Ch 21 :

5. SSM ***REASONING AND SOLUTION*** The magnitude of the force can be determined using Equation 21.1, $F = |q| vB \sin \theta$, where θ is the angle between the velocity and the magnetic field. The direction of the force is determined by using Right-Hand Rule No. 1.

a. $F = |q| vB \sin 30.0° = (8.4 \times 10^{-6}\text{ C})(45\text{ m/s})(0.30\text{ T}) \sin 30.0° = \boxed{5.7 \times 10^{-5}\text{ N}}$, directed $\boxed{\text{into the paper}}$.

b. $F = |q| vB \sin 90.0° = (8.4 \times 10^{-6}\text{ C})(45\text{ m/s})(0.30\text{ T}) \sin 90.0° = \boxed{1.1 \times 10^{-4}\text{ N}}$, directed $\boxed{\text{into the paper}}$.

c. $F = |q| vB \sin 150° = (8.4 \times 10^{-6}\text{ C})(45\text{ m/s})(0.30\text{ T}) \sin 150° = \boxed{5.7 \times 10^{-5}\text{ N}}$, directed $\boxed{\text{into the paper}}$.

6. ***REASONING*** When a charge q_0 travels at a speed v and its velocity makes an angle θ with respect to a magnetic field of magnitude B, the magnetic force acting on the charge has a magnitude F that is given by $F = |q_0| vB \sin\theta$ (Equation 21.1). We will solve this problem by applying this expression twice, first to the motion of the charge when it moves perpendicular to the field so that $\theta = 90.0°$ and then to the motion when $\theta = 38°$.

SOLUTION When the charge moves perpendicular to the field so that $\theta = 90.0°$, Equation 21.1 indicates that

$$F_{90.0°} = |q_0| vB \sin 90.0°$$

When the charge moves so that $\theta = 38°$, Equation 21.1 shows that

$$F_{38°} = |q_0| vB \sin 38°$$

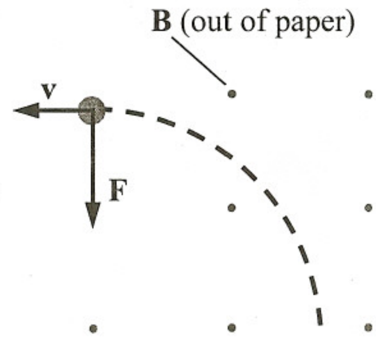
Dividing the second expression by the first expression gives

$$\frac{F_{38°}}{F_{90.0°}} = \frac{|q_0| vB \sin 38°}{|q_0| vB \sin 90.0°}$$

$$F_{38°} = F_{90.0°}\left(\frac{\sin 38°}{\sin 90.0°}\right) = \left(2.7\times10^{-3}\text{ N}\right)\left(\frac{\sin 38°}{\sin 90.0°}\right) = \boxed{1.7\times10^{-3}\text{ N}}$$

11. ***REASONING***

a. The drawing shows the velocity **v** of the particle at the top of its path. The magnetic force **F**, which provides the centripetal force, must be directed toward the center of the circular path. Since the directions of **v**, **F**, and **B** are known, we can use Right-Hand Rule No. 1 (RHR-1) to determine if the charge is positive or negative.



b. The radius of the circular path followed by a charged particle is given by Equation 21.2 as $r = mv/|q|B$. The mass m of the particle can be obtained directly from this relation, since all other variables are known.

SOLUTION

a. If the particle were positively charged, an application of RHR-1 would show that the force would be directed straight up, opposite to that shown in the drawing. Thus, the charge on the particle must be $\boxed{\text{negative}}$.

b. Solving Equation 21.2 for the mass of the particle gives

$$m = \frac{|q|Br}{v} = \frac{\left(8.2\times10^{-4}\text{ C}\right)\left(0.48\text{ T}\right)\left(960\text{ m}\right)}{140\text{ m/s}} = \boxed{2.7\times10^{-3}\text{ kg}}$$

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19. $\boxed{\text{SSM}}$ ***REASONING AND SOLUTION*** According to Right-Hand Rule No. 1, the magnetic force on the positively charged particle is toward the bottom of the page in the drawing in the text. If the presence of the electric field is to double the magnitude of the net force on the charge, the electric field must also be $\boxed{\text{directed toward the bottom of the page}}$. Note that this results in the electric field being perpendicular to the magnetic field, even though the electric force and the magnetic force are in the same direction.

