Q1.

What phase difference between two identical traveling waves of amplitude A, moving in the same direction along a stretched string, results in the combined traveling wave having an amplitude of A/2? Express your answer in wavelengths.

A) 0.42 λ
B) 0.11 λ
C) 0.27 λ
D) 0.33 λ
E) 0.66 λ

Ans:

$$\frac{A}{2} = 2A\cos\left(\frac{\Phi}{2}\right)$$

$$\frac{1}{4} = \cos\left(\frac{\Phi}{2}\right)$$

$$\Phi = 2\cos^{-1}\left(\frac{1}{4}\right) = 151° = 0.84\pi rad = 0.42\,\lambda$$

Q2.

The speed of sound in a liquid is1.508×10^3 m/s. If density of the liquid is1.029×10^3 kg/m^3, what is the bulk modulus of the liquid?

A) 2.340×10^9 N/m^2
B) 1.151×10^9 N/m^2
C) 3.377×10^9 N/m^2
D) 4.551×10^9 N/m^2
E) 5.233×10^9 N/m^2

Ans:

$$B = \rho v^2 = 1.029\times10^3\times(1.508\times10^3)^2 = 2.340\times10^9\ \mathrm{N/m^2}$$

Q3.

A sound wave in a fluid medium is reflected at a barrier so that a standing wave is formed. The distance between two adjacent nodes is 5.3 cm, and the speed of sound in the medium is 1.5×10^3 m/s. Find the frequency of the sound wave?

A) 1.4×10^4 Hz
B) 1.9×10^4 Hz
C) 2.4×10^4 Hz
D) 2.7×10^4 Hz
E) 2.9×10^4 Hz

Ans:

$$\frac{\lambda}{2} = 0.053\,m \Rightarrow \lambda = 0.106\,m$$

$$f = \frac{v}{\lambda} = \frac{1.5\times10^3}{0.106} = 1.4\times10^4\ \mathrm{Hz}$$

Q4.

How much energy must be removed from 0.550 kg of water that is initially at 10.0°C so that it becomes ice at 0.000 °C?

A) 2.06×10^5 J
B) 1.11×10^5 J
C) 1.35×10^5 J
D) 1.59×10^5 J
E) 3.06×10^5 J

Ans:

$$\Delta Q = \left(C \times \Delta T + L_f\right) \times m$$

$$\Delta Q = (4187 \times 10 + 333 \times 10^3) \times 0.550 = 206178.5 = 2.06 \times 10^5 \mathrm{J}$$

Q5.

One mole of an ideal gas does 3.00×10^3 J of work on its surroundings as it expands isothermally to a final pressure of 1.00 atm and a volume of 25.0 L. Determine the initial volume of the gas.

A) 7.62 L
B) 6.60 L
C) 8.11 L
D) 8.99 L
E) 9.05 L

Ans:

$$W = nRT ln\left(\frac{V_f}{V_i}\right) = P_f V_f ln\left(\frac{V_f}{V_i}\right)$$

$$\frac{V_f}{V_i} = exp\left(\frac{W}{P_f V_f}\right) = exp\left(\frac{3000}{1.01 \times 10^5 \times 25 \times 10^{-3}}\right) = \exp(1.188) = 3.280$$

$$V_i = \frac{V_f}{3.280} = \frac{25}{3.280} = 7.62\ L$$

Q6.

An ideal heat engine is one that

A) uses only reversible processes and is called Carnot engine.
B) uses only irreversible processes.
C) has an efficiency of 100%.
D) has an efficiency of 50%.
E) does no work.

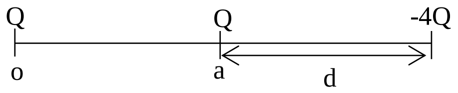
Ans:

A

Q7.

A charge Q_1 is placed on the x-axis at $x = a$. Where should a charge $Q_2 = -4Q_1$ be placed to produce a net zero electrostatic force on a third charge, $Q_3 = Q_1$, located at the origin?

