Exercise 25.1

Part A

During lightning strikes from a cloud to the ground, currents as high as $2.50\times10^{4}\,\mathrm{A}$ can occur and last for about $40.0\,\mu s$. How much charge is transferred from the cloud to the earth during such a strike?

q = 1.00 C

25.1. **IDENTIFY** and **SET UP:** The lightning is a current that lasts for a brief time. $I = \dfrac{\Delta Q}{\Delta t}$.

EXECUTE: $\Delta Q = I\Delta t = (25{,}000\ \mathrm{A})(40\times10^{-6}\ \mathrm{s}) = 1.0\ \mathrm{C}$.

EVALUATE: Even though it lasts for only 40 μs, the lightning carries a huge amount of charge since it is an enormous current.

Exercise 25.13

A 14.0 gauge copper wire of diameter $1.628\,\mathrm{mm}$ carries a current of $12.5\,\mathrm{mA}$.

25.13. **IDENTIFY:** Knowing the resistivity of a metal, its geometry and the current through it, we can use Ohm's law to find the potential difference across it.

SET UP: $V = IR$. For copper, Table 25.1 gives that $\rho = 1.72\times10^{-8}\ \Omega\cdot\mathrm{m}$ and for silver, $\rho = 1.47\times10^{-8}\ \Omega\cdot\mathrm{m}$. $R = \dfrac{\rho L}{A}$.

EXECUTE: **(a)** $R = \dfrac{\rho L}{A} = \dfrac{(1.72\times10^{-8}\ \Omega\cdot\mathrm{m})(2.00\ \mathrm{m})}{\pi(0.814\times10^{-3}\ \mathrm{m})^2} = 1.65\times10^{-2}\ \Omega$.

$V = (12.5\times10^{-3}\ \mathrm{A})(1.65\times10^{-2}\ \Omega) = 2.06\times10^{-4}\ \mathrm{V}$.

(b) $V = \dfrac{I\rho L}{A}$. $\dfrac{V}{\rho} = \dfrac{IL}{A} = \text{constant}$, so $\dfrac{V_s}{\rho_s} = \dfrac{V_c}{\rho_c}$.

8.50 x 11.00 in

EXECUTE: **(a)** $R = \dfrac{\rho L}{A} = \dfrac{(1.72\times10^{-8}\ \Omega\cdot\text{m})(2.00\ \text{m})}{\pi(0.814\times10^{-3}\ \text{m})^2} = 1.65\times10^{-2}\ \Omega.$

$V = (12.5\times10^{-3}\ \text{A})(1.65\times10^{-2}\ \Omega) = 2.06\times10^{-4}\ \text{V}.$

(b) $V = \dfrac{I\rho L}{A}.\ \ \dfrac{V}{\rho} = \dfrac{IL}{A} = \text{constant, so } \dfrac{V_s}{\rho_s} = \dfrac{V_c}{\rho_c}.$

$$V_s = V_c\left(\frac{\rho_s}{\rho_c}\right) = (2.06\times10^{-4}\ \text{V})\left(\frac{1.47\times10^{-8}\ \Omega\cdot\text{m}}{1.72\times10^{-8}\ \Omega\cdot\text{m}}\right) = 1.76\times10^{-4}\ \text{V}.$$

EVALUATE: The potential difference across a 2-m length of wire is less than 0.2 mV, so normally we do not need to worry about these potential drops in laboratory circuits.

Exercise 25.29

A copper transmission cable 160 km long and 10.0 cm in diameter carries a current of 110 A .

6.00 Ω

25.29. **IDENTIFY:** Use $R = \dfrac{\rho L}{A}$ to calculate R and then apply $V = IR$. $P = VI$ and energy $= Pt$.

SET UP: For copper, $\rho = 1.72\times10^{-8}\ \Omega\cdot\text{m}$. $A = \pi r^2$, where $r = 0.050$ m.

EXECUTE: **(a)** $R = \dfrac{\rho L}{A} = \dfrac{(1.72\times10^{-8}\ \Omega\cdot\text{m})(100\times10^{3}\text{m})}{\pi(0.050\ \text{m})^2} = 0.219\ \Omega.$ $V = IR = (125\ \text{A})(0.219\ \Omega) = 27.4\ \text{V}.$

(b) $P = VI = (27.4\ \text{V})(125\ \text{A}) = 3422\ \text{W} = 3422\ \text{J/s}$ and energy $= Pt = (3422\ \text{J/s})(3600\ \text{s}) = 1.23\times10^{7}\ \text{J}.$

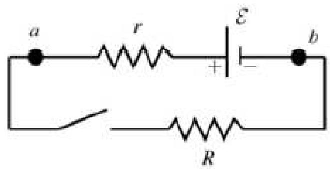
EVALUATE: The rate of electrical energy loss in the cable is large, over 3 kW.

Exercise 25.33

When switch S in the figure (Figure 1) is open, the voltmeter V of the battery reads 3.15 V . When the switch is closed, the voltmeter reading drops to 3.00 V , and the ammeter A reads 1.65 A . Assume that the two meters are ideal, so they don't affect the circuit.