Furthermore, if the magnitude of the net force on the particle is twice the magnetic force, the electric force must be equal in magnitude to the magnetic force. In other words, combining Equations 18.2 and 21.1, we find $|q|E = |q|vB\sin\theta$, with $\sin\theta = \sin 90.0° = 1.0$. Then, solving for E

$$E = vB\sin\theta = (270\text{ m/s})(0.52\text{ T})(1.0) = \boxed{140\text{ V/m}}$$

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21. ***REASONING*** When the proton moves in the magnetic field, its trajectory is a circular path. The proton will just miss the opposite plate if the distance between the plates is equal to the radius of the path. The radius is given by Equation 21.2 as $r = mv/(|q|B)$. This relation can be used to find the magnitude B of the magnetic field, since values for all the other variables are known.

SOLUTION Solving the relation $r = mv/(|q|B)$ for the magnitude of the magnetic field, and realizing that the radius is equal to the plate separation, we find that

$$B = \frac{mv}{|q|r} = \frac{(1.67 \times 10^{-27}\ \text{kg})(3.5\times 10^{6}\ \text{m/s})}{(1.60 \times 10^{-19}\ \text{C})(0.23\ \text{m})} = \boxed{0.16\ \text{T}}$$

The values for the mass and the magnitude of the charge (which is the same as that of the electron) have been taken from the inside of the front cover.

30. ***REASONING*** The magnitude of the magnetic force exerted on a long straight wire is given by Equation 21. 3 as $F = ILB \sin \theta$. The direction of the magnetic force is predicted by Right-Hand Rule No. 1. The net force on the triangular loop is the vector sum of the forces on the three sides.

SOLUTION

a. The direction of the current in side AB is opposite to the direction of the magnetic field, so the angle θ between them is $\theta = 180°$. The magnitude of the magnetic force is

$$F_{AB} = ILB \sin\theta = ILB \sin 180° = \boxed{0\ \text{N}}$$

For the side BC, the angle is $\theta = 55.0°$, and the length of the side is

$$L = \frac{2.00\ \text{m}}{\cos 55.0°} = 3.49\ \text{m}$$

The magnetic force is

$$F_{BC} = ILB \sin\theta = (4.70\ \text{A})(3.49\ \text{m})(1.80\ \text{T}) \sin 55.0° = \boxed{24.2\ \text{N}}$$

An application of Right-Hand No. 1 shows that the magnetic force on side BC is directed **[perpendicularly out of the paper]**, toward the reader.

For the side AC, the angle is $\theta = 90.0°$. We see that the length of the side is

$$L = (2.00\ \text{m}) \tan 55.0° = 2.86\ \text{m}$$

The magnetic force is

$$F_{AC} = ILB \sin\theta = (4.70\ \text{A})(2.86\ \text{m})(1.80\ \text{T}) \sin 90.0° = \boxed{24.2\ \text{N}}$$

An application of Right-Hand No. 1 shows that the magnetic force on side AC is directed **[perpendicularly into the paper]**, away from the reader.

b. The net force is the vector sum of the forces on the three sides. Taking the positive direction as being out of the paper, the net force is

$$\sum F = 0\ \text{N} + 24.2\ \text{N} + (-24.2\ \text{N}) = \boxed{0\ \text{N}}$$

34. ***REASONING*** Since the rod does not rotate about the axis at P, the net torque relative to that axis must be zero; $\Sigma\tau = 0$ (Equation 9.2). There are two torques that must be considered, one due to the magnetic force and another due to the weight of the rod. We consider both of these to act at the rod's center of gravity, which is at the geometrical center of the rod (length = L), because the rod is uniform. According to Right-Hand Rule No. 1, the magnetic force acts perpendicular to the rod and is directed up and to the left in the drawing. Therefore, the magnetic torque is a counterclockwise (positive) torque. Equation 21.3 gives the magnitude F of the magnetic force as $F = ILB\sin 90.0°$, since the current is perpendicular to the magnetic field. The weight is mg and acts downward, producing a clockwise (negative) torque. The magnitude of each torque is the magnitude of the force times the lever arm (Equation 9.1). Thus, we have for the torques:

$$\tau_{\text{magnetic}} = +\underbrace{(ILB)}_{\text{force}}\underbrace{(L/2)}_{\text{lever arm}} \quad \text{and} \quad \tau_{\text{weight}} = -\underbrace{(mg)}_{\text{force}}\underbrace{\left[(L/2)\cos\theta\right]}_{\text{lever arm}}$$

Setting the sum of these torques equal to zero will enable us to find the angle θ that the rod makes with the ground.

