Unit 3 Review, pages 426–433

Knowledge

1. (c)
2. (d)
3. (b)
4. (c)
5. (b)
6. (a)
7. (d)
8. (d)
9. (b)
10. (a)
11. (c)
12. (b)
13. (c)
14. (a)
15. True
16. False. Satellites orbit Earth in circular *and elliptical* pathways.
17. True
18. False. The orbit of Earth around the Sun would *remain the same* if you could increase its mass.
19. True
20. True
21. False. Two positive charges are placed along the *x*-axis. Other than at points infinitely far away, there *is one place* where the electric field is equal to zero.
22. False. As an electron moves away from a positively charged plate toward a negatively charged plate, the potential energy of the system *increases.*
23. False. Both ends of the magnet will be attracted to and stick to the refrigerator door.
24. True
25. False. The magnetic force applied on a moving charged particle will always be *perpendicular to* the particle's velocity.
26. False. *A superconducting magnet* is used to create the 2.0 T magnetic fields inside an MRI machine.

Understanding

27. No, the value of acceleration due to gravity varies on Earth with altitude and the distance from Earth's centre.

28. The orbital velocity of a satellite is independent of the mass of the satellite. Therefore, the speeds of the artificial satellites will be the same.

29. It is not possible to keep a military intelligence satellite in geosynchronous orbit over Antarctica. Satellites in geosynchronous orbit can only exist above the equator because they must make a complete orbit about Earth's centre while also staying over the same geographic location.

30. (a) The rod causes a rearrangement of the charges in the wooden stick. This causes induced charge separation in the stick. An electric force between their electric charges then causes a slight attraction between the rod and the stick.

(b) If the negatively charged rod were brought near the other end of the metre stick, the metre stick and the rod would still show a slight attraction.

(c) If the plastic rod were positively charged, the metre stick and the rod would still show a slight attraction.

31. (a) conductor

(b) insulator

(c) insulator

(d) conductor

(e) conductor

(f) insulator

32. (a) Given: $q_1 = q$; $q_2 = -3q$; $r = 1.2$ m; $q = 4.5$ C; $k = 8.99 \times 10^9$ N·m/C^2
Required: F_E

Analysis: $F_E = \dfrac{kq_1q_2}{r^2}$

Solution:
$$\begin{aligned} F_E &= \frac{kq_1q_2}{r^2} \\ &= \frac{kq(-3q)}{r^2} \\ &= \frac{-3kq^2}{r^2} \\ &= \frac{-3\left(8.99\times10^9\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\cancel{\text{C}^2}}\right)(4.5\ \cancel{\text{C}})^2}{(1.2\ \cancel{\text{m}})^2} \\ F_E &= -3.8\times10^{11}\ \text{N} \end{aligned}$$

Statement: The magnitude of the electric force between the particles is 3.8×10^{11} N.

(b) It does not matter if the value is positive or negative because squaring q makes them both positive: $F_E = \dfrac{-3kq^2}{r^2}$.

33. Given: $q_1 = 1.0$ C; $q_2 = 1.0$ C; $m = 50$ kg; $k = 8.99 \times 10^9$ N·m/C^2; $g = 9.8$ m/s^2
Required: r

Analysis: $F_E = \dfrac{kq_1q_2}{r^2}$; $F_g = mg$; $F_E = F_g$;

$$F_E = \frac{kq_1q_2}{r^2}$$

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

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

$$r = \sqrt{\frac{kq_1^2}{mg}}$$

Solution: $r = \sqrt{\frac{kq_1^2}{mg}}$

$$= \sqrt{\frac{\left(8.99 \times 10^9 \ \text{kg} \cdot \frac{\text{m}}{\text{s}^2} \cdot \frac{\text{m}^2}{\text{C}^2}\right)(1.0 \ \text{C})^2}{(50 \ \text{kg})\left(9.8 \ \frac{\text{m}}{\text{s}^2}\right)}}$$

$$r = 4.3 \times 10^3 \text{ m}$$

Statement: The separation required is 4.3×10^3 m, or 4300 m.

34. Given: r = 1.0 cm = 0.010 m; $k = 8.99 \times 10^9 \text{ N} \cdot \text{m/C}^2$

Required: minimum F_E

Analysis: $F_E = \frac{kq_1q_2}{r^2}$; the minimum force would occur when each charge is 1.60×10^{-19} C

Solution: $F_E = \frac{kq_1q_2}{r^2}$

$$= \frac{\left(8.99 \times 10^9 \ \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right)(1.60 \times 10^{-19} \ \text{C})^2}{(0.010 \ \text{m})^2}$$

$$F_E = 2.3 \times 10^{-24} \text{ N}$$

Statement: The minimum possible magnitude of the electric force is 2.3×10^{-24} N.

35. Given: $q_1 = 1.60 \times 10^{-19}$ C; $q_2 = 1.60 \times 10^{-19}$ C; $r = 10^{-15}$ m; $k = 8.99 \times 10^9 \text{ N} \cdot \text{m/C}^2$

Required: F_E

Analysis: $F_E = \frac{kq_1q_2}{r^2}$

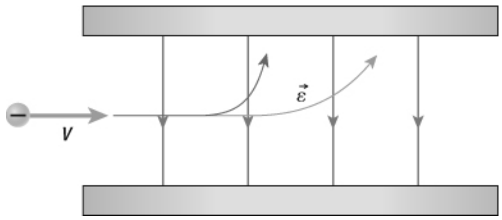
Solution: $F_E = \frac{kq_1q_2}{r^2}$

$$= \frac{\left(8.99 \times 10^9 \ \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right)(1.60 \times 10^{-19} \ \text{C})^2}{(10^{-15} \ \text{m})^2}$$

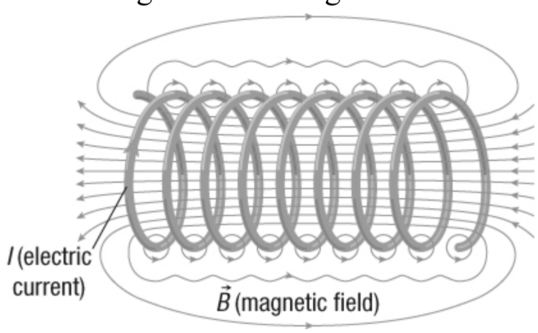
$$F_E = 230 \text{ N}$$

Statement: The electric force between the protons is 230 N.

36. (a) Charge q_1 is positive because it repels the proton, and q_2 is negative.
(b) Charge q_1 has a greater magnitude of charge. The net force has some upward component, so the repelling force from q_1 must be greater than the attracting force from q_2.
37. (a) The negatively charged ion is attracted to the top plate, so it must have a positive charge. Since the top plate is positive, the bottom plate must be negative.
(b) The path would be parabolic with sharper curvature, reaching the top plate sooner (farther to the left) than the first path.

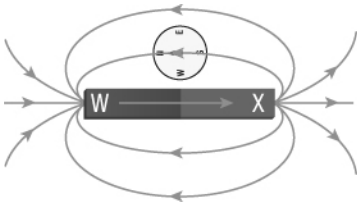


38. Small birds can put both feet on a power line and still be safe because their feet are at the same potential difference so there is no reason for a charge to flow through the bird.
39. The magnetic field of a solenoid is composed of the combined fields of all its loops. Coiling the wire for a solenoid means that inside the coil, all the magnetic field lines point from one end of the solenoid to the other, while on the outside, the field lines point in the opposite direction. This configuration of magnetic field lines is similar to that of a bar magnet.



40. (a) In Edmonton, Canada, the needle would point slightly downward in line with Earth's magnetic field.
(b) In Quito, Ecuador, the needle would lie level because the magnetic field lines are parallel with Earth's surface.
(c) In Santiago, Chile, the needle would point slightly upward in line with Earth's magnetic field.
41. (a) The steel post was aligned with Earth's magnetic field. Striking the post with the sledgehammer agitates the molecules, and some line up with the magnetic field they are in, creating a weak magnet.
(b) The opposite end of the compass needle would be strongly attracted to the bottom of the steel post.

42. Diagrams may vary. Students should draw magnetic field lines pointing from X to W to match the compass. The direction of the field lines indicates that X is the north pole and W is the south pole.



43. The geographic north pole is a fixed point and it marks the axis around which Earth rotates. The magnetic north pole is a moving point in far north-central Canada. A compass will point west of true north in eastern Canada, and east of true north in western Canada.
44. To direct the particle right, use a magnetic field that is directed out of the page. According to the right-hand rule, the magnetic force will be directed to the right.
45. (a) The direction of the magnetic force on the bottom of loop is down. On the top of loop, the direction is up. On the right side, the direction is left. On the left side, the direction is right.
(b) The net force is directed down because the bottom side is closer to the long, straight wire and it experiences a force of greater magnitude than the top side of the loop.
46. The force on a charged particle moving in a uniform magnetic field always acts in a direction perpendicular to the direction of motion of the charge. Since the work done by the magnetic field on the charge is zero, the energy of the charged particle does not change.

