= \dfrac{50.0\text{ V}}{5.0\text{ A}}$

$= 10\ \Omega$

For half the current,

$R = \dfrac{50.0\text{ V}}{2.5\text{ A}}$

$= 20\ \Omega$

$R_{\text{added}} = 20\ \Omega - 10\ \Omega = 10\ \Omega$

**34.** $R_{\text{phone}} = \dfrac{V}{I}$

$= \dfrac{5.0\text{ V}}{0.200\text{ A}}$

$= 25\ \Omega$

For 12.0 V and 0.200 A

$R_{\text{added}} = \dfrac{12.0\text{ V}}{0.200\text{ A}} - 25\ \Omega$

$= 60\ \Omega - 25\ \Omega$

$= 35\ \Omega$

**35. a)** (1) $I_T = I_1 = I_2 = I_3 = 3\text{ A}$

(2) $R_2 = \dfrac{V_2}{I_2}$

$= \dfrac{9\text{ V}}{3\text{ A}}$

$= 3\ \Omega$

(3) $R_T = \dfrac{V_T}{I_T}$

$= \dfrac{54\text{ V}}{3\text{ A}}$

$= 18\ \Omega$

(4) $R_1 = R_T - R_2 - R_3$

$= 18\ \Omega - 3\ \Omega - 7\ \Omega$

$= 8\ \Omega$

(5) $V_1 = I_1R_1 = (3\text{ A})(8\ \Omega)$

$= 24\text{ V}$

(6) $V_2 = I_2R_2 = (3\text{ A})(3\ \Omega)$

$= 9\text{ V}$

(7) $V_3 = I_3R_3 = (3\text{ A})(7\ \Omega)$

$= 21\text{ V}$

| | $V$(V) | $I$(A) | $R(\Omega)$ |
|---|---|---|---|
| $R_1$ | (5) 24 | 3 | (4) 8 |
| $R_2$ | (6) 9 | (2) 3 | 3 |
| $R_3$ | (7) 21 | 3 | 7 |
| $R_T$ | 54 | (1) 3 | (3) 18 |

**b)** (1) $V_T = V_1 = V_2 = 9\text{ V}$

(2) $R_1 = \dfrac{V_1}{I_2}$

$= \dfrac{9\text{ V}}{2\text{ A}}$

$= 4.5\ \Omega$

(3) $R_1 = R_2 = 4.5\ \Omega$

(4) $I_T = 2\text{ A} + 2\text{ A}$

$= 4\text{ A}$

(5) $R_T = \dfrac{V}{I}$

$= \dfrac{9\text{ V}}{4\text{ A}}$

$= 2.25\ \Omega$

| | $V$(V) | $I$(A) | $R$(V) |
|---|---|---|---|
| $R_1$ | 9 | 2 | (2) 4.5 |
| $R_2$ | 9 | 2 | (3) 4.5 |
| $R_T$ | (1) 9 | (4) 4 | (5) 2.25 |

**c)** (1) $R_T = R_{1\text{-}2} + R_3$

$= \left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)^{-1} + R_3$

$= 9.4 + 10\ \Omega$

$= 19.4\ \Omega$

(2) $I_T = \dfrac{V_T}{R_T}$

$= \dfrac{50\text{ V}}{19.4\ \Omega}$

$= 2.58\text{ A}$

(3) $I_3 = I_T = 2.58\text{ A}$

(4) $V_3 = I_3R_3$

$= (2.58\text{ A})(10\ \Omega)$

$= 25.8\text{ V}$

(5) $V_1 = V_2 = V_T - V_3$

$= 50\text{ V} - 25.8\text{ V}$

$= 24.2\text{ V}$

(6) $I_1 = \dfrac{V_1}{R_1}$

$= \dfrac{24.2\text{ V}}{25\ \Omega}$

$= 0.97\text{ A}$

(7) $I_2 = I_T - I_1$

$= 2.58\text{ A} - 0.97\text{ A}$

$= 1.61\text{ A}$

| | $V$(V) | $I$(A) | $R$(Ω) |
|---|---|---|---|
| $R_1$ | (5) 24.2 | (6) 0.97 | 25 |
| $R_2$ | (5) 24.2 | (7) 1.61 | 15 |
| $R_3$ | (4) 25.8 | (3) 2.58 | 10 |
| $R_T$ | 50 | (2) 2.58 | (1) 19.4 |

**d)** (1) $V_1 = I_1R_1 = (3\text{ A})(25\ \Omega) = 75\text{ V}$

(2) $$R_T = R_1 + \left(\frac{1}{R_2} + \frac{1}{R_3 + R_4}\right)^{-1} = 25\ \Omega + 6.67\ \Omega \cong 31.7\ \Omega$$

(3) $I_T = I_1$

(4) $V_2 = V_{3\text{-}4} = V_T - V_1 = 95\text{ V} - 75\text{ V} = 20\text{ V}$

(5) $$I_2 = \frac{V_2}{R_2} = \frac{20\text{ V}}{10\ \Omega} = 2\text{ A}$$

(6) $I_3 = I_4 = I_T - I_2 = 3\text{ A} - 2\text{ A} = 1\text{ A}$

(7) $V_3 = I_3R_3 = 1\text{ A}(5\ \Omega) = 5\text{ V}$

(8) $V_4 = I_4R_4 = 1\text{ A}(15\ \Omega) = 15\text{ V}$

| | $V$(V) | $I$(A) | $R$(V) |
|---|---|---|---|
| $R_1$ | (1) 75 | (3) 3 | 25 |
| $R_2$ | (4) 20 | (5) 2 | 10 |
| $R_3$ | (7) 5 | (6) 1 | 5 |
| $R_4$ | (8) 15 | (6) 1 | 15 |
| $R_T$ | 95 | 3 | (2) 31.7 |

**e)** (1) $$R_T = R_1 + \left[\left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} + \left(\frac{1}{R_4} + \frac{1}{R_5}\right)^{-1}\right]^{-1} + R_6$$

$$= 5\ \Omega + \left[\left(\frac{1}{1\ \Omega} + \frac{1}{15\ \Omega}\right)^{-1} + \left(\frac{1}{10\ \Omega} + \frac{1}{1\ \Omega}\right)^{-1}\right]^{-1} + 20\ \Omega$$

$$= 5\ \Omega + 0.4615\ \Omega + 20\ \Omega = 25.5\ \Omega$$

(2) $$I_T = \frac{V_T}{R_T} = \frac{150\text{ V}}{25.5\ \Omega} = 5.9\text{ A}$$

(3) $I_1 = I_6 = I_T = 5.9\text{ A}$

(4) $V_1 = I_1R_1 = (5.9\text{ A})(5\ \Omega) = 29.5\text{ V}$

(5) $V_6 = I_6R_6 = (5.9\text{ A})(20\ \Omega) = 118\text{ V}$

(6) $V_2 = V_3 = V_4 = V_5 = V_T - V_1 - V_6 = 150\text{ V} - 29.5\text{ V} - 118\text{ V} = 2.5\text{ V}$

(7) $$I_2 = I_5 = \frac{V_2}{R_2} = \frac{2.5\text{ V}}{1\ \Omega} = 2.5\text{ A}$$

(8) $$I_3 = \frac{V_3}{R_3} = \frac{2.5\text{ V}}{15\ \Omega} = 0.17\text{ A}$$

(9) $$I_4 = \frac{V_4}{R_4} = \frac{2.5\text{ V}}{10\ \Omega} = 0.25\text{ A}$$

| | $V$(V) | $I$(A) | $R$(V) |
|---|---|---|---|
| $R_1$ | (4) 29.5 | (3) 5.9 | 5 |
| $R_2$ | (6) 2.5 | (7) 2.5 | 1 |
| $R_3$ | (6) 2.5 | (8) 0.17 | 15 |
| $R_4$ | (6) 2.5 | (9) 0.25 | 10 |
| $R_5$ | (6) 2.5 | (7) 2.5 | 1 |
| $R_6$ | (5) 118 | (3) 5.9 | 20 |
| $R_T$ | 150 | (2) 5.9 | (1) 25.5 |

**f)** (1) $$R_T = R_1 + R_{2\text{-}3} + R_4 = 15\ \Omega + \left(\frac{1}{10\ \Omega} + \frac{1}{5\ \Omega}\right)^{-1} + 12\ \Omega = 30.3\ \Omega$$

(2) $I_T = \dfrac{V_T}{R_T}$
$= \dfrac{12\ \text{V}}{30.3\ \Omega}$
$= 0.40\ \text{A}$

(3) $I_1 = I_4 = I_T$
$= 0.40\ \text{A}$

(4) $V_1 = I_1R_1$
$= (0.40\ \text{A})(15\ \Omega)$
$= 6\ \text{V}$

(5) $V_4 = I_4R_4$
$= (0.40\ \text{A})(12\ \Omega)$
$= 4.8\ \text{V}$

(6) $I_2 = \dfrac{V_2}{R_2}$
$= \dfrac{1.2\ \text{V}}{10\ \Omega}$
$= 0.12\ \text{A}$

(7) $I_3 = \dfrac{V_3}{R_3}$
$= \dfrac{1.2\ \text{V}}{5\ \Omega}$
$= 0.24\ \text{A}$

(8) $V_2 = V_3 = V_T - V_1 - V_4$
$= 12\ \text{V} - 6\ \text{V} - 4.8\ \text{V}$
$= 1.2\ \text{V}$

| | $V$(V) | $I$(A) | $R$(V) |
|---|---|---|---|
| $R_1$ | (4) 6 | (3) 0.4 | 15 |
| $R_2$ | (8) 1.2 | (6) 0.12 | 10 |
| $R_3$ | (8) 1.2 | (7) 0.24 | 5 |
| $R_4$ | (5) 4.8 | (3) 0.40 | 12 |
| $R_T$ | 12 | (2) 0.40 | (1) 30.3 |

**36. a)** $P = IV$
$= (13.0\ \text{A})(240\ \text{V})$
$= 3120\ \text{W}$
$= 3.12 \times 10^3\ \text{W}$

**b)** $P = I^2R$
$= (11.0\ \text{A})^2\,(11.6\ \Omega)$
$= 1403.6\ \text{W}$
$= 1.4 \times 10^3\ \text{W}$

**c)** $P = \dfrac{V^2}{\text{R}}$
$= \dfrac{(120\ \text{V})^2}{2057\ \Omega}$
$= 7.00\ \text{W}$

**37. a)** $P = IV$
$P = (15\ \text{A})(120\ \text{V})$
$= 1800\ \text{W}$
$= 1.8 \times 10^3\ \text{W}$

**b)** $P_{\text{remaining}} = 1800\ \text{W} - 600\ \text{W} - 1200\ \text{W}$
$= 0.00\ \text{W}$

Therefore, no more current could be drawn from the circuit.