SOLUTION Setting the sum of the torques equal to zero gives $\Sigma\tau = \tau_{\text{magnetic}} + \tau_{\text{weight}} = 0$, and we have

$$+(ILB)(L/2) - (mg)\left[(L/2)\cos\theta\right] = 0 \quad \text{or} \quad \cos\theta = \frac{ILB}{mg}$$

$$\theta = \cos^{-1}\left[\frac{(4.1\text{ A})(0.45\text{ m})(0.36\text{ T})}{(0.094\text{ kg})(9.80\text{ m/s}^2)}\right] = \boxed{44°}$$

41. SSM WWW ***REASONING*** The torque on the loop is given by Equation 21.4, $\tau = NIAB\sin\phi$. From the drawing in the text, we see that the angle ϕ between the normal to the plane of the loop and the magnetic field is $90° - 35° = 55°$. The area of the loop is $0.70\text{ m} \times 0.50\text{ m} = 0.35\text{ m}^2$.

SOLUTION

a. The magnitude of the net torque exerted on the loop is

$$\tau = NIAB\sin\phi = (75)(4.4\text{ A})(0.35\text{ m}^2)(1.8\text{ T})\sin 55° = \boxed{170\text{ N}\cdot\text{m}}$$

b. As discussed in the text, when a current-carrying loop is placed in a magnetic field, the loop tends to rotate such that its normal becomes aligned with the magnetic field. The normal to the loop makes an angle of 55° with respect to the magnetic field. Since this angle decreases as the loop rotates, the $\boxed{35° \text{ angle increases}}$.

54. ***REASONING AND SOLUTION*** The net force on the wire loop is a sum of the forces on each segment of the loop. The forces on the two segments perpendicular to the long straight wire cancel each other out. The net force on the loop is therefore the sum of the forces on the parallel segments (near and far). These are

$$F_{near} = \mu_o I_1 I_2 L/(2\pi d_{near}) = \mu_0(12\text{ A})(25\text{ A})(0.50\text{ m})/[2\pi\ (0.11\text{ m})] = 2.7\times 10^{-4}\text{ N}$$

$$F_{far} = \mu_o I_1 I_2 L/(2\pi d_{far}) = \mu_0(12\text{ A})(25\text{ A})(0.50\text{ m})/[2\pi\ (0.26\text{ m})] = 1.2\times 10^{-4}\text{ N}$$

Note: F_{near} is a force of attraction, while F_{far} is a repulsive one. The magnitude of the net force is, therefore,

$$F = F_{near} - F_{far} = 2.7\times 10^{-4}\text{ N} - 1.2\times 10^{-4}\text{ N} = \boxed{1.5\times 10^{-4}\text{ N}}$$

Ch 22

5. SSM WWW ***REASONING AND SOLUTION*** For the three rods in the drawing, we have the following:

***Rod A*:** The motional emf is zero, because the velocity of the rod is parallel to the direction of the magnetic field, and the charges do not experience a magnetic force.

***Rod B*:** The motional emf ξ is, according to Equation 22.1,

$$\xi = vBL = (2.7\text{ m/s})(0.45\text{ T})(1.3\text{ m}) = \boxed{1.6\text{ V}}$$

The positive end of Rod B is end 2.

***Rod C*:** The motional emf is zero, because the magnetic force F on each charge is directed perpendicular to the length of the rod. For the ends of the rod to become charged, the magnetic force must be directed parallel to the length of the rod.

16. ***REASONING AND SOLUTION*** The change in flux $\Delta\Phi$ is given by $\Delta\Phi = B\,\Delta A\cos\phi$, where ΔA is the area of the loop that leaves the region of the magnetic field in a time Δt. This area is the product of the width of the rectangle (0.080 m) and the length $v\,\Delta t$ of the side that leaves the magnetic field, $\Delta A = (0.080\text{ m})\,v\,\Delta t$.

$$\Delta\Phi = B\,\Delta A\cos\phi = (2.4\text{ T})\,(0.080\text{ m})(0.020\text{ m/s})(2.0\text{ s})\cos 0.0° = \boxed{7.7\times 10^{-3}\text{ Wb}}$$

18. ***REASONING*** The magnitude $|\xi|$ of the emf induced in the loop can be found using Faraday's law of electromagnetic induction:

$$|\xi| = \left| -N\frac{\Phi - \Phi_0}{t - t_0} \right| \quad (22.3)$$

where N is the number of turns, Φ and Φ_0 are, respectively, the final and initial fluxes, and $t - t_0$ is the elapsed time. The magnetic flux is given by $\Phi = BA\cos\phi$ (Equation 22.2), where B is the magnitude of the magnetic field, A is the area of the surface, and ϕ is the angle between the direction of the magnetic field and the normal to the surface.