25.33. **IDENTIFY:** The voltmeter reads the potential difference V_{ab} between the terminals of the battery.

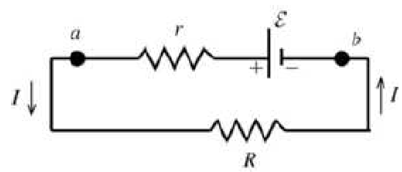
SET UP: open circuit $I = 0$. The circuit is sketched in Figure 25.33a.



EXECUTE: $V_{ab} = \mathcal{E} = 3.08\ \text{V}$

Figure 25.33a

SET UP: switch closed The circuit is sketched in Figure 25.33b.



EXECUTE: $V_{ab} = \mathcal{E} - Ir = 2.97\ \text{V}$

$$r = \frac{\mathcal{E} - 2.97\ \text{V}}{I}$$

$$r = \frac{3.08\ \text{V} - 2.97\ \text{V}}{1.65\ \text{A}} = 0.067\ \Omega$$

Figure 25.33b

And $V_{ab} = IR$ so $R = \dfrac{V_{ab}}{I} = \dfrac{2.97\ \text{V}}{1.65\ \text{A}} = 1.80\ \Omega.$

EVALUATE: When current flows through the battery there is a voltage drop across its internal resistance and its terminal voltage V is less than its emf.

Exercise 25.41

In Europe the standard voltage in homes is 220 V instead of the 120 V used in the United States. Therefore a "100-W" European bulb would be intended for use with a 220-V potential difference.

25.41. **IDENTIFY:** A "100-W" European bulb dissipates 100 W when used across 220 V.

(a) SET UP: Take the ratio of the power in the U.S. to the power in Europe, as in the alternative method for Problem 25.40, using $P = V^2/R$.

EXECUTE: $\dfrac{P_{\text{US}}}{P_{\text{E}}} = \dfrac{V_{\text{US}}^2/R}{V_{\text{E}}^2/R} = \left(\dfrac{V_{\text{US}}}{V_{\text{E}}}\right)^2 = \left(\dfrac{120\ \text{V}}{220\ \text{V}}\right)^2$. This gives $P_{\text{US}} = (100\ \text{W})\left(\dfrac{120\ \text{V}}{220\ \text{V}}\right)^2 = 29.8\ \text{W}.$

(b) SET UP: Use $P = IV$ to find the current.

EXECUTE: $I = P/V = (29.8\ \text{W})/(120\ \text{V}) = 0.248\ \text{A}$

EVALUATE: The bulb draws considerably less power in the U.S., so it would be much dimmer than in Europe.

Exercise 26.8

Three resistors having resistances of 1.60Ω , 2.30 Ω , and 4.60Ω are connected in parallel to a 30.0 V battery that has negligible internal resistance.

26.8. **IDENTIFY:** Eq. (26.2) gives the equivalent resistance of the three resistors in parallel. For resistors in parallel, the voltages are the same and the currents add.

(a) SET UP: The circuit is sketched in Figure 26.8a.

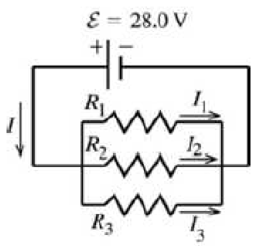


Figure 26.8a

EXECUTE: parallel

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{eq}} = \frac{1}{1.60\ \Omega} + \frac{1}{2.40\ \Omega} + \frac{1}{4.80\ \Omega}$$

$$R_{eq} = 0.800\ \Omega$$

(b) For resistors in parallel the voltage is the same across each and equal to the applied voltage;

$$V_1 = V_2 = V_3 = \varepsilon = 28.0\ \mathrm{V}$$

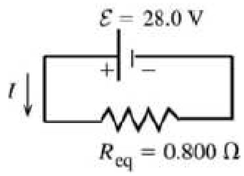
$$V = IR \text{ so } I_1 = \frac{V_1}{R_1} = \frac{28.0\ \mathrm{V}}{1.60\ \Omega} = 17.5\ \mathrm{A}$$

$$I_2 = \frac{V_2}{R_2} = \frac{28.0\ \text{V}}{2.40\ \Omega} = 11.7\ \text{A and } I_3 = \frac{V_3}{R_3} = \frac{28.0\ \text{V}}{4.8\ \Omega} = 5.8\ \text{A}$$

(c) The currents through the resistors add to give the current through the battery:

$I = I_1 + I_2 + I_3 = 17.5\ \text{A} + 11.7\ \text{A} + 5.8\ \text{A} = 35.0\ \text{A}$

EVALUATE: Alternatively, we can use the equivalent resistance R_{eq} as shown in Figure 26.8b.



$$\mathcal{E} - IR_{eq} = 0$$

$$I = \frac{\mathcal{E}}{R_{eq}} = \frac{28.0\ \text{V}}{0.800\ \Omega} = 35.0\ \text{A, which checks}$$

Figure 26.8b

(d) As shown in part (b), the voltage across each resistor is 28.0 V.