**38. a)** $P = IV$
$I = \dfrac{P}{V}$
$= \dfrac{1200\ \text{W}}{120\ \text{V}}$
$= 10\ \text{A}$

**b)** $\dfrac{I_2}{I_1} = \dfrac{V_2}{V_1}$
$I_2 = \left(\dfrac{V_2}{V_1}\right)I_1$
$= \left(\dfrac{240\ \text{V}}{120\ \text{V}}\right)10\ \text{A}$
$= 20\ \text{A}$

**c)** $P = IV$
$= (20\ \text{A})(240\ \text{V})$
$= 4800\ \text{W}$
$= 4.8 \times 10^3\ \text{W}$

**d)** When the conductor is connected at the higher voltage, the increased current will burn out/through a conductor in the circuit.

**39.** $P = IV$
$= (3.5\ \text{A})(120\ \text{V})$
$= 420\ \text{W}$

$P = 420\ \text{W}\left(\dfrac{1\ \text{kW}}{1000\ \text{W}}\right) = 0.420\ \text{kW}$

$t = 9\ \text{min}\left(\dfrac{1\ \text{h}}{60\ \text{min}}\right)\left(\dfrac{8\ \text{h}}{1\ \text{d}}\right)\left(\dfrac{365\ \text{d}}{1\ \text{a}}\right) = \dfrac{438\ \text{h}}{1\ \text{a}}$

$\text{Cost} = 0.420\ \text{kW}\left(\dfrac{438\ \text{h}}{1\ \text{a}}\right)(\$0.082)$
$= \$15.08$ per year

**40.** $P_{\text{kWh}} = 7\ \dfrac{\text{W}}{\text{b}}\left(\dfrac{1\ \text{kW}}{1000\ \text{W}}\right)\left(\dfrac{25\ \text{bulbs}}{\text{strand}}\right)(4\ \text{strands})$
$= 0.7\ \text{kW}$

$t_{(h)} = \dfrac{4\ \text{h}}{1\ \text{d}}(41\ \text{d})$ (Dec. 1 – Jan. 10)
$= 164\ \text{h}$

$\text{Cost} = (0.7\ \text{kW})(164\ \text{h})(\$0.082)$
$= \$9.41$

## Chapter 15

**17.** $I = 12.5$ A

$B = 3.1 \times 10^{-5}$ T

$$B = \frac{\mu I}{2\pi r}$$

$$r = \frac{\mu I}{2\pi B}$$

$$r = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(12.5\ \text{A})}{2\pi(3.1 \times 10^{-5}\ \text{T})}$$

$r = 8.1 \times 10^{-2}$ m

**18.** $r = 12$ m

$I = 4.50 \times 10^3$ A

$$B = \frac{\mu I}{2\pi r}$$

$$B = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(4.50 \times 10^3\ \text{A})}{2\pi(12\ \text{m})}$$

$B = 7.5 \times 10^{-5}$ T

**19.** $I = 8.0$ A

$B = 1.2 \times 10^{-3}$ T

$N = 1$

$$B = \frac{\mu NI}{2r}$$

$$r = \frac{\mu NI}{2B}$$

$$r = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(1)(8.0\ \text{A})}{2(1.2 \times 10^{-3}\ \text{T})}$$

$r = 4.2 \times 10^{-3}$ m

**20.** $N = 12$

$r = 0.025$ m

$I = 0.52$ A

$$B = \frac{\mu NI}{2r}$$

$$B = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(12)(0.52\ \text{A})}{2(0.025\ \text{m})}$$

$B = 1.6 \times 10^{-4}$ T

**21.** $$\frac{N}{L} = \frac{35\ \text{turns}}{1\ \text{cm}} \times \frac{100\ \text{cm}}{1\ \text{m}}$$

$$\frac{N}{L} = 3500\ \text{turns/m}$$

$I = 4.0$ A

$$B = \frac{\mu NI}{L}$$

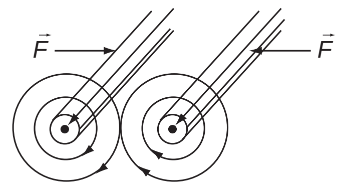
$$B = \mu \frac{N}{L} I$$

$$B = (4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})\left(\frac{3500\ \text{turns}}{1\ \text{m}}\right)(4.0\ \text{A})$$

$B = 1.8 \times 10^{-2}$ T

NOTE: The solutions to problem 22 are based on a distance between the two conductors of 1 cm.

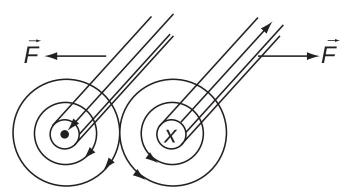
**22. a)**




Currents in the same direction—
wires forced together

Referring to the above diagram, the magnetic fields will cancel each other out because the field from each wire is of the same magnitude but is in the opposite direction.

**b)**




Currents in opposite directions—
wires forced apart

$I = 10$ A

$r = 1.0 \times 10^{-2}$ m

$$B = \frac{\mu I}{2\pi r}$$

$$B = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(10\ \text{A})}{2\pi(1.0 \times 10^{-2}\ \text{m})}$$

$B = 2.0 \times 10^{-4}$ T

But this field strength ($2.0 \times 10^{-4}$ T) is for each of the two wires. Referring to the above diagram, the two fields flow in the same direction when the current in the two wires moves in the opposite direction. The result is that the two fields will add to produce one field with double the strength ($4.0 \times 10^{-4}$ T).

**23.** Coil 1:

$N = 400$

$L = 0.1$ m

$I = 0.1$ A

Coil 2:

$N = 200$

$L = 0.1$ m

$I = 0.1$ A

$B_{Total} = B_{coil1} - B_{coil2}$

$B_{Total} = \dfrac{\mu NI}{L} - \dfrac{\mu NI}{L}$

$B_{Total} = \dfrac{(4\pi \times 10^{-7}\ T \cdot m/A)(400)(0.1\ A)}{(0.1\ m)} - \dfrac{(4\pi \times 10^{-7}\ T \cdot m/A)(200)(0.1\ A)}{(0.1\ m)}$

$B_{Total} = 2.5 \times 10^{-4}\ T$

**24.** The single loop:

$B_{single} = \dfrac{\mu NI}{2r}$

$B_{single} = \dfrac{(4\pi \times 10^{-7}\ T \cdot m/A)(1)I}{2(0.02\ m)}$

Solenoid:

$L = 2\pi r_{single\ loop}$

$L = 2\pi(0.02\ m)$

$L = 0.04\pi$

$N = \dfrac{15\ turns}{1\ cm} \times \dfrac{100\ cm}{1\ m} \times L$

$N = (1500\ turns/m)(0.04\pi\ m)$

$N = 188$

$B_{sol} = \dfrac{\mu NI}{L}$

$B_{sol} = \dfrac{(4\pi \times 10^{-7}\ T \cdot m/A)(188)(0.4\ A)}{0.04\pi}$

$B_{sol} = 7.5 \times 10^{-4}\ T$

To cancel the field, the magnitude of the two fields must be equal but opposite in direction.

$B_{sol} = B_{single}$

$7.5 \times 10^{-4}\ T = \dfrac{(4\pi \times 10^{-7}\ T \cdot m/A)(1)I}{2(0.02\ m)}$

$I = \dfrac{(7.5 \times 10^{-4}\ T)2(0.02\ m)}{4\pi \times 10^{-7}\ T \cdot m/A}$

$I = 24\ A$

**25. a)** $\theta = 45°$

$L = 6.0\ m$

$B = 0.03\ T$

$I = 4.5\ A$

$F = BIL \sin\theta$

$F = (0.03\ T)(4.5\ A)(6.0\ m) \sin 45°$

$F = 0.57\ N$

The direction of this force is at 90° to the plane described by the direction of the current vector and that of the magnetic field, i.e., downwards.

**b)** If the current through the wire was to be reversed, the magnitude and direction of the resultant force would be 0.57 N [upwards].

**26. a)** $d$(linear density) $= 0.010\ kg/m$

$B = 2.0 \times 10^{-5}\ T$

$\theta = 90°$

$\dfrac{F}{L} = dg$

$\dfrac{F}{L} = (0.010\ kg/m)(9.8\ N/kg)$

$\dfrac{F}{L} = 9.8 \times 10^{-2}\ N/m$ (linear weight)

$F = BIL \sin\theta$

$I = \dfrac{F}{BL \sin\theta}$

$I = \dfrac{\frac{F}{L}}{B \sin\theta}$

$I = \dfrac{9.8 \times 10^{-2}\ N/m}{(2.0 \times 10^{-5}\ T) \sin 90°}$

$I = 4900\ A$

**b)** This current would most likely melt the wire.

**27. a)** $N = 60$

$I = 2.2\ A$

$B = 0.12\ T$

$B = \dfrac{\mu NI}{L}$

$L = \dfrac{\mu NI}{B}$

$L = \dfrac{(4\pi \times 10^{-7}\ T \cdot m/A)(60)(2.2\ A)}{0.12\ T}$

$L = 1.38 \times 10^{-3}\ m$

$F = BIL \sin\theta$

$F = (0.12\ T)(2.2\ A)(1.38 \times 10^{-3}\ m)(\sin 90°)$

$F = 3.64 \times 10^{-4}\ N$

**b)** $F = ma$

$a = \dfrac{F}{m}$

$a = \dfrac{3.64 \times 10^{-4}\ N}{0.025\ kg}$

$a = 1.46 \times 10^{-2}\ m/s^2$

**28.** $B = 0.02\ T$

$v = 1.5 \times 10^{7}\ m/s$

$\theta = 90°$

$q = 1.602 \times 10^{-19}$ C
$m = 9.11 \times 10^{-31}$ kg

$$F_c = F_B$$

$$\frac{mv^2}{r} = qvB \sin \theta$$

$$r = \frac{mv}{qB}$$

$$r = \frac{(9.11 \times 10^{-31}\ \text{kg})(1.5 \times 10^{7}\ \text{m/s})}{(1.602 \times 10^{-19}\ \text{C})(0.02\ \text{T})}$$

$$r = 4.3 \times 10^{-3}\ \text{m}$$

**29.** $q_{\text{alpha}} = 2(1.602 \times 10^{-19}\ \text{C})$
$q_{\text{alpha}} = 3.204 \times 10^{-19}$ C
$v = 2 \times 10^{6}$ m/s
$B = 2.9 \times 10^{-5}$ T
$m_{\text{alpha}} = 2(\text{protons}) + 2(\text{neutrons})$
$m_{\text{alpha}} = 4(1.67 \times 10^{-27}\ \text{kg})$
$m_{\text{alpha}} = 6.68 \times 10^{-27}$ kg

$$r = \frac{mv}{qB}$$

$$r = \frac{(6.68 \times 10^{-27}\ \text{kg})(2 \times 10^{6}\ \text{m/s})}{(3.204 \times 10^{-19}\ \text{C})(2.9 \times 10^{-5}\ \text{T})}$$

$$r = 1.4 \times 10^{3}\ \text{m}$$

**30.** $F_g = mg$
$F_g = (9.11 \times 10^{-31}\ \text{kg})(9.8\ \text{N/kg})$
$F_g = 8.9 \times 10^{-30}$ N
$F_{\text{mag}} = Bqv \sin \theta$
$F_{\text{mag}} = (5.0 \times 10^{-5}\ \text{T})(1.602 \times 10^{-19}\ \text{C})(2.8 \times 10^{7}\ \text{m/s})$
$F_{\text{mag}} = 2.24 \times 10^{-16}$ N
The magnetic force has considerably more influence on the electron.