SOLUTION Setting $N = 1$ since there is only one turn, noting that the final area is $A = 0\ \text{m}^2$ and the initial area is $A_0 = 0.20\ \text{m} \times 0.35\ \text{m}$, and noting that the angle ϕ between the magnetic field and the normal to the surface is 0°, we find that the magnitude of the emf induced in the coil is

$$|\xi| = \left| -N\frac{BA\cos\phi - BA_0\cos\phi}{t - t_0} \right|$$

$$= \left| -(1)\frac{(0.65\ \text{T})(0\ \text{m}^2)\cos 0° - (0.65\ \text{T})(0.20\ \text{m} \times 0.35\ \text{m})\cos 0°}{0.18\ \text{s}} \right| = \boxed{0.25\ \text{V}}$$

30. ***REASONING*** According to Lenz's law, the induced current in the triangular loop flows in such a direction so as to create an induced magnetic field that opposes the original flux change.

SOLUTION
a. As the triangle is crossing the $+y$ axis, the magnetic flux down into the plane of the paper is increasing, since the field now begins to penetrate the loop. To offset this increase, an induced magnetic field directed up and out of the plane of the paper is needed. By applying RHR-2 it can be seen that such an induced magnetic field will be created within the loop by a [counterclockwise induced current].

b. As the triangle is crossing the $-x$ axis, there is no flux change, since all parts of the triangle remain in the magnetic field, which remains constant. Therefore, there is no induced magnetic field, and [no induced current appears].

c. As the triangle is crossing the $-y$ axis, the magnetic flux down into the plane of the paper is decreasing, since the loop now begins to leave the field region. To offset this decrease, an induced magnetic field directed down and into the plane of the paper is needed. By applying RHR-2 it can be seen that such an induced magnetic field will be created within the loop by a [clockwise induced current].

23. ***REASONING*** The magnitude $|\xi|$ of the average emf induced in the triangle is given by $|\xi| = \left|-N\dfrac{\Delta\Phi}{\Delta t}\right|$ (see Equation 22.3), which is Faraday's law. This expression can be used directly to calculate the magnitude of the average emf. Since the triangle is a single-turn coil, the number of turns is $N = 1$. According to Equation 22.2, the magnetic flux Φ is

$$\Phi = BA\cos\phi = BA\cos 0° = BA \qquad (1)$$

where B is the magnitude of the field, A is the area of the triangle, and $\phi = 0°$ is the angle between the field and the normal to the plane of the triangle (the magnetic field is perpendicular to the plane of the triangle). It is the change $\Delta\Phi$ in the flux that appears in Faraday's law, so that we use Equation (1) as follows:

$$\Delta\Phi = BA - BA_0 = BA$$

where $A_0 = 0\ \text{m}^2$ is the initial area of the triangle just as the bar passes point A, and A is the area after the time interval Δt has elapsed. The area of a triangle is one-half the base (d_{AC}) times the height (d_{CB}) of the triangle. Thus, the change in flux is

$$\Delta\Phi = BA = B\left(\tfrac{1}{2}d_{AC}d_{CB}\right)$$

The base and the height of the triangle are related, according to $d_{CB} = d_{AC}\tan\theta$, where $\theta = 19°$. Furthermore, the base of the triangle becomes longer as the rod moves. Since the rod moves with a speed v during the time interval Δt, the base is $d_{AC} = v\Delta t$. With these substitutions the change in flux becomes

$$\Delta\Phi = B\left(\tfrac{1}{2}d_{AC}d_{CB}\right) = B\left[\tfrac{1}{2}d_{AC}\left(d_{AC}\tan\theta\right)\right] = \tfrac{1}{2}B\left(v\Delta t\right)^2\tan\theta \qquad (2)$$

SOLUTION Substituting Equation (2) for the change in flux into Faraday's law, we find that the magnitude of the induced emf is

$$|\xi| = \left|-N\frac{\Delta\Phi}{\Delta t}\right| = \left|-N\frac{\tfrac{1}{2}B\left(v\Delta t\right)^2\tan\theta}{\Delta t}\right| = N\tfrac{1}{2}Bv^2\Delta t\tan\theta$$

$$= (1)\tfrac{1}{2}(0.38\ \text{T})(0.60\ \text{m/s})^2(6.0\ \text{s})\tan 19° = \boxed{0.14\ \text{V}}$$

31. SSM ***REASONING*** In solving this problem, we apply Lenz's law, which essentially says that the change in magnetic flux must be opposed by the induced magnetic field.