Analysis and Application

47. Given: $m_1 = 40$ kg; $m_2 = 15$ kg; $r = 63$ cm $= 0.63$ m; $F_g = 1.0 \times 10^{-7}$ N
Required: G
Analysis: $F_g = \dfrac{Gm_1m_2}{r^2}$

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

Solution: $G = \dfrac{F_g r^2}{m_1 m_2}$

$$= \frac{(1.0 \times 10^{-7}\ \text{N})(0.63\ \text{m})^2}{(40\ \text{kg})(15\ \text{kg})}$$

$$G = 6.6 \times 10^{-11}\ \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2}$$

Statement: The gravitational constant is 6.6×10^{-11} N·m^2/kg^2.
48. Given: $m_E = 6.0 \times 10^{24}$ kg; $m_M = 7.4 \times 10^{22}$ kg; $r = 3.8 \times 10^8$ m; $F_E = F_M$
Required: r_M
Analysis: Use the universal law of gravitation, $F_g = \dfrac{Gm_1m_2}{r^2}$, to determine the ratio of the two distances, then determine the distance from the centre of the Moon to the rocket.

$$F_E = F_M$$
$$\frac{\cancel{G} m_E m_{rocket}}{r_E^2} = \frac{\cancel{G} m_M m_{rocket}}{r_M^2}$$
$$\frac{m_E}{r_E^2} = \frac{m_M}{r_M^2}$$
$$\frac{m_E}{m_M} = \frac{r_E^2}{r_M^2}$$

Solution:
$$\frac{m_E}{m_M} = \frac{r_E^2}{r_M^2}$$
$$\frac{(6.0 \times 10^{24}\ \text{N})}{(7.4 \times 10^{22}\ \text{N})} = \left(\frac{r_E}{r_M}\right)^2$$
$$\frac{r_E}{r_M} = \sqrt{\frac{6.0 \times 10^{24}\ \cancel{\text{N}}}{7.4 \times 10^{22}\ \cancel{\text{N}}}}$$
$$\frac{r_E}{r_M} = 9.00$$

The distance to Earth is 9 times the distance to the Moon. Therefore, the distance from the rocket to the Moon is one tenth of *r*:

$$\frac{1}{10}(3.8 \times 10^8\ \text{m}) = 3.8 \times 10^7\ \text{m}$$

Statement: The gravitational force is zero when the rocket is 3.8×10^7 m from the Moon.

49. Given: $m_E = 6.0 \times 10^{24}$ kg; $m_{apple} = 0.25$ kg; $r_E = 6.38 \times 10^6$ m; $G = 6.67 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2$

Required: a_E; a_{apple}

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

Solution: Determine the acceleration of the apple:

$$a_{apple} = \frac{Gm_E}{r^2}$$
$$= \frac{\left(6.67 \times 10^{-11}\ \frac{\text{N} \cdot \cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)(6.0 \times 10^{24}\ \cancel{\text{kg}})}{(6.38 \times 10^6\ \cancel{\text{m}})^2}$$
$$a_{apple} = 9.8\ \text{m/s}^2$$

Determine the acceleration of Earth:

$$a_E = \frac{Gm_{apple}}{r^2}$$

$$= \frac{\left(6.67 \times 10^{-11}\ \frac{\text{N} \cdot \cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)(0.25\ \cancel{\text{kg}})}{\left(6.38 \times 10^6\ \cancel{\text{m}}\right)^2}$$

$$a_E = 4.1 \times 10^{-25}\ \text{m/s}^2$$

Statement: The acceleration of the apple is 9.8 m/s^2, and the acceleration of Earth is 4.1×10^{-25} m/s^2.

50. Substitute the values $m_{new} = \frac{1}{2}m$ and $r_{new} = \frac{1}{2}r$ in the gravitational field strength equation.

$$g_{new} = \frac{Gm_{new}}{r_{new}^2}$$

$$= \frac{G\left(\frac{1}{2}m\right)}{\left(\frac{1}{2}r\right)^2}$$

$$= \frac{\frac{1}{2}Gm}{\frac{1}{4}r^2}$$

$$= 2\left(\frac{Gm}{r^2}\right)$$

$$g_{new} = 2g$$

The planet's acceleration due to gravity would be double the value on Earth, 2g.

51. Given: m = 60 kg; F_g = 300 N; g = 9.8 m/s^2

Required: g

Analysis: $F_g = mg$

$$g = \frac{F_g}{\text{m}}$$

Solution: $g = \frac{F_g}{\text{m}}$

$$= \frac{(300\ \text{N})}{(60\ \text{kg})}$$

$$g = 5\ \text{N/kg}$$

Statement: The gravitational field strength on the planet is 5 N/kg.

52. (a) Given: $m_1 = 2.0 \times 10^{30}$ kg; $m_2 = 50$ kg; $r = 1.5 \times 10^{11}$ m; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: F_g

Analysis: $F_g = \dfrac{Gm_1m_2}{r^2}$

Solution: $F_g = \dfrac{Gm_1m_2}{r^2}$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)\left(2.0\times10^{30}\ \cancel{\text{kg}}\right)\left(50\ \cancel{\text{kg}}\right)}{\left(1.5\times10^{11}\ \cancel{\text{m}}\right)^2}$$

$= 0.296$ N (one extra digit carried)

$F_g = 0.30$ N

Statement: The gravitational force due to the Sun on a 50 kg person is 0.30 N.

(b) Given: $m_1 = 2.0 \times 10^{30}$ kg; $m_2 = 50$ kg; $r = 1.5 \times 10^{11}$ m; $F_{g_{Sun}} = 0.296$ N; $g = 9.8$ m/s²

Required: $\dfrac{F_{g_{Sun}}}{F_{g_{Earth}}}$

Analysis: $F_{g_{Earth}} = mg$

Solution: $\dfrac{F_{g_{Sun}}}{F_{g_{Earth}}} = \dfrac{F_{g_{Sun}}}{mg}$

$$= \frac{\left(0.296\ \cancel{\text{kg}}\cdot\frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)}{\left(50\ \cancel{\text{kg}}\right)\left(9.8\ \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)}$$

$\dfrac{F_{g_{Sun}}}{F_{g_{Earth}}} = 6.1\times10^{-4}$

Statement: The ratio of the gravitational forces due to the Sun and Earth is 6.1×10^{-4} to 1.

53. (a) Given: $r = 7.0 \times 10^6$ m; $m_E = 6.0 \times 10^{24}$ kg; $G = 6.67 \times 10^{-11}$ N·m²/kg²
Required: v; T

Analysis: $v = \sqrt{\dfrac{Gm}{r}}$

Solution: $v = \sqrt{\dfrac{Gm}{r}}$

$$= \sqrt{\frac{\left(6.67\times10^{-11}\ \frac{\cancel{\text{kg}}\cdot\frac{\cancel{\text{m}}}{\text{s}^2}\cdot\text{m}^2}{\text{kg}^{\cancel{2}}}\right)\left(6.0\times10^{24}\ \cancel{\text{kg}}\right)}{7.0\times10^6\ \cancel{\text{m}}}}$$

$= 7.561\times10^3$ m/s (two extra digits carried)

$v = 7.6\times10^3$ m/s

Statement: The orbital speed of the satellite is 7.6×10^3 m/s.

(b) Given: $r = 7.0 \times 10^6$ m; $m_E = 6.0 \times 10^{24}$ kg; $v = 7.561 \times 10^3$ m/s
Required: T

Analysis: $T = \frac{2\pi r}{v}$

Solution: $T = \frac{2\pi r}{v}$

$$= \frac{2\pi(7.0\times10^6\ \cancel{\text{m}})}{\left(7.561\times10^3\ \frac{\cancel{\text{m}}}{\text{s}}\right)}$$

$$= \left(5.817\times10^3\ \cancel{\text{s}}\right)\frac{1\text{ min}}{60\ \cancel{\text{s}}}$$

$$T = 97\text{ min}$$

Statement: The orbital period of the satellite is 97 min.

54. Given: $v = 2.3 \times 10^5$ m/s; $r = 6.9 \times 10^9$ m; $G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
Required: r

Analysis: $v = \sqrt{\frac{Gm}{r}}$

$$m = \frac{rv^2}{G}$$

Solution: $m = \frac{rv^2}{G}$

$$= \frac{\left(6.9\times10^9\ \cancel{\text{m}}\right)\left(2.3\times10^5\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)^2}{\left(6.67\times10^{-11}\ \frac{\cancel{\text{kg}}\cdot\frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\cdot\cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}\right)}$$

$$m = 5.5\times10^{30}\text{ kg}$$

Statement: The mass of the star is 5.5×10^{30} kg.

