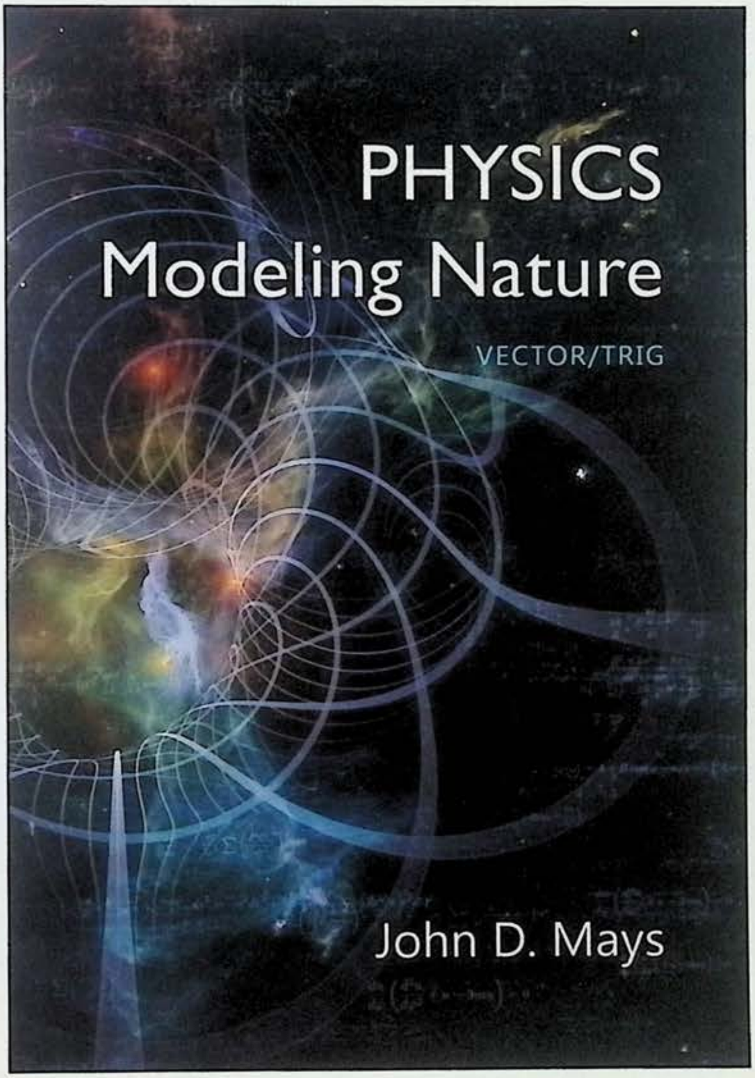
Solutions Manual to Accompany
Physics: Modeling Nature

John D. Mays



Contents

Chapter 1

4. a.

$$35.4\ \text{mm}\cdot\frac{1\ \text{m}}{1000\ \text{mm}}=0.0354\ \text{m}$$

4. b.

$$76.991\ \text{mL}\cdot\frac{1\ \text{L}}{1000\ \text{mL}}\cdot\frac{10^6\ \mu\text{L}}{1\ \text{L}}=776{,}991\ \mu\text{L}$$

4. c.

$$34.44\ \text{cm}^3\cdot\frac{1\ \text{mL}}{1\ \text{cm}^3}\cdot\frac{1\ \text{L}}{1000\ \text{mL}}=0.03444\ \text{L}$$

4. d.

$$6.33\ \frac{\text{g}}{\text{cm}^2}\cdot\frac{1\ \text{kg}}{1000\ \text{g}}\cdot\frac{100\ \text{cm}}{1\ \text{m}}\cdot\frac{100\ \text{cm}}{1\ \text{m}}=63.3\ \frac{\text{kg}}{\text{m}^2}$$

4. e.

$$9.35\ \frac{\text{m}}{\text{s}^2}\cdot\frac{1000\ \text{mm}}{1\ \text{m}}\cdot\frac{1\ \text{s}}{1000\ \text{ms}}\cdot\frac{1\ \text{s}}{1000\ \text{ms}}=0.00935\ \frac{\text{mm}}{\text{ms}^2}$$

4. f.

$$542.2\ \frac{\text{mJ}}{\text{s}}\cdot\frac{1\ \text{J}}{1000\ \text{mJ}}=0.5422\ \frac{\text{J}}{\text{s}}$$

4. g.

$$56.6\ \mu\text{s}\cdot\frac{1\ \text{s}}{10^6\ \mu\text{s}}\cdot\frac{10^3\ \text{ms}}{1\ \text{s}}=0.0566\ \text{ms}$$

4. h.

$$44.19\ \text{mL}\cdot\frac{1\ \text{cm}^3}{1\ \text{mL}}=44.19\ \text{cm}^3$$

4. i.

$$532\ \text{nm}\cdot\frac{1\ \text{m}}{10^9\ \text{nm}}\cdot\frac{10^6\ \mu\text{m}}{1\ \text{m}}=0.532\ \mu\text{m}$$

4. j.

$$96{,}963{,}000\ \frac{\text{mL}}{\text{ms}}\cdot\frac{1\ \text{L}}{1000\ \text{mL}}\cdot\frac{1\ \text{m}^3}{1000\ \text{L}}\cdot\frac{1000\ \text{ms}}{1\ \text{s}}=96{,}963\ \frac{\text{m}^3}{\text{s}}$$

4. k.

$$295.6\text{ cL}\cdot\frac{1\text{ L}}{100\text{ cL}}\cdot\frac{10^6\ \mu\text{L}}{\text{L}}=2{,}956{,}000\ \mu\text{L}$$

4. l.

$$0.007873\text{ m}^3\cdot\frac{100\text{ cm}}{1\text{ m}}\cdot\frac{100\text{ cm}}{1\text{ m}}\cdot\frac{100\text{ cm}}{1\text{ m}}\cdot\frac{1\text{ mL}}{1\text{ cm}^3}=7873\text{ mL}$$

4. m.

$$8750\text{ mm}^2\cdot\frac{1\text{ m}}{1000\text{ mm}}\cdot\frac{1\text{ m}}{1000\text{ mm}}=0.00875\text{ m}^2$$

4. n.

$$87.1\ \frac{\text{cm}}{\text{s}^2}\cdot\frac{1\text{ m}}{100\text{ cm}}=0.871\ \frac{\text{m}}{\text{s}^2}$$

4. o.

$$15.75\ \frac{\text{kg}}{\text{m}^3}\cdot\frac{1000\text{ g}}{1\text{ kg}}\cdot\frac{1\text{ m}}{100\text{ cm}}\cdot\frac{1\text{ m}}{100\text{ cm}}\cdot\frac{1\text{ m}}{100\text{ cm}}=0.01575\ \frac{\text{g}}{\text{cm}^3}$$

4. p.

$$0.875\text{ km}\cdot\frac{1000\text{ m}}{1\text{ km}}=875\text{ m}$$

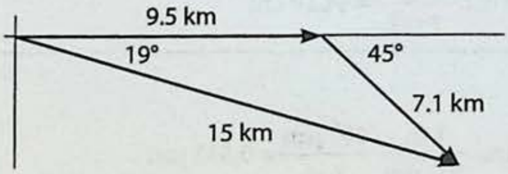
4. q.

$$16{,}056\text{ MPa}\cdot\frac{10^6\text{ Pa}}{1\text{ MPa}}\cdot\frac{1\text{ kPa}}{10^3\text{ Pa}}=16{,}056{,}000\text{ kPa}$$

4. r.

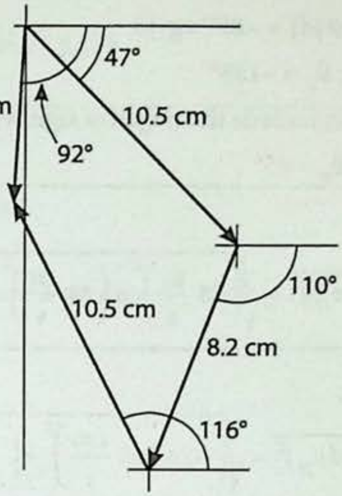
$$7845\ \mu\text{A}\cdot\frac{1\text{ A}}{10^6\ \mu\text{A}}\cdot\frac{1000\text{ mA}}{1\text{ A}}=7.845\text{ mA}$$

16.