(e) IDENTIFY and SET UP: We can use any of the three expressions for P: $P = VI = I^2R = V^2/R$. They will all give the same results, if we keep enough significant figures in intermediate calculations.

EXECUTE: Using $P = V^2/R$, $P_1 = V_1^2/R_1 = \frac{(28.0\ \text{V})^2}{1.60\ \Omega} = 490\ \text{W}$, $P_2 = V_2^2/R_2 = \frac{(28.0\ \text{V})^2}{2.40\ \Omega} = 327\ \text{W}$, and

$$P_3 = V_3^2/R_3 = \frac{(28.0\ \text{V})^2}{4.80\ \Omega} = 163\text{W}.$$

EVALUATE: The total power dissipated is $P_{out} = P_1 + P_2 + P_3 = 980\ \text{W}$. This is the same as the power $P_{in} = \mathcal{E}I = (2.80\ \text{V})(35.0\ \text{A}) = 980\ \text{W}$ delivered by the battery.

(f) $P = V^2/R$. The resistors in parallel each have the same voltage, so the power P is largest for the one with the least resistance.

Exercise 26.17

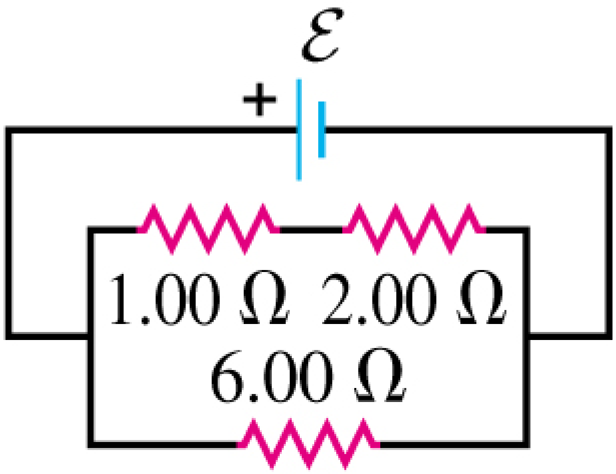
In the circuit shown in the figure (Figure 1) , the voltage across the 2.00-Ω resistor is 12.3V .

26.17. IDENTIFY: Apply Ohm's law to each resistor.

SET UP: For resistors in parallel the voltages are the same and the currents add. For resistors in series the currents are the same and the voltages add.

EXECUTE: The current through the 2.00-Ω resistor is 6.00 A. Current through the 1.00-Ω resistor also is 6.00 A and the voltage is 6.00 V. Voltage across the 6.00-Ω resistor is $12.0\ \text{V} + 6.0\ \text{V} = 18.0\ \text{V}$. Current through the 6.00-Ω resistor is $(18.0\ \text{V})/(6.00\ \Omega) = 3.00\ \text{A}$. The battery emf is 18.0 V.

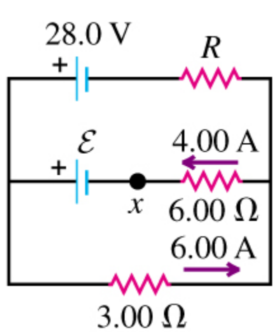
EVALUATE: The current through the battery is $6.00\ \text{A} + 3.00\ \text{A} = 9.00\ \text{A}$. The equivalent resistor of the resistor network is $2.00\ \Omega$, and this equals $(18.0\ \text{V})/(9.00\ \text{A})$.



Exercise 26.25

In the circuit shown in the figure (Figure 1) find

Figure 1 of 1



Part A

the current in resistor R

I = 2.00 A

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Correct

Part B

the resistance R

R = 5.00 Ω

Submit My Answers Give Up

Correct

Part C

the unknown emf $\mathcal{E}$

$\mathcal{E}$ = 42.0 V

Submit My Answers Give Up

Correct

Part D

If the circuit is broken at point x, what is the current in resistor R?

third loop.

26.25. **IDENTIFY:** Apply Kirchhoff's point rule at point a to find the current through R. Apply Kirchhoff's loop rule to loops (1) and (2) shown in Figure 26.25a to calculate R and ε. Travel around each loop in the direction shown.

(a) SET UP:

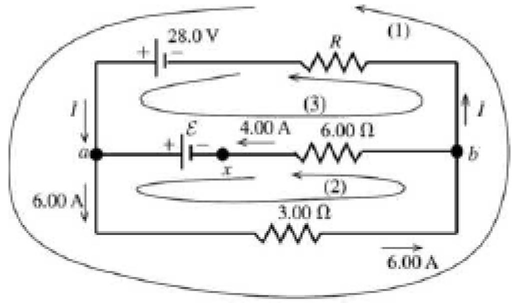


Figure 26.25a

EXECUTE: Apply Kirchhoff's point rule to point a: $\sum I = 0$ so $I + 4.00\text{ A} - 6.00\text{ A} = 0$

$I = 2.00\text{ A}$ (in the direction shown in the diagram).