55. Given: $\Delta d = 5.2 \times 10^5$ m; $m = 6.4 \times 10^{23}$ kg; $r_{\text{Mars}} = 3.4 \times 10^6$ m; $G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
Required: v; T

Analysis: $v = \sqrt{\frac{Gm}{r}}$; $T = \frac{2\pi r}{v}$

Solution: Determine the orbital velocity of the satellite:

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

$$v = \sqrt{\frac{Gm}{r_{\text{Mars}} + \Delta d}}$$

$$= \sqrt{\frac{\left(6.67 \times 10^{-11} \ \frac{\cancel{\text{kg}} \cdot \frac{\cancel{\text{m}}}{\text{s}^2} \cdot \text{m}^2}{\text{kg}^{\cancel{2}}}\right)\left(6.4 \times 10^{23} \ \cancel{\text{kg}}\right)}{\left(3.4 \times 10^6 \ \cancel{\text{m}} + 5.2 \times 10^5 \ \cancel{\text{m}}\right)}}$$

$$v = 3.3 \times 10^3 \text{ m/s}$$

Determine the orbital period of the satellite:

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

$$T = \frac{2\pi\left(r_{\text{Mars}} + \Delta d\right)}{v}$$

$$= \frac{2\pi\left(3.4 \times 10^6 \ \cancel{\text{m}} + 5.2 \times 10^5 \ \cancel{\text{m}}\right)}{\left(3.3 \times 10^3 \ \frac{\cancel{\text{m}}}{\text{s}}\right)}$$

$$= \left(7.464 \times 10^3 \ \cancel{\text{s}}\right)\frac{1 \text{ min}}{60 \ \cancel{\text{s}}}$$

$$T = 124 \text{ min}$$

Statement: The orbital velocity of the satellite is 3.3×10^3 m/s, and the orbital period is 124 min.

56. Given: T =96 min; $r_E = 6.38 \times 10^6$ m; $G = 6.67 \times 10^{-11}$ $\text{N} \cdot \text{m}^2/\text{kg}^2$

Required: v; Δd

Analysis: $v = \sqrt{\frac{Gm}{r}}$; $T = \frac{2\pi r}{v}$

Solution: Isolate r in each equation:

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

$$r = \frac{Tv}{2\pi}$$

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

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

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

Set the two equations equal to each other and solve for *v*:

$$\frac{Tv}{2\pi} = \frac{Gm}{v^2}$$

$$v^3 = \frac{2\pi Gm}{T}$$

$$= \frac{2\pi\left(6.67\times10^{-11}\ \frac{\cancel{\text{kg}}\cdot\frac{\text{m}}{\text{s}^2}\cdot\text{m}^2}{\cancel{\text{kg}^2}}\right)\left(5.98\times10^{24}\ \cancel{\text{kg}}\right)}{96\ \cancel{\text{min}}\times\frac{60\ \text{s}}{1\ \cancel{\text{min}}}}$$

$v = 7.578\times10^3$ m/s (two extra digits carried)

$v = 7.6\times10^3$ m/s

Determine the altitude of the satellite:

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

$$T = \frac{2\pi\left(r_\text{E} + \Delta d\right)}{v}$$

$$r_\text{E} + \Delta d = \frac{Tv}{2\pi}$$

$$\Delta d = \frac{Tv}{2\pi} - r_\text{E}$$

$$= \frac{\left(5760\ \cancel{\text{s}}\right)\left(7.578\times10^3\ \frac{\text{m}}{\cancel{\text{s}}}\right)}{2\pi} - \left(6.38\times10^6\ \text{m}\right)$$

$\Delta d = 5.7\times10^5$ m

Statement: The orbital speed of Sputnik 1 was 7.6×10^3 m/s, and its altitude was 5.7×10^5 m.

57. (a) Given: $q_1 = 0.4\ \mu\text{C} = 4 \times 10^{-7}$ C; $q_2 = -0.8\ \mu\text{C} = -8 \times 10^{-7}$ C; $F_\text{E} = 0.2$ N; $k = 8.99 \times 10^9\ \text{N}\cdot\text{m/C}^2$

Required: *r*

Analysis: $F_\text{E} = \frac{kq_1q_2}{r^2}$

Solution: $F_\text{E} = \frac{kq_1q_2}{r^2}$

$$r = \sqrt{\frac{kq_1q_2}{F_\text{E}}}$$

$$= \sqrt{\frac{\left(8.99\times10^9\ \frac{\cancel{\text{N}}\cdot\text{m}^2}{\cancel{\text{C}^2}}\right)\left(4\times10^{-7}\ \cancel{\text{C}}\right)\left(8\times10^{-7}\ \cancel{\text{C}}\right)}{0.2\ \cancel{\text{N}}}}$$

$r = 0.12$ m

Statement: The distance between the two spheres is 0.12 m.

(b) The spheres have opposite charges, so the force is attractive.

58. (a) The distance doubles from 10 cm to 20 cm:

$$F_E = \frac{kq_1q_2}{(2r)^2}$$

$$F_E = \frac{1}{4}\frac{kq_1q_2}{r^2}$$

The force is one quarter of 80 mN, or 20 mN.

(b) The distance is one fifth of 10 cm, 2 cm:

$$F_E = \frac{kq_1q_2}{\left(\frac{1}{5}r\right)^2}$$

$$F_E = 25\frac{kq_1q_2}{r^2}$$

The force is 25 times 80 mN, or 2.0 N.

(c) Given: r = 10 cm = 0.1 m; F_E = 80 mN = 0.080 N; $k = 8.99 \times 10^9\ \text{N}\cdot\text{m/C}^2$

Required: q

Analysis: $F_E = \frac{kq_1q_2}{r^2}$

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

$$q = \sqrt{\frac{F_E r^2}{k}}$$

Solution: $q = \sqrt{\frac{F_E r^2}{k}}$

$$= \sqrt{\frac{(0.080\ \cancel{\text{N}})(0.1\ \cancel{\text{m}})^2}{\left(8.99\times 10^9\ \frac{\cancel{\text{N}}\cdot\cancel{\text{m}^2}}{\text{C}^2}\right)}}$$

$$q = 3.0\times 10^{-7}\ \text{C}$$

Statement: The charge on each particle is 3.0×10^{-7} C.

59. (a) Given: ε = 300 N/C; $q = -1.60 \times 10^{-19}$ C

Required: F_E

Analysis: $F_E = q\varepsilon$

Solution: $F_E = q\varepsilon$

$$= \left(-1.60\times 10^{-19}\ \cancel{\text{C}}\right)\left(300\ \frac{\text{N}}{\cancel{\text{C}}}\right)$$

$$F_E = -4.8\times 10^{-17}\ \text{N}$$

Statement: The magnitude of the electric force is 4.8×10^{-17} N.

(b) Given: $F_E = 4.8 \times 10^{-17}$ N; $m = 9.11 \times 10^{-31}$ kg
Required: a
Analysis: $F_E = ma$

$$a = \frac{F_E}{m}$$

Solution: $a = \dfrac{F_E}{m}$

$$= \frac{4.8 \times 10^{-17}\ \cancel{\text{kg}} \cdot \dfrac{\text{m}}{\text{s}^2}}{9.11 \times 10^{-31}\ \cancel{\text{kg}}}$$

$$= 5.269 \times 10^{13}\ \text{m/s}^2 \text{ (two extra digits carried)}$$

$$a = 5.3 \times 10^{13}\ \text{m/s}^2$$

Statement: The magnitude of the electron's acceleration is 5.3×10^{13} m/s^2.
(c) Given: $\Delta d = 1.5$ cm $= 0.015$ m; $a = 5.3 \times 10^{13}$ m/s^2
Required: v_f
Analysis: $v_f^2 = v_i^2 + 2a\Delta d$

$$v_f^2 = 2a\Delta d$$

$$v_f = \sqrt{2a\Delta d}$$

Solution: $v_f = \sqrt{2a\Delta d}$

$$= \sqrt{2\left(5.3 \times 10^{13}\ \frac{\text{m}}{\text{s}^2}\right)(0.015\ \text{m})}$$

$$v_f = 1.3 \times 10^6\ \text{m/s}$$

Statement: The final speed of the electron is 1.3×10^6 m/s.
60. (a) Given: $\vec{\varepsilon} = 2.0 \times 10^3$ N/C [+x]; $q = -1.60 \times 10^{-19}$ C; $m = 9.11 \times 10^{-31}$ kg
Required: F_E
Analysis: $F_E = q\varepsilon$; $F_E = ma$; since the electric force on a negative charges is in the opposite direction as the electric field, the direction of the electron will be $-x$.

$$F_E = q\varepsilon$$

$$ma = q\varepsilon$$

$$a = \frac{q\varepsilon}{m}$$

Solution: $a = \dfrac{q\varepsilon}{m}$

$$= \frac{\left(-1.60 \times 10^{-19}\ \cancel{\text{C}}\right)\left(2.0 \times 10^3\ \dfrac{\cancel{\text{kg}}}{\cancel{\text{C}}} \cdot \dfrac{\text{m}}{\text{s}^2}\right)}{9.11 \times 10^{-31}\ \cancel{\text{kg}}}$$

$$= 3.513 \times 10^{14}\ \text{m/s}^2 \text{ (two extra digits carried)}$$

$$a = 3.5 \times 10^{14}\ \text{m/s}^2$$

Statement: The magnitude of the electron's acceleration is 3.5×10^{14} m/s^2 [$-x$].
(b) Given: Δt = 1.0 min = 60 s; $a = 3.513 \times 10^{14}$ m/s^2
Required: v_f
Analysis: $v_f = a\Delta t$
Solution:

$$\begin{aligned} v_f &= a\Delta t \\ &= \left(3.513\times10^{14}\ \frac{\text{m}}{\text{s}^{\not 2}}\right)(60\ \not\text{s}) \\ v_f &= 2.1\times10^{16}\ \text{m/s} \end{aligned}$$