**31.** $q = 1.5 \times 10^{-6}$ C
$v = 450$ m/s
$r = 0.15$ m
$I = 1.5$ A
$\theta = 90°$
$F = Bqv \sin \theta$

$$B = \frac{\mu I}{2\pi r}$$

$$F = \frac{\mu I q v \sin \theta}{2\pi r}$$

$$F = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(1.5\ \text{A})(1.5 \times 10^{-6}\ \text{C})(450\ \text{m/s})\sin 90°}{2\pi(0.15\ \text{m})}$$

$$F = 1.3 \times 10^{-9}\ \text{N}$$

According to the left-hand rules #1 and #3, this charge would always be forced toward the wire.

**32. a)** $v = 5 \times 10^{7}$ m/s
$r = 0.05$ m
$I = 35$ A
$q = -1.602 \times 10^{-19}$ C
$F = Bqv \sin \theta$

$$B = \frac{\mu I}{2\pi r}$$

$$F = \frac{\mu I q v \sin \theta}{2\pi r}$$

$$F = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(35\ \text{A})(-1.602 \times 10^{-19}\ \text{C})(5 \times 10^{7}\ \text{m/s}) \sin 90°}{2\pi(0.05)}$$

$F = 1.12 \times 10^{-15}$ N
According to the left-hand rules #1 and #3, this charge would always be forced away from the wire.

**b)** If the electron moved in the same direction as the current, then it would be forced toward the wire.

**33. a)** $v = 2.2 \times 10^{6}$ m/s
$r = 5.3 \times 10^{-11}$ m
$q = -1.602 \times 10^{-19}$ C
$m = 9.11 \times 10^{-31}$ kg
At any given instant, the electron can be considered to be moving in a straight line tangentially around the proton.

$$F_{\text{mag}} = F_c$$

$$qvB \sin \theta = \frac{mv^2}{r}$$

$$B = \frac{mv}{qr}$$

$$B = \frac{(9.11 \times 10^{-31}\ \text{kg})(2.2 \times 10^{6}\ \text{m/s})}{(-1.602 \times 10^{-19}\ \text{C})(5.3 \times 10^{11}\ \text{m})}$$

$B = 2.36 \times 10^{5}$ T
But this field would always be met by a field of the same magnitude but opposite direction when the electron was on the other side of its orbit. Therefore, the net field strength at the proton is zero.

**b)** To keep an electron moving in a circular artificially simulated orbit, the scientist must apply a field strength of $2.36 \times 10^{5}$ T.

**34.** $\varepsilon = 475$ V/m

$B = 0.1$ T

The electron experiences no net force because the forces from both the electric and magnetic fields are equal in magnitude but opposite in direction.

If all the directions are mutually perpendicular, both the electric and magnetic fields will move the electron in the same direction (based on the left-hand rule #3). Therefore,

$$F_{mag} = F_e$$
$$qvB = q\varepsilon$$
$$v = \frac{\varepsilon}{B}$$
$$v = \frac{(475\ \text{V/m})}{(0.1\ \text{T})}$$
$$v = 4750\ \text{m/s}$$

**35.** $B = 5.0 \times 10^{-2}$ T

$d = 0.01$ m

$v = 5 \times 10^6$ m/s

$q = 1.602 \times 10^{-19}$ C

$$F_{mag} = F_e$$
$$qvB = q\varepsilon$$
$$qvB = q\frac{V}{d}$$
$$V = dvB$$
$$V = (0.01\ \text{m})(5 \times 10^6\ \text{m/s})(5.0 \times 10^{-2}\ \text{T})$$
$$V = 2500\ \text{V}$$

**36.** $r = 3.5$ m

$I = 1.5 \times 10^4$ A

$$F = \frac{\mu I_1 I_2 L}{2\pi r}$$
$$F = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(1.5 \times 10^4\ \text{A})^2(190\ \text{m})}{2\pi(3.5\ \text{m})}$$
$$F = 2.44 \times 10^3\ \text{N}$$

**37.** $L = 0.65$ m

$I = 12$ A

$B = 0.20$ T

$$F = BIL \sin\theta$$
$$F = (0.20\ \text{T})(12\ \text{A})(0.65\ \text{m})(\sin 90°)$$
$$F = 1.56\ \text{N [perpendicular to wire]}$$

At the angle shown, the force is:

$(1.56\ \text{N})\sin 30° = 0.78$ N

**38. a)** $v = 5.0 \times 10^6$ m/s

$r = 0.001$ m

$q = -1.602 \times 10^{-19}$ C

$m = 9.11 \times 10^{-31}$ kg

$$F_c = F_{mag}$$
$$\frac{mv^2}{r} = qvB$$
$$B = \frac{vm}{qr}$$
$$B = \frac{(5.0 \times 10^6\ \text{m/s})(9.11 \times 10^{-31}\ \text{kg})}{(-1.602 \times 10^{-19}\ \text{C})(0.001\ \text{m})}$$
$$B = -2.8 \times 10^{-2}\ \text{T}$$

**b)**
$$F_c = ma_c$$
$$F_c = qvB$$
$$ma_c = qvB$$
$$a_c = \frac{qvB}{m}$$
$$a_c = \frac{(1.602 \times 10^{-19}\ \text{C})(5.0 \times 10^6\ \text{m/s})(0.028\ \text{T})}{9.11 \times 10^{-31}\ \text{kg}}$$
$$a_c = 2.5 \times 10^{16}\ \text{m/s}^2$$

**39. a)** $r = 0.22$ m

$B = 0.35$ T

$q = 1.602 \times 10^{-19}$ C

$m = 1.67 \times 10^{-27}$ kg

$$\frac{q}{m} = \frac{v}{Br}$$
$$v = \frac{qBr}{m}$$
$$v = \frac{(1.602 \times 10^{-19}\ \text{C})(0.35\ \text{T})(0.22\ \text{m})}{(1.67 \times 10^{-27}\ \text{kg})}$$
$$v = 7.4 \times 10^6\ \text{m/s}$$

**b)**
$$F_c = \frac{mv^2}{r}$$
$$F_c = \frac{(1.67 \times 10^{-27}\ \text{kg})(7.4 \times 10^6\ \text{m/s})^2}{0.22\ \text{m}}$$
$$F_c = 4.2 \times 10^{-13}\ \text{N}$$

**40.** $\frac{e}{m} = 5.7 \times 10^8$ C/kg

$B = 0.75$ T

$$\frac{q}{m} = \frac{v}{Br}$$

$$r = \frac{mv}{Bq}$$

$$v = \frac{d}{t}$$

$$v = \frac{2\pi r}{\mathrm{T}}$$

$$T = \frac{2\pi r}{v}$$

$$T = \frac{2\pi\left(\frac{mv}{Bq}\right)}{v}$$

$$T = \frac{2\pi}{B\left(\frac{q}{m}\right)}$$

$$T = \frac{2\pi}{(0.75 \text{ T})(5.7 \times 10^8 \text{ C/kg})}$$

$$T = 1.5 \times 10^{-8} \text{ s}$$

**41.** $m = 6.0 \times 10^{-8}$ kg

$q = 7.2 \times 10^{-6}$ C

$B = 3.0$ T

$$t = \frac{1}{2}T$$

$$t = \left(\frac{1}{2}\right)\left(\frac{2\pi m}{Bq}\right)$$

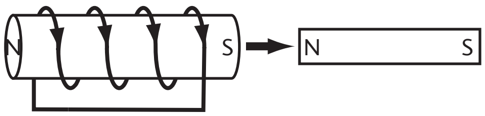
$$t = \frac{\pi(6.0 \times 10^{-8} \text{ kg})}{(3.0 \text{ T})(7.2 \times 10^{-6} \text{ C})}$$