(b) Apply Kirchhoff's loop rule to loop (1): $-(6.00\text{ A})(3.00\ \Omega) - (2.00\text{ A})R + 28.0\text{ V} = 0$

$-18.0\text{ V} - (2.00\ \Omega)R + 28.0\text{ V} = 0$

$$R = \frac{28.0\text{ V} - 18.0\text{ V}}{2.00\text{ A}} = 5.00\ \Omega$$

(c) Apply Kirchhoff's loop rule to loop (2): $-(6.00\text{ A})(3.00\ \Omega) - (4.00\text{ A})(6.00\ \Omega) + \varepsilon = 0$

$\varepsilon = 18.0\text{ V} + 24.0\text{ V} = 42.0\text{ V}$

EVALUATE: Can check that the loop rule is satisfied for loop (3), as a check of our work:

$28.0\text{ V} - \varepsilon + (4.00\text{ A})(6.00\ \Omega) - (2.00\text{ A})R = 0$

$28.0\text{ V} - 42.0\text{ V} + 24.0\text{ V} - (2.00\text{ A})(5.00\ \Omega) = 0$

$52.0\text{ V} = 42.0\text{ V} + 10.0\text{ V}$

$52.0\text{ V} = 52.0\text{ V}$, so the loop rule is satisfied for this loop.

(d) IDENTIFY: If the circuit is broken at point x there can be no current in the $6.00\text{-}\Omega$ resistor. There is now only a single current path and we can apply the loop rule to this path.

SET UP: The circuit is sketched in Figure 26.25b.

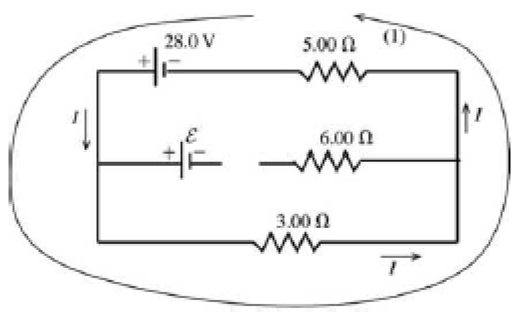


Figure 26.25b

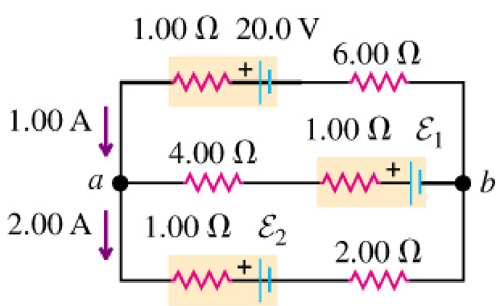
EXECUTE: $+28.0\text{ V} - (3.00\ \Omega)I - (5.00\ \Omega)I = 0$

$$I = \frac{28.0\text{ V}}{8.00\ \Omega} = 3.50\text{ A}$$

EVALUATE: Breaking the circuit at x removes the 42.0-V emf from the circuit and the current through the $3.00\text{-}\Omega$ resistor is reduced.

Exercise 26.26

Figure 1 of 1



Part A

Find the emf $\mathcal{E}_1$ in the circuit of the figure (Figure 1) .

$\mathcal{E}_1$ = 18.0 V

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Answer Requested

Part B

Find the emf $\mathcal{E}_2$ in the circuit of the figure.

$\mathcal{E}_2$ = 7.00 V

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Answer Requested

Part C

Find the potential difference of point b relative to point a.

V_{ba} = -13.0 V

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Answer Requested

5.00-Ω resistor is reduced.

26.26. **IDENTIFY:** Apply the loop rule and junction rule.

SET UP: The circuit diagram is given in Figure 26.26. The junction rule has been used to find the magnitude and direction of the current in the middle branch of the circuit. There are no remaining unknown currents.

EXECUTE: The loop rule applied to loop (1) gives:

$+20.0\text{V} - (1.00\ \text{A})(1.00\ \Omega) + (1.00\ \text{A})(4.00\ \Omega) + (1.00\ \text{A})(1.00\ \Omega) - \varepsilon_1 - (1.00\ \text{A})(6.00\ \Omega) = 0$

$\varepsilon_1 = 20.0\ \text{V} - 1.00\ \text{V} + 4.00\ \text{V} + 1.00\ \text{V} - 6.00\ \text{V} = 18.0\ \text{V}$. The loop rule applied to loop (2) gives:

$+20.0\ \text{V} - (1.00\ \text{A})(1.00\ \Omega) - (2.00\ \text{A})(1.00\ \Omega) - \varepsilon_2 - (2.00\ \text{A})(2.00\ \Omega) - (1.00\ \text{A})(6.00\ \Omega) = 0$

$\varepsilon_2 = 20.0\ \text{V} - 1.00\ \text{V} - 2.00\ \text{V} - 4.00\ \text{V} - 6.00\ \text{V} = 7.0\ \text{V}$. Going from b to a along the lower branch,

$V_b + (2.00\ \text{A})(2.00\ \Omega) + 7.0\ \text{V} + (2.00\ \text{A})(1.00\ \Omega) = V_a \cdot V_b - V_a = -13.0\ \text{V}$; point b is at 13.0 V lower potential than point a.