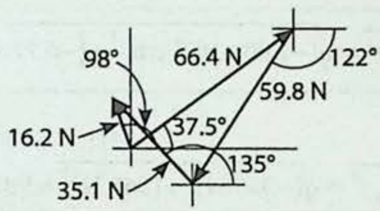
magnitude = 15 km, direction, –19°

17.



magnitude = 6.0 cm, direction, −92°

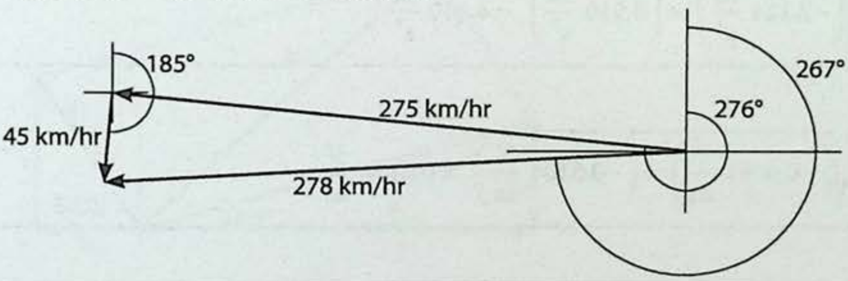
18.



magnitude = 16.2 N, direction, 98°

19.

magnitude = 278 km/hr, bearing, 267°



20. a.

$(4.31 \times 10^{-26}\ \text{kg}) \cdot (2.994 \times 10^{6}\ \text{m/s}) = 1.29 \times 10^{-19}\ \text{kg} \cdot \text{m/s}$

$p = 1.29 \times 10^{-19}\ \text{kg} \cdot \text{m/s},\ \theta_p = 23°$

20. b.

$-(2.25 \times 10^{-6}\ \text{C}) \cdot (19.95\ \text{V/m}) = -4.49 \times 10^{-5}\ \text{N}$

$F = -4.49 \times 10^{-5}\ \text{N},\ \theta_F = 161°$

Re-expressing to include the negative sign with the angle, $\theta_F = 161° - 180° = -19°$

$F = 4.49 \times 10^{-5}\ \text{N},\ \theta_F = -19°$

20. c.

$-(15.5\ \text{xg})\cdot(57.9\ \text{jd}) = -897\ \text{xg}\cdot\text{jd}$

$R = -897\ \text{xg}\cdot\text{jd},\ \theta_R = -135°$

Re-expressing to include the negative sign with the angle, $\theta_R = -135° + 180° = 45°$

$R = 897\ \text{xg}\cdot\text{jd},\ \theta_R = 45°$

21. a.

$$|\mathbf{v}| = \sqrt{(v_{1x})^2 + (v_{1y})^2} = \sqrt{\left(25\ \frac{\text{m}}{\text{s}}\right)^2 + \left(14\ \frac{\text{m}}{\text{s}}\right)^2} = 29\ \frac{\text{m}}{\text{s}}$$

21. b.

$$|\mathbf{v}_f| = \sqrt{(v_{fx})^2 + (v_{fy})^2} = \sqrt{\left(-24.765\ \frac{\text{cm}}{\text{s}}\right)^2 + \left(-67.001\ \frac{\text{cm}}{\text{s}}\right)^2} = 71.431\ \frac{\text{cm}}{\text{s}}$$

21. c.

$$|\mathbf{d}| = \sqrt{(d_x)^2 + (d_y)^2} = \sqrt{\left(-1.00\times10^{-3}\ \text{cm}\right)^2 + \left(-6.77\times10^{-4}\ \text{cm}\right)^2} = 0.00121\ \text{cm}$$

21. d.

$$|\mathbf{F}_1| = \sqrt{(F_{1x})^2 + (F_{1y})^2} = \sqrt{(-355\ \text{N})^2 + (865\ \text{N})^2} = 935\ \text{N}$$

21. e.

$$|\mathbf{a}| = \sqrt{(a_x)^2 + (a_y)^2} = \sqrt{\left(-2.124\ \frac{\text{m}}{\text{s}^2}\right)^2 + \left(3.910\ \frac{\text{m}}{\text{s}^2}\right)^2} = 4.450\ \frac{\text{m}}{\text{s}^2}$$

21. f.

$$|\mathbf{E}| = \sqrt{(E_x)^2 + (E_y)^2} = \sqrt{\left(-0.0091\ \frac{\text{V}}{\text{m}}\right)^2 + \left(-0.0104\ \frac{\text{V}}{\text{m}}\right)^2} = 0.0138\ \frac{\text{V}}{\text{m}}$$

22. a.

$$\theta_{v1} = \tan^{-1}\frac{v_{1y}}{v_{1x}} = \tan^{-1}\left(\frac{14\ \frac{\text{m}}{\text{s}}}{25\ \frac{\text{m}}{\text{s}}}\right) = 29°$$

22. b.

$$\theta_{vf} = \tan^{-1}\frac{v_{fy}}{v_{fx}} - 180° = \tan^{-1}\left(\frac{-67.001\ \frac{\text{cm}}{\text{s}}}{-24.765\ \frac{\text{cm}}{\text{s}}}\right) - 180° = -110.29°$$

22. c.

$$\theta_d = \tan^{-1}\frac{d_y}{d_x} - 180° = \tan^{-1}\left(\frac{-6.77\times10^{-4}\text{ cm}}{-1.00\times10^{-3}\text{ cm}}\right) - 180° = -34.1°$$

---

22. d.

$$\theta_{F1} = \tan^{-1}\frac{F_{1y}}{F_{1x}} + 180° = \tan^{-1}\left(\frac{865\text{ N}}{-355\text{ N}}\right) + 180 = 112.3°$$

Note that prior to adding 180°, the result should have 3 sig digs. By adding 180 we gain a digit of precision.

---

22. e.

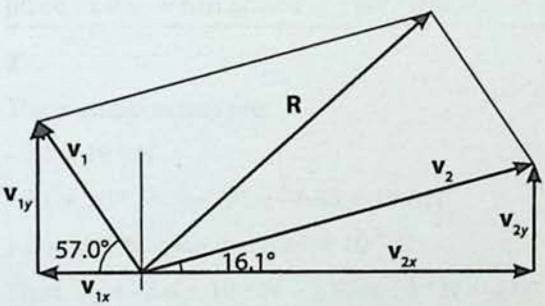
$$\theta_a = \tan^{-1}\frac{a_y}{a_x} + 180° = \tan^{-1}\left(\frac{3.910\ \frac{\text{m}}{\text{s}^2}}{-2.124\ \frac{\text{m}}{\text{s}^2}}\right) + 180 = 118.51°$$

---

22. f.

$$\theta_E = \tan^{-1}\frac{E_y}{E_x} - 180° = \tan^{-1}\left(\frac{-0.0104\ \frac{\text{V}}{\text{m}}}{-0.0091\ \frac{\text{V}}{\text{m}}}\right) - 180 = -131°$$

23.



$v_{1x} = -(45.6\text{ cm/s})\cdot\cos 57.0° = -24.84\text{ cm/s}$ $\quad v_{1y} = (45.6\text{ cm/s})\cdot\sin 57.0° = 38.24\text{ cm/s}$

$v_{2x} = (98.1\text{ cm/s})\cdot\cos 16.1° = 94.25\text{ cm/s}$ $\quad v_{2y} = (98.1\text{ cm/s})\cdot\sin 16.1° = 27.20\text{ cm/s}$

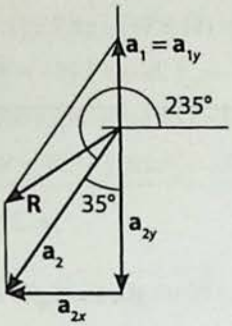
$R_x = v_{1x} + v_{2x} = -24.84\text{ cm/s} + 94.25\text{ cm/s} = 69.41\text{ cm/s}$

$R_y = v_{1y} + v_{2y} = 38.24\text{ cm/s} + 27.20\text{ cm/s} = 65.44\text{ cm/s}$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{\left(69.41\ \frac{\text{cm}}{\text{s}}\right)^2 + \left(65.44\ \frac{\text{cm}}{\text{s}}\right)^2} = 95.4\text{ cm/s}$$

$$\theta_R = \tan^{-1}\frac{R_y}{R_x} = \tan^{-1}\left(\frac{65.44}{69.41}\right) = 43.3°$$

24.



$a_{1x} = 0 \quad a_{1y} = 45.0 \text{ m/s}^2$

$a_{2x} = -(100.7 \text{ m/s}^2) \cdot \sin 35° = -57.76 \text{ m/s}^2 \qquad a_{2y} = -(100.7 \text{ m/s}^2) \cdot \cos 35° = -82.49 \text{ m/s}^2$

$R_x = a_{1x} + a_{2x} = 0 - 57.76 \text{ m/s}^2 = -57.76 \text{ m/s}^2$

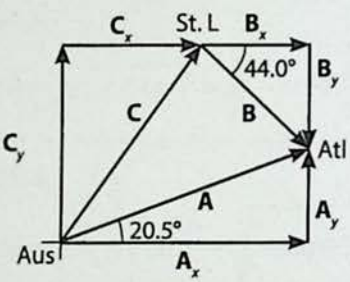
$R_y = a_{1y} + a_{2y} = 45.0 - 82.49 \text{ m/s}^2 = -37.49 \text{ m/s}^2$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{\left(-57.76 \ \frac{\text{m}}{\text{s}^2}\right)^2 + \left(-37.49 \ \frac{\text{m}}{\text{s}^2}\right)^2} = 68.9 \text{ m/s}^2$$

$$\theta_R = \tan^{-1}\frac{R_y}{R_x} + 180° = \tan^{-1}\left(\frac{37.49}{57.76}\right) + 180° = 213°$$

25.