A) at $x = 2a$
B) at the origin
C) at $x = -2a$
D) at $x = -a$
E) at $x = -3a$



Ans:

$$\frac{KQ^2}{a^2} = \frac{K4Q^2}{(a+d)^2}$$

$$\frac{1}{a} = \frac{2}{a+d}$$

$$a + d = 2a \Rightarrow d = a$$

$$x = a + d = a + a = 2a$$

Q8.

What are the magnitude and direction of an electric field that will balance the weight of a 1.5 g plastic sphere that has been charged to –3.0 μC? The sphere is suspended in air.

A) 4.9×10^3 N/C, downward
B) 1.0×10^3 N/C, upward
C) 1.7×10^3 N/C, downward
D) 2.6×10^3 N/C, upward
E) 3.9×10^3 N/C, downward

Ans:

$$|qE| = |mg|$$

$$|E| = \frac{|mg|}{|q|} = \frac{1.5\times10^{-3}\times9.8}{3\times10^{-6}} = 4.9\times10^3\ \mathrm{N/C}$$

Q9.

A point charge of 2.5×10^{-6} C is at the center of a Gaussian cube of edge length 72 cm. What is the net electric flux through the cube?

A) 2.8×10^5 N.m^2/C
B) 1.0×10^5 N.m^2/C
C) 1.5×10^5 N.m^2/C
D) 1.7×10^5 N.m^2/C
E) 3.3×10^5 N.m^2/C

Ans:

$$\Phi = \frac{q_{enc}}{\varepsilon_0} = \frac{2.5\times10^{-6}}{8.85\times10^{-12}} = 2.8\times10^5\ \mathrm{N\cdot cm^2/C}$$

Q10.

A solid conducting sphere of radius *R* has a charge *q*, producing an electric potential V_0 at the surface. How much charge must be added to the sphere to increase the potential at the surface to $2V_0$?

A) q
B) $q/2$
C) $3q$
D) q^2
E) $2q^2$

Ans:

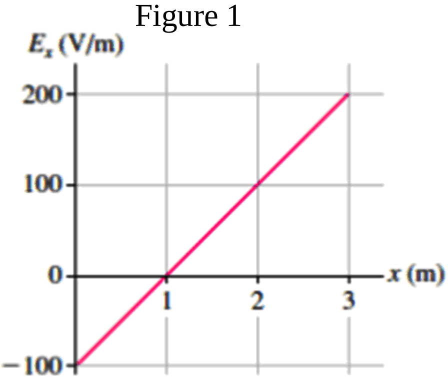
$$\frac{V'}{V_0} = \frac{q'}{q_0} = 2 \Rightarrow q' = 2q_0 = 2q$$

$$\text{charge added} = 2q - q = q$$

Q11.

Figure 1 shows a graph of E_x (V/m) as a function of *x* in m. The potential at the origin is –50 V. What is the electric potential at *x* = 3.0 m?

Figure 1



A) – 200 V
B) + 200 V
C) + 250 V
D) – 250 V
E) – 300 V

Ans:

$$\Delta V = V_3 - V_0 = -\int_0^3 E dx = -Area$$

$$V_3 - V_0 = -\left[-\frac{100 \times 1}{2} + \frac{2 \times 200}{2}\right] = -150$$

$$V_3 = V_0 - 150 = -50 - 150 = -200 \text{ V}$$

Q12.

A group of identical capacitors are connected first all in series and then all in parallel. The equivalent capacitance in the parallel combination is 225 times larger than that for the series combination. How many capacitors are in the group?

A) 15.0
B) 11.0
C) 18.0
D) 21.0
E) 25.0

Ans:

$$C_p = 225C_s \; but C_p = nC \; and \; C_s = \frac{C}{n}$$

$$nC = 225 \times \frac{C}{n}$$

$$n^2 = 225 \;\; \Rightarrow n = 15.0$$

Q13.

The current in an electric device is 10.0 A. How many electrons flow through the device in 5.00 min?