EVALUATE: We can also calculate $V_b - V_a$ by going from b to a along the upper branch of the circuit. $V_b - (1.00\ \text{A})(6.00\ \Omega) + 20.0\ \text{V} - (1.00\ \text{A})(1.00\ \Omega) = V_a$ and $V_b - V_a = -13.0\ \text{V}$. This agrees with $V_b - V_a$ calculated along a different path between b and a.

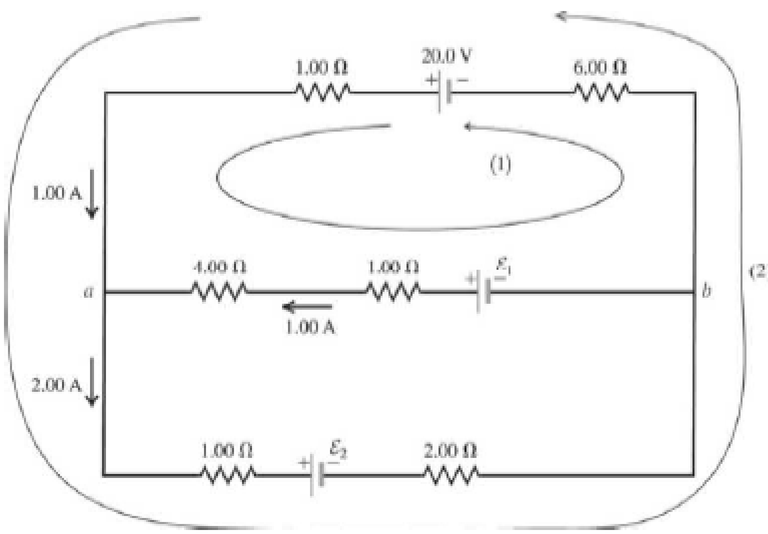

Figure 26.26

Exercise 26.45

An emf source with a magnitude of $\mathcal{E}$ = 120V , a resistor with a resistance of R = 88.0Ω , and a capacitor with a capacitance of C = 6.00μF are connected in series.

Part A

As the capacitor charges, when the current in the resistor is 0.700A , what is the magnitude of the charge on each plate of the capacitor?

Q = 3.50×10^{-4} C

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decreased and for capacitors in parallel the capacitance is increased.

26.45. **IDENTIFY and SET UP:** Apply the loop rule. The voltage across the resistor depends on the current through it and the voltage across the capacitor depends on the charge on its plates.

EXECUTE: $\varepsilon - V_R - V_C = 0$

$\varepsilon = 120\ \text{V}$, $V_R = IR = (0.900\ \text{A})(80.0\ \Omega) = 72\ \text{V}$, so $V_C = 48\ \text{V}$

$Q = CV = (4.00\times10^{-6}\ \text{F})(48\ \text{V}) = 192\ \mu\text{C}$

EVALUATE: The initial charge is zero and the final charge is $C\varepsilon = 480\ \mu\text{C}$. Since current is flowing at the instant considered in the problem the capacitor is still being charged and its charge has not reached its final value.

Exercise 26.48

A 10.0 $-\mu F$ capacitor is charged to a potential of 50.0 V and then discharged through a 185 $-\Omega$ resistor.

Part A

How long does it take the capacitor to lose half of its charge?

t = 1.28 ms

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All attempts used; correct answer displayed

Part B

How long does it take the capacitor to lose half of its stored energy?

t = 0.641 ms

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26.48. IDENTIFY: Both the charge and energy decay exponentially, but not with the same time constant since the energy is proportional to the *square* of the charge.

SET UP: The charge obeys the equation $Q = Q_0 e^{-t/RC}$ but the energy obeys the equation $U = Q^2/2C = (Q_0 e^{-t/RC})/2C = U_0 e^{-2t/RC}$.

EXECUTE: (a) The charge is reduced by half: $Q_0/2 = Q_0 e^{-t/RC}$. This gives

$$t = RC \ln 2 = (175\ \Omega)(12.0\ \mu F)(\ln 2) = 1.456\ \text{ms} = 1.46\ \text{ms}.$$

(b) The energy is reduced by half: $U_0/2 = U_0 e^{-2t/RC}$. This gives

$$t = (RC \ln 2)/2 = (1.456\ \text{ms})/2 = 0.728\ \text{ms}.$$

EVALUATE: The energy decreases faster than the charge because it is proportional to the square of the charge.

Exercise 27.11

A circular area with a radius of 6.90cm lies in the xy-plane.

Part A

What is the magnitude of the magnetic flux through this circle due to a uniform magnetic field with a magnitude of 0.300T in the + z -direction?

Φ_B = 4.49×10^{-3} Wb

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Correct

Part B

What is the magnitude of the magnetic flux through this circle due to the same magnetic field (with a magnitude of 0.300T), now at an angle of 53.7° from the + z -direction?

Φ_B = 2.66×10^{-3} Wb

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Correct

Part C

What is the magnitude of the magnetic flux through this circle due to the same magnetic field (with a magntiude of 0.300T), now in the + y -direction?