Statement: The final speed of the electron is 2.1×10^{16} m/s. This is not reasonable because the speed of light is 3×10^8 m/s.
61. Given: m = 100.0 g = 0.1000 kg; ε = 100.0 N/C; θ = 30.0°
Required: q
Analysis: Use $F_g = mg$ to determine the gravitational force. Then use the tangent ratio to determine the electric force before using $F_E = q\varepsilon$ to determine the charge. Since the sphere is moving in the opposite direction as the electric field, it must have a negative charge.
Solution: Determine the force of gravity:

$$\begin{aligned} F_g &= mg \\ &= (0.1000\ \text{kg})(9.8\ \text{m/s}^2) \\ F_g &= 0.98\ \text{N} \end{aligned}$$

Determine the electric force:

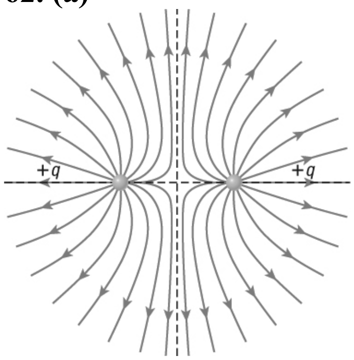
$$\begin{aligned} \tan\theta &= \frac{F_E}{F_g} \\ F_E &= F_g \tan\theta \\ &= (0.98\ \text{N})\tan 30.0° \\ F_E &= 0.566\ \text{N} \end{aligned}$$

Determine the charge on the sphere:

$$\begin{aligned} F_E &= q\varepsilon \\ q &= \frac{F_E}{\varepsilon} \\ &= \frac{(0.566\ \not\text{N})}{\left(100.0\ \frac{\not\text{N}}{\text{C}}\right)} \\ q &= 5.66\times10^{-3}\ \text{C} \end{aligned}$$

Statement: The charge is negative, so the sphere has a charge of -5.66×10^{-3} C.

62. (a)



(b) (i) This point is an equal distance from the two equal charges, so the electric field is 0 N/C.
(ii) Given: $q = 5.8 \times 10^{-8}$ C; $x_1 = 0$ m; $x_2 = 0.10$ m; $x = 0.07$ m; $k = 8.99 \times 10^9\ \text{N} \cdot \text{m/C}^2$
Required: $\vec{\varepsilon}_{\text{net}}$
Analysis: The net electric field at the point equals the vector sum of the electric fields from the two charges. Use $\varepsilon = \dfrac{kq}{r^2}$ to determine the electric field for each charge, then calculate their sum.
Solution: Determine the electric field from the first point:

$$\varepsilon_1 = \frac{kq_1}{r_1^2}$$

$$= \frac{\left(8.99 \times 10^9\ \frac{\text{N} \cdot \cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)\left(5.0 \times 10^{-8}\ \cancel{\text{C}}\right)}{\left(0\ \cancel{\text{m}} - 0.07\ \cancel{\text{m}}\right)^2}$$

$\varepsilon_1 = 9.173 \times 10^4$ N/C (two extra digits carried)

Determine the electric field from the first point:

$$\varepsilon_2 = \frac{kq_2}{r_2^2}$$

$$= \frac{\left(8.99 \times 10^9\ \frac{\text{N} \cdot \cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)\left(5.0 \times 10^{-8}\ \cancel{\text{C}}\right)}{\left(0.10\ \cancel{\text{m}} - 0.07\ \cancel{\text{m}}\right)^2}$$

$\varepsilon_2 = 4.994 \times 10^5$ N/C (two extra digits carried)

Both electric fields point toward the point. Calculate the vector sum:

$$\begin{aligned}\vec{\varepsilon}_{\text{net}} &= \vec{\varepsilon}_1 + \vec{\varepsilon}_2 \\ &= 9.173 \times 10^4\ \text{N/C}\ [x] + 4.994 \times 10^5\ \text{N/C}\ [-x] \\ &= -9.173 \times 10^4\ \text{N/C}\ [-x] + 4.994 \times 10^5\ \text{N/C}\ [-x]\end{aligned}$$

$\vec{\varepsilon}_{\text{net}} = 4.1 \times 10^5$ N/C $[-x]$

Statement: The electric field at the point is 4.1×10^5 N/C in the $-x$ direction.

63. (a)

(b) Given: m = 15.1 g = 0.0151 kg; $\vec{\varepsilon}$ = 585 N/C [up]; F_T = 0.167 N

Required: $\vec{F}_E$

Analysis: Use $F_g = mg$ to determine the gravitational force. Then use the fact that the sum of the three forces on the sphere is 0 N to determine the electric force.

Solution: Determine the force of gravity:

$$\begin{aligned} F_g &= mg \\ &= (0.0151\ \text{kg})(9.8\ \text{m/s}^2) \\ F_g &= 0.1480\ \text{N (two extra digits carried)} \end{aligned}$$

Determine the electric force:

$$\begin{aligned} \vec{F}_g + \vec{F}_E + \vec{F}_T &= 0 \\ 0.1480\ \text{N [down]} + \vec{F}_E + 0.167\ \text{N [up]} &= 0 \\ 0.1480\ \text{N [down]} + \vec{F}_E - 0.167\ \text{N [down]} &= 0 \\ \vec{F}_E &= 0.019\ \text{N [down]} \end{aligned}$$

Solution: The electric force is 0.019 N [down].

(c) Given: F_E = 0.019 N; ε = 585 N/C

Required: q

Analysis: $F_E = q\varepsilon$; since the sphere is moving in the opposite direction as the electric field, it must have a negative charge.

Solution: $F_E = q\varepsilon$

$$\begin{aligned} q &= \frac{F_E}{\varepsilon} \\ &= \frac{(0.019\ \cancel{\text{N}})}{\left(585\ \frac{\cancel{\text{N}}}{\text{C}}\right)} \\ q &= 3.2 \times 10^{-5}\ \text{C} \end{aligned}$$

Statement: The charge is negative, so the sphere has a charge of -3.2×10^{-5} C.

64. (a) Given: ΔV = 8000 V; $m = 1.67 \times 10^{-27}$ kg; $q = 1.60 \times 10^{-19}$ C

Required: ΔE_k

Analysis: $\Delta E_k = -\Delta E_E$; $\Delta V = \dfrac{\Delta E_E}{q}$

$$\Delta V = \frac{\Delta E_{\text{E}}}{q}$$

$$\Delta V = \frac{-\Delta E_{\text{k}}}{q}$$

$$\Delta E_{\text{k}} = -q\Delta V$$

Solution: $\Delta E_{\text{k}} = -q\Delta V$

$$= -\left(1.60\times10^{-19}\ \cancel{\text{C}}\right)\left(8000\ \frac{\text{J}}{\cancel{\text{C}}}\right)$$

$$= -1.28\times10^{-15}\ \text{J (one extra digit carried)}$$

$$\Delta E_{\text{k}} = -1.3\times10^{-15}\ \text{J}$$

Statement: The kinetic energy of the proton is 1.3×10^{-15} J.

(b) Given: $m = 1.67 \times 10^{-27}$ kg; $q = 1.60 \times 10^{-19}$ C; $\Delta E_{\text{k}} = 1.28 \times 10^{-15}$ J

Required: v

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

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

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

$$= \sqrt{\frac{2\left(1.28\times10^{-15}\ \cancel{\text{kg}}\cdot\frac{\text{m}}{\text{s}^2}\cdot\text{m}\right)}{\left(1.67\times10^{-27}\ \cancel{\text{kg}}\right)}}$$

$$v = 1.2\times10^{6}\ \text{m/s}$$

Statement: The final speed of the proton is 1.2×10^6 m/s.

65. (a) Given: $q = 4.0 \times 10^{-7}$ C; $r = 9.0$ cm = 0.090 m; $k = 8.99 \times 10^9\ \text{N}\cdot\text{m/C}^2$

Required: V

Analysis: $V = \frac{kq}{r}$

Solution: $V = \frac{kq}{r}$

$$= \frac{\left(8.99\times10^{9}\ \frac{\text{J}\cdot\cancel{\text{m}}}{\text{C}^{\cancel{2}}}\right)\left(4.0\times10^{-7}\ \cancel{\text{C}}\right)}{0.090\ \cancel{\text{m}}}$$

$$V = 4.0\times10^{4}\ \text{V}$$

Statement: The electric potential at the point is 4.0×10^4 V.

(b) Given: $q_1 = 4.0 \times 10^{-7}$ C; $q_2 = 2.0 \times 10^{-9}$ C; $r_i \rightarrow \infty$; $r_f = 9.0$ cm = 0.090 m;
$k = 8.99 \times 10^9$ N·m/C^2

Required: W

Analysis: $W = \dfrac{kq_1q_2}{r_f} - \dfrac{kq_1q_2}{r_i}$

Solution: $W = \dfrac{kq_1q_2}{r_f} - \dfrac{kq_1q_2}{r_i}$

$$= \frac{kq_1q_2}{r_f}$$

$$= \frac{\left(8.99 \times 10^9 \ \frac{\text{J} \cdot \cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(4.0 \times 10^{-7} \ \cancel{\text{C}}\right)\left(2.0 \times 10^{-9} \ \cancel{\text{C}}\right)}{0.090 \ \cancel{\text{m}}}$$

$$W = 8.0 \times 10^{-5} \text{ J}$$

Statement: The work required to bring the charge to point P is 8.0×10^{-5} J.