SOLUTION

a. The magnetic field due to the wire in the vicinity of position 1 is directed out of the paper. The coil is moving closer to the wire into a region of higher magnetic field, so the flux through the coil is increasing. Lenz's law demands that the induced field counteract this increase. The direction of the induced field, therefore, must be into the paper. The current in the coil must be $\boxed{\text{clockwise}}$.

b. At position 2 the magnetic field is directed into the paper and is decreasing as the coil moves away from the wire. The induced magnetic field, therefore, must be directed into the paper, so the current in the coil must be $\boxed{\text{clockwise}}$.

69. ***REASONING*** Using Equation 22.3 (Faraday's law) and recognizing that $N = 1$, we can write the magnitude of the emfs for parts a and b as follows:

$$|\xi_a| = \left| -\left(\frac{\Delta\Phi}{\Delta t}\right)_a \right| \quad (1) \qquad \text{and} \qquad |\xi_b| = \left| -\left(\frac{\Delta\Phi}{\Delta t}\right)_b \right| \quad (2)$$

To solve this problem, we need to consider the change in flux $\Delta\Phi$ and the time interval Δt for both parts of the drawing.

SOLUTION The change in flux is the same for both parts of the drawing and is given by

$$(\Delta\Phi)_a = (\Delta\Phi)_b = \Phi_{\text{inside}} - \Phi_{\text{outside}} = \Phi_{\text{inside}} = BA \quad (3)$$

In Equation (3) we have used the fact that initially the coil is outside the field region, so that $\Phi_{\text{outside}} = 0$ Wb for both cases. Moreover, the field is perpendicular to the plane of the coil and has the same magnitude B over the entire area A of the coil, once it has completely entered the field region. Thus, $\Phi_{\text{inside}} = BA$ in both cases, according to Equation 22.2.

The time interval required for the coil to entire the field region completely can be expressed as the distance the coil travels divided by the speed at which it is pushed. In part a of the drawing the distance traveled is W, while in part b it is L. Thus, we have

$$(\Delta t)_a = W/v \quad (4) \qquad (\Delta t)_b = L/v \quad (5)$$

Substituting Equations (3), (4), and (5) into Equations (1) and (2), we find

$$|\xi_a| = \left| -\left(\frac{\Delta\Phi}{\Delta t}\right)_a \right| = \frac{BA}{W/v} \quad (6) \qquad |\xi_b| = \left| -\left(\frac{\Delta\Phi}{\Delta t}\right)_b \right| = \frac{BA}{L/v} \quad (7)$$

Dividing Equation (6) by Equation (7) gives

$$\frac{|\xi_a|}{|\xi_b|} = \frac{\dfrac{BA}{W/v}}{\dfrac{BA}{L/v}} = \frac{L}{W} = 3.0 \qquad \text{or} \qquad |\xi_b| = \frac{|\xi_a|}{3.0} = \frac{0.15\text{ V}}{3.0} = \boxed{0.050\text{ V}}$$

Ch 23

4. ***REASONING*** The two capacitors, each of capacitance C and wired in parallel, are equivalent to a single capacitor C_P that is the sum of the capacitances; $C_P = C + C = 2C$ (Equation 20.18). The equivalent capacitance is related to the capacitive reactance X_C of the circuit by Equation 23.2; $C_P = 1/(2\pi f X_C)$. We can determine X_C by using Equation 23.1, $X_C = V_{rms}/I_{rms}$, since the voltage and current are known.

SOLUTION Since $C_P = 1/(2\pi f X_C)$ and we know that $C_P = 2C$, the capacitance of each capacitor can be obtained as follows:

$$C_P = 2C = \frac{1}{2\pi f X_C} \qquad \text{or} \qquad C = \frac{1}{4\pi f X_C}$$

Since the capacitive reactance is related to the voltage and current by $X_C = V_{rms}/I_{rms}$, we have that

$$C = \frac{1}{4\pi f X_C} = \frac{1}{4\pi f\left(\dfrac{V_{rms}}{I_{rms}}\right)} = \frac{1}{4\pi(610\text{ Hz})\left(\dfrac{24\text{ V}}{0.16\text{ A}}\right)} = \boxed{8.7\times10^{-7}\text{ F}}$$

12. ***REASONING*** The rms voltage across and the rms current in the inductor are related according to $V_{rms} = I_{rms}X_L$ (Equation 23.3), where the inductive reactance X_L is given by $X_L = 2\pi f L$ (Equation 23.4). The frequency is denoted by f and the inductance by L. Since the voltage, current, and frequency are given, we can use these two expressions to determine the inductance.