Φ_B = 0 Wb

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Correct

27.11. **IDENTIFY and SET UP:** $\Phi_B = \int \vec{B} \cdot d\vec{A}$

Circular area in the *xy*-plane, so $A = \pi r^2 = \pi(0.0650\text{ m})^2 = 0.01327\text{ m}^2$ and $d\vec{A}$ is in the z-direction. Use Eq. (1.18) to calculate the scalar product.

EXECUTE: (a) $\vec{B} = (0.230\text{ T})\hat{k}$; $\vec{B}$ and $d\vec{A}$ are parallel ($\phi = 0°$) so $\vec{B} \cdot d\vec{A} = B\,dA$.

B is constant over the circular area so

$\Phi_B = \int \vec{B} \cdot d\vec{A} = \int B\,dA = B\int dA = BA = (0.230\text{ T})(0.01327\text{ m}^2) = 3.05\times10^{-3}\text{ Wb}$

(b) The directions of $\vec{B}$ and $d\vec{A}$ are shown in Figure 27.11a.

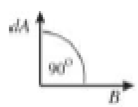
$\vec{B} \cdot d\vec{A} = B\cos\phi\,dA$
with $\phi = 53.1°$

Figure 27.11a

B and ϕ are constant over the circular area so $\Phi_B = \int \vec{B} \cdot d\vec{A} = \int B\cos\phi\,dA = B\cos\phi\int dA = B\cos\phi A$

$\Phi_B = (0.230\text{ T})\cos 53.1°(0.01327\text{ m}^2) = 1.83\times10^{-3}\text{ Wb}$.

(c) The directions of $\vec{B}$ and $d\vec{A}$ are shown in Figure 27.11b.



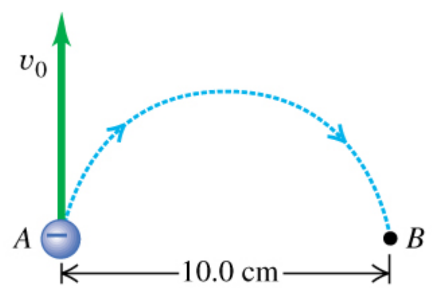
$\vec{B} \cdot d\vec{A} = 0$ since $d\vec{A}$ and $\vec{B}$ are perpendicular ($\phi = 90°$)
$\Phi_B = \int \vec{B} \cdot d\vec{A} = 0$.

Figure 27.11b

EVALUATE: Magnetic flux is a measure of how many magnetic field lines pass through the surface. It is maximum when $\vec{B}$ is perpendicular to the plane of the loop (part a) and is zero when $\vec{B}$ is parallel to the plane of the loop (part c).

An electron at point **A** in the figure (Figure 1) has a speed v_0 of $1.10 \times 10^6 \mathrm{m/s}$.

Figure 1 of 1



Part A

Find the magnitude of the magnetic field that will cause the electron to follow the semicircular path from **A** to **B**.

B = 1.25×10^{-4} T

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Correct

Part B

Find the direction of the magnetic field that will cause the electron to follow the semicircular path from **A** to **B**.

- into the page
- out of the page

Submit My Answers Give Up

Correct

Part C

Find the time required for the electron to move from **A** to **B**.

t = 1.43×10^{-7} s

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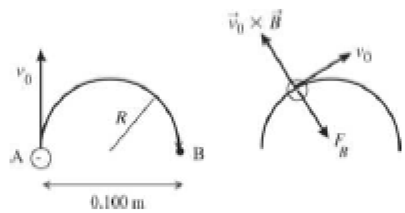
Correct

Provide Feedback Continue

27.15. (a) **IDENTIFY:** Apply Eq. (27.2) to relate the magnetic force $\vec{F}$ to the directions of $\vec{v}$ and $\vec{B}$. The electron has negative charge so $\vec{F}$ is opposite to the direction of $\vec{v} \times \vec{B}$. For motion in an arc of a circle the acceleration is toward the center of the arc so $\vec{F}$ must be in this direction. $a = v^2/R$.

SET UP:



As the electron moves in the semicircle, its velocity is tangent to the circular path. The direction of $\vec{v}_0 \times \vec{B}$ at a point along the path is shown in Figure 27.15.

Figure 27.15

EXECUTE: For circular motion the acceleration of the electron $\vec{a}_{rad}$ is directed in toward the center of the circle. Thus the force $\vec{F}_B$ exerted by the magnetic field, since it is the only force on the electron, must be radially inward. Since q is negative, $\vec{F}_B$ is opposite to the direction given by the right-hand rule for $\vec{v}_0 \times \vec{B}$. Thus $\vec{B}$ is directed into the page. Apply Newton's second law to calculate the magnitude of $\vec{B}$:

$\sum \vec{F} = m\vec{a}$ gives $\sum F_{rad} = ma$ $\quad F_B = m(v^2/R)$

$F_B = |q| vB \sin\phi = |q| vB$, so $|q| vB = m(v^2/R)$

$$B = \frac{mv}{|q|R} = \frac{(9.109\times10^{-31}\text{ kg})(1.41\times10^{6}\text{ m/s})}{(1.602\times10^{-19}\text{ C})(0.050\text{ m})} = 1.60\times10^{-4}\text{ T}$$

(b) **IDENTIFY and SET UP:** The speed of the electron as it moves along the path is constant. ($\vec{F}_B$ changes the direction of $\vec{v}$ but not its magnitude.) The time is given by the distance divided by v_0.