(c) No, the work done only depends the initial and final distances from the other charge.

66. Given: $q_1 = +2.5 \times 10^{-6}$ C; $q_2 = +4.5 \times 10^{-6}$ C; $q_3 = -3.5 \times 10^{-6}$ C; $L = 1.5$ m;
$k = 8.99 \times 10^9$ N·m/C^2

Required: E_E

Analysis: The total electric potential energy is the sum of the three electric potential energies of a pair of charges. Use $E_E = \dfrac{kq_1q_2}{r}$ to calculate each electric potential energy of a pair of charges.

Solution: Calculate the electric potential energy between q_1 and q_2, E_{E1}:

$$E_{E1} = \frac{kq_1q_2}{r}$$

$$= \frac{kq_1q_2}{\sqrt{L^2 + L^2}}$$

$$= \frac{kq_1q_2}{L\sqrt{2}}$$

$$= \frac{\left(8.99 \times 10^9 \ \frac{\text{J} \cdot \cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(2.5 \times 10^{-6} \ \cancel{\text{C}}\right)\left(4.5 \times 10^{-6} \ \cancel{\text{C}}\right)}{\left(1.5 \ \cancel{\text{m}}\right)\sqrt{2}}$$

$E_{E1} = 4.768 \times 10^{-2}$ J (two extra digits carried)

Calculate the electric potential energy between q_1 and q_3, E_{E2}:

$$E_{E2} = \frac{kq_1q_2}{r}$$
$$= \frac{kq_1q_3}{\sqrt{L^2 + (2L)^2}}$$
$$= \frac{kq_1q_3}{L\sqrt{5}}$$
$$= \frac{\left(8.99 \times 10^9 \ \frac{\text{J} \cdot \cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(2.5 \times 10^{-6} \ \cancel{\text{C}}\right)\left(-3.5 \times 10^{-6} \ \cancel{\text{C}}\right)}{(1.5 \ \cancel{\text{m}})\sqrt{5}}$$

$E_{E2} = -2.345 \times 10^{-2}$ J (two extra digits carried)

Calculate the electric potential energy between q_2 and q_3, E_{E3}:

$$E_{E3} = \frac{kq_1q_2}{r}$$
$$= \frac{kq_2q_3}{L + 2L}$$
$$= \frac{kq_1q_3}{3L}$$
$$= \frac{\left(8.99 \times 10^9 \ \frac{\text{J} \cdot \cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(4.5 \times 10^{-6} \ \cancel{\text{C}}\right)\left(-3.5 \times 10^{-6} \ \cancel{\text{C}}\right)}{3(1.5 \ \cancel{\text{m}})}$$

$E_{E3} = -3.146 \times 10^{-2}$ J (two extra digits carried)

Calculate the total electric potential energy, E_E:

$$E_E = E_{E1} + E_{E2} + E_{E3}$$
$$= (4.768 \times 10^{-2} \text{ J}) + (-2.345 \times 10^{-2} \text{ J}) + (-3.146 \times 10^{-2} \text{ J})$$
$$E_E = -7.2 \times 10^{-3} \text{ J}$$

Statement: The total electric potential energy of the group of charges is -7.2×10^{-3} J.

67. (a) Given: $q_1 = +2.5 \times 10^{-6}$ C; $q_2 = +4.5 \times 10^{-6}$ C; $q_3 = -3.5 \times 10^{-6}$ C; $q_4 = -5.0 \times 10^{-6}$ C; $r_i \to \infty$; $r_{f1} = 1.5$ m; $r_{f2} = 1.5$ m; $r_{f3} = 3.0$ m; $k = 8.99 \times 10^9 \text{ N} \cdot \text{m/C}^2$

Required: W_{net}

Analysis: $W = \frac{kq_1q_2}{r_f} - \frac{kq_1q_2}{r_i}$; since r_i is very far away, the work equation is simply $W = \frac{kq_1q_2}{r_f}$; determine the work associated with each charge then calculate the sum.

Solution: Calculate the work required to bring q_4 close to q_1, W_1:

$$W = \frac{kq_1q_2}{r_\text{f}}$$

$$W_1 = \frac{kq_1q_4}{r_\text{f1}}$$

$$= \frac{\left(8.99\times10^9\ \frac{\text{J}\cdot\cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(2.5\times10^{-6}\ \cancel{\text{C}}\right)\left(-5.0\times10^{-6}\ \cancel{\text{C}}\right)}{1.5\ \cancel{\text{m}}}$$

$W_1 = -7.492\times10^{-2}$ J (two extra digits carried)

Calculate the work required to bring q_4 close to q_2, W_2:

$$W = \frac{kq_1q_2}{r_\text{f}}$$

$$W_2 = \frac{kq_2q_4}{r_\text{f2}}$$

$$= \frac{\left(8.99\times10^9\ \frac{\text{J}\cdot\cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(4.5\times10^{-6}\ \cancel{\text{C}}\right)\left(-5.0\times10^{-6}\ \cancel{\text{C}}\right)}{1.5\ \cancel{\text{m}}}$$

$W_2 = -1.348\times10^{-1}$ J (two extra digits carried)

Calculate the work required to bring q_4 close to q_3, W_3:

$$W = \frac{kq_1q_2}{r_\text{f}}$$

$$W_3 = \frac{kq_3q_4}{r_\text{f3}}$$

$$= \frac{\left(8.99\times10^9\ \frac{\text{J}\cdot\cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(-3.5\times10^{-6}\ \cancel{\text{C}}\right)\left(-5.0\times10^{-6}\ \cancel{\text{C}}\right)}{3.0\ \cancel{\text{m}}}$$

$W_3 = 5.244\times10^{-2}$ J (two extra digits carried)

Calculate the total work, W_net:

$$W_\text{net} = W_1 + W_2 + W_3$$

$$= \left(-7.492\times10^{-2}\ \text{J}\right) + \left(-1.348\times10^{-1}\ \text{J}\right) + \left(5.244\times10^{-2}\ \text{J}\right)$$

$W_\text{net} = -0.16$ J

Statement: The work required to bring the charge to the origin is –0.16 J.

(b) The work required to move the charge from the origin to a very far away distance is the opposite of the work required to bring the charge to the origin from a very far away distance. Since –0.16 J of work is required to bring the charge to the origin, 0.16 J of work is required to move it from the origin.

68. Given: $q_1 = +1.60 \times 10^{-19}$ C; $q_2 = -1.60 \times 10^{-19}$ C; $r_i = 7.5 \times 10^{-9}$ m; $2r_i = r_f$; $k = 8.99 \times 10^9$ N·m/C^2

Required: W

Analysis:
$$W = \frac{kq_1q_2}{r_f} - \frac{kq_1q_2}{r_i}$$
$$= \frac{kq_1q_2}{2r_i} - \frac{kq_1q_2}{r_i}$$
$$= \frac{kq_1q_2}{2r_i} - \frac{2kq_1q_2}{2r_i}$$
$$W = -\frac{kq_1q_2}{2r_i}$$

Solution:
$$W = -\frac{kq_1q_2}{2r_i}$$
$$= -\frac{\left(8.99 \times 10^9 \ \frac{\text{J} \cdot \cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(-1.60 \times 10^{-19} \ \cancel{\text{C}}\right)\left(1.60 \times 10^{-19} \ \cancel{\text{C}}\right)}{2\left(7.5 \times 10^{-9} \ \cancel{\text{m}}\right)}$$
$$W = 1.5 \times 10^{-20} \text{ J}$$

Statement: The work required to double the separation distance is 1.5×10^{-20} J.

69. Given: $q_1 = 3.20 \times 10^{-19}$ C; $q_2 = 1.60 \times 10^{-19}$ C; $r_i = 5.0 \times 10^{-10}$ m; $r_f \rightarrow \infty$; $k = 8.99 \times 10^9$ N·m/C^2

Required: ΔE_E

Analysis:
$$\Delta E_E = \frac{kq_1q_2}{r_f} - \frac{kq_1q_2}{r_i}$$

Solution:
$$\Delta E_E = \frac{kq_1q_2}{r_f} - \frac{kq_1q_2}{r_i}$$
$$= -\frac{kq_1q_2}{r_i}$$
$$= -\frac{\left(8.99 \times 10^9 \ \frac{\text{J} \cdot \cancel{\text{m}}}{\cancel{\text{C}^2}}\right)\left(3.20 \times 10^{-19} \ \cancel{\text{C}}\right)\left(1.60 \times 10^{-19} \ \cancel{\text{C}}\right)}{\left(5.0 \times 10^{-10} \ \cancel{\text{m}}\right)}$$
$$\Delta E_E = 9.2 \times 10^{-19} \text{ J}$$

Statement: The work required to double the separation distance is 9.2×10^{-19} J.

70. The charge on an electron is 1.60×10^{-19} C, which is much less than 1 C.
$$N = \frac{1 \ \cancel{\text{C}}}{1.6 \times 10^{-19} \ \cancel{\text{C}}}$$
$$N = 6.25 \times 10^{18}$$
There are 6.25×10^{18} electrons in 1 C.