Let Austin to Atlanta vector = A, St. Louis to Atlanta vector = B, Austin to St. Louis vector = C



$\mathbf{C} + \mathbf{B} = \mathbf{A}$, thus $\mathbf{C} = \mathbf{A} - \mathbf{B}$

$A_x = 1319 \text{ km} \cdot \cos 20.5° = 1235 \text{ km} \qquad A_y = 1319 \text{ km} \cdot \sin 20.5° = 462 \text{ km}$

$B_x = 753 \text{ km} \cdot \cos 44.0° = 542 \text{ km} \qquad B_y = -753 \text{ km} \cdot \sin 44.0° = -523 \text{ km}$

$C_x = A_x - B_x = 1235 \text{ km} - 542 \text{ km} = 693 \text{ km}$

$C_y = A_y - B_y = 462 \text{ km} - (-523 \text{ km}) = 985 \text{ km}$

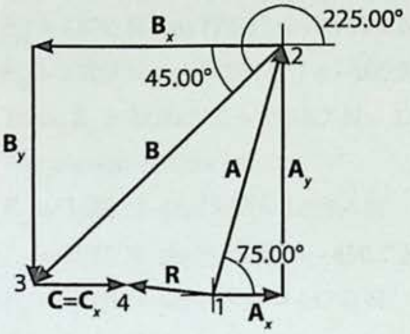
$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{(693 \text{ km})^2 + (985 \text{ km})^2} = 1204 \text{ km}$$

$$\theta_C = \tan^{-1}\frac{C_y}{C_x} = \tan^{-1}\left(\frac{693}{985}\right) = 35.1°$$

Note that when calculating *C*, the sum under the radical has four sig digs, allowing us to keep four digits in the magnitude of *C*.

26.

Let vector from 1 to 2 = **A**, from 2 to 3 = **B**, and from 3 to 4 = **C**



$A_x = 13.00\text{ cm}\cdot\cos 75.00° = 3.3646\text{ cm}$ $\qquad A_y = 13.00\text{ cm}\cdot\sin 75.00° = 12.557\text{ cm}$

$B_x = -17.00\text{ cm}\cdot\cos 45.00° = -12.021\text{ cm}$ $\qquad B_y = -17.00\text{ cm}\cdot\sin 45.00° = -12.021\text{ cm}$

$C_x = 4.50\text{ cm}$ $\qquad C_y = 0$

$R_x = A_x + B_x + C_x = 3.3646\text{ cm} - 12.021\text{ cm} + 4.50\text{ cm} = -4.156\text{ cm}$

$R_y = A_y + B_y = 12.557\text{ cm} - 12.021\text{ cm} = 0.536\text{ cm}$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(-4.156\text{ cm})^2 + (0.536\text{ cm})^2} = 4.19\text{ cm}$$

$$\theta_R = \tan^{-1}\frac{R_y}{R_x} + 180° = \tan^{-1}\left(-\frac{0.536}{4.156}\right) + 180° = -7.35° + 180° = 172.7°$$

Note that the −7.35° still carries an extra digit of precision. With two digits, it has one decimal place, and so when added to 180° (which is exact), results in an angle with one decimal place.

27.

The *x*-components are:

$-3.4 \times 10^{-6}\text{ N}$

$-3.2 \times 10^{-6}\text{ N}\cdot\cos 59° = -1.65 \times 10^{-6}\text{ N}$

$1.2 \times 10^{-6}\text{ N}\cdot\cos 67° = 4.69 \times 10^{-7}\text{ N}$

Thus, $R_x = -3.4 \times 10^{-6}\text{ N} - 1.65 \times 10^{-6}\text{ N} + 4.69 \times 10^{-7}\text{ N} = -4.58 \times 10^{-6}\text{ N}$

The *y*-components are:

0

$3.2 \times 10^{-6}\text{ N}\cdot\sin 59° = 2.74 \times 10^{-6}\text{ N}$

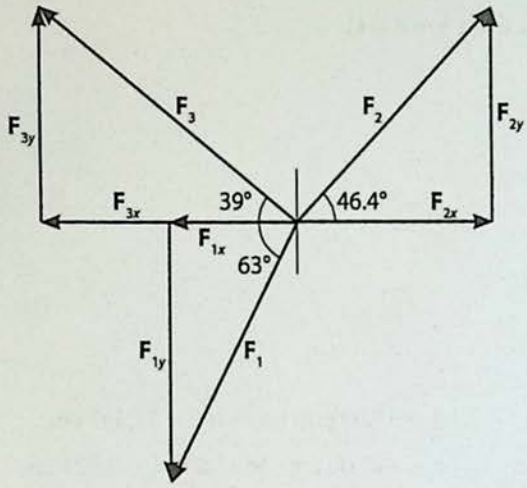
$1.2 \times 10^{-6}\text{ N}\cdot\sin 67° = 1.11 \times 10^{-6}\text{ N}$

Thus, $R_y = 2.74 \times 10^{-6}\text{ N} + 1.11 \times 10^{-6}\text{ N} = 3.85 \times 10^{-6}\text{ N}$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{\left(-4.58\times10^{-6}\text{ N}\right)^2 + \left(3.85\times10^{-6}\text{ N}\right)^2} = 6.0\times10^{-6}\text{ N}$$

$$\theta_R = \tan^{-1}\frac{R_y}{R_x} + 180° = \tan^{-1}\left(-\frac{3.85}{4.8}\right) + 180° = -40.0° + 180° = 1.40\times10^2\text{ degrees}$$

28.



The x-components are:

$F_{1x} = -72.1\text{ N}\cdot\cos 63° = -32.73\text{ N}$

$F_{2x} = 73.0\text{ N}\cdot\cos 46.4° = 50.34\text{ N}$

$F_{3x} = -84.2\text{ N}\cdot\cos 39° = -65.44\text{ N}$

Thus, $R_x = -32.73\text{ N} + 50.34\text{ N} - 65.44\text{ N} = -47.83\text{ N}$

The y-components are:

$F_{1y} = -72.1\text{ N}\cdot\sin 63° = -64.24\text{ N}$

$F_{2y} = 73.0\text{ N}\cdot\sin 46.4° = 52.86\text{ N}$

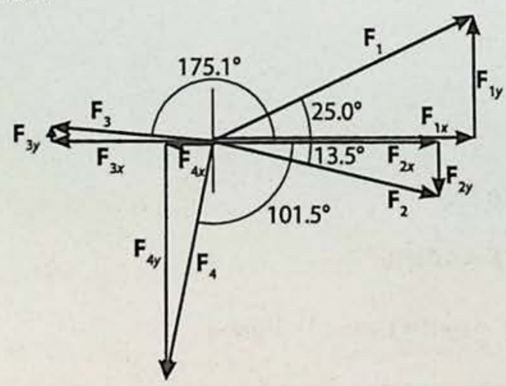
$F_{3y} = 84.2\text{ N}\cdot\sin 39° = 52.99\text{ N}$

Thus, $R_y = -64.24\text{ N} + 52.86\text{ N} + 52.99\text{ N} = 41.61\text{ N}$

$$R=\sqrt{R_x^2+R_y^2}=\sqrt{(-47.83\text{ N})^2+(41.61\text{ N})^2}=63.4\text{ N}$$

$$\theta_R=\tan^{-1}\frac{R_y}{R_x}+180°=\tan^{-1}\left(-\frac{41.61}{47.83}\right)+180°=-41.0°+180°=139°$$

29.