$$t = 8.7 \times 10^{-3} \text{ s}$$

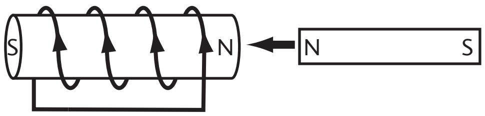
# Chapter 16

**16.**

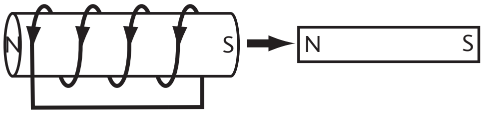
**(a)**



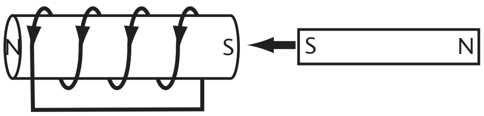

**(b)**




**(c)**

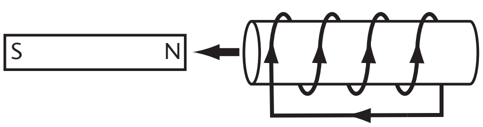



**(d)**

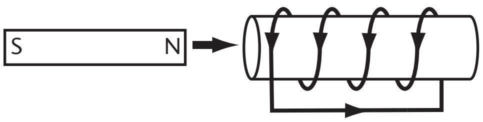



**17.**

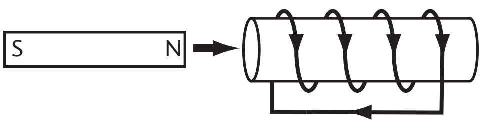
**(a)**



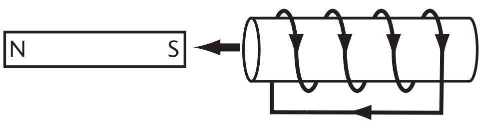

**(b)**




**(c)**

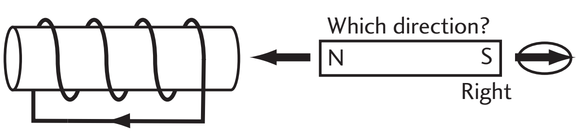



**(d)**

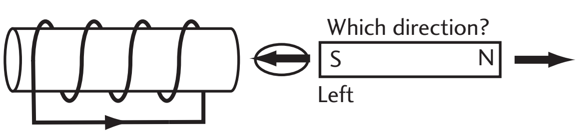



**18.**

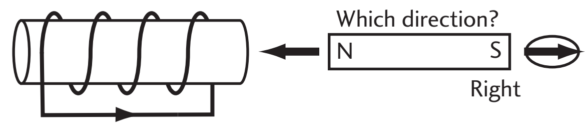
**(a)**



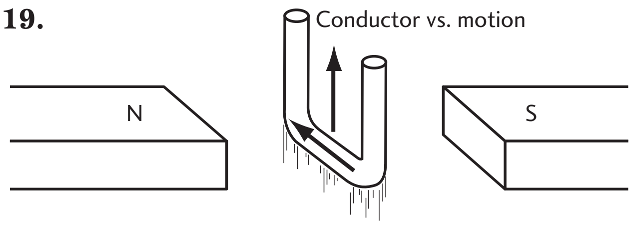

**(b)**



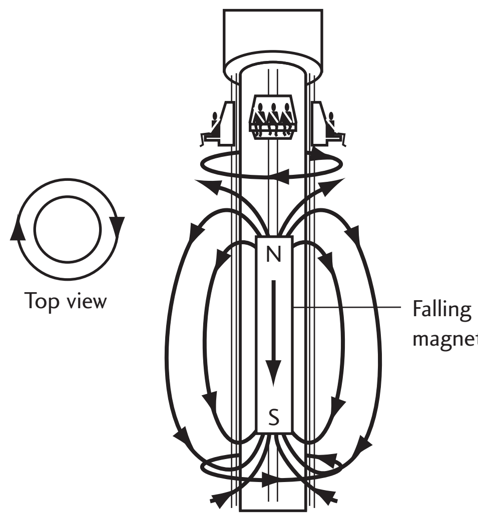

**(c)**




**19.**




**20. a)** Lenz's law dictates that the current will flow in a direction opposite to the falling motion of the magnet. The current in the pipe will flow horizontally clockwise (see Fig. 16.31).




**21.** The potential difference is:

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$V_p = V_s\left(\frac{N_p}{N_s}\right)$$

$$= (6.0 \times 10^2\ \text{V})\left(\frac{100}{600}\right)$$

$$= 100\ \text{V}$$

The current is:

$$P_p = P_s$$

$$I_pV_p = I_sV_s$$

$$I_p = \frac{I_sV_s}{V_p}$$

$$= 2\ \text{A}\left(\frac{6.0 \times 10^2\ \text{V}}{100\ \text{V}}\right)$$

$$= 12\ \text{A}$$

**22. a)** $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

$$N_s = \frac{N_p V_s}{V_p}$$
$$= \frac{(1100)(6\ V)}{120\ V}$$
$$= 55\text{ turns}$$

**b)** $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

$$N_s = \frac{N_p V_s}{V_{ps}}$$
$$= \frac{(1100)(3\ V)}{120\ V}$$
$$= 27.5\text{ turns}$$

**23. a)** $\frac{N_p}{N_s} = \frac{4}{7} = 0.57$

**b)** $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

$$V_s = V_p\left(\frac{N_s}{N_p}\right)$$
$$= (12\ V)(\tfrac{7}{4})$$
$$= 21\ V$$

**c)** This is a step-up transformer (low voltage to high voltage).

**24. a)** $P = \frac{V^2}{R}$

$$= \frac{(1.0 \times 10^3\ V)^2}{300\ \Omega}$$
$$= 3.3 \times 10^3\ W$$

**b)** $P_p = P_s$

$$I_p V_p = 3.3 \times 10^3\ W$$
$$I_p = \frac{3.3 \times 10^3\ W}{120\ V}$$
$$= 2.75 \times 10^1\ A$$
$$\cong 2.8 \times 10^1\ A$$

**c)** $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

$$= \frac{120\ V}{1.0 \times 10^3\ V}$$
$$= 0.12$$

**25. a)** This is a step-up transformer (from 12 V to 120 V).

**b)** The 12 V DC must be converted to AC before the transformer will work.

**c)** $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

$$= \frac{12\ V}{120\ V}$$
$$= 0.1$$

**d)** $P = I_p V_p$

$$I_p = \frac{P}{V_p}$$
$$= \frac{60\ W}{12\ V}$$
$$= 5\ A$$

**26.** $N_p = 1150$

$N_s = 80$

$V_p = 120\ V$

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$
$$V_s = \frac{V_p N_s}{N_p}$$
$$= \frac{(120\ V)(80)}{1150}$$
$$= 8.3\ V$$

**27. a)** $N_p = 750$

$N_s = 12$

$V_p = 720\ V$

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$
$$V_s = \frac{V_p N_s}{N_p}$$
$$= \frac{(720\ V)(12)}{750}$$
$$= 11.5\ V$$

**b)** $I_s = 3.6\ A$

$$\frac{N_p}{N_s} = \frac{I_s}{I_p}$$
$$I_p = \frac{I_s N_s}{N_p}$$
$$= \frac{(3.6\ A)(12)}{750}$$
$$= 5.8 \times 10^{-2}\ A$$

**c)** $P = I_p V_p$

$$= (720\ V)(5.8 \times 10^{-2}\ A)$$
$$= 41.8\ W$$

**28. a)** $N_p = 500$

$N_s = 15\ 000$

$V_s = 3600$ V

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$V_p = V_s\left(\frac{N_p}{N_s}\right)$$

$$= (3600 \text{ V})\left(\frac{500}{15\ 000}\right)$$

$$= 120 \text{ V}$$

**b)** $I_s = 3.0$ A

$P_p = P_s$

$I_pV_p = I_sV_s$

$$I_p = \frac{I_sV_s}{V_p}$$

$$= 3.0 \text{ A}\left(\frac{3600 \text{ V}}{120 \text{ V}}\right)$$

$$= 90 \text{ A}$$

**c)** $P = I_sV_s$

$$= (3.0 \text{ A})(3600 \text{ V})$$

$$= 1.1 \times 10^4 \text{ W}$$

**29. a)** $V_p = 240$ V

$V_s = 120$ V

$$\frac{N_p}{N_s} = \frac{N_p}{V_s}$$

$$= \frac{240 \text{ V}}{120 \text{ V}}$$

$$= 2$$

**b)** $$I_p = \frac{I_sV_s}{V_p}$$

$$= \frac{(10 \text{ A})(120 \text{ V})}{(240 \text{ V})}$$

$$= 5 \text{ A}$$

**c)** The iron has an internal resistance that inherently draws a 10 A current from a 120 V source.

$$R = \frac{V}{I} = \frac{120 \text{ V}}{10 \text{ A}} = 12\ \Omega$$

In Europe, the iron would draw twice as much current, which would burn out the internal wiring that is not rated for that current.

$$I_{\text{Europe}} = \frac{V}{R} = \frac{240 \text{ V}}{12\ \Omega} = 20 \text{ A}$$

**d)** In North America, the 240 V outlets are designed so that 120 V electrical plugs are not compatible and will not fit. The electric dryer and stove have special block plugs that also take advantage of the house 120 V line. In a workshop, 240 V outlets only accept plugs that have a circular spade configuration. The plug requires a quarter twist before it will operate.

**30. a)** The increase in voltage indicates a step-up transformer with a turn ratio of:

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$= \frac{20 \text{ kV}}{230 \text{ kV}}$$

$$= 8.7 \times 10^{-2}$$

**b)** $I_p = 60.0$ A

$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

$$I_s = \frac{I_pV_p}{V_s}$$

$$= \frac{(60.0 \text{ A})(20 \text{ kV})}{230 \text{ kV}}$$

$$= 5.2 \text{ A}$$

**31. a)** $P = 180$ kW

$R = 0.045\ \Omega$

$V_s = 1.1$ kV

$P = IV$

$$I = \frac{P}{V}$$

$$= \frac{180\ 000 \text{ W}}{1100 \text{ V}}$$

$$I = 164 \text{ A}$$

$$= 1.6 \times 10^2 \text{ A}$$

**b)** $P = I^2R$

$$= (164 \text{ A})^2(0.045\ \Omega)$$

$$= 1210 \text{ W}$$

$$= 1.2 \times 10^3 \text{ W}$$

**c)** $$\%P_{\text{Lost}} = \frac{1210 \text{ W}}{180\ 000 \text{ W}} \times 100$$

$$= 0.67\%$$

**d)** The voltage on the secondary side could be stepped up even more to prevent power loss. Step up the voltage to 1.5 kV now to verify a lower power loss.

$P = 180$ kW

$R = 0.045$ V

$V_s = 1.5$ kV

$P = IV$

$$I = \frac{P}{V}$$

$$= \frac{180\ 000\ \text{W}}{1500\ \text{V}}$$

$I = 120$ A

$= 1.2 \times 10^2$ A

$P = I^2R$

$= (120\ \text{A})^2(0.045)$

$= 648$ W

$= 6.5 \times 10^2$ W

The new power loss is even less when the voltage is stepped up higher.

**32. a)** $P_{89\,\%} = P_{100\,\%}(0.89)$

$$P_{100\,\%} = \frac{P_{89\,\%}}{0.89}$$

$$= \frac{500\ \text{MW}}{0.89}$$

$= 562$ MW

**b)** $m = 2.0 \times 10^6$ kg

$E_g = E_e$

$E_g = mg\Delta h = 2.0 \times 10^6\ \text{kg}(9.8\ \text{N/kg})\Delta h$

$mg\Delta h = 562 \times 10^6$ W

$$\Delta h = \frac{562 \times 10^6\ \text{W}}{mg}$$

$$= \frac{562 \times 10^6\ \text{W}}{(2.0 \times 10^6\ \text{kg/s})(9.8\ \text{N/kg})}$$

$= 28.7$ m

# Chapter 17

**19.** $\lambda_{max} = 597 \text{ nm} = 5.97 \times 10^{-7} \text{ m}$

The temperature can be found using Wien's law:

$$\lambda_{max} = \frac{2.898 \times 10^{-3}}{T}$$

$$T = \frac{2.898 \times 10^{-3}}{\lambda_{max}}$$

$$T = \frac{2.898 \times 10^{-3}}{5.97 \times 10^{-7} \text{ m}}$$

$T = 4854.27 \text{ K}$

$T = 4854.27 - 273°\text{C}$

$T = 4581.27°\text{C}$

**20.** $T = 2.7 \text{ K}$

$\lambda_{max}$ can be found using Wien's law:

$$\lambda_{max} = \frac{2.898 \times 10^{-3}}{T}$$

$$\lambda_{max} = \frac{2.898 \times 10^{-3}}{2.7\ K}$$

$\lambda_{max} = 1.07 \times 10^{-3} \text{ m}$

**21.** $T = 125 \text{ K}$

$\lambda_{max}$ can be found using Wien's law:

$$\lambda_{max} = \frac{2.898 \times 10^{-3}}{T}$$

$$\lambda_{max} = \frac{2.898 \times 10^{-3}}{125 \text{ K}}$$

$\lambda_{max} = 2.32 \times 10^{-5} \text{ m}$

The peak wavelength of Jupiter's cloud is $2.32 \times 10^{-5}$ m. It belongs to the infrared part of the electromagnetic spectrum.