SOLUTION According to Equation 23.3 the rms voltage and current are related by

$$V_{rms} = I_{rms}X_L$$

Substituting $X_L = 2\pi f L$ (Equation 23.4) for the inductive reactance gives

$$V_{rms} = I_{rms}X_L = I_{rms}(2\pi f L)$$

Solving for the inductance L, we find that

$$L = \frac{V_{rms}}{I_{rms}2\pi f} = \frac{39\text{ V}}{(42\times10^{-3}\text{ A})2\pi(7.5\times10^{3}\text{ Hz})} = \boxed{0.020\text{ H}}$$

19. SSM ***REASONING*** We can use the equations for a series RCL circuit to solve this problem provided that we set $X_C = 0$ since there is no capacitor in the circuit. The current in the circuit can be found from Equation 23.6, $V_{rms} = I_{rms}Z$, once the impedance of the

circuit has been obtained. Equation 23.8, $\tan\phi = (X_L - X_C)/R$, can then be used (with $X_C = 0\ \Omega$) to find the phase angle between the current and the voltage.

SOLUTION The inductive reactance is (Equation 23.4)

$$X_L = 2\pi f L = 2\pi(106\text{ Hz})(0.200\text{ H}) = 133\ \Omega$$

The impedance of the circuit is

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + X_L^2} = \sqrt{(215\ \Omega)^2 + (133\ \Omega)^2} = 253\ \Omega$$

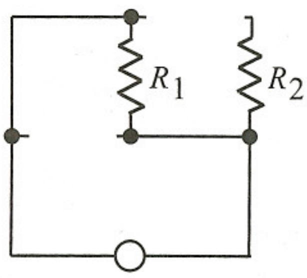
a. The current through each circuit element is, using Equation 23.6,

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{234\text{ V}}{253\ \Omega} = \boxed{0.925\text{ A}}$$

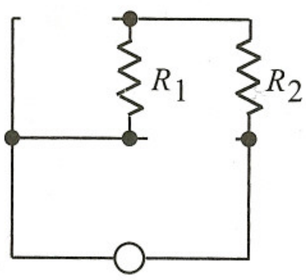
b. The phase angle between the current and the voltage is, according to Equation 23.8 (with $X_C = 0\ \Omega$),

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{X_L}{R} = \frac{133\ \Omega}{215\ \Omega} = 0.619 \quad \text{or} \quad \phi = \tan^{-1}(0.619) = \boxed{31.8^\circ}$$

24. ***REASONING AND SOLUTION*** At very low frequencies the capacitors behave as if they were cut out of the circuit, while the inductors behave as if they were replaced with wires that have zero resistance. The circuit behaves as shown in drawing A, and the current delivered by the generator in the limit of very low frequency is $I_{\text{low frequency}} = V/R_1$.



A: Low frequency



B: High frequency

At very high frequencies the capacitors behave as if they were replaced with wires that have zero resistance, while the inductors behave as if they were cut out of the circuit. The circuit now behaves as in drawing B, and the two resistors are in series. The current at very high frequencies is $I_{\text{high frequency}} = V/(R_1 + R_2)$.

The ratio of the currents is known, so that we can obtain the ratio of the resistances:

$$\frac{I_{\text{low frequency}}}{I_{\text{high frequency}}} = \frac{V/R_1}{V/(R_1 + R_2)} = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1} = 4 \quad \text{or} \quad \boxed{\frac{R_2}{R_1} = 3}$$

Ch 24:

8. ***REASONING*** The wavelength λ of a wave is related to its speed v and frequency f by $\lambda = v/f$ (Equation 16.1). Since blue light and orange light are electromagnetic waves, they travel through a vacuum at the speed of light c; thus, $v = c$.

SOLUTION

a. The wavelength of the blue light is

$$\lambda = \frac{c}{f} = \frac{3.00\times10^{8}\ \text{m/s}}{6.34\times10^{14}\ \text{Hz}} = 4.73\times10^{-7}\ \text{m}$$

Since 1 nm = 10^{-9} m,

$$\lambda = \left(4.73\times10^{-7}\ \cancel{\text{m}}\right)\left(\frac{1\ \text{nm}}{10^{-9}\ \cancel{\text{m}}}\right) = \boxed{473\ \text{nm}}$$

b. In a similar manner, we find that the wavelength of the orange light is

$$\lambda = \frac{c}{f} = \frac{3.00\times10^{8}\ \text{m/s}}{4.95\times10^{14}\ \text{Hz}} = 6.06\times10^{-7}\ \text{m} = \boxed{606\ \text{nm}}$$

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15. SSM ***REASONING*** We proceed by first finding the time t for sound waves to travel between the astronauts. Since this is the same time it takes for the electromagnetic waves to travel to earth, the distance between earth and the spaceship is $d_{\text{earth-ship}} = ct$.