EXECUTE: The distance along the semicircular path is πR, so $t = \dfrac{\pi R}{v_0} = \dfrac{\pi(0.050\text{ m})}{1.41\times10^{6}\text{ m/s}} = 1.11\times10^{-7}\text{ s}$.

EVALUATE: The magnetic field required increases when v increases or R decreases and also depends on the mass to charge ratio of the particle.

Exercise 27.17

A ball with a mass of 100g which contains 3.80×10^{8} excess electrons is dropped into a vertical shaft with a height of 125m . At the bottom of the shaft, the ball suddenly enters a uniform horizontal magnetic field that has a magnitude of 0.290T and direction from east to west.

Part A

If air resistance is negligibly small, find the magnitude of the force that this magnetic field exerts on the ball just as it enters the field.

Use 1.602×10^{-19}C for the magnitude of the charge on an electron.

$F =$ 8.74×10^{-10} N

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Correct

Part B

Find the direction of the force that this magnetic field exerts on the ball just as it enters the field.

- (•) from north to south
- ( ) from south to north

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Correct

27.17. IDENTIFY and SET UP: Use conservation of energy to find the speed of the ball when it reaches the bottom of the shaft. The right-hand rule gives the direction of $\vec{F}$ and Eq. (27.1) gives its magnitude. The number of excess electrons determines the charge of the ball.

EXECUTE: $q = (4.00 \times 10^{8})(-1.602 \times 10^{-19} \text{ C}) = -6.408 \times 10^{-11} \text{ C}$

speed at bottom of shaft: $\frac{1}{2}mv^2 = mgy$; $v = \sqrt{2gy} = 49.5 \text{ m/s}$

$\vec{v}$ is downward and $\vec{B}$ is west, so $\vec{v} \times \vec{B}$ is north. Since $q < 0$, $\vec{F}$ is south.

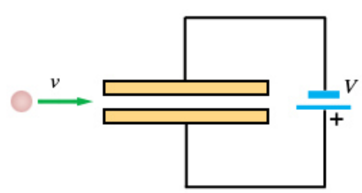
$F = |q|vB\sin\theta = (6.408 \times 10^{-11} \text{ C})(49.5 \text{ m/s})(0.250 \text{ T})\sin 90° = 7.93 \times 10^{-10} \text{ N}$

EVALUATE: Both the charge and speed of the ball are relatively small so the magnetic force is small, much less than the gravity force of 1.5 N.

Exercise 27.31

A V = 130-V battery is connected across two parallel metal plates of area 28.5 $\mathrm{cm^2}$ and separation 8.40mm . A beam of alpha particles (charge $+2e$, mass 6.64×10^{-27} kg) is accelerated from rest through a potential difference of 1.80kV and enters the region between the plates perpendicular to the electric field, as shown in the figure.(Figure 1)

Figure 1 of 1



Part A

What magnitude of magnetic field is needed so that the alpha particles emerge undeflected from between the plates?

B = 3.72×10^{-2} T

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Correct

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positively and negatively charged particles.

27.31. **IDENTIFY:** For the alpha particles to emerge from the plates undeflected, the magnetic force on them must exactly cancel the electric force. The battery produces an electric field between the plates, which acts on the alpha particles.

SET UP: First use energy conservation to find the speed of the alpha particles as they enter the region between the plates: $qV = 1/2\, mv^2$. The electric field between the plates due to the battery is $E = V_b d$. For the alpha particles not to be deflected, the magnetic force must cancel the electric force, so $qvB = qE$, giving $B = E/v$.

EXECUTE: Solve for the speed of the alpha particles just as they enter the region between the plates. Their charge is $2e$.

$$v_\alpha = \sqrt{\frac{2(2e)V}{m}} = \sqrt{\frac{4(1.60\times 10^{-19}\ \text{C})(1750\text{V})}{6.64\times 10^{-27}\ \text{kg}}} = 4.11\times 10^5\ \text{m/s}$$

The electric field between the plates, produced by the battery, is

$$E = V_b/d = (150\ \text{V})/(0.00820\ \text{m}) = 18{,}300\ \text{V/m}$$

The magnetic force must cancel the electric force:

$$B = E/v_\alpha = (18{,}300\ \text{V/m})/(4.11\times 10^5\ \text{m/s}) = 0.0445\ \text{T}$$

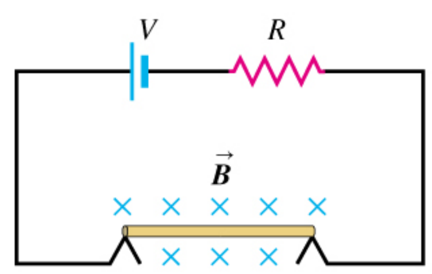
The magnetic field is perpendicular to the electric field. If the charges are moving to the right and the electric field points upward, the magnetic field is out of the page.