**22.** $P = 2 \text{ W}, \lambda = 632.4 \text{ nm} = 6.324 \times 10^{-7} \text{ m}$

We are to find the number of photons leaving the laser tube per second. Let us symbolize this quantity by $N_\gamma$.

Using Planck's equation, we can express the energy for a single photon:

$$E_\gamma = \frac{hc}{\lambda}$$

The number of photons leaving the tube can be found as follows:

$$N_\gamma = \frac{P}{E_\gamma}$$

$$N_\gamma = \frac{P\lambda}{hc}$$

$$N_\gamma = \frac{(2 \text{ W})(6.324 \times 10^{-7} \text{ m})}{(6.626 \times 10^{-34} \text{ J}\cdot\text{s})(3.0 \times 10^{8} \text{ m/s})}$$

$N_\gamma = 6.36 \times 10^{18}$ photons/s

**23.** $E_\gamma = 4.5 \text{ eV}, W_{0(\text{gold})} = 5.37 \text{ eV}$

$E_\gamma < W_0$. The gold will absorb all of the energy of the incident photons, hence there will be no photoelectric effect observed (see Figure 12.13).

**24.** $\lambda = 440 \text{ nm} = 4.4 \times 10^{-7} \text{ m}$,

$W_{0(\text{nickel})} = 5.15 \text{ eV}$

First, we shall calculate the energy of the incident photons. Using Planck's equation:

$$E_\gamma = \frac{hc}{\lambda}$$

$$E_\gamma = \frac{(6.626 \times 10^{-34} \text{ J}\cdot\text{s})(3.0 \times 10^{8} \text{ m/s})}{4.4 \times 10^{-7} \text{ m}}$$

$E_\gamma = 4.52 \times 10^{-19} \text{ J}$

$$E_\gamma = \frac{4.52 \times 10^{-19} \text{ J}}{1.6 \times 10^{-19} \text{ C}}$$

$E_\gamma = 2.82 \text{ eV}$

Since $E_\gamma < W_0$, the photoelectric effect will not be exhibited (see Figure 12.13).

**25.** $P = 30 \text{ W}, \lambda = 540 \text{ nm} = 5.4 \times 10^{-7} \text{ m}$

We are to find the number of photons radiated by the headlight per second. Let us symbolize this quantity by $N_\gamma$.

Using Planck's equation, we can express the energy for a single photon:

$$E_\gamma = \frac{hc}{\lambda}$$

The number of photons radiated by the headlight can be found as follows:

$$N_\gamma = \frac{P}{E_\gamma}$$

$$N_\gamma = \frac{P\lambda}{hc}$$

$$N_\gamma = \frac{(30 \text{ W})(5.4 \times 10^{-7} \text{ m})}{(6.626 \times 10^{-34} \text{ J}\cdot\text{s})(3.0 \times 10^{8} \text{ m/s})}$$

$N_\gamma = 8.15 \times 10^{19}$ photons/s

**26.** $W_0 = 3 \text{ eV} = 4.8 \times 10^{-19} \text{ J}$,

$\lambda = 219 \text{ nm} = 2.19 \times 10^{-7} \text{ m}$

**a)** The energy of photons with cut-off frequency is equal to the work function of the metal. Hence,

$E_\gamma = W_0 = 4.8 \times 10^{-19} \text{ J}$

The frequency can be found using Planck's equation:

$E_\gamma = hf$

$f = \frac{E_\gamma}{h}$

$f = \frac{4.8 \times 10^{-19}\text{ J}}{6.626 \times 10^{-34}\text{ J}\cdot\text{s}}$

$f = 7.24 \times 10^{14}$ Hz

**b)** The maximum energy of the ejected photons can be found using the equation:

$E_{\text{kmax}} = E_\gamma - W_0$

$E_{\text{kmax}} = \frac{hc}{\lambda} - W_0$

$E_{\text{kmax}} = \frac{(6.626 \times 10^{-34}\text{ J}\cdot\text{s})(3.0 \times 10^8\text{ m/s})}{2.19 \times 10^{-7}\text{ m}} -$

$4.8 \times 10^{-19}$ J

$E_{\text{kmax}} = 4.28 \times 10^{-19}$ J

**27. a)** To avoid unwanted electrical currents and change in bonding structure of the material of the satellite, the number of electrons ejected from the material should be minimal. The greater the work function of the metal, the more photon energy it will absorb and the fewer electrons will be ejected. Hence, the material selected should have a relatively high work function.

**b)** The longest wavelength of the photons that could affect this satellite would have an energy equal to the work function of the material, i.e.,

$E_\gamma = W_0$

Using Planck's equation $E_\gamma = \frac{hc}{\lambda}$,

$\lambda_{\text{max}} = \frac{hc}{W_0}$ (if $W_0$ is in Joules)

$\lambda_{\text{max}} = \frac{hc}{W_0 e}$ (if $W_0$ is in eV)

**28.** $W_{0(\text{platinum})} = 5.65\text{ eV} = 9.04 \times 10^{-19}$ J

From problem 27, we know that:

$\lambda_{\text{max}} = \frac{hc}{W_0}$

$\lambda_{\text{max}} = \frac{(6.626 \times 10^{-34}\text{ J}\cdot\text{s})(3.0 \times 10^8\text{ m/s})}{9.04 \times 10^{-19}\text{ J}}$

$\lambda_{\text{max}} = 2.2 \times 10^{-7}$ m

The maximum wavelength of the photon that could generate the photoelectric effect on the platinum surface is $2.2 \times 10^{-7}$ m.

**29. a)** For a material with a work function greater than zero, the typical photoelectric effect graph has a positive $x$ intercept. If the graph passes through the origin, the work function of the material is zero, which means that the photoelectric effect would be observed with incident photons having any wavelength.

**b)** If the graph has a positive $y$ intercept, we would observe the photoelectric effect without the presence of incident photons.

**30.** $\lambda = 400\text{ pm} = 4.0 \times 10^{-10}$ m

**a)** The frequency of the photon can be found using the wave equation:

$f = \frac{c}{\lambda}$

$f = \frac{3.0 \times 10^8\text{ m/s}}{4.0 \times 10^{-10}\text{ m}}$

$f = 7.5 \times 10^{17}$ Hz

**b)** The momentum of the photon can be computed using de Broglie's equation:

$p = \frac{h}{\lambda}$

$p = \frac{6.626 \times 10^{-34}\text{ J}\cdot\text{s}}{4.0 \times 10^{-10}\text{ m}}$

$p = 1.66 \times 10^{-24}\text{ N}\cdot\text{s}$

**c)** The mass equivalence can be found using de Broglie's equation:

$p = mv$

$m = \frac{p}{c}$

$m = \frac{1.66 \times 10^{-24}\text{ N}\cdot\text{s}}{3.0 \times 10^8\text{ m/s}}$

$m = 5.53 \times 10^{-33}$ kg

**31.** $m_{\text{proton}} = 1.673 \times 10^{-27}$ kg

First, we have to express the rest energy of the proton. It can be found using:

$E_{\text{proton}} = mc^2$

The energy of the photon, which is equal to the rest energy of the proton, can be expressed using Planck's equation:

$E_\gamma = \frac{hc}{\lambda}$

Then,

$E_{proton} = E_{\gamma}$

$mc^2 = \dfrac{hc}{\lambda}$

$mc = \dfrac{h}{\lambda}$

Using de Broglie's equation:

$p = \dfrac{h}{\lambda}$

Hence,

$p = mc$

$p = (1.673 \times 10^{-27}\ \text{kg})(3.0 \times 10^{8}\ \text{m/s})$

$p = 5.02 \times 10^{-19}\ \text{N}\cdot\text{s}$

**32.** $\lambda = 10\ \mu\text{m} = 1 \times 10^{-5}\ \text{m}$

Using de Broglie's equation:

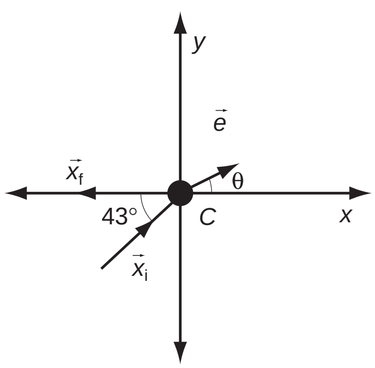
$p = \dfrac{h}{\lambda}$

$p = \dfrac{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}}{1 \times 10^{-5}\ \text{m}}$

$p = 6.63 \times 10^{-29}\ \text{N}\cdot\text{s}$

**33.** $\lambda_f = 1\ \text{nm} = 1 \times 10^{-9}\ \text{m}$

Consider the following diagram:




From the conservation of energy,

$E_i = E_f + E_k$

$\dfrac{hc}{\lambda_i} = \dfrac{hc}{\lambda_f} + \dfrac{1}{2}mv_f^2$ (eq. 1)

From the conservation of momentum,

$p_i = p_f + p_e$

In the direction of the $x$ axis:

$\dfrac{h}{\lambda_i}\cos 43° = -\dfrac{h}{\lambda_f} + mv_f \cos\theta$ (eq. 2)

In the direction of the $y$ axis:

$\dfrac{h}{\lambda_i}\sin 43° = mv_f \sin\theta$ (eq. 3)

Using math software to solve the system of equations that consists of equations 1, 2, and 3, the value for $\lambda_i = 9.9552 \times 10^{-10}$ m.

To find the Compton shift,

$\Delta\lambda = \lambda_f - \lambda_i$

$\Delta\lambda = 1 \times 10^{-9}\ \text{m} - 9.9552 \times 10^{-10}\ \text{m}$

$\Delta\lambda = 4.48 \times 10^{-12}\ \text{m}$

The Compton shift is $4.48 \times 10^{-12}$ m.