SOLUTION The time it takes for sound waves to travel at 343 m/s through the air between the astronauts is

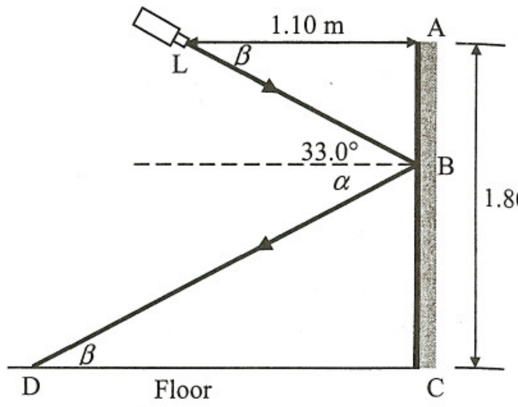
$$t = \frac{d_{\text{astronaut}}}{v_{\text{sound}}} = \frac{1.5\ \text{m}}{343\ \text{m/s}} = 4.4\times10^{-3}\ \text{s}$$

Therefore, the distance between the earth and the spaceship is

$$d_{\text{earth-ship}} = ct = (3.0\times10^{8}\ \text{m/s})(4.4\times10^{-3}\ \text{s}) = \boxed{1.3\times10^{6}\ \text{m}}$$

Ch 25

4. ***REASONING*** The drawing at the right shows the laser beam after reflecting from the plane mirror. The angle of reflection is α, and it is equal to the angle of incidence, which is 33.0°. Note that the angles labeled β in the drawing are also 33.0°, since they are angles formed by a line that intersects two parallel lines. Knowing these angles, we can use trigonometry to determine the distance d_{DC}, which locates the spot where the beam strikes the floor.



SOLUTION Applying trigonometry to triangle DBC, we see that

$$\tan\beta = \frac{d_{BC}}{d_{DC}} \qquad \text{or} \qquad d_{DC} = \frac{d_{BC}}{\tan\beta} \qquad (1)$$

The distance d_{BC} can be determined from $d_{BC} = 1.80\text{ m} - d_{AB}$, which can be substituted into Equation (1) to show that

$$d_{DC} = \frac{d_{BC}}{\tan\beta} = \frac{1.80\text{ m} - d_{AB}}{\tan\beta} \qquad (2)$$

The distance d_{AB} can be found by applying trigonometry to triangle LAB, which shows that

$$\tan\beta = \frac{d_{AB}}{1.10\text{ m}} \qquad \text{or} \qquad d_{AB} = (1.10\text{ m})\tan\beta$$

Substituting this result into Equation (2), gives

$$d_{DC} = \frac{1.80\text{ m} - d_{AB}}{\tan\beta} = \frac{1.80\text{ m} - (1.10\text{ m})\tan\beta}{\tan\beta} = \frac{1.80\text{ m} - (1.10\text{ m})\tan 33.0°}{\tan 33.0°} = \boxed{1.67\text{ m}}$$

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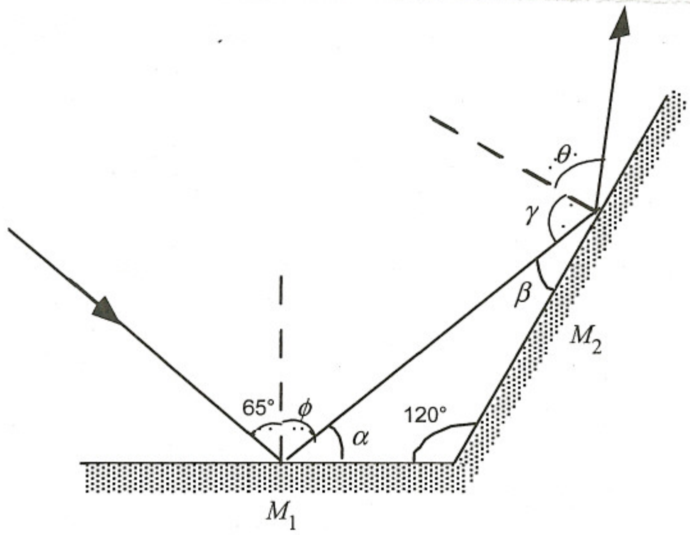
5. SSM ***REASONING*** The geometry is shown below. According to the law of reflection, the incident ray, the reflected ray, and the normal to the surface all lie in the same plane, and the angle of reflection θ_r equals the angle of incidence θ_i . We can use the law of reflection and the properties of triangles to determine the angle θ at which the ray leaves M_2.



