Solutions Manual to Accompany

PHYSICS

Modeling Nature

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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.

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

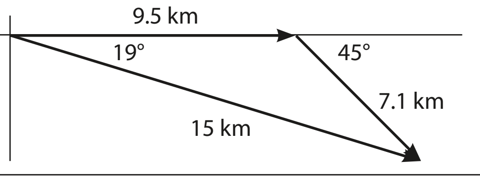
4. q.

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

4. r.

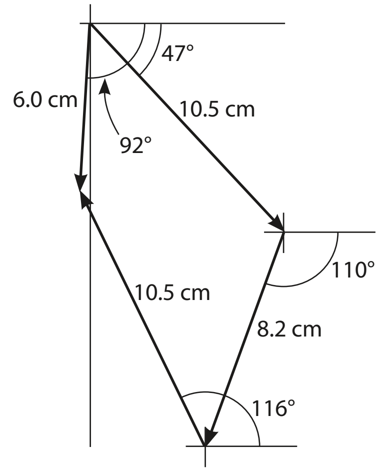
$$7845\ \mu\text{A} \cdot \frac{1\ \text{A}}{10^6\ \mu\text{A}} \cdot \frac{1000\ \text{mA}}{1\ \text{A}} = 7.845\ \text{mA}$$

16.



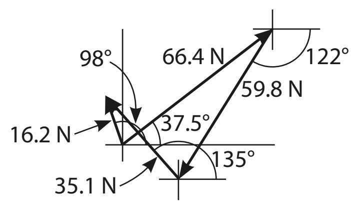
magnitude = 15 km, direction, –19°

17.



magnitude = 6.0 cm, direction, –92°

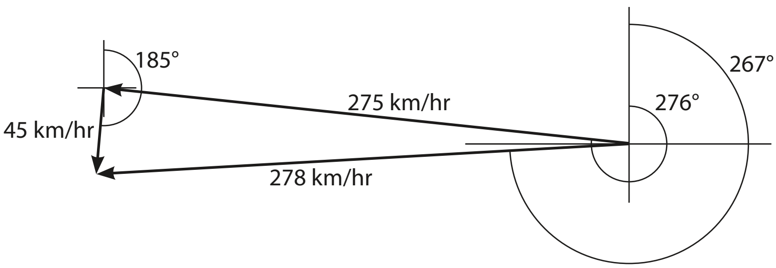
18.



magnitude = 16.2 N, direction, 98°

19.

magnitude = 278 km/hr, bearing, 267°



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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.

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

---

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.

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

---

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.

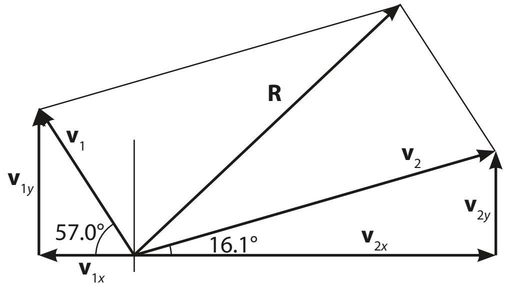
$$\theta_a = \tan^{-1}\frac{a_y}{a_x} + 180° = \tan^{-1}\left(\frac{3.910\ \frac{\text{m}}{\text{s}^2}}{-2.124\ \frac{\text{m}}{\text{s}^2}}\right) + 180 = 118.51°$$

---

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.



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

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

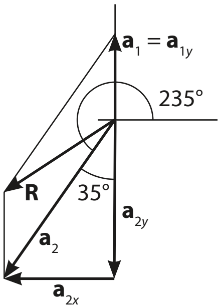
$R_x = v_{1x} + v_{2x} = -24.84\ \text{cm/s} + 94.25\ \text{cm/s} = 69.41\ \text{cm/s}$

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

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

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

24.



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

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

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

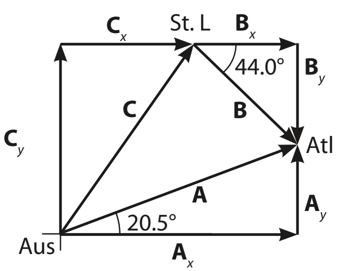
$R_y = a_{1y} + a_{2y} = 45.0 - 82.49\ \text{m/s}^2 = -37.49\ \text{m/s}^2$

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

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

25.