A) 1.88×10^{22}
B) 2.33×10^{22}
C) 4.01×10^{22}
D) 3.75×10^{22}
E) 2.55×10^{22}

Ans:

$$i = \frac{q}{t}$$

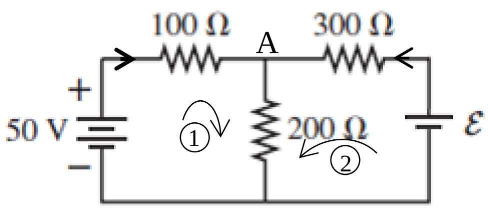
$$q_{tot} = 2 \times t_{tot} = 10 \times 5 \times 60 \; C = 3000 \; C$$

$$\text{Number of electron} = \frac{3000}{1.6 \times 10^{-19}} = 1.88 \times 10^{22} \text{electrons}$$

Q14.

What is the magnitude of the ideal emf $\boldsymbol{\mathcal{E}}$ shown in **Figure 2** if the current through the 200 Ω resistor is zero?

Figure 2



A) 150 V
B) 90.0 V
C) 95.5 V
D) 101 V
E) 192 V

Ans:

In Loop 1 $50 - 100\, i_1 = 0$

$i_1 = 0.5$ A

At junction A $i_1 + i_2 = 0$

$i_2 = -i_1 = -0.5\,A$

In Loop 2 $\varepsilon - 300\, i_2 = 0$

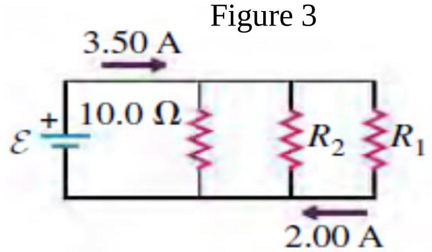
$\varepsilon = 300\, i_2 = 300(-0.5)$

$\varepsilon = -150\,V \Rightarrow |\varepsilon| = 150\,V$

Q15.

In the circuit shown in **Figure 3**, the power dissipated in resistor R_1 is 20.0 W. Find the resistors R_1 and R_2 respectively.

Figure 3



A) 5.00 Ω, 20.0 Ω
B) 2.00 Ω, 15.0 Ω
C) 15.0 Ω, 25.0 Ω
D) 8.00 Ω, 12.0 Ω
E) 20.0 Ω, 10.0 Ω

Ans:

$$R_1 = \frac{P_{R1}}{i_1^2} = \frac{20}{(2)^2} = 5\Omega$$

$$i_{10\Omega} = \frac{V_1}{10} = \frac{5 \times 2}{10} = 1A$$

$$i_2 = 3.5 - i_1 - i_{10\Omega} = 3.5 - 2 - 1 = 0.5\,A$$

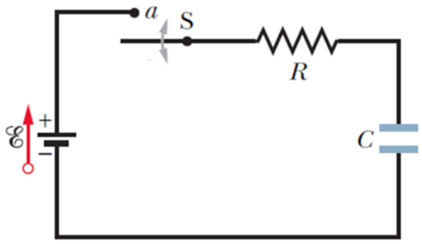
$$R_2 = \frac{V_1}{i_2} = \frac{5 \times 2}{0.5} = 20\ \Omega$$

Q16.

A capacitor-charging circuit, as shown in **Figure 4** has a time constant RC = 40.0 $\times 10^{-3}$ s. When the switch is closed to charge the 50.0 μF capacitor, the initial current is 65.0 $\times$ 10^{-3} A. What is the potential difference across the capacitor at a time 20.0 $\times 10^{-3}$ s after closing the switch? Assume the capacitor was completely uncharged when the switch was closed.