**34.** $\theta = 180°,\ v_f = 7.12 \times 10^{5}\ \text{m/s}$

From the conservation of energy,

$E_i = E_f + E_k$

$\dfrac{hc}{\lambda_i} = \dfrac{hc}{\lambda_f} + \dfrac{1}{2}mv_f^2$ (eq. 1)

From the conservation of momentum,

$p_i = p_f + p_e$

$\dfrac{h}{\lambda_i} = -\dfrac{h}{\lambda_f} + mv_f$ (eq. 2)

(The negative sign signifies a scatter angle θ equal to 180°.)

Multiplying equation 2 by $c$ and adding the result to equation 1,

$\dfrac{2hc}{\lambda_i} = \dfrac{1}{2}mv_f^2 + cmv_f$

$\lambda_i = \dfrac{2hc}{m\left(\dfrac{1}{2}v_f^2 + cv_f\right)}$

$\lambda_i = \dfrac{2(6.626 \times 10^{-34}\ \text{J}\cdot\text{s})(3.0 \times 10^{8}\ \text{m/s})}{(9.11 \times 10^{-31}\ \text{kg})\left[\frac{1}{2}(7.12 \times 10^{5}\ \text{m/s})^2 + (3.0 \times 10^{8}\ \text{m/s})(7.12 \times 10^{5}\ \text{m/s})\right]}$

$\lambda_i = 2.04 \times 10^{-9}\ \text{m}$

**35.** $\lambda_i = 18\ \text{pm} = 1.8 \times 10^{-11}\ \text{m}$, energy loss is 67%

The initial energy of the photon can be computed using Planck's equation:

$E_i = \dfrac{hc}{\lambda_i}$

$E_i = \dfrac{(6.626 \times 10^{-34}\ \text{J}\cdot\text{s})(3.0 \times 10^{8}\ \text{m/s})}{1.8 \times 10^{-11}\ \text{m}}$

$E_i = 1.1 \times 10^{-14}\ \text{J}$

Since 67% of the energy is lost, the final energy of the photon is:

$E_f = 0.33E_i$

$E_f = 0.33(1.1 \times 10^{-14}\ \text{J})$

$E_f = 3.64 \times 10^{-15}\ \text{J}$

The final wavelength can be calculated using Planck's equation:

$\lambda_f = \dfrac{hc}{E_f}$

$\lambda_f = \dfrac{(6.626 \times 10^{-34}\ \text{J}\cdot\text{s})(3.0 \times 10^{8}\ \text{m/s})}{3.64 \times 10^{-15}\ \text{J}}$

$\lambda_f = 5.45 \times 10^{-11}\ \text{m}$

The Compton shift as a percentage is:

$$\frac{\lambda_f}{\lambda_i} = \frac{5.45 \times 10^{-11}\ \text{m}}{1.8 \times 10^{-11}\ \text{m}} \times 100\,\%$$

$$\frac{\lambda_f}{\lambda_i} = 302\,\%$$

The wavelength of a photon increases by 302 %.

**36.** $m = 45\ \text{g} = 0.045\ \text{kg}$, $v = 50\ \text{m/s}$

Using de Broglie's equation:

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}}{(0.045\ \text{kg})(50\ \text{m/s})}$$

$$\lambda = 2.9 \times 10^{-34}\ \text{m}$$

The wavelength associated with this ball is $2.9 \times 10^{-34}$ m.

**37.** $m_n = 1.68 \times 10^{-27}$ kg,

$\lambda = 0.117\ \text{nm} = 1.17 \times 10^{-10}\ \text{m}$

Using de Broglie's equation:

$$\lambda = \frac{h}{mv}$$

$$v = \frac{h}{m\lambda}$$

$$v = \frac{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}}{(1.68 \times 10^{-27}\ \text{kg})(1.17 \times 10^{-10}\ \text{m})}$$

$$v = 3371\ \text{m/s}$$

The velocity of the neutron is 3371 m/s.

**38.** $m_p = 1.67 \times 10^{-27}\ \text{kg}$, $\lambda = 2.9 \times 10^{-34}\ \text{m}$

Using de Broglie's equation:

$$\lambda = \frac{h}{mv}$$

$$v = \frac{h}{m\lambda}$$

$$v = \frac{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}}{(1.67 \times 10^{-27}\ \text{kg})(2.9 \times 10^{-34}\ \text{m})}$$

$$v = 1.37 \times 10^{27}\ \text{m/s}$$

The speed of the proton would have to be $1.37 \times 10^{27}$ m/s. Since $v$ is much greater than $c$, this speed is impossible.

**39.** $E_k = 50\ \text{eV} = 8 \times 10^{-18}\ \text{J}$,

$m_e = 9.11 \times 10^{-31}$ kg

**a)** We shall first compute the velocity using the kinetic energy value:

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

$$v = \sqrt{\frac{2E_k}{m}}$$

$$v = \sqrt{\frac{2(8 \times 10^{-18}\ \text{J})}{9.11 \times 10^{-31}\ \text{kg}}}$$

$$v = 4.19 \times 10^{6}\ \text{m/s}$$

Now $\lambda$ can be found using de Broglie's equation:

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}}{(9.11 \times 10^{-31}\ \text{kg})(4.19 \times 10^{6}\ \text{m/s})}$$

$$\lambda = 1.73 \times 10^{-10}\ \text{m}$$

**b)** The Bohr radius is $5.29 \times 10^{-11}$ m. The wavelength associated with an electron is longer than a hydrogen atom.

**40.** The photon transfers from $n = 5$ to $n = 2$.

The energy at level $n$ is given by:

$$E_n = \frac{-13.6\ \text{eV}}{n^2}$$

The energy released when the photon transfers from $n = 5$ to $n = 2$ is:

$$\Delta E = E_5 - E_2$$

$$\Delta E = \frac{-13.6\ \text{eV}}{5^2} + \frac{13.6\ \text{eV}}{2^2}$$

$$\Delta E = 2.86\ \text{eV}$$

$$\Delta E = 4.58 \times 10^{-19}\ \text{J}$$

To compute the wavelength:

$$\lambda = \frac{hc}{E_\gamma}$$

$$\lambda = \frac{(6.626 \times 10^{-34}\ \text{J}\cdot\text{s})(3.0 \times 10^{8}\ \text{m/s})}{4.58 \times 10^{-19}\ \text{J}}$$

$$\lambda = 4.34 \times 10^{-7}\ \text{m}$$

The wavelength released when the photon transfers from $n = 5$ to $n = 2$ is $4.34 \times 10^{-7}$ m. It is in the visual spectrum and it would appear as violet.

**41. a)** The electron transfers from $n = 1$ to $n = 4$. The energy of the electron is given by:

$$E_n = \frac{-13.6\ \text{eV}}{n^2}$$

The energy needed to transfer the electron from $n = 1$ to $n = 4$ is:

$$\Delta E = E_4 - E_1$$

$$\Delta E = \frac{-13.6\ \text{eV}}{4^2} + \frac{13.6\ \text{eV}}{1^2}$$

$$\Delta E = 12.75\ \text{eV}$$

**b)** The electron transfers from $n = 2$ to $n = 4$. Similarly, the energy needed to transfer the electron from $n = 2$ to $n = 4$ is:

$\Delta E = E_4 - E_2$

$$\Delta E = \frac{-13.6\text{ eV}}{4^2} + \frac{13.6\text{ eV}}{2^2}$$

$\Delta E = 2.55\text{ eV}$

**42.** We need to find the difference in the radius between the second and third energy levels. The radius at a level $n$ is given by

$r_n = (5.29 \times 10^{-11}\text{ m})n^2$

The difference in radii is:

$\Delta r = r_3 - r_2$

$\Delta r = (5.29 \times 10^{-11}\text{ m})(3)^2 - (5.29 \times 10^{-11}\text{ m})(2)^2$

$\Delta r = 2.64 \times 10^{-10}\text{ m}$

**43.** $n = 1$

The radius of the first energy level can be found using:

$r_n = (5.29 \times 10^{-11}\text{ m})n^2$

$r_n = (5.29 \times 10^{-11}\text{ m})(1)^2$

$r_n = 5.29 \times 10^{-11}\text{ m}$

The centripetal force is equal to the electrostatic force of attraction:

$$F = \frac{ke^2}{r^2}$$

$$F = \frac{(8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(1.6 \times 10^{-19}\text{ C})^2}{(5.29 \times 10^{-11}\text{ m})^2}$$

$F = 8.22 \times 10^{-8}\text{ N}$

The centripetal force acting on the electron to keep it in the first energy level is $8.22 \times 10^{-8}$ N.

**44.** $F = 8.22 \times 10^{-8}\text{ N}$, $r = 5.29 \times 10^{-11}\text{ m}$

$F = m4\pi^2 rf^2$

$$f = \frac{1}{2\pi}\sqrt{\frac{F}{mr}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{8.22 \times 10^{-8}\text{ N}}{(9.11 \times 10^{-31}\text{ kg})(5.29 \times 10^{-11}\text{ m})}}$$

$f = 6.56 \times 10^{15}\text{ Hz}$

The electron is orbiting the nucleus $6.56 \times 10^{15}$ times per second.

**45.** Consider an electron transferring from $n = 4$ to $n = 1$. As computed in problem 41, the energy released is equal to $12.75\text{ eV} = 2.04 \times 10^{-18}$ J. The frequency is then equal to:

$$f = \frac{E_\gamma}{h}$$

$$f = \frac{2.04 \times 10^{-18}\text{ J}}{6.626 \times 10^{-34}\text{ J}\cdot\text{s}}$$

$f = 3.08 \times 10^{15}\text{ Hz}$

The frequency of the photon is $3.08 \times 10^{15}$ Hz, or one-half the number of cycles per second completed by the electron in problem 44.

**46.** Bohr predicted a certain value for energy at a given energy level. From the quantization of energy, there can be only specific values for velocity, $v$, and radius, $r$. Thus, the path of the orbiting electron can attain a specific path (orbit) around the nucleus, which is an orbital.

**48.** $v = 1000\text{ m/s}$, $m = 9.11 \times 10^{-31}\text{ kg}$

$\Delta p_y \Delta y \geq \hbar$

$\Delta p = m\Delta v$

$$\Delta y \geq \frac{\hbar}{m\Delta v}$$

$$\Delta y \geq \frac{1.0546 \times 10^{-34}\text{ J}\cdot\text{s}}{(9.11 \times 10^{-31}\text{ kg})(1000\text{ m/s})}$$

$\Delta y \geq 1.16 \times 10^{-7}\text{ m}$

Hence, the position is uncertain to $1.16 \times 10^{-7}$ m.