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



C + **B** = **A**, thus **C** = **A** – **B**

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

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

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

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

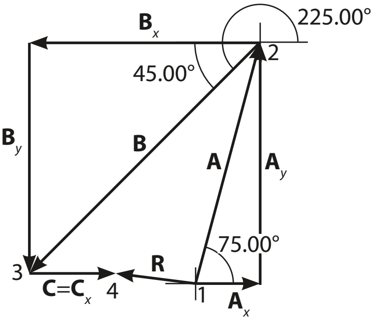
$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{(693\ \text{km})^2 + (985\ \text{km})^2} = 1204\ \text{km}$$

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

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**



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

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

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

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

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

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

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

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:

-3.4×10^{-6} N

$-3.2\times10^{-6}\text{ N}\cdot\cos 59° = -1.65\times10^{-6}$ N

$1.2\times10^{-6}\text{ N}\cdot\cos 67° = 4.69\times10^{-7}$ N

Thus, $R_x = -3.4\times10^{-6}\text{ N} - 1.65\times10^{-6}\text{ N} + 4.69\times10^{-7}\text{ N} = -4.58\times10^{-6}$ N

The y-components are:

0

$3.2\times10^{-6}\text{ N}\cdot\sin 59° = 2.74\times10^{-6}$ N

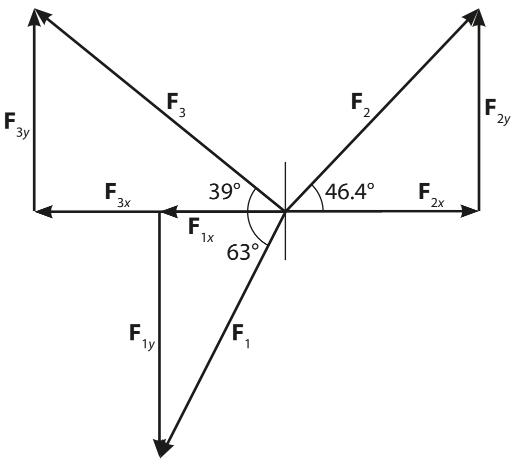
$1.2\times10^{-6}\text{ N}\cdot\sin 67° = 1.11\times10^{-6}$ N

Thus, $R_y = 2.74\times10^{-6}\text{ N} + 1.11\times10^{-6}\text{ N} = 3.85\times10^{-6}$ N

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

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

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:

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

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

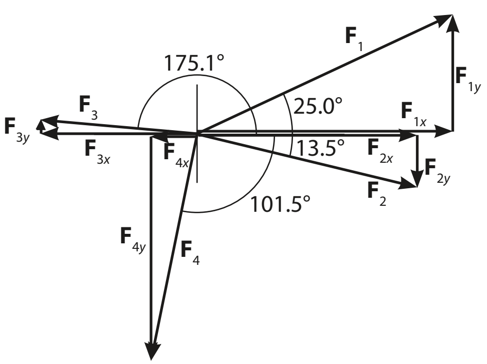
$F_{3y} = 84.2\text{ N}\cdot\sin 39° = 52.99\text{ N}$

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

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

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

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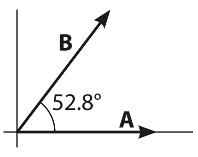
30. a.



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

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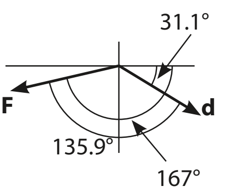
30. b.



$W = \mathbf{F}\cdot\mathbf{d} = Fd\cos\theta = (9.21\times10^4\text{ N})(4.021\times10^{-5}\text{ m})\cos 135.9° = -2.66\text{ N}\cdot\text{m}$

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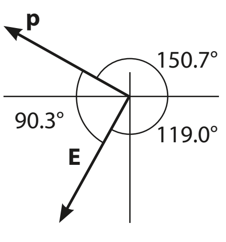
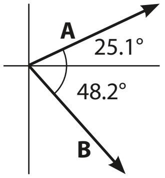
30. c.



$U = -\mathbf{p}\cdot\mathbf{E} = -pE\cos\theta = -(0.0258\text{ m}\cdot\text{C})(6.02\times10^4\text{ N/C})\cos 90.3° = 8.13\text{ m}\cdot\text{N}$

(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·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.

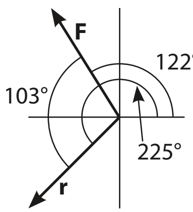
31. b.

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.

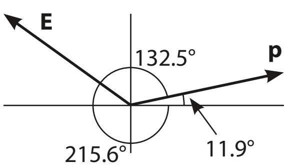
31. c.



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

The direction of $\boldsymbol{\tau}$ is into the page.

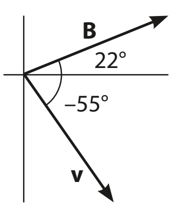
31. d.



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

The result is written in scientific notation because three sig digs are required. The direction of $\boldsymbol{\tau}$ 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.