A) 20.5 V
B) 25.0 V
C) 14.5 V
D) 12.9 V
E) 11.5 V

Figure 4



Ans:

$$V(t) = \varepsilon\,(1 - e^{-t/RC})$$

$$i(t=0) = \frac{\varepsilon}{R} \Longrightarrow \varepsilon = Ri(t=0)$$

$$C = 50 \times 10^{-6}\,F;\;\; R = \frac{\tau}{C} = \frac{40 \times 10^{-3}}{50 \times 10^{-6}} = 800\,\Omega$$

$$\varepsilon = R\,i\,(t=0) = 800 \times 65 \times 10^{-3} = 52\text{ V}$$

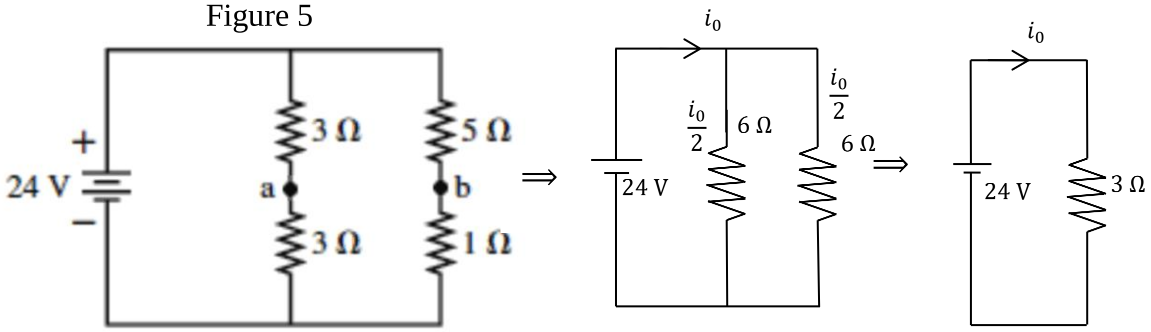
$$V(t = 20 \times 10^{-3} S) = \varepsilon(1 - e^{-t/RC}) = 52\left(1 - e^{\frac{-20\times10^{-3}}{40\times10^{-3}}}\right)$$

$$= 52\,(1 - e^{-0.5}) = 52 \times 0.393 = 20.5\text{ V}$$

Q17.

What is the potential difference between the points *a* and *b* i.e. $V_a - V_b$ in the circuit shown in **Figure 5**.

Figure 5



A) 8.0 V
B) 6.2 V
C) 6.9 V
D) 7.1 V
E) 8.8 V

Ans:

$$i_0 = \frac{24}{3} = 8A, \frac{i_0}{2} = 4A$$

$$24 - \frac{i_0}{2} \times 3 = V_a$$

$$24 - \frac{i_0}{2} \times 5 = V_b$$

$$V_a - V_b = \frac{i_0}{2} \times 5 - \frac{i_0}{2} \times 3 = i_0 \times 1 = 8\,V$$

Q18.

A particle with 2.58 ×10^{-15} kg mass and a negative charge is traveling through a region containing a uniform magnetic field $\vec{\mathbf{B}} = -(0.120\hat{\mathbf{k}})$ T. At a particular instant the velocity of the particle is $\vec{\mathbf{v}} = (1.05\times10^{6})(-3.00\,\hat{\mathbf{i}} + 4.00\,\hat{\mathbf{j}} + 12.0\,\hat{\mathbf{k}})$m/s and the force $\vec{\mathbf{F}}$ on the particle has a magnitude of 2.45 N. Determine the magnitude of the charge of the particle

A) 3.89×10^{-6} C
B) 1.11×10^{-6} C
C) 2.33×10^{-6} C
D) 3.05×10^{-6} C
E) 4.88×10^{-6} C

Ans:

$$F_B = q(\vec{v} \times \vec{B}) = -|q|\,(1.05 \times 10^6)(-3\vec{\imath} + 4\vec{\jmath} + 12\vec{k}) \times (0.12\vec{k})$$

$$|F_B| = 2.45 = |\mathrm{q}|(1.05 \times 10^6 \times 0.12)(3\vec{\jmath} + 4\vec{\imath})$$

$$2.45 = |\mathrm{q}|(1.05 \times 0.12 \times 10^6 \times 5)$$

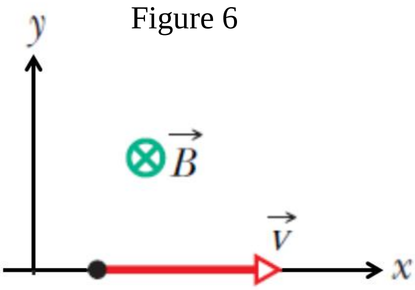
$$|\mathrm{q}| = 3.888 \times 10^{-6} C$$

Q19.