71. Given: ΔV_b = 2.0 kV; Δd = 8 mm = 0.008 m; $m = 4.9 \times 10^{-14}$ kg; $e = 1.602 \times 10^{-19}$ C; g = 9.8 m/s^2

Required: q; N

Analysis: $q = \dfrac{mg\Delta d}{\Delta V_b}$; $q = Ne$; Since the top plate is positively charged, the field between the plates points downward but the electric force is balancing the gravitational force, so the particle is moving against the electric field. Therefore the charge will be negative.

Solution: Determine the charge on the oil drop:

$$q = \frac{mg\Delta d}{\Delta V_b}$$

$$= \frac{\left(4.9\times10^{-14}\ \cancel{\text{kg}}\right)\left(10\ \dfrac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)\left(0.008\ \cancel{\text{m}}\right)}{2000\ \cancel{\text{kg}}\cdot\dfrac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\cdot\dfrac{\cancel{\text{m}}}{\text{C}}}$$

$q = 1.96\times10^{-18}$ C (two extra digits carried)

Determine the excess of electrons:

$$q = Ne$$

$$N = \frac{q}{e}$$

$$= \frac{1.96\times10^{-18}\ \cancel{\text{C}}}{1.602\times10^{-19}\ \cancel{\text{C}}}$$

$$N = 12$$

Statement: The oil drop has an excess of 12 electrons.

72. (a) Given: $q = 1.60 \times 10^{-19}$ C; $v = 5.9 \times 10^6$ m/s; B = 0.800 T; $\theta = 90°$

Required: F_M

Analysis: $F_M = qvB \sin \theta$

Solution: $F_M = qvB\sin\theta$

$$= \left(1.60\times10^{-19}\ \cancel{\text{C}}\right)\left(5.9\times10^{6}\ \text{m/s}\right)\left(0.800\ \frac{\text{kg}}{\cancel{\text{C}}\cdot\text{s}}\right)\sin 90°$$

$$F_M = 7.6\times10^{-13}\ \text{N}$$

Statement: The magnetic force on the proton is 7.6×10^{-13} N.

(b) The proton will initially move up, then circle around back to the west, and continue in a circle as long as it is in the magnetic field.

73. Given: L = 15 cm = 0.15 m; I = 5.1 A; $\theta = 90°$; $F_{\text{on wire}}$ = 0.05 N

Required: B

Analysis: $F_{\text{on wire}} = ILB\sin\theta$

$$B = \frac{F_{\text{on wire}}}{IL\sin\theta}$$

Solution: $B = \dfrac{F_{\text{on wire}}}{IL\sin\theta}$

$$= \dfrac{\left(0.05\ \text{kg}\cdot\dfrac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}\right)}{\left(5.1\ \dfrac{\text{C}}{\cancel{\text{s}}}\right)(0.15\ \cancel{\text{m}})\sin 90°}$$

$B = 0.06\ \text{T}$

Statement: The magnitude of the magnetic field is 0.06 T.

74. (a) The direction of the current is from the negative terminal to the positive and the magnetic field is directed up from the north pole to the south pole. By the right-hand rule, the copper bar experiences a force away from the magnet.

(b) To increase the magnitude of the force in $F_{\text{on wire}} = ILB \sin \theta$, increase the current ($I$) or the magnetic field (B).

(c) The force would decrease because the angle would decrease from 90°, which decreases the value of $\sin \theta$.

75. By the right-hand rule, the magnetic field is perpendicular to the force, so it must point 35° below the y-axis or 55° to the left of the x-axis in the diagram. The magnetic field may point above the x-y plane as long as the angle between it and the $+z$-axis is greater than 0° and no more than 90°.

76. Given: $q = 1.60 \times 10^{-19}$ C; $m = 2.0 \times 10^{-26}$ kg; $v = 6.5 \times 10^{5}$ m/s; $r = 35$ cm $= 0.35$ m

Required: B

Analysis: $r = \dfrac{mv}{qB}$

$B = \dfrac{mv}{qr}$

Solution: $B = \dfrac{mv}{qr}$

$$= \dfrac{\left(2.0\times10^{-26}\ \text{kg}\right)\left(6.5\times10^{5}\ \dfrac{\cancel{\text{m}}}{\text{s}}\right)}{\left(1.60\times10^{-19}\ \text{C}\right)(0.35\ \cancel{\text{m}})}$$

$B = 0.23\ \text{T}$

Statement: The magnetic field strength in the mass spectrometer must be 0.23 T.

77. Recalculate the radius if $m_{\text{p}} = 1840m_{\text{e}}$:

$$r_{\text{p}} = \dfrac{m_{\text{p}}v}{qB}$$

$$= \dfrac{\left(1840m_{\text{e}}\right)v}{qB}$$

$$= 1840\dfrac{m_{\text{e}}v}{qB}$$

$$r_{\text{p}} = 1840r_{\text{e}}$$

Since the speed, charge, and magnetic field are all the same, the ratio of the radii is 1840:1.

78. Given: $q = 1.60 \times 10^{-19}$ C; $m = 9.3 \times 10^{-26}$ kg; $v = 1.2 \times 10^7$ m/s; $B = 5.5 \times 10^{-5}$ T
Required: B

Analysis: $r = \dfrac{mv}{qB}$

Solution: $r = \dfrac{mv}{qB}$

$$= \frac{\left(9.3\times10^{-27}\ \cancel{\text{kg}}\right)\left(1.2\times10^{7}\ \dfrac{\text{m}}{\cancel{\text{s}}}\right)}{\left(1.60\times10^{-19}\ \cancel{\text{C}}\right)\left(5.5\times10^{-5}\ \dfrac{\cancel{\text{kg}}}{\cancel{\text{C}}\cdot\cancel{\text{s}}}\right)}$$

$r = 1.3\times10^{5}$ m

Statement: The radius of the ion's path is 1.3×10^5 m.

Evaluation

79. Given: $g_{\text{Moon}} = 1.7$ m/s^2; $r_{\text{Moon}} = 0.27r_{\text{Earth}}$; $g_{\text{Earth}} = 9.8$ m/s^2

Required: $\dfrac{m_{\text{Earth}}}{m_{\text{Moon}}}$

Analysis:

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

$$m = \frac{gr^2}{G}$$

$$\frac{m_{\text{Earth}}}{m_{\text{Moon}}} = \frac{\dfrac{g_{\text{Earth}}r_{\text{Earth}}^2}{G}}{\dfrac{g_{\text{Moon}}r_{\text{Moon}}^2}{G}}$$

$$\frac{m_{\text{Earth}}}{m_{\text{Moon}}} = \frac{g_{\text{Earth}}r_{\text{Earth}}^2}{g_{\text{Moon}}r_{\text{Moon}}^2}$$

Solution: $\dfrac{m_{\text{Earth}}}{m_{\text{Moon}}} = \dfrac{g_{\text{Earth}}r_{\text{Earth}}^2}{g_{\text{Moon}}r_{\text{Moon}}^2}$

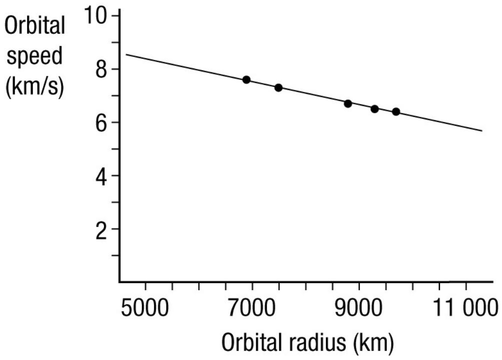
$$= \frac{\left(9.8\ \text{m/s}^2\right)r_{\text{Earth}}^2}{\left(1.7\ \text{m/s}^2\right)\left(0.27r_{\text{Earth}}\right)^2}$$

$$= \frac{\left(9.8\ \dfrac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)}{\left(1.7\ \dfrac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)(0.27)^2}$$

$$\frac{m_{\text{Earth}}}{m_{\text{Moon}}} = \frac{79}{1}$$

Statement: The astronaut will estimate that the mass of Earth is 79 times the mass of the Moon.

80. (a), (b)



(i) From the graph, a satellite with orbital radius 10 300 km would have an orbital speed of about 6.2 km/s.
(ii) From the graph, a satellite with an orbital speed 7.9 km/s would have an orbital radius of 6400 km.
81. (a) Io:
Given: T = 1.8 days; r = 422 000 km
Required: v
Analysis: $T = \frac{2\pi r}{v}$
Solution: Convert the period to seconds:

$$T = 1.8\ \cancel{d} \times \frac{24\ \cancel{h}}{1\ \cancel{d}} \times \frac{60\ \cancel{min}}{1\ \cancel{h}} \times \frac{60\ s}{1\ \cancel{min}}$$

$T = 1.555 \times 10^5$ s (two extra digits carried)
Determine the orbital speed of Io:

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

$$\begin{aligned} v &= \frac{2\pi r}{T} \\ &= \frac{2\pi(422\ 000\ \text{km})}{(1.555 \times 10^5\ \text{s})} \\ &= 17.05\ \text{km/s (two extra digits carried)} \\ v &= 17\ \text{km/s} \end{aligned}$$

Statement: The orbital speed of Io is 17 km/s.
Europa:
Given: T = 3.5 days; r = 670 000 km
Required: v
Analysis: $T = \frac{2\pi r}{v}$

Solution: Convert the period to seconds:

$$T = 3.5\ \cancel{d} \times \frac{24\ \cancel{h}}{1\ \cancel{d}} \times \frac{60\ \cancel{min}}{1\ \cancel{h}} \times \frac{60\ s}{1\ \cancel{min}}$$

$$= 3.024 \times 10^5\ \text{s (two extra digits carried)}$$

$$T = 3.0 \times 10^5\ \text{s}$$

Determine the orbital speed of Europa:

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

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

$$= \frac{2\pi(670\ 000\ \text{km})}{(3.024 \times 10^5\ \text{s})}$$

$$= 13.92\ \text{km/s (two extra digits carried)}$$

$$v = 14\ \text{km/s}$$

Statement: The orbital speed of Europa is 14 km/s.