The x-components are:

$F_{1x} = 2450 \text{ N} \cdot \cos 25.0° = 2220.5 \text{ N}$

$F_{2x} = 1965 \text{ N} \cdot \cos(-13.5°) = 1910.7 \text{ N}$

$F_{3x} = 1370 \text{ N} \cdot \cos 175.1° = -1365.0 \text{ N}$

$F_{4x} = 2009 \text{ N} \cdot \cos(-101.5°) = -400.5 \text{ N}$

Thus, $R_x = 2220.5 \text{ N} + 1910.7 \text{ N} - 1365.0 \text{ N} - 400.5 \text{ N} = 2365.7 \text{ N}$

The *y*-components are:

$F_{1y} = 2450 \text{ N} \cdot \sin 25.0° = 1035.4 \text{ N}$

$F_{2y} = 1965 \text{ N} \cdot \sin(-13.5°) = -458.7 \text{ N}$

$F_{3y} = 1370 \text{ N} \cdot \sin 175.1° = 117.0 \text{ N}$

$F_{4y} = 2009 \text{ N} \cdot \sin(-101.5°) = -1968.7 \text{ N}$

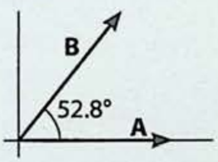
Thus, $R_y = 1035.4 \text{ N} - 458.7 \text{ N} + 117.0 \text{ N} - 1968.7 \text{ N} = -1275.0 \text{ N}$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(2365.7 \text{ N})^2 + (-1275.0 \text{ N})^2} = 2690 \text{ N}$$

$$\theta_R = \tan^{-1}\frac{R_y}{R_x} = \tan^{-1}\left(-\frac{1275.0 \text{ N}}{2365.7 \text{ N}}\right) = -28.3°$$

---

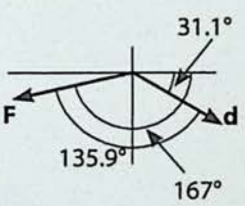
30. a.



$\mathbf{A} \cdot \mathbf{B} = AB\cos\theta = (14.6 \text{ N})(16.0 \text{ m})\cos 52.8° = 141 \text{ N} \cdot \text{m}$

---

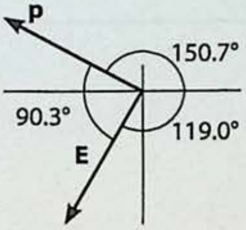
30. b.



$W = \mathbf{F} \cdot \mathbf{d} = Fd\cos\theta = (9.21 \times 10^4 \text{ N})(4.021 \times 10^{-5} \text{ m})\cos 135.9° = -2.66 \text{ N} \cdot \text{m}$

---

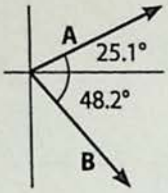
30. c.



$U = -\mathbf{p} \cdot \mathbf{E} = -pE\cos\theta = -(0.0258 \text{ m} \cdot \text{C})(6.02 \times 10^4 \text{ N/C})\cos 90.3° = 8.13 \text{ m} \cdot \text{N}$

(I wrote the units as they would appear they should be written from the problem statement. But actually, more advanced physics students might recognize that this is an actual equation in which the variable U represents potential energy, which has units of $N \cdot m$ or J.)

31. a.



$|\mathbf{A} \times \mathbf{B}| = AB\sin\theta = (53.2\ \text{m})(16.0\ \text{N})\sin 73.3° = 815\ \text{m} \cdot \text{N}$

The direction of $\mathbf{A} \times \mathbf{B}$ is into the page.

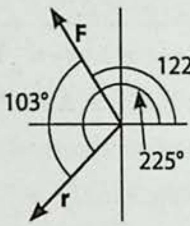
31. b.

Since these are the same vectors as in 31. a.

$|\mathbf{B} \times \mathbf{A}| = |\mathbf{A} \times \mathbf{B}| = 815\ \text{m} \cdot \text{N}$

The direction of $|\mathbf{B} \times \mathbf{A}|$ is out of the page.

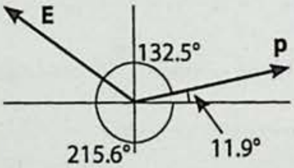
31. c.



$\tau = |\mathbf{r} \times \mathbf{F}| = rF\sin\theta = (0.0234\ \text{m})(6.18 \times 10^{-5}\ \text{N})\sin 103° = 1.41 \times 10^{-6}\ \text{m} \cdot \text{N}$

The direction of τ is into the page.

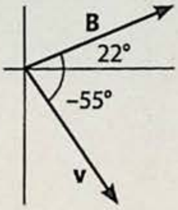
31. d.



$\tau = |\mathbf{p} \times \mathbf{E}| = pE\sin\theta = (1.75 \times 10^{-3}\ \text{m} \cdot \text{C})(4.96 \times 10^{5}\ \text{N/C})\sin 132.5° = 6.40 \times 10^{2}\ \text{m} \cdot \text{N}$

The result is written in scientific notation because three sig digs are required. The direction of τ is out of the page.

32.



For a proton, $q = +1.60 \times 10^{-19}$ C. Thus,

$|\mathbf{F}| = q(|\mathbf{v} \times \mathbf{B}|) = qvB\sin\theta = (1.60 \times 10^{-19}\text{ C})(750\text{ m/s})(0.15\text{ T})\sin 77° = 1.8 \times 10^{-17}\text{ N}$

The direction of **F** is out of the page.

For an electron, $q = -1.60 \times 10^{-19}$ C. The negative sign reverses the direction of **F**, so the magnitude of **F** is the same, but the direction is into the page.

Chapter 2

2.

$d = 541\text{ mi}$

$t = 7\text{ hr }52\text{ min} = 7.87\text{ hr}$

$v = ?$

$d = vt$

$$v = \frac{d}{t} = \frac{541\text{ mi}}{7.87\text{ hr}} = 68.7\text{ mi/hr}$$

3.

$$d = 36.55\text{ cm} \cdot \frac{1\text{ m}}{100\text{ cm}} = 0.3655\text{ m}$$

$$v = 2.9979 \times 10^8\ \frac{\text{m}}{\text{s}}$$

$t = ?$

$d = vt$

$$t = \frac{d}{v} = \frac{0.3655\text{ m}}{2.9979 \times 10^8\ \frac{\text{m}}{\text{s}}} = 1.219 \times 10^{-9}\text{ s} \cdot \frac{10^9\text{ ns}}{1\text{ s}} = 1.219\text{ ns}$$

4.

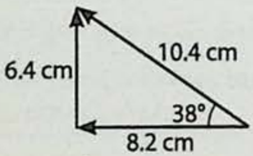
$d = 8.2\text{ cm} + 6.4\text{ cm} = 14.6\text{ cm}$

$t = 4.5\text{ s}$

$d = vt$

$$v = \frac{d}{t} = \frac{14.6\text{ cm}}{4.5\text{ s}} = 3.2\text{ cm/s}$$

The displacement vector has a magnitude of 10.4 cm at an angle of 38° above the negative x-axis.



From Equation (2.1) and comments after Equation (2.3),

$$\overline{v} = \frac{\Delta d}{t}$$

Thus the magnitude of the average velocity is 10.4 cm/4.5 s = 2.3 cm/s. The direction is the same as the direction of the displacement vector, 38° above the negative x-axis.

5.

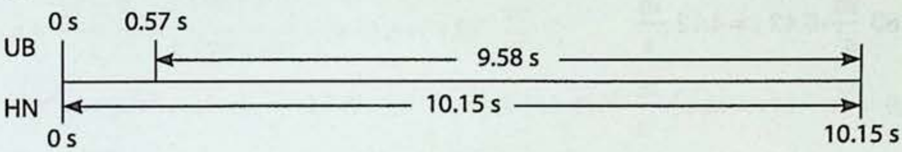
a. $\overline{v} = \frac{\Delta d}{\Delta t} = \frac{10.0\text{ cm} - 4.0\text{ cm}}{6.0\text{ s} - 3.0\text{ s}} = 2.0\text{ cm/s}$

b. $\overline{v} = \frac{\Delta d}{\Delta t} = \frac{10.0\text{ cm} - 10.0\text{ cm}}{9.0\text{ s} - 6.0\text{ s}} = 0.0\text{ cm/s}$

c. $\overline{v} = \frac{\Delta d}{\Delta t} = \frac{6.0\text{ cm} - 0.0\text{ cm}}{10.0\text{ s} - 0.0\text{ s}} = 0.60\text{ cm/s}$

d. $\overline{v} = \frac{\Delta d}{\Delta t} = \frac{10.0\text{ cm} - 4.0\text{ cm}}{6.0\text{ s} - 5.0\text{ s}} = 6.0\text{ cm/s}$

8.



Neal needs a 0.57 s head start.

9.

Instantaneous velocity is equal to slope of a *d* vs. *t* graph. Velocities are:

A: –80 m/2 min = –40 m/min

B: 0

C: 40 m/1 min = 40 m/min

Overall: Magnitude of displacement is 0 m, so average velocity is d/t = 0 m/11 min = 0 m/min.

10.

Instantaneous velocity is equal to slope of a line tangent to the *d* vs. *t* graph.