EVALUATE: The sign of the charge of the alpha particle does not enter the problem, so negative charges of the same magnitude would also not be deflected.

Exercise 27.41

A thin, 45.0cm long metal bar with mass 780g rests on, but is not attached to, two metallic supports in a uniform magnetic field with a magnitude of 0.500T , as shown in the figure (Figure 1) . A battery and a resistor of resistance 23.0Ω are connected in series to the supports.

Figure 1 of 1



Part A

What is the largest voltage the battery can have without breaking the circuit at the supports?

V = 781 V

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Correct

Part B

The battery voltage has the maximum value calculated in part (a). If the resistor suddenly gets partially short-circuited, decreasing its resistance to 2.10Ω , find the initial acceleration of the bar.

a = 97.5 $\mathrm{m/s^2}$

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Correct

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27.41. IDENTIFY and SET UP: The magnetic force is given by Eq. (27.19). $F_I = mg$ when the bar is just ready to levitate. When I becomes larger, $F_I > mg$ and $F_I - mg$ is the net force that accelerates the bar upward. Use Newton's second law to find the acceleration.

(a) EXECUTE: $IlB = mg,\ I = \dfrac{mg}{lB} = \dfrac{(0.750\text{ kg})(9.80\text{ m/s}^2)}{(0.500\text{ m})(0.450\text{ T})} = 32.67\text{ A}$

$\mathcal{E} = IR = (32.67\text{ A})(25.0\ \Omega) = 817\text{ V}$

(b) $R = 2.0\ \Omega,\ I = \mathcal{E}/R = (816.7\text{ V})/(2.0\ \Omega) = 408\text{ A}$

$F_I = IlB = 92\text{ N}$

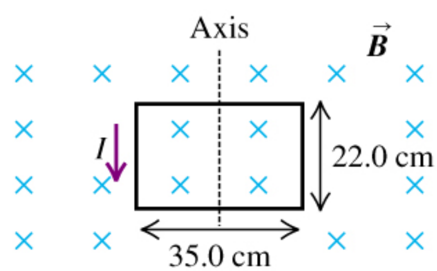
$a = (F_I - mg)/m = 113\text{ m/s}^2$

EVALUATE: I increases by over an order of magnitude when R changes to $F_I >> mg$ and a is an order of magnitude larger than g.

Exercise 27.46

A rectangular coil of wire, 22.0 cm by 35.0 cm and carrying a current of 1.40 A, is oriented with the plane of its loop perpendicular to a uniform 1.50-T magnetic field, as shown in the figure. (Figure 1)

Figure 1 of 1



Part A

Calculate the net force which the magnetic field exerts on the coil.

F = 0 N

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Correct

Part B

Calculate the torque which the magnetic field exerts on the coil.

τ = 0 $\mathrm{N \cdot m}$

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Correct

Part C

The coil is rotated through a 30.0 $^{\circ}$ angle about the axis shown, the left side coming out of the plane of the figure and the right side going into the plane. Calculate the net force which the magnetic field now exerts on the coil. (*Hint:* In order to help visualize this 3-dimensional problem, make a careful drawing of the coil when viewed along the rotation axis.)

F = 0 N

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Correct

Part D

Calculate the torque which the magnetic field now exerts on the coil.

τ = 8.09×10^{-2} $\mathrm{N \cdot m}$

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27.46. **IDENTIFY:** $\tau = IAB\sin\phi$, where ϕ is the angle between $\vec{B}$ and the normal to the loop.

SET UP: The coil as viewed along the axis of rotation is shown in Figure 27.46a for its original position and in Figure 27.46b after it has rotated $30.0°$.

EXECUTE: **(a)** The forces on each side of the coil are shown in Figure 27.46a. $\vec{F}_1 + \vec{F}_2 = 0$ and $\vec{F}_3 + \vec{F}_4 = 0$. The net force on the coil is zero. $\phi = 0°$ and $\sin\phi = 0$, so $\tau = 0$. The forces on the coil produce no torque.

(b) The net force is still zero. $\phi = 30.0°$ and the net torque is $\tau = (1)(1.40\text{ A})(0.220\text{ m})(0.350\text{ m})(1.50\text{ T})\sin 30.0° = 0.0808\text{ N}\cdot\text{m}$. The net torque is clockwise in Figure 27.46b and is directed so as to increase the angle ϕ.

EVALUATE: For any current loop in a uniform magnetic field the net force on the loop is zero. The torque on the loop depends on the orientation of the plane of the loop relative to the magnetic field direction.

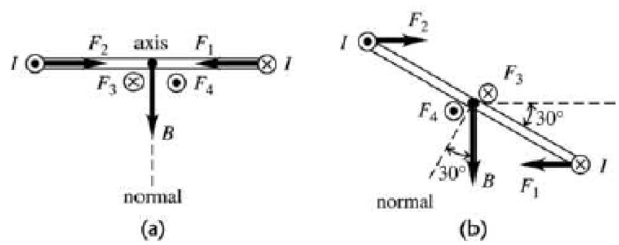

Figure 27.46