In **Figure 6**, an electron moves at a constant speed *v* = 114 m/s along *x* axis through uniform electric and magnetic fields. The magnetic field $\vec{\mathbf{B}}$ is directed into the page and has a magnitude of 7.50 T. In unit-vector notation, what is the electric field?

A) $(-855\,\hat{\mathbf{j}})$ V/m
B) $(+855\,\hat{\mathbf{j}})$ V/m
C) $(-251\,\hat{\mathbf{j}})$ V/m
D) $(-301\,\hat{\mathbf{j}})$ V/m
E) $(+301\,\hat{\mathbf{j}})$ V/m

Figure 6



Ans:

$$F_B = q(\vec{E} + \vec{v} \times \vec{B}) = 0$$

$$q\vec{E} = -q(\vec{v} \times \vec{B}) = -114\vec{\imath} \times (-7.50\,\vec{k})$$

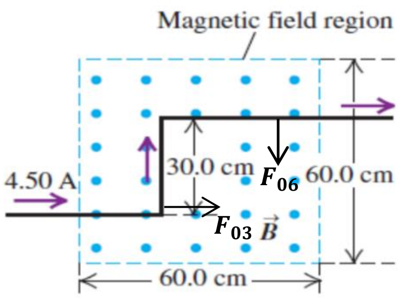
$$\vec{E} = 114 \times 7.50\,(\vec{\imath} \times \vec{k}) = -855\,\vec{\jmath}\,\mathrm{V/m}$$

Q20.

A long wire carrying 4.50 A of current makes two 90.0° bends, as shown in **Figure 7**. The bent part of the wire passes through a uniform 0.240 T magnetic field, which is confined to a limited space region, as shown in the figure. Find the magnitude of the net force that the magnetic field exerts on the wire.

A) 0.724 N
B) 0.224 N
C) 0.323 N
D) 0.444 N
E) 0.175 N

Figure 7



Ans:

$$F_{0.6} = il_{0.6}B = 4.5 \times 0.6 \times 0.24 = 0.648\ N$$

$$F_{0.3} = il_{0.3}B = 4.5 \times 0.3 \times 0.24 = 0.324\ N$$

$$|F_{net}| = \sqrt{F_{0.6}^2 + F_{0.3}^2} = \sqrt{(0.648)^2 + (0.324)^2}$$

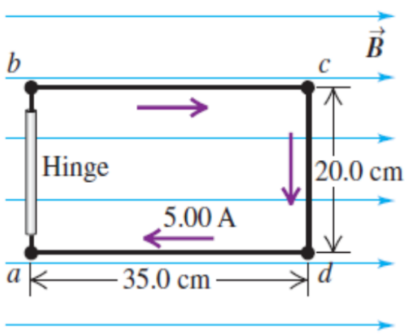
$$= 0.724\ N$$

Q21.

The 20.0 cm × 35.0 cm rectangular loop, as shown in **Figure 8**, is hinged along side *ab*.It carries a clockwise 5.0 A current and is located in a uniform 1.20 T magnetic field oriented perpendicular to two of its shorter sides, as shown. Calculate the magnitude of the torque that the magnetic field exerts on the coil about the hinge axis *ab*.

A) 0.420 N.m
B) 0.670 N.m
C) 0.220 N.m
D) 0.320 N.m
E) 0.120 N.m

Figure 8



Ans:

$$\vec{\tau} = \vec{\mu} \times \vec{B} = \mu B \sin\theta (\theta = 90°)$$

$$|\tau| = \mu B = N_i\ A \cdot B$$

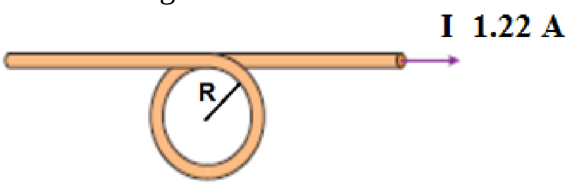
$$= 1 \times 5 \times 0.35 \times 0.2 \times 1.2$$

$$|\tau| = 0.42\ \mathrm{N \cdot m}$$

Q22.