**49.** $\Delta y = 1 \times 10^{-4}\text{ m}$

The molecular mass of oxygen is 32 mol. The mass of one oxygen molecule is

$$\frac{32\text{ mol}}{6.02 \times 10^{23}\text{ mol/g}} = 5.32 \times 10^{-26}\text{ kg}$$

From $\Delta p_y \Delta y \geq \hbar$ and $\Delta p = m\Delta v$, the maximum speed is:

$$v = \frac{\hbar}{m\Delta v}$$

$$v = \frac{1.0546 \times 10^{-34}\text{ J}\cdot\text{s}}{(5.32 \times 10^{-26}\text{ kg})(1 \times 10^{-4}\text{ m})}$$

$v = 1.98 \times 10^{-5}\text{ m/s}$

## Chapter 18

**36.** **a)** Cl
**b)** Rn
**c)** Be
**d)** U
**e)** Md

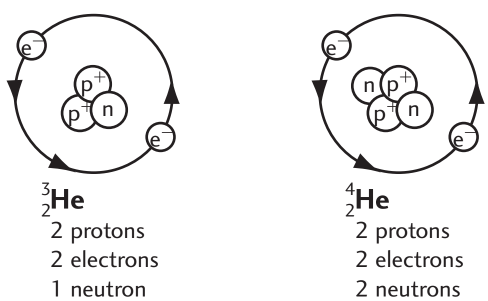
**37.** For ${}^{A}_{Z}X$, $Z$ is the number of protons and $A - Z$ is the number of neutrons:
**a)** 17 protons, 18 neutrons
**b)** 86 protons, 136 neutrons
**c)** 4 protons, 5 neutrons
**d)** 92 protons, 146 neutrons
**e)** 101 protons, 155 neutrons

**38.** Since 1 u = 931.5 MeV/$c^2$, then
18.998 u × 931.5 MeV/$c^2$/u = 17 697 MeV/$c^2$.

**39.** Conversely, $\dfrac{106 \text{ MeV}/c^2}{931.5 \text{ MeV}/c^2/\text{u}} = 0.114$ u.

**40.** To find the weighted average of the two isotopes:
0.69(62.9296 u) + 0.31(64.9278 u) = 63.55 u
This is closest to the mean atomic mass of Cu.

**41.** Two isotopes of helium are similar in that they both have the same number of protons (2) and electrons (2). The difference is that one isotope has an additional neutron.




**42.** $Z$ is the number of protons and is found on the periodic table. It is the bottom number in the ${}^{A}_{Z}X$ notation. $A$ is the mass number (atomic weight), the number of protons plus neutrons, and is found in the upper position in the ${}^{A}_{Z}X$ notation. $N$ is the number of neutrons and is found by subtracting $Z$ from $A$ ($N = A - Z$).

| Symbol | $Z$ | $A$ | $N$ | ${}^{A}_{Z}X$ |
|---|---|---|---|---|
| H | 1 | 3 | 2 | ${}^{3}_{1}$H |
| Li | 3 | 7 | 4 | ${}^{7}_{3}$Li |
| C | 6 | 14 | 8 | ${}^{14}_{6}$C |
| N | 7 | 14 | 7 | ${}^{14}_{7}$N |
| Na | 11 | 24 | 13 | ${}^{24}_{11}$Na |
| Co | 27 | 59 | 32 | ${}^{59}_{27}$Co |
| Sr | 38 | 88 | 50 | ${}^{88}_{38}$Sr |
| U | 92 | 238 | 146 | ${}^{238}_{92}$U |
| Pu | 94 | 239 | 145 | ${}^{239}_{94}$Pu |

**43.** **a)** ${}^{1}_{1}p^{+}$
**b)** ${}^{4}_{2}\text{He}^{2+}$
**c)** ${}^{1}_{0}n$
**d)** ${}^{0}_{-1}e$

**44.** All values were calculated by considering that the sum of the $Z$ values of the reactants must equal the sum of the $Z$ values of the products. Similarly, the sum of the $A$ values of the reactants must equal the sum of the $A$ values of the products.
**a)** ${}^{14}_{7}$N. Both $A$ and $Z$ are calculated by subtracting the values of the known reactant from the sum of the product values, i.e., $Z = (8 + 1) - 2 = 7$. $Z = 7$ means the element is a nitrogen (N) isotope.
**b)** ${}^{1}_{0}n$
**c)** ${}^{4}_{2}$He
**d)** ${}^{0}_{-1}e$
**e)** ${}^{20}_{10}$Ne

**45.** All values were calculated by considering that the sum of the $Z$ values of the products must equal the $Z$ value of the reactant. Similarly, the sum of the $A$ values of the products must equal the $A$ value of the reactant. The missing $Z$ value was used to select the correct element symbol from the periodic table. Care must be taken to recognize the nuclear particle transitions that occur in beta decay in problems a), e), and f). Recall that in beta decay, a neutron is converted to a proton (+) and an electron (−).
**a)** ${}^{0}_{-1}e$(beta)
**b)** ${}^{2}_{4}$He(alpha)
**c)** ${}^{2}_{1}$H
**d)** ${}^{4}_{2}$He(alpha)
**e)** ${}^{0}_{-1}e$(beta)

**f)** ${}_{-1}^{0}e$(beta)

**46.** A neutron can more easily penetrate the nucleus because it is neutral and therefore not influenced by the overall positive charge of the nucleus. A proton (+) would be repelled by the similar positive charge of the nucleus.

**47.** Since ${}_{6}^{14}C \rightarrow {}_{7}^{14}N + {}_{-1}^{0}e + \bar{\nu}$, the $\frac{N}{Z}$ ratio changes from $\frac{8}{6}$ to $\frac{7}{7}$ or from $\frac{4}{3}$ to the more stable $\frac{1}{1}$.

**48.** Since ${}_{92}^{232}U \rightarrow {}_{90}^{228}Th + {}_{2}^{4}He + E_k$,

$$E_k = [m_U - m_{Th} - m_\alpha]c^2$$
$$E_k = [232.037\ 131\ u - 228.028\ 716\ u - 4.002\ 603\ u]c^2 \times 931.5\ MeV/c^2/u$$
$$E_k = 5.41\ MeV$$

**49.** Assuming the uranium nucleus is fixed at rest and the kinetic energy of the alpha particle becomes electrical potential,

$$E_k = \frac{kq_1q_2}{r}$$
$$r = \frac{kq_1q_2}{E_k}$$
$$r = \frac{(8.99 \times 10^9\ J\cdot m/C^2)(1.6 \times 10^{-19}\ C)^2(2)(92)}{(5.3 \times 10^6\ eV)(1.6 \times 10^{-19}\ J/eV)}$$
$$r = 5.0 \times 10^{-14}\ m$$

**50.** ${}_{90}^{231}Th \rightarrow {}_{91}^{231}Pa + {}_{-1}^{0}e + \bar{\nu}$

${}_{92}^{235}U \rightarrow {}_{90}^{231}Th + {}_{2}^{4}He$

**51.** The mass difference is:

$$\Delta m = m_n - (m_p + m_e)$$
$$\Delta m = [939.57 - 938.27 - 0.511]\ MeV/c^2$$
$$\Delta m = 0.789\ MeV/c^2$$

**52.** From problem 51, the energy equivalent of $0.789\ MeV/c^2$ is 0.789 MeV.

Thus $\frac{2}{3}(0.789\ MeV) = 0.526\ MeV$.

**53.** Since the total momentum before decay is equal to the total momentum after decay, and $p = 0 = p'$, the three momentum vectors must form a right-angle triangle. From Pythagoras' theorem:

$$p_C{}^2 = p_e{}^2 + p_\nu{}^2$$
$$p_C = \sqrt{(2.64 \times 10^{-21})^2 + (4.76 \times 10^{-21})^2}$$
$$p_C = 5.44 \times 10^{-21}\ N\cdot s$$

**54.** Using $E_k = \frac{p^2}{2m}$, the recoiling carbon nucleus will have

$$E_k = \frac{(5.44 \times 10^{-21}\ N\cdot s)^2}{2(12.011\ u)(1.6605 \times 10^{-27}\ kg/u)}$$
$$E_k = 7.42 \times 10^{-16}\ J$$

**55.** For a fixed gold nucleus at rest, the kinetic energy of the 449-MeV alpha particle is converted to electrical potential. Thus, for the radius,

$$E_k = \frac{kq_1q_2}{r}$$
$$r = \frac{kq_1q_2}{E_k}$$
$$r = \frac{(8.99 \times 10^9\ J\cdot m/C^2)(1.6 \times 10^{-19}\ C)^2(2)(79)}{(449 \times 10^6\ eV)(1.6 \times 10^{-19}\ J/eV)}$$
$$r = 5.07 \times 10^{-16}\ m$$

**56.**
$$\frac{A}{A_o} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$
$$\log\left(\frac{A}{A_o}\right) = \frac{t}{T_{\frac{1}{2}}}\log\left(\frac{1}{2}\right)$$
$$t = T_{\frac{1}{2}}\left[\frac{\log\left(\frac{A}{A_o}\right)}{\log\left(\frac{1}{2}\right)}\right]$$
$$t = (15\ h)\left[\frac{\log\left(\frac{125}{1000}\right)}{\log\left(\frac{1}{2}\right)}\right]$$
$$= 45\ h$$

**57.** $t$ = Sept. 1 – June 30

$= 30 + 31 + 30 + 31 + 31 + 28 + 31 + 30 + 31 + 30$

$= 303\ d\left(\frac{1\ a}{365\ d}\right)$

$= 0.83\ a$

On June 30, the sample would be 0.83 years old.

**a)** $A_o = 2.0 \times 10^6\ Bq$

$T_{\frac{1}{2}} = 5.3\ a$

$$A = A_o\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$
$$= 2 \times 10^6\ Bq\left(\frac{1}{2}\right)^{\frac{0.83\ a}{5.3\ a}}$$
$$= 1.8 \times 10^6\ Bq$$

**b)** $\dfrac{M}{M_0} = \dfrac{1}{64} = \left(\dfrac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$$\log\left(\frac{1}{64}\right) = \log\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$

$$\text{Therefore, } \frac{t}{T_{\frac{1}{2}}} = \frac{\log\left(\frac{1}{64}\right)}{\log\left(\frac{1}{2}\right)}$$

$$= 6$$

$$\text{Therefore, } t = 6(5.3 \text{ a})$$

$$= 31.8 \text{ a}\left(\frac{365 \text{ d}}{1 \text{ a}}\right)$$

$$= 1.16 \times 10^4 \text{ d}$$

**58.** $T_{\frac{1}{2}} = 25.0$ d

$m_o = 140$ g

$m = 17.5$ g

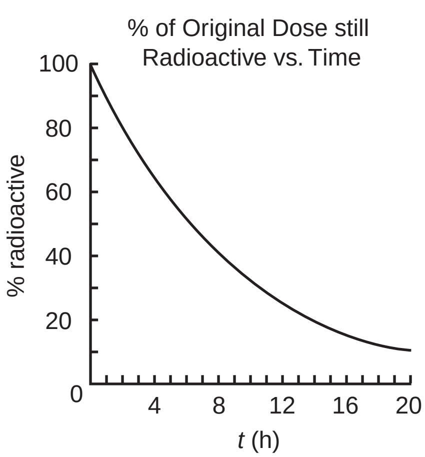
$$t = T_{\frac{1}{2}}\left(\frac{\log\left(\frac{m}{m_o}\right)}{\log\left(\frac{1}{2}\right)}\right)$$

$$t = T_{\frac{1}{2}}\left(\frac{\log\left(\frac{17.5 \text{ g}}{140 \text{ g}}\right)}{\log\left(\frac{1}{2}\right)}\right)$$

$$= (3)25.0 \text{ d}$$

$$= 75.0 \text{ d}$$

**59.**




When $t = 8$ h, 39.7 % of the original dose is still radioactive.