Ganymede:

Given: T = 7.5 days; r = 1 070 000 km

Required: v

Analysis: $T = \frac{2\pi r}{v}$

Solution: Convert the period to seconds:

$$T = 7.5\ \cancel{d} \times \frac{24\ \cancel{h}}{1\ \cancel{d}} \times \frac{60\ \cancel{min}}{1\ \cancel{h}} \times \frac{60\ s}{1\ \cancel{min}}$$

$$= 6.480 \times 10^5\ \text{s (two extra digits carried)}$$

$$T = 6.5 \times 10^5\ \text{s}$$

Determine the orbital speed of Ganymede:

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

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

$$= \frac{2\pi(1070000\ \text{km})}{(6.480 \times 10^5\ \text{s})}$$

$$= 10.38\ \text{km/s (two extra digits carried)}$$

$$v = 1.0 \times 10^1\ \text{km/s}$$

Statement: The orbital speed of Ganymede is 1.0×10^1 km/s.

Callisto:

Given: T = 17 days; r = 1 880 000 km

Required: v

Analysis: $T = \frac{2\pi r}{v}$

Solution: Convert the period to seconds:

$$T = 17\ \cancel{\text{d}} \times \frac{24\ \cancel{\text{h}}}{1\ \cancel{\text{d}}} \times \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}} \times \frac{60\ \text{s}}{1\ \cancel{\text{min}}}$$

$$= 1.469 \times 10^6\ \text{s (two extra digits carried)}$$

$$T = 1.5 \times 10^6\ \text{s}$$

Determine the orbital speed of Callisto:

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

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

$$= \frac{2\pi(1\ 880\ 000\ \text{km})}{(1.469 \times 10^6\ \text{s})}$$

$$= 8.041\ \text{km/s (two extra digits carried)}$$

$$v = 8.0\ \text{km/s}$$

Statement: The orbital speed of Callisto is 8.0 km/s.

(b) Given: r_I = 422 000 km = 4.22 × 10^8 m; r_E = 670 000 km = 6.7 × 10^8 m; r_G = 1 070 000 km = 1.07 × 10^9 m; r_C = 1 880 000 km = 1.88 × 10^9 m; v_I = 17.05 km/s = 1.705 × 10^4 m/s; v_E = 13.92 km/s = 1.392 × 10^4 m/s; v_C = 10.38 km/s = 1.038 × 10^4 m/s; v_G = 8.04 km/s = 8.04 × 10^3 m/s; $G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$

Required: m

Analysis: $v = \sqrt{\dfrac{Gm}{r}}$

Solution: Use the Io data to calculate the mass of Jupiter:

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

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

$$m = \frac{rv^2}{G}$$

$$= \frac{(4.22 \times 10^8\ \cancel{\text{m}})\left(1.705 \times 10^4\ \dfrac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)^2}{6.67 \times 10^{-11}\ \dfrac{\cancel{\text{kg}} \cdot \dfrac{\cancel{\text{m}}}{\cancel{\text{s}^2}} \cdot \cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}}$$

$$m = 1.84 \times 10^{27}\ \text{kg (one extra digit carried)}$$

Use the Europa data to calculate the mass of Jupiter:

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

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

$$m = \frac{rv^2}{G}$$

$$= \frac{(6.7 \times 10^8 \ \cancel{\text{m}})\left(1.392 \times 10^4 \ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)^2}{6.67 \times 10^{-11} \ \frac{\cancel{\text{kg}} \cdot \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}} \cdot \cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}}$$

$m = 1.95 \times 10^{27}$ kg (one extra digit carried)

Use the Ganymede data to calculate the mass of Jupiter:

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

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

$$m = \frac{rv^2}{G}$$

$$= \frac{(1.07 \times 10^9 \ \cancel{\text{m}})\left(1.038 \times 10^4 \ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)^2}{6.67 \times 10^{-11} \ \frac{\cancel{\text{kg}} \cdot \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}} \cdot \cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}}$$

$m = 1.73 \times 10^{27}$ kg (one extra digit carried)

Use the Callisto data to calculate the mass of Jupiter:

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

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

$$m = \frac{rv^2}{G}$$

$$m = \frac{rv^2}{G}$$

$$= \frac{(1.88 \times 10^9 \ \cancel{\text{m}})\left(8.04 \times 10^3 \ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)^2}{6.67 \times 10^{-11} \ \frac{\cancel{\text{kg}} \cdot \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}} \cdot \cancel{\text{m}^2}}{\text{kg}^{\cancel{2}}}}$$

$m = 1.82 \times 10^{27}$ kg (one extra digit carried)

Determine the average value of the experimental results:

$$m_{\text{av}} = \frac{m_1 + m_2 + m_3 + m_4}{4}$$

$$= \frac{(1.84 \times 10^{27} \text{ kg}) + (1.95 \times 10^{27} \text{ kg}) + (1.73 \times 10^{27} \text{ kg}) + (1.82 \times 10^{27} \text{ kg})}{4}$$

$m_{\text{av}} = 1.8 \times 10^{27}$ kg

Statement: The mass of Jupiter is approximately 1.8×10^{27} kg.

82. Both the human body and copper rod conduct electricity. When you attempt to charge a copper rod by rubbing it with a piece of cloth, the charge flows from the rod to Earth through your hand and body. However, when the ebonite rod is charged by rubbing, the charges added to the ebonite rod stay on the rod as it is a poor conductor of electricity.

83. (a) Given: $m_1 = 9.11 \times 10^{-31}$ kg; $m_2 = 1.67 \times 10^{-27}$ kg; $r = 1.0$ nm $= 1.0 \times 10^{-9}$ m; $G = 6.67 \times 10^{-11}$ N·m²/kg²

Required: F_g

Analysis: $F_g = \frac{Gm_1m_2}{r^2}$

Solution: $F_g = \frac{Gm_1m_2}{r^2}$

$$= \frac{\left(6.67 \times 10^{-11} \ \frac{\text{N} \cdot \cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)(9.11 \times 10^{-31} \ \cancel{\text{kg}})(1.67 \times 10^{-27} \ \cancel{\text{kg}})}{(1.0 \times 10^{-9} \ \cancel{\text{m}})^2}$$

$F_g = 1.0 \times 10^{-49}$ N

Statement: The gravitational force between the electron and the proton is 1.0×10^{-49} N.

(b) Given: $q_1 = 1.60 \times 10^{-19}$ C; $q_2 = -1.60 \times 10^{-19}$ C; $r = 1.0$ nm $= 1.0 \times 10^{-9}$ m; $k = 8.99 \times 10^9$ N·m/C²

Required: F_E

Analysis: $F_E = \frac{kq_1q_2}{r^2}$

Solution: $F_E = \frac{kq_1q_2}{r^2}$

$$= \frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(1.60\times10^{-19}\ \text{C}\right)^2}{\left(1.0\times10^{-9}\ \text{m}\right)^2}$$

$$F_E = 2.3\times10^{-10}\ \text{N}$$

Statement: The electric force between the electron and the proton is 2.3×10^{-10} N.

(c) The denominator in both equations is r^2, so changing the distance will not affect the ratio of the gravitational force and the electric force.

84. Answers may vary. Sample answer with 60 kg student who lives 4 km from school:

(a) Given: q_1 = 1 C; q_2 = 1 C; r = 4 km = 4×10^3 m; $k = 8.99 \times 10^9\ \text{N}\cdot\text{m/C}^2$

Required: F_E

Analysis: $F_E = \frac{kq_1q_2}{r^2}$

Solution: $F_E = \frac{kq_1q_2}{r^2}$

$$= \frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(1\ \text{C}\right)^2}{\left(4\times10^3\ \text{m}\right)^2}$$

$$F_E = 600\ \text{N}$$

Statement: The electric force between the charges is 600 N.