SOLUTION From the law of reflection, we know that $\phi = 65°$. We see from the figure that $\phi + \alpha = 90°$, or $\alpha = 90° - \phi = 90° - 65° = 25°$. From the figure and the fact that the sum of the interior angles in any triangle is 180°, we have $\alpha + \beta + 120° = 180°$. Solving for β, we find that $\beta = 180° - (120° + 25°) = 35°$. Therefore, since $\beta + \gamma = 90°$, we find that the angle γ is given by $\gamma = 90° - \beta = 90° - 35° = 55°$. Since γ is the angle of incidence of the ray on mirror M_2, we know from the law of reflection that $\boxed{\theta = 55°}$.

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16. ***REASONING*** Since the image is behind the mirror, the image is virtual, and the image distance is negative, so that $d_i = -34.0\text{ cm}$. The object distance is given as $d_o = 7.50\text{ cm}$. The mirror equation relates these distances to the focal length *f* of the mirror. If the focal length is positive, the mirror is concave. If the focal length is negative, the mirror is convex.

SOLUTION According to the mirror equation (Equation 25.3), we have

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad \text{or} \quad f = \frac{1}{\dfrac{1}{d_o} + \dfrac{1}{d_i}} = \frac{1}{\dfrac{1}{7.50\text{ cm}} + \dfrac{1}{(-34.0\text{ cm})}} = \boxed{9.62\text{ cm}}$$

Since the focal length is positive, the mirror is $\boxed{\text{concave}}$.

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17. $\boxed{\text{SSM}}$ ***REASONING*** We have seen that a convex mirror always forms a *virtual image* as shown in Figure 25.22*a* of the text, where the image is *upright* and *smaller* than the object. These characteristics should bear out in the results of our calculations.

SOLUTION The radius of curvature of the convex mirror is 68 cm. Therefore, the focal length is, from Equation 25.2, $f = -(1/2)R = -34\text{ cm}$. Since the image is virtual, we know that $d_i = -22\text{ cm}$.

a. With $d_i = -22\text{ cm}$ and $f = -34\text{ cm}$, the mirror equation gives

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{-34\text{ cm}} - \frac{1}{-22\text{ cm}} \quad \text{or} \quad \boxed{d_o = +62\text{ cm}}$$

b. According to the magnification equation, the magnification is

$$m = -\frac{d_i}{d_o} = -\frac{-22\text{ cm}}{62\text{ cm}} = \boxed{+0.35}$$

c. Since the magnification *m* is positive, the image is $\boxed{\text{upright}}$.

d. Since the magnification *m* is less than one, the image is $\boxed{\text{smaller}}$ than the object.

18. ***REASONING*** The magnification of the mirror is related to the image and object distances via the magnification equation. The image distance is given, and the object distance is unknown. However, we can obtain the object distance by using the mirror equation, which relates the image and object distances to the focal length, which is also given.

SOLUTION According to the magnification equation, the magnification m is related to the image distance d_i and the object distance d_o according to

$$m = -\frac{d_i}{d_o} \qquad (25.4)$$

According to the mirror equation, the image distance d_i and the object distance d_o are related to the focal length f as follows:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \quad \text{or} \quad \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} \qquad (25.3)$$

Substituting this expression for $1/d_o$ into Equation 25.4 gives

$$m = -\frac{d_i}{d_o} = -d_i\left(\frac{1}{f} - \frac{1}{d_i}\right) = -\frac{d_i}{f} + 1$$

$$= -\left(\frac{36\text{ cm}}{12\text{ cm}}\right) + 1 = \boxed{-2.0}$$

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22. ***REASONING***

a. We are given that the focal length of the mirror is $f = 45$ cm and that the image distance is one-third the object distance, or $d_i = \frac{1}{3}d_o$. These two pieces of information, along with the mirror equation, will allow us to find the object distance.

b. Once the object distance has been determined, the image distance is one-third that value, since we are given that $d_i = \frac{1}{3}d_o$.

SOLUTION

a. The mirror equation indicates that

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad (25.3)$$

Substituting $d_i = \frac{1}{3}d_o$ and solving for d_o gives

$$\frac{1}{d_o} + \frac{1}{\frac{1}{3}d_o} = \frac{1}{f} \quad \text{or} \quad \frac{4}{d_o} = \frac{1}{f} \quad \text{or} \quad d_o = 4f = 4(45\text{ cm}) = \boxed{180\text{ cm}}$$

b. The image distance is

$$d_i = \tfrac{1}{3}d_o = \tfrac{1}{3}(180\text{ cm}) = \boxed{6.0\times10^1\text{ cm}}$$