A: 15.0 m/1.0 s = 15 m/s

B: $\frac{17.5\text{ m} - 7.5\text{ m}}{8.0\text{ s} - 4.0\text{ s}} = 2.5\text{ m/s}$

Average velocity is displacement over time: 5.0 m/8.0 s = 0.625 m/s (or 0.63 m/s with two sig digs).

11.

a) Acceleration is equal to slope on a **v** vs. *t* graph.

First interval: 0 m/s^2

Second interval: $v = \frac{\Delta d}{\Delta t} = \frac{10.0\text{ m/s} - 15.0\text{ m/s}}{4.0\text{ s} - 2.0\text{ s}} = -2.5\text{ m/s}^2$

Third interval: 0 m/s^2

Fourth interval: $v = \frac{\Delta d}{\Delta t} = \frac{20.0\text{ m/s} - 10.0\text{ m/s}}{10.0\text{ s} - 7.0\text{ s}} = 3.3\text{ m/s}^2$

b) $v_{av} = \frac{10\ \frac{\text{m}}{\text{s}} + 20\ \frac{\text{m}}{\text{s}}}{2} = 15\ \frac{\text{m}}{\text{s}}$

c) At $t = 2$ s, $v = 15.0$ m/s. At $t = 8.5$ s, $v = 15.0$ m/s.

12.

Orienting the coordinate system so that down is positive:

$$a = g = 9.80\ \frac{\text{m}}{\text{s}^2}$$

$$t = 0.42\ \text{s}$$

$$v_0 = 0$$

$$d = ?$$

$$v_f = ?$$

$$v_f = v_0 + at = 0 + 9.80\ \frac{\text{m}}{\text{s}^2} \cdot 0.42\ \text{s} = 4.12\ \frac{\text{m}}{\text{s}}$$

$$\boxed{v_f = 4.1\ \frac{\text{m}}{\text{s}}}$$

$$d = \cancel{v_0 t} + \tfrac{1}{2}at^2 = \tfrac{1}{2} \cdot 9.80\ \frac{\text{m}}{\text{s}^2} \cdot (0.42\ \text{s})^2 = 0.86\ \text{m}$$

13.

$$v_0 = 15\ \frac{\text{km}}{\text{hr}} \cdot \frac{1000\ \text{m}}{1\ \text{km}} \cdot \frac{1\ \text{hr}}{3600\ \text{s}} = 4.17\ \frac{\text{m}}{\text{s}}$$

$$v_f = 24.5\ \frac{\text{km}}{\text{hr}} \cdot \frac{1000\ \text{m}}{1\ \text{km}} \cdot \frac{1\ \text{hr}}{3600\ \text{s}} = 6.81\ \frac{\text{m}}{\text{s}}$$

$$t = 37.5\ \text{s}$$

$$a = ?$$

$$v_f = v_0 + at$$

$$a = \frac{v_f - v_0}{t} = \frac{6.81\ \frac{\text{m}}{\text{s}} - 4.17\ \frac{\text{m}}{\text{s}}}{37.5\ \text{s}} = 0.070\ \text{m/s}^2$$

14.

$v_0 = 351.1\ \frac{\text{m}}{\text{s}}$

$v_f = 0$

$t = 227.9\ \mu\text{s} \cdot \frac{1\ \text{s}}{10^6\ \mu\text{s}} = 2.279 \times 10^{-4}\ \text{s}$

$a = ?$

$d = ?$

$v_f = v_0 + at$

$$a = \frac{\cancel{v_f} - v_0}{t} = \frac{-351.1\ \frac{\text{m}}{\text{s}}}{2.279 \times 10^{-4}\ \text{s}} = -1.541 \times 10^6\ \frac{\text{m}}{\text{s}^2}$$

$$d = v_0 t + \tfrac{1}{2}at^2 = 351.1\ \frac{\text{m}}{\text{s}} \cdot 2.279 \times 10^{-4}\ \text{s} - \tfrac{1}{2} \cdot 1.541 \times 10^6\ \frac{\text{m}}{\text{s}^2} \cdot \left(2.279 \times 10^{-4}\ \text{s}\right)^2 = 0.039997\ \text{m}$$

$d = 4.000\ \text{cm}$

15.

Orienting the coordinate system so that up is positive:

$v_0 = 67.01\ \frac{\text{m}}{\text{s}}$

$a = -g = -9.80\ \frac{\text{m}}{\text{s}^2}$

$v_f = 0$

$d = ?$

$t = ?$

$v_f^2 = v_0^2 + 2ad$

$$d = \frac{\cancel{v_f^2} - v_0^2}{2a} = \frac{-\left(67.01\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-9.80\ \frac{\text{m}}{\text{s}^2}\right)} = 229\ \text{m}$$

$v_f = v_0 + at$

$$t = \frac{\cancel{v_f} - v_0}{a} = \frac{-67.01\ \frac{\text{m}}{\text{s}}}{-9.80\ \frac{\text{m}}{\text{s}^2}} = 6.84\ \text{s}$$

16.

Parts a and b:

$d = 300.0\text{ m}$

$t = 3.70\text{ s}$

$v_0 = 0$

$a = ?$

$v_f = ?$

$d = \cancel{v_0 t} + \frac{1}{2}at^2$

$$a = \frac{2d}{t^2} = \frac{2 \cdot 300.0\text{ m}}{(3.70\text{ s})^2} = 43.83\ \frac{\text{m}}{\text{s}^2}$$

$$\boxed{a = 43.8\ \frac{\text{m}}{\text{s}^2}}$$

$$v_f = \cancel{v_0} + at = 43.83\ \frac{\text{m}}{\text{s}^2} \cdot 3.70\text{ s} = 162\ \frac{\text{m}}{\text{s}}$$

Part c:

$t = 10.0\text{ s}$

$a = 43.83\ \frac{\text{m}}{\text{s}^2}$

$$v_f = \cancel{v_0} + at = 43.83\ \frac{\text{m}}{\text{s}^2} \cdot 10.0\text{ s} = 438\ \frac{\text{m}}{\text{s}}$$

17.

$a = 15{,}300{,}000\ \frac{\text{m}}{\text{s}^2}$

$t = 75\ \mu\text{s} \cdot \frac{1\text{ s}}{10^6\ \mu\text{s}} = 7.5 \times 10^{-5}\text{ s}$

$v_0 = 0$

$v_f = ?$

$$v_f = \cancel{v_0} + at = 15{,}300{,}000\ \frac{\text{m}}{\text{s}^2} \cdot 7.5 \times 10^{-5}\text{ s} = 1100\ \frac{\text{m}}{\text{s}}$$

18.

$v_0 = 0$

$v_f = 0.610 \cdot 2.9979 \times 10^8 \ \frac{\text{m}}{\text{s}} = 1.829 \times 10^8 \ \frac{\text{m}}{\text{s}}$

$d = 26.33 \text{ cm} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = 0.2633 \text{ m}$

$a = ?$

$t = ?$

$v_f^2 = v_0^2 + 2ad$

$$a = \frac{v_f^2 - \cancel{v_0^2}}{2d} = \frac{\left(1.829 \times 10^8 \ \frac{\text{m}}{\text{s}}\right)^2}{2 \cdot 0.2633 \text{ m}} = 6.353 \times 10^{16} \ \frac{\text{m}}{\text{s}^2}$$

$$\boxed{a = 6.35 \times 10^{16} \ \frac{\text{m}}{\text{s}^2}}$$

$v_f = v_0 + at$

$$t = \frac{v_f - \cancel{v_0}}{a} = \frac{1.829 \times 10^8 \ \frac{\text{m}}{\text{s}}}{6.353 \times 10^{16} \ \frac{\text{m}}{\text{s}^2}} = 2.88 \times 10^{-9} \text{ s} \cdot \frac{10^9 \text{ ns}}{1 \text{ s}} = 2.88 \text{ ns}$$

19.

$d = 16.5 \text{ m}$

$a = g = 9.80 \ \frac{\text{m}}{\text{s}^2}$

$v_0 = 12.85 \ \frac{\text{m}}{\text{s}}$

$t = ?$

$v_f = ?$

$v_f^2 = v_0^2 + 2ad$

$$v_f = \sqrt{v_0^2 + 2ad} = \sqrt{\left(12.85 \ \frac{\text{m}}{\text{s}}\right)^2 + 2 \cdot 9.80 \ \frac{\text{m}}{\text{s}^2} \cdot 16.5 \text{ m}} = 22.10 \ \frac{\text{m}}{\text{s}}$$

$$\boxed{v_f = 22.1 \ \frac{\text{m}}{\text{s}}}$$

$v_f = v_0 + at$

$$t = \frac{v_f - v_0}{a} = \frac{22.10 \ \frac{\text{m}}{\text{s}} - 12.85 \ \frac{\text{m}}{\text{s}}}{9.80 \ \frac{\text{m}}{\text{s}^2}} = 0.944 \text{ s}$$

20.