(b) Since my weight is my mass (60 kg) multiplied by g, the force exerted by the particles on each other is roughly equal to my weight:

$(60\ \text{kg})(9.8\ \text{m/s}^2) = 588\ \text{N}$

85. Given: $q = 2.0 \times 10^{-6}$ C; $\theta = 60°$; r = 5.0 cm = 0.050 m; $k = 8.99 \times 10^9\ \text{N}\cdot\text{m/C}^2$

Required: F_E

Analysis: The charges all have the same sign and magnitude, so the force will be repulsive and equal. Determine the net force on one particle and it applies to the other two particles;

$F_E = \frac{kq_1q_2}{r^2}$

Solution: Determine the force between two charges:

$$F_E = \frac{kq_1q_2}{r^2}$$
$$= \frac{kq^2}{r^2}$$
$$= \frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\cancel{\text{C}^2}}\right)\left(2.0\times10^{-6}\ \cancel{\text{C}}\right)^2}{\left(0.050\ \cancel{\text{m}}\right)^2}$$
$$= 14.38\ \text{N (two extra digits carried)}$$
$$F_E = 14\ \text{N}$$

For the top charge (assuming the equilateral triangle is positioned like a capital delta), the horizontal components of the forces will net zero. Determine the total force in y-direction:

$$F_{net} = 2F_E\cos\left(\frac{60°}{2}\right)$$
$$= 2(14.38\ \text{N})\cos 30°$$
$$F_{net} = 25\ \text{N}$$

Statement: The net force on each particle is 25 N [away from the centre].

86. The total electric force on one of the charged objects can be determined by calculating the vector sum of the forces due to each of the other charged objects.

87. The electric charges on an electron and a proton are of opposite signs but equal magnitudes. That means the electric forces on them will be equal in magnitude but opposite in direction. Since the mass of the electron is much less than the mass of the proton, the acceleration of the electron will be much greater than the acceleration of the proton.

88. (a) Yes, the work done depends only on the location of initial and final positions of the charge and not on the path followed.

(b) No, the electrostatic potential is not necessarily zero at a point where the electric field strength is zero. For example, at a point midway between two equal charges, the electric field strength is zero but the electrostatic potential is twice that due to a single charge.

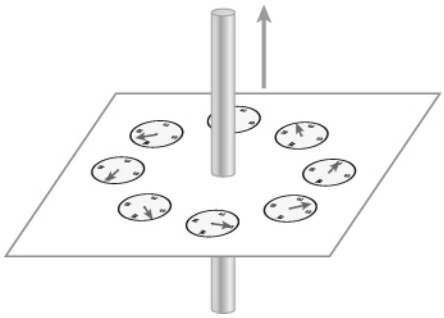
89. (a) To use this data to find the value of the elementary charge, try to find a number that is an integer divisor of all these numbers.

(b) The least difference and lowest common divisor of all these numbers is 1.62×10^{-19} C.

(c) The data I obtained is greater than the value of e. The problem might be that not enough data in the table to make a proper conclusion.

90. Answers may vary. Students' Venn diagrams should show that both electric fields and magnetic involve two opposite "poles" (positive/negative in electric fields and north/south in magnetic fields). Another similarity is that both forces decrease with increasing distance, and both types of field can be attractive or repulsive depending on the sign of a charge. A way that the fields are different is this: magnetic fields circulate around moving charges, and electric fields start at positive charges and terminate on negative charges.

91. By the right-hand rule, the magnetic field is directed counterclockwise around the current, when viewed from above.



92. (a) The proton experiences a maximum magnetic force when its velocity is perpendicular to the magnetic field.
(b) The proton experiences a minimum magnetic force when velocity is parallel to the magnetic field.
93. The force is zero when the direction of the current is parallel to the magnetic field.
94. (a) By the right-hand rule, the force is in the direction of the x-axis.
(b) Given: $L = 1.5$ m; $I = 2.5$ A; $B = 1.4$ T; $\theta = 25°$
Required: $F_{\text{on wire}}$
Analysis: $F_{\text{on wire}} = ILB \sin \theta$
Solution:
$$\begin{aligned} F_{\text{on wire}} &= ILB\sin\theta \\ &= \left(2.5\ \frac{\cancel{C}}{\text{s}}\right)(1.5\ \text{m})\left(1.4\ \frac{\text{kg}}{\cancel{C}\cdot\text{s}}\right)\sin 25° \\ F_{\text{on wire}} &= 2.2\ \text{N} \end{aligned}$$
Statement: The magnitude of the force on the wire is 2.2 N.
95. Recalculate the radius if $v_A = 4v_B$:
$$\begin{aligned} r_A &= \frac{mv_A}{qB} \\ &= \frac{m(4v_B)}{qB} \\ &= 4\frac{mv_B}{qB} \\ r_A &= 4r_B \end{aligned}$$
Since the mass, charge, and magnetic field are all the same, the ratio of the radii is also 4:1.
96. (a) Given: $r_1 = 4.0$ cm = 0.040 m; $I_1 = 10.4$ A; $r_2 = 8.0$ cm = 0.080 m; $I_2 = 21.3$ A; $r_3 = 12.0$ cm = 0.120 m; $I_3 = 32.1$ A
Required: B_{av}
Analysis: $B = \dfrac{(1.3\times10^{-6})I}{2\pi r}$

Solution: Determine the first experimental value of Earth's magnetic field, B_1:

$$B = \frac{(1.3\times10^{-6})I}{2\pi r}$$

$$B_1 = \frac{(1.3\times10^{-6})I_1}{2\pi r_1}$$

$$= \frac{(1.3\times10^{-6})(10.4 \text{ A})}{2\pi(0.040 \text{ m})}$$

$B_1 = 5.379\times10^{-5}$ T (two extra digits carried)

Determine the second experimental value of Earth's magnetic field, B_2:

$$B = \frac{(1.3\times10^{-6})I}{2\pi r}$$

$$B_2 = \frac{(1.3\times10^{-6})I_2}{2\pi r_2}$$

$$= \frac{(1.3\times10^{-6})(21.3 \text{ A})}{2\pi(0.080 \text{ m})}$$

$B_2 = 5.509\times10^{-5}$ T (two extra digits carried)

Determine the third experimental value of Earth's magnetic field, B_3:

$$B = \frac{(1.3\times10^{-6})I}{2\pi r}$$

$$B_3 = \frac{(1.3\times10^{-6})I_3}{2\pi r_3}$$

$$= \frac{(1.3\times10^{-6})(32.1 \text{ A})}{2\pi(0.120 \text{ m})}$$

$B_3 = 5.535\times10^{-5}$ T (two extra digits carried)

Determine the average value of the experimental results:

$$B_{\text{av}} = \frac{B_1 + B_2 + B_3}{3}$$

$$= \frac{(5.379\times10^{-5} \text{ T})+(5.509\times10^{-5} \text{ T})+(5.535\times10^{-5} \text{ T})}{3}$$

$$B_{\text{av}} = 5.5\times10^{-5} \text{ T}$$

Statement: The average value for Earth's magnetic field, based on the experimental results, is 5.5×10^{-5} T.

(b) In Canada, there is a large vertical component of Earth's magnetic field. This experiment only measures the horizontal component, and therefore calculates a value that is less than the true value.

(c) By the right-hand rule, the magnetic field is directed counterclockwise around the current, when viewed from above. Therefore, the compass needle would be deflected to its left in the direction N 45° W.

97. Given that $r_i = 2$ cm, recalculate the radius if $v_f = 2v_i$:

$$r_f = \frac{mv_f}{qB}$$
$$= \frac{m(2v_f)}{qB}$$
$$= 2\frac{mv_f}{qB}$$
$$= 2r_i$$
$$= 2(2 \text{ cm})$$
$$r_f = 4 \text{ cm}$$

Since the mass, charge, and magnetic field are all the same, the radius is 4 cm when the speed is doubled.

Reflect on Your Learning

98. Answers may vary. Sample answer: The most surprising thing I learned was that magnetic fields have no effect on stationary particles. I also found it fascinating that Millikan could calculate the primary charge. The most challenging topic for me was the concept of electric potential differences. To gain greater understanding about electric potential differences, I will ask several classmates to explain it to me in a different way that what the textbook shows, or I will search the Internet for other sources that could explain the concept.
99. Answers may vary. Sample answer: Both fields radiate from a point and decrease as distance increases, but an electric force can repel as well as attract, depending on the charges involved.
100. Answers may vary. Students' lists may include MRI machines, loudspeakers, LCD screens, printers, and satellites.

Research

101. Answers may vary. Students' answers should include an up-to-date number of exoplanets (over 700 in 2012) and methods of detection, such as timing, imaging, microlensing, and astrometry.
102. Answers may vary. Students' posters should include a diagram of Earth highlighting points of strong and weak gravitational forces. Gravity appears to be weakest north in the Indian Ocean and strongest at varied locations such as the Andes and the north Atlantic.
103. Answers may vary. Sample answers:
(a) The wings are rubbing against the atmosphere during flight, so a charge due to friction builds up.
(b) The charge can lead to arcing and disrupt the radio or navigation systems.
(c) Static wicks are conductors to allow the easy flow of electrons and are pointed to attract electrons to them from the rest of the plane's exterior.
104. Answers may vary. Students' presentation should include how changing the direction and strength of the magnetic field, changing the sign and magnitude of the charge, and changing the speed of the particle result in circular paths of varying radii.
105. Answers may vary. Students' posters should include a diagram similar to Figure 8 from Section 8.3, page 395, and an explanation of how a solenoid and a permanent magnet work together to cause the speaker cone to vibrate at different frequencies, resulting in sound waves.