**60.** For carbon-14, $T_{\frac{1}{2}} = 5730$ a. Comparing the relative amount, $N_R$, of a 2000-a relic with the amount, $N_S$, in a shroud suspected of being 2002 a − 1350 a ≈ 650 a, yields:

$$\frac{N_R}{N_S} = \frac{\left(\frac{1}{2}\right)^{\frac{t_R}{T_{\frac{1}{2}}}}}{\left(\frac{1}{2}\right)^{\frac{t_R}{T_{\frac{1}{2}}}}}$$

$$\frac{N_R}{N_S} = \left(\frac{1}{2}\right)^{\frac{2000 \text{ a} - 650 \text{ a}}{5730 \text{ a}}}$$

$$\frac{N_R}{N_S} = 0.85$$

**61.** The half-life of Po-210 is:

$T_{\frac{1}{2}} = 138 \text{ d} = 198\,720$ min

The half-life of Po-218 is $T_{\frac{1}{2}} = 3.1$ min

After 7.0 min, there will be:

$$^{210}\text{Po: } N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}} = \left(\frac{1}{2}\right)^{\frac{7.0 \text{ min}}{198\,720 \text{ min}}}$$

$$\log N = (3.5 \times 10^{-5})\log\frac{1}{2}$$

$$N = 100\,\%$$

$$^{218}\text{Po: } N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}} = \left(\frac{1}{2}\right)^{\frac{7.0 \text{ min}}{3.1 \text{ min}}}$$

$$\log N = (2.26)\log\frac{1}{2}$$

$$N = 20.9\,\%$$

There will be a total of:

$1(1\ \mu\text{g}) + 0.209(1\ \mu\text{g}) = 1.21\ \mu\text{g}$

Therefore, $1.21 \times 10^{-6}$ g of radioactive Po remains.

**62.** If the amount of radioactive material is 23 % of the original amount after 30 d, then,

$$N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$

$$0.23N_0 = N_0\left(\frac{1}{2}\right)^{\frac{30 \text{ d}}{T_{\frac{1}{2}}}}$$

$$\log(0.23) = \left(\frac{30 \text{ d}}{T_{\frac{1}{2}}}\right)\log\left(\frac{1}{2}\right)$$

$$T_{\frac{1}{2}} = \frac{(30 \text{ d})\log\left(\frac{1}{2}\right)}{\log(0.23)}$$

$$T_{\frac{1}{2}} = 14 \text{ d}$$

**63.** The molar amount of $^{235}U$ is $\frac{5.12}{235} = 0.0218$ and of $^{207}Pb$ is $\frac{3.42}{207} = 0.0165$. The original molar amount of $^{235}U$ was $0.0218 + 0.0165 = 0.0383$. Using the decay formula where $T_{\frac{1}{2}} = 7.1 \times 10^8$ a,

$$N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$

$$0.0218 = 0.0383\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$

$$\log\left(\frac{0.0218}{0.0383}\right) = \left(\frac{t}{7.1 \times 10^8 \text{ a}}\right)\log\left(\frac{1}{2}\right)$$

$$t = \frac{\log\left(\frac{0.0218}{0.0383}\right)(7.1 \times 10^8 \text{ a})}{\log\left(\frac{1}{2}\right)}$$

$$t = 5.78 \times 10^8 \text{ a}$$

**64.** Using the activity decay formula where $T_{\frac{1}{2}} = 5730$ a for $^{14}C$ decay,

$$N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$

$$750 = 900\left(\frac{1}{2}\right)^{\frac{t}{5730 \text{ a}}}$$

$$\log\left(\frac{750}{900}\right) = \left(\frac{t}{5730 \text{ a}}\right)\log\left(\frac{1}{2}\right)$$

$$t = \frac{\log\left(\frac{5}{6}\right)(5730 \text{ a})}{\log\left(\frac{1}{2}\right)}$$

$$t = 1507 \text{ a}$$

**65. a)** Recall, $1\ H_2 + 1\ F_2 \rightarrow 2\ HF$

$$2 \text{ kmol HF}\left(\frac{1 \text{ kmol } H_2}{2 \text{ kmol HF}}\right)\left(\frac{1000 \text{ mol}}{1 \text{ kmol}}\right)\left(\frac{500 \text{ kJ}}{\text{mol}}\right)$$

$$= 5.0 \times 10^5 \text{ kJ}$$

**b)** $5.0 \times 10^5 \text{ kJ}\left(\frac{1000 \text{ J}}{1 \text{ kJ}}\right) = 5.0 \times 10^8 \text{ J}$

$$E = mc^2$$

$$m = \frac{E}{c^2}$$

$$= \frac{5.0 \times 10^8 \text{ J}}{(3.0 \times 10^8 \text{ m/s})^2}$$

$$= 5.6 \times 10^{-9} \text{ kg}$$

**c)** $\%_{\text{mass defect}} = \frac{5.6 \times 10^{-9} \text{ kg}}{40 \text{ kg}} \times 100\,\%$

$$= 1.4 \times 10^{-10}\ \%$$

**66. a)** $E = 55$ EJ

$$= 5.5 \times 10^{19} \text{ J}$$

$$E = mc^2$$

$$m = \frac{E}{c^2}$$

$$= \frac{5.5 \times 10^{19} \text{ J}}{(3.0 \times 10^8 \text{ m/s})^2}$$

$$= 6.1 \times 10^2 \frac{\text{kg}}{\text{d}}$$

**b)** $\left(\frac{6.1 \times 10^2 \text{ kg}}{\text{d}}\right)\left(\frac{365 \text{ d}}{\text{a}}\right)$

$$= 2.2 \times 10^5 \text{ kg/a}$$

$$\%_{\text{increase}} = \frac{2.2 \times 10^5 \text{ kg/a}}{6 \times 10^{24} \text{ kg}} \times 100\,\%$$

$$= 3.7 \times 10^{-18}\,\%/\text{a}$$

**67.** At 500 MW + 3(500 MW) heat = 2000 MW of power

number of fission reactions

$$= 2.0 \times 10^3 \text{ MW}\left(\frac{1.0 \times 10^6 \text{ W}}{1 \text{ MW}}\right)\left(\frac{1.0 \text{ J/s}}{1 \text{ W}}\right)\left(\frac{1 \text{ mol}}{100 \text{ J}}\right)$$

$$= \frac{0.0200 \text{ mol}}{\text{s}}$$

$$= \frac{0.0200 \text{ mol}}{\text{s}}\left(\frac{6.023 \times 10^{23} \text{ fissions}}{\text{mol}}\right)$$

$$= 1.20 \times 10^{22} \text{ fissions/s}$$

**68.** At 500 MW + 3(500 MW), heat = 2000 MW of power.

$$E = Pt$$

$$= \frac{2000 \times 10^6 \text{ J}}{\text{s}}\left(\frac{3600 \text{ s}}{1 \text{ h}}\right)\left(\frac{24 \text{ h}}{\text{d}}\right) \times 550 \text{ d}$$

$$= 9.50 \times 10^{16} \text{ J}$$

Therefore, $m = \frac{E}{c^2}$

$$= \frac{9.50 \times 10^{16} \text{ J}}{(3.0 \times 10^8 \text{ m/s})^2}$$

$$= 1.056 \text{ kg}$$

$$\text{fraction converted} = \frac{1.056 \text{ kg}}{70 \text{ kg}} \times 100\,\%$$

$$= 1.5\ \%$$

**69.**

| Aspect | CANDU | American (PWR) |
|---|---|---|
| Fuel | Non-purified/enriched uranium that has been processed into pellets. This fuel requires that heavy water be present in this reactor. | Enriched uranium that has been processed into pellets. Enriched fuel means that regular water may be used instead of heavy water. |
| Refueling | Constantly being refueled while reactor is running. | Reactor is fueled and then run until fuel is spent. The reactor is then shut down for refueling. |
| General operation | Continuous operation | Intermittent operation (refueling) |

**70.** A breeder reactor makes use of excess neutrons by capturing them with a breeding material. For example, when $^{238}$U accepts a neutron, it becomes unstable $^{239}$U, which decays to $^{239}$Pu. These reactors are called breeder reactors because they "breed" a new fuel: $^{239}$Pu from $^{238}$U. The advantages of this process are two-fold. First, the breeding process helps to moderate the initial fission reaction as energy is being generated. Second, the process creates new fuel from an isotope of uranium that could not otherwise be used in nuclear reactions.

**71.** Before the sale of any nuclear technology to other countries, great care must be taken to reduce the risk of that country using the technology in an undesirable fashion. The stability of the government, involvement in political alliances, and human/civil rights record must all come under close scrutiny. CANDU reactors can produce large quantities of cheap electricity to help countries develop socially and economically. However, they could also be used in a political/military power struggle.

**72.** **a)** ${}^{1}_{0}n + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{1}\mathrm{H}$

**b)** Tritium, $^{3}$H, is radioactive. When heavy water is made up of a large quantity of tritium ($^{3}$H) nuclei, it loses its effectiveness as a moderator because the heavy water becomes "poisoned" by a material that becomes more and more radioactive. Even though this radioactive heavy water does not mix with any regular water, it is still circulated about the plant. It poses a risk; therefore, it must be removed.

**73.** With the assumption that there will be a continued increase in the global demand for electrical energy and conservation methods are unsatisfactory, nuclear power may be the only choice for generating electrical energy. Nuclear power provides a concentrated supply of energy wherever it is needed. Alternatives to nuclear power, such as those burning fossil fuels, are too environmentally problematic to establish for the amount of energy that is required. The supply of uranium, although limited, is plentiful.

Controlled nuclear fusion faces many problems that have not been circumvented in the last 10 years of research. Promising cold fusion experiments have not been repeated successfully. The level of technology and the amount of energy required to contain a fusion reaction may not be worth the large quantities of energy that it could produce. Some people also believe that large quantities of cheap electrical energy would be detrimental to the planet.