First, solve for the height using half the total time:

$t = 3.6 \text{ s}$

$v_f = 0$

$a = -g = -9.80 \dfrac{\text{m}}{\text{s}^2}$

$d = ?$

$v_f = v_0 + at$

$$v_0 = \cancel{v_f} - at = -\left(-9.80 \frac{\text{m}}{\text{s}^2}\right) \cdot 3.6 \text{ s} = 35.3 \frac{\text{m}}{\text{s}}$$

$$d = v_0 t + \tfrac{1}{2} a t^2 = 35.3 \frac{\text{m}}{\text{s}} \cdot 3.6 \text{ s} - \tfrac{1}{2}\left(9.80 \frac{\text{m}}{\text{s}^2}\right)(3.6 \text{ s})^2 = 64 \text{ m}$$

Using symmetry, the velocity when the catcher catches the ball has the same magnitude as the initial velocity, thus $v_f = -35$ m/s.

21.

Parts a and b:

$d = -6.25 \text{ m}$

$a = -g = -9.80 \dfrac{\text{m}}{\text{s}^2}$

$v_0 = 19.05 \dfrac{\text{m}}{\text{s}}$

$v_f = ?$

$t = ?$

$v_f^2 = v_0^2 + 2ad$

$$v_f = \sqrt{v_0^2 + 2ad} = \sqrt{\left(19.05 \frac{\text{m}}{\text{s}}\right)^2 + 2\left(-9.80 \frac{\text{m}}{\text{s}^2}\right)(-6.25 \text{ m})} = -22.03 \frac{\text{m}}{\text{s}}$$

Note: There are always +/− roots to a radical. Since the ball is going down when it hits the ground, we know to take the negative root for v_f.

$$\boxed{v_f = -22.0 \frac{\text{m}}{\text{s}}}$$

$v_f = v_0 + at$

$$t = \frac{v_f - v_0}{a} = \frac{-22.03 \frac{\text{m}}{\text{s}} - 19.05 \frac{\text{m}}{\text{s}}}{-9.80 \frac{\text{m}}{\text{s}^2}} = 4.19 \text{ s}$$

Part c:

For this part, use v_0 and set $v_f = 0$.

$$a = -g = -9.80\ \frac{\text{m}}{\text{s}^2}$$

$$v_0 = 19.05\ \frac{\text{m}}{\text{s}}$$

$$v_f = 0$$

$$d = ?$$

$$v_f^2 = v_0^2 + 2ad$$

$$d = \frac{\cancel{v_f^2} - v_0^2}{2a} = \frac{-\left(19.05\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-9.80\ \frac{\text{m}}{\text{s}^2}\right)} = 18.5\ \text{m}$$

This is the height above where the boy throws the ball. The maximum height above the ground is this value plus his height:

18.5 m + 6.25 m = 24.8 m

22.

$$v_0 = 68.5\ \frac{\text{mi}}{\text{hr}} \cdot \frac{1609\ \text{m}}{\text{mi}} \cdot \frac{1\ \text{hr}}{3600\ \text{s}} = 30.62\ \frac{\text{m}}{\text{s}}$$

$$d = 37.2\ \text{m}$$

$$v_f = 47.7\ \frac{\text{mi}}{\text{hr}} \cdot \frac{1609\ \text{m}}{\text{mi}} \cdot \frac{1\ \text{hr}}{3600\ \text{s}} = 21.32\ \frac{\text{m}}{\text{s}}$$

$$a = ?$$

$$t = ?$$

$$v_f^2 = v_0^2 + 2ad$$

$$a = \frac{v_f^2 - v_0^2}{2d} = \frac{\left(21.32\ \frac{\text{m}}{\text{s}}\right)^2 - \left(30.62\ \frac{\text{m}}{\text{s}}\right)^2}{2 \cdot 37.2\ \text{m}} = -6.493\ \frac{\text{m}}{\text{s}^2}$$

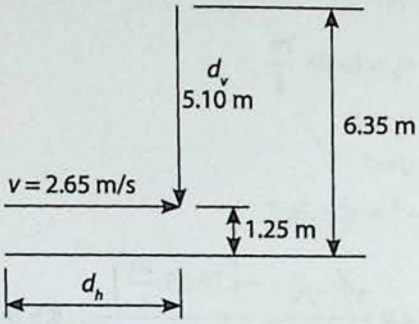
$$\boxed{a = -6.49\ \frac{\text{m}}{\text{s}^2}}$$

$$v_f = v_0 + at$$

$$t = \frac{v_f - v_0}{a} = \frac{21.32\ \frac{\text{m}}{\text{s}} - 30.62\ \frac{\text{m}}{\text{s}}}{-6.493\ \frac{\text{m}}{\text{s}^2}} = 1.43\ \text{s}$$

23.

For the first ball $t = 3.25$ s. For the second ball, $t = 3.25\ \text{s} - 1.10\ \text{s} = 2.15$ s. Each falls freely during the corresponding time, and the heights they are released from are the distances fallen.



Ball 1 (down is positive)

$v_0 = 0$

$a = g = 9.80\ \dfrac{\text{m}}{\text{s}^2}$

$t = 3.25$ s

$d = ?$

$d = \cancel{v_0 t} + \frac{1}{2}at^2 = \frac{1}{2}\cdot 9.80\ \dfrac{\text{m}}{\text{s}^2}\cdot(3.25\ \text{s})^2 = 51.8\ \text{m}$

Ball 2 (down is positive)

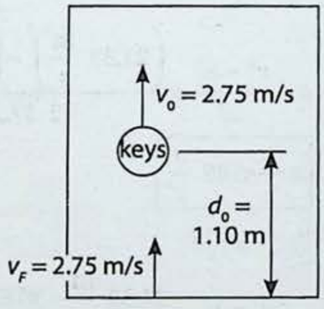
$v_0 = 0$

$a = g = 9.80\ \dfrac{\text{m}}{\text{s}^2}$

$t = 2.15$ s

$d = ?$

$d = \cancel{v_0 t} + \frac{1}{2}at^2 = \frac{1}{2}\cdot 9.80\ \dfrac{\text{m}}{\text{s}^2}\cdot(2.15\ \text{s})^2 = 22.7\ \text{m}$



24.

We calculate the time required for the water balloon to fall 5.10 m, then use this time and the speed of the running brother to determine where he started from. We will set downward to be the positive direction for the fall.

Vertical Fall

$v_0 = 0$

$a = g = 9.80\ \dfrac{\text{m}}{\text{s}^2}$

$d_v = 5.10\ \text{m}$

$t = ?$

$d = \cancel{v_0 t} + \frac{1}{2}at^2$

$$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2 \cdot 5.10\ \text{m}}{9.80\ \frac{\text{m}}{\text{s}^2}}} = 1.020\ \text{s}$$

Horizontal Run

$t = 1.020\ \text{s}$

$v = 2.65\ \dfrac{\text{m}}{\text{s}}$

$d_h = ?$

$$d_h = vt = 2.65\ \frac{\text{m}}{\text{s}} \cdot 1.020\ \text{s} = 2.70\ \text{m}$$

25.

The floor travels up at a constant speed while the keys accelerate. At impact with the floor, the floor and the keys are at the same displacement from 0 at the same time. The amount of time taken for the keys to move to where the floor is at the time of impact is the same as the time taken for the floor to rise to the point of impact. We will choose up to be positive and the position of the elevator floor at $t = 0$ to be $d = 0$ for both objects. We must use this convention consistently for the motion of both objects. This means the displacement for the keys, d_K, is equal to the starting displacement of $d_0 = 1.10$ m plus the additional displacement during the fall. (Note that the keys may not actually ever "fall" downward, since they start out with the same upward velocity that the elevator floor has.) At impact, the displacement for the floor, d_F, is equal to the total displacement for the keys, d_K ($d_K = d_F$). The solution strategy is to use the simpler motion (the constant velocity floor) to solve for time in terms of known quantities and variables in the keys' motion. Then use this time in the keys' motion to solve for the displacement of the keys during the motion, d_K. After that, the time can be computed.

We note that d_K is measured from the location of the floor at $t=0$.
So d_K is equal to its starting position, d_0, plus the additional displacement acquired during the motion. When the keys kit the floor, $d_K = d_F$.

$d_0 = 1.10 \text{ m}$

$d_K = d_F$

Floor:

$d_F = v_F t$

Keys:

$v_0 = v_F = 2.75 \ \frac{\text{m}}{\text{s}}$

$a = -g = -9.80 \ \frac{\text{m}}{\text{s}^2}$

$d_K = ?$

$d_K = d_0 + v_0 t + \frac{1}{2} a t^2$

$d_K = d_F = v_F t$

$v_F t = d_0 + v_0 t - \frac{1}{2} g t^2$

$v_0 t = d_0 + v_0 t - \frac{1}{2} g t^2$

$\frac{1}{2} g t^2 = d_0$

$$t = \sqrt{\frac{2d_0}{g}} = \sqrt{\frac{2 \cdot 1.10 \text{ m}}{9.80 \ \frac{\text{m}}{\text{s}^2}}} = 0.474 \text{ s}$$

Note: This result is exactly the same as the time required when dropping the keys from a height of 1.10 m while standing on the ground, which can be calculated in one step from $d = 1/2\, at^2$. This is because the elevator is moving at a constant speed, so it is what Einstein called an inertial (i.e., non-accelerating) frame of reference.

26.

Vertical

$d_v = -73.66 \text{ cm} = -0.7366 \text{ m}$

$a = -g = -9.80 \ \frac{\text{m}}{\text{s}^2}$

$v_0 = 0$

$t = ?$

$d_v = \cancel{v_0 t} + \frac{1}{2} a t^2$

$$t = \sqrt{\frac{2d_v}{a}} = \sqrt{\frac{2(-0.7366 \text{ m})}{-9.80 \ \frac{\text{m}}{\text{s}^2}}} = 0.3877 \text{ s}$$

Horizontal

$v_h = 15.6 \ \frac{\text{cm}}{\text{s}} = 0.156 \ \frac{\text{m}}{\text{s}}$

$t = 0.3877 \text{ s}$

$d_h = ?$

$d_h = v_h t = 0.156 \ \frac{\text{m}}{\text{s}} \cdot 0.3877 \text{ s} = 0.0605 \text{ m}$

27.

Vertical

$v_0 = 0$

$a = -g = -9.80\ \dfrac{\text{m}}{\text{s}^2}$

$t = 0.065963\ \text{s}$

$d_v = ?$

$d_v = \cancel{v_0 t} + \frac{1}{2}at^2 = \frac{1}{2}\left(-9.80\ \dfrac{\text{m}}{\text{s}^2}\right)(0.065963\ \text{s})^2 = 0.0213\ \text{m}$

Horizontal

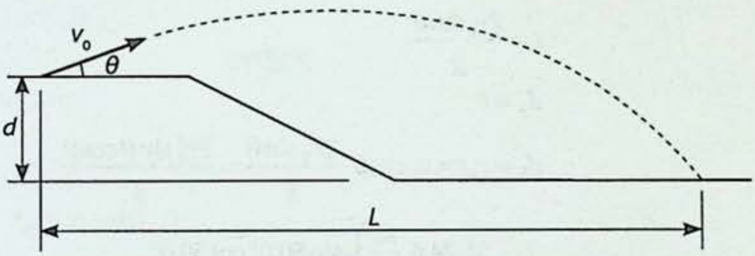
$d_h = 125.0\ \text{m}$

$v_h = 1895\ \dfrac{\text{m}}{\text{s}}$

$d_h = v_h t$

$t = \dfrac{d_h}{v_h} = \dfrac{125.0\ \text{m}}{1895\ \dfrac{\text{m}}{\text{s}}} = 0.065963\ \text{s}$

28.



Vertical

$v_{0v} = v_0 \sin\theta$

$a = -g$

$d_v = -d$

$t = \dfrac{L}{v_0 \cos\theta}$

$d_v = v_{0v}t + \frac{1}{2}at^2$

$-d = v_0 \sin\theta \cdot \dfrac{L}{v_0\cos\theta} - \dfrac{g}{2}\left(\dfrac{L}{v_0\cos\theta}\right)^2$

$-d = L\tan\theta - \dfrac{gL^2}{2v_0^2\cos^2\theta}$

$d + L\tan\theta = \dfrac{gL^2}{2v_0^2\cos^2\theta}$

$v_0^2 = \dfrac{gL^2}{2\cos^2\theta(d + L\tan\theta)}$

$v_0 = \sqrt{\dfrac{gL^2}{2\cos^2\theta(d + L\tan\theta)}}$

Horizontal

$v_h = v_0 \cos\theta$

$d_h = L$

$d_h = v_h t$

$L = v_0 \cos\theta \cdot t$

$t = \dfrac{L}{v_0 \cos\theta}$

29.

$v_0 = 24.6\text{ m/s}$

$\theta = 50.0°$

Vertical | Horizontal

$v_{0v} = v_0 \sin\theta$

$a = -g = -9.80\ \frac{\text{m}}{\text{s}^2}$

$d_v = 0$

$t = ?$

$\cancel{d_v} = v_{0v}t + \frac{1}{2}at^2$

$v_0 \sin\theta \cdot t = \frac{g}{2}t^2$

$t = \frac{2v_0 \sin\theta}{g}$

$v_h = v_0 \cos\theta$

$t = \frac{2v_0 \sin\theta}{g}$

$d_h = ?$

$d_h = v_h t = v_0 \cos\theta \cdot \frac{2v_0 \sin\theta}{g} = \frac{2v_0^2 \sin\theta \cos\theta}{g}$

$$d_h = \frac{2\left(24.6\ \frac{\text{m}}{\text{s}}\right)^2 \sin 50.0° \cos 50.0°}{9.80\ \frac{\text{m}}{\text{s}^2}} = 60.8\text{ m}$$

30.

Vertical | Horizontal

$d_v = -30.5\text{ in} \cdot \frac{2.54\text{ cm}}{\text{in}} \cdot \frac{1\text{ m}}{100\text{ cm}} = -0.7747\text{ m}$

$d_h = 57.9\text{ in} \cdot \frac{2.54\text{ cm}}{\text{in}} \cdot \frac{1\text{ m}}{100\text{ cm}} = 1.471\text{ m}$

$v_{0v} = 0$

$a = -g = -9.80\ \frac{\text{m}}{\text{s}^2}$

$t = ?$

$d_v = \cancel{v_{0v}t} + \frac{1}{2}at^2$

$t = \sqrt{\frac{2d_v}{-g}} = \sqrt{\frac{2 \cdot 0.7747\text{ m}}{9.80\ \frac{\text{m}}{\text{s}^2}}} = 0.3976\text{ s}$

$t = 0.3976\text{ s}$

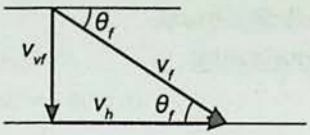
$d_h = v_h t$

$v_h = \frac{d_h}{t} = \frac{1.471\text{ m}}{0.3976\text{ s}} = 3.700\ \frac{\text{m}}{\text{s}}$

$\boxed{v_h = 3.70\ \frac{\text{m}}{\text{s}}}$

Now we go back to the vertical side to find v_{fv} so we can determine v_f

$v_{fv} = \cancel{v_{0v}} + at = -9.80\ \frac{\text{m}}{\text{s}^2} \cdot 0.3976\text{ s} = -3.896\ \frac{\text{m}}{\text{s}}$



$$v_f=\sqrt{v_h^2+v_{fv}^2}=\sqrt{\left(3.700\ \frac{\text{m}}{\text{s}}\right)^2+\left(-3.896\ \frac{\text{m}}{\text{s}}\right)^2}=5.37\ \frac{\text{m}}{\text{s}}$$

$$\theta_f=\tan^{-1}\frac{v_{fv}}{v_h}=\tan^{-1}\frac{-3.896\ \frac{\text{m}}{\text{s}}}{3.700\ \frac{\text{m}}{\text{s}}}=-46.5°$$

31.

$\theta = 33.0°$

$t = 3.27$ s

Vertical

$d_v = 0$

$a=-g=-9.80\ \frac{\text{m}}{\text{s}^2}$

$v_{0v}=v_0\sin\theta$

$\not{d_v}=v_{0v}t+\frac{1}{2}at^2=v_0\sin\theta\cdot t-\frac{g}{2}t^2$

$v_0\sin\theta=\frac{g}{2}t$

$$v_0=\frac{gt}{2\sin\theta}=\frac{9.80\ \frac{\text{m}}{\text{s}^2}\cdot 3.27\text{ s}}{2\sin 33.0°}=29.4\ \frac{\text{m}}{\text{s}}$$

32.

From the solution to Problem 29, maximum horizontal distance occurs when the product $\sin\theta\cos\theta$ is at a maximum. Note that

$2\sin\theta\cos\theta=\sin 2\theta$

This has a maximum at $2\theta = 90°$, or $\theta = 45°$.

33.

Initial thoughts suggest that the motorcycle trajectory should peak at the edge of the platform, but since the angle is given along with both the horizontal and vertical distances, this situation is over-specified. All these criteria cannot be met simultaneously unless there just happens to be a parabola that fits this exact description, an unlikely possibility we can ignore.

Thus, the peak must occur before the platform and the parabolic arc must intersect with the edge of the platform. In this way, the motorcycle barely makes it and any additional velocity would simply make the motorcycle go higher and land further down the platform.

Thus the strategy is as follows: Develop expressions for time in both vertical and horizontal directions. Since v_0 is unknown, both expressions will contain v_0. Then set these two expressions for time equal to one another. If we are lucky, the expression we get will be soluble for v_0. This is indeed what happens, although there is a bit more algebra involved than usual.

Vertical

$$v_{0v} = v_0 \sin\theta$$
$$d_v = 2.35 \text{ m}$$
$$a = -g = -9.80 \ \frac{\text{m}}{\text{s}^2}$$
$$t = ?$$
$$d_v = v_{0v}t + \tfrac{1}{2}at^2$$
$$\tfrac{1}{2}at^2 + v_{0v}t - d_v = 0$$
$$\frac{g}{2}t^2 - v_0 \sin\theta \cdot t + d_v = 0$$
$$t = \frac{v_0 \sin\theta \pm \sqrt{v_0^2 \sin^2\theta - 2gd_v}}{g}$$

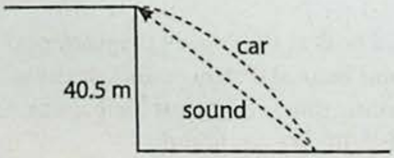
Horizontal

$$v_h = v_0 \cos\theta$$
$$d_h = 16.1 \text{ m}$$
$$d_h = v_h t$$
$$t = \frac{d_h}{v_h} = \frac{d_h}{v_0 \cos\theta}$$

Now set these two expressions equal to each other and solve for v_0.

$$\frac{d_h}{v_0 \cos\theta} = \frac{v_0 \sin\theta \pm \sqrt{v_0^2 \sin^2\theta - 2gd_v}}{g}$$
$$gd_h = v_0^2 \sin\theta\cos\theta \pm v_0 \cos\theta\sqrt{v_0^2 \sin^2\theta - 2gd_v}$$
$$gd_h - v_0^2 \sin\theta\cos\theta = \pm v_0 \cos\theta\sqrt{v_0^2 \sin^2\theta - 2gd_v}$$
$$g^2d_h^2 - 2gd_h v_0^2 \sin\theta\cos\theta + v_0^4 \sin^2\theta\cos^2\theta = v_0^2\cos^2\theta\left(v_0^2 \sin^2\theta - 2gd_v\right)$$
$$g^2d_h^2 - 2gd_h v_0^2 \sin\theta\cos\theta + v_0^4 \sin^2\theta\cos^2\theta = v_0^4 \sin^2\theta\cos^2\theta - 2gd_v v_0^2 \cos^2\theta$$
$$gd_h^2 - 2d_h v_0^2 \sin\theta\cos\theta = -2d_v v_0^2\cos^2\theta$$
$$v_0^2\left(2d_h \sin\theta\cos\theta - 2d_v\cos^2\theta\right) = gd_h^2$$
$$v_0^2 = \frac{gd_h^2}{2d_h \sin\theta\cos\theta - 2d_v\cos^2\theta} = \frac{9.80 \ \frac{\text{m}}{\text{s}^2}(16.1 \text{ m})^2}{2\left(16.1 \text{ m}\cdot\sin 24.0°\cos 24.0° - 2.35\text{m}\cdot\cos^2 24.0°\right)} = 315.9 \ \frac{\text{m}^2}{\text{s}^2}$$
$$v_0 = 17.8 \ \frac{\text{m}}{\text{s}}$$

34.



The given height allows us to calculate the length of time the car falls. Subtracting this from the time it takes to hear the splash, we can use this time difference and the speed of sound to work out the right triangle whose base is the distance we seek.

Vertical | Horizontal

$v_{0v} = 0$

$d_v = -40.5$ m

$a = -g = -9.80\ \frac{\text{m}}{\text{s}^2}$

$t = ?$

$d_v = \cancel{v_{0v}t} + \frac{1}{2}at^2$

$$t = \sqrt{\frac{2d_v}{a}} = \sqrt{\frac{2\cdot(-40.5\ \text{m})}{-9.80\ \frac{\text{m}}{\text{s}^2}}} = 2.875\ \text{s}$$

The sound of the splash starts when the car hits the river 2.875 s after the car leaves the cliff, so the time to travel to where the criminals hear it is 0.133 s. Traveling at the speed of sound, the distance traveled by the sound, which is the dashed arrow in the figure, is

$d = vt = 342$ m/s · 0.133 s = 45.49 m

$$d_h = \sqrt{(45.49\ \text{m})^2 - (40.5\ \text{m})^2} = 20.7\ \text{m}$$

The car travels this horizontal distance in 2.875 s. Thus its horizontal velocity is

$v = 20.7$ m/(2.875 s) = 7.20 m/s

35.

$v_0 = 128.9$ m/s

$\theta = 38.5°$

Vertical	Horizontal
$v_{0v} = v_0 \sin\theta$	$v_h = v_0 \cos\theta$
$d_v = -13.5$ m	$d_h = v_h t$

$$a = -g = -9.80\ \frac{\text{m}}{\text{s}^2}$$

$$d_v = v_{0v}t + \tfrac{1}{2}at^2$$

$$\tfrac{1}{2}at^2 + v_{0v}t - d_v = 0$$

$$\frac{g}{2}t^2 - v_0 \sin\theta \cdot t + d_v = 0$$

$$t = \frac{v_0 \sin\theta \pm \sqrt{v_0^2 \sin^2\theta - 2gd_v}}{g}$$

$$t = \frac{128.9\ \frac{\text{m}}{\text{s}} \cdot \sin 38.5° \pm \sqrt{\left(128.9\ \frac{\text{m}}{\text{s}}\right)^2 \sin^2 38.5° - 2 \cdot 9.80\ \frac{\text{m}}{\text{s}^2} \cdot (-13.5\ \text{m})}}{9.80\ \frac{\text{m}}{\text{s}^2}}$$

$$t = 8.188 \pm 8.355\ \text{s}$$

$$t = 16.54\ \text{s}$$

Horizontal:

$$t = 16.54\ \text{s}$$

$$d_h = v_h t = v_0 \cos\theta \cdot t$$

$$d_h = 128.9\ \frac{\text{m}}{\text{s}} \cdot \cos 38.5° \cdot 16.54\ \text{s}$$

$$d_h = 1670\ \text{m}$$

36.

We can assume that the window is at the peak of the water's trajectory, so $v_{fv} = 0$.

Vertical

$$v_{0v} = v_0 \sin\theta$$
$$v_{fv} = 0$$
$$a = -g = -9.80\ \frac{\text{m}}{\text{s}^2}$$
$$d_v = 11.7\ \text{m}$$
$$v_{0v} = ?$$
$$t = ?$$
$$\cancel{v_{fv}^2} = v_{0v}^2 + 2ad_v$$

$v_{0v}^2 = 2gd_v$ (Note: This means $v_0^2 \sin^2\theta - 2gd_v = 0$, a fact we use below.)

$$v_{0v} = \sqrt{2gd_v} = \sqrt{2 \cdot 9.80\ \frac{\text{m}}{\text{s}^2} \cdot 11.7\ \text{m}} = 15.14\ \frac{\text{m}}{\text{s}}$$
$$v_0 = \frac{v_{0v}}{\sin\theta} = \frac{15.14\ \frac{\text{m}}{\text{s}}}{\sin 45°} = 21.41\ \frac{\text{m}}{\text{s}}$$
$$d_v = v_{0v}t + \tfrac{1}{2}at^2$$
$$\tfrac{1}{2}at^2 + v_{0v}t - d_v = 0$$
$$\frac{g}{2}t^2 - v_0 \sin\theta \cdot t + d_v = 0$$
$$t = \frac{v_0 \sin\theta \pm \sqrt{v_0^2 \sin^2\theta - 2gd_v}}{g}$$

From the note above, $v_0^2 \sin^2\theta - 2gd_v = 0$. Thus,

$$t = \frac{v_0 \sin\theta}{g} = \frac{v_{0v}}{g} = \frac{15.14\ \frac{\text{m}}{\text{s}}}{9.80\ \frac{\text{m}}{\text{s}^2}} = 1.545\ \text{s}$$

Horizontal

$$v_h = v_0 \cos\theta$$
$$d_h = v_h t$$
$$d_h = v_0 \cos\theta \cdot t$$
$$d_h = 21.41\ \frac{\text{m}}{\text{s}} \cdot \cos 45° \cdot 1.545\ \text{s}$$
$$d_h = 23.4\ \text{m}$$

NOVARE
CLASSICAL ACADEMIC PRESS

ISBN 978-0-9863529-4-2
90000>
9 780986 352942