For what value of the radius R of the loop shown in **Figure 9** is the magnitude of the net magnetic field at the center of the loop equals 5.00 × 10^{-5} T. The loop carries a current

Figure 9



A) 2.02 ×10^{-2} m
B) 1.10 ×10^{-2} m
C) 1.30 ×10^{-2} m
D) 1.50 ×10^{-2} m
E) 2.90 ×10^{-2} m

Ans:

$$\mathrm{B}_{wire} = \frac{\mu_0 i}{2\pi R};\ \mathrm{B}_{loop} = \frac{\mu_0 i}{2R}$$

$$\mathrm{B}_{net} = \mathrm{B}_{wire} + \mathrm{B}_{loop} = \frac{\mu_0 i}{2R}\left(1 + \frac{1}{\pi}\right)$$

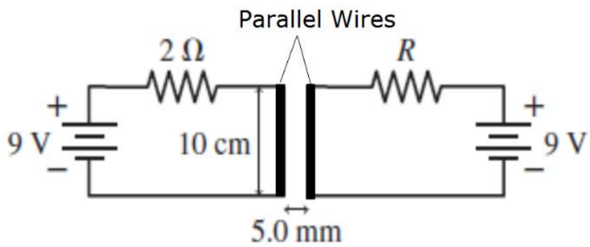
$$R = \frac{\mu_0 i}{2B_{net}}\left(1 + \frac{1}{\pi}\right)$$

$$R = \frac{4\pi \times 10^{-7} \times 1.22}{2 \times 5 \times 10^{-5}}(1 + 0.318) = 2.02 \times 10^{-2}\mathrm{m}$$

Q23.

The two 10 cm long parallel wires, shown in **Figure 10** are separated by 5.0 mm. Figure is drawn not to the scale. For what value of the resistor *R* will the force between the two wires be 5.4 × 10^{-5} N?

Figure 10



A) 3.0 Ω
B) 1.2 Ω
C) 1.9 Ω
D) 2.1 Ω
E) 3.9 Ω

Ans:

$$F = \frac{\mu_0 l i_2 i_R}{2\pi d} = \frac{4\pi \times 10^{-7} \times l \times i_2 \times i_R}{2\pi d}$$

$$F = 2 \times 10^{-7} \times l \times i_2 \times \frac{9}{R} \times \frac{1}{d}$$

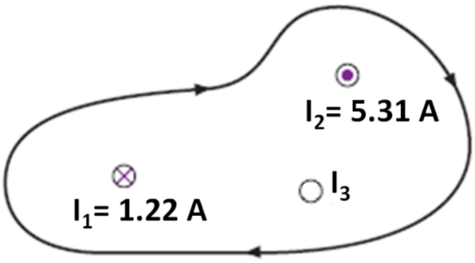
$$R = 2 \times 10^{-7} \times l \times i_2 \times \frac{9}{F} \times \frac{1}{d}$$

$$R = 2 \times 10^{-7} \times (0.1) \times \left(\frac{9}{2}\right) \times \frac{9}{5.4 \times 10^{-5}} \times \frac{1}{5 \times 10^{-3}} = 3.0\ \Omega$$

Q24.

The value of the line integral $\oint \vec{\mathbf{B}}.\mathbf{d}\vec{\mathbf{s}}$ of $\vec{\mathbf{B}}$ around the closed path in **Figure 11** is 7.54×10^{-7} T.m. What are the direction (into or out of the page) and magnitude of **I**$_3$?

Figure 11



A) 4.69 A into the page
B) 4.69 A out of the page
C) 3.53 A into the page
D) 2.22 A into the page
E) 1.19 A out of the page

Ans:

$$\oint Bids = \mu_0 i_{encl}$$

$$7.54 \times 10^{-7} = \mu_0(1.22 - 5.31 + I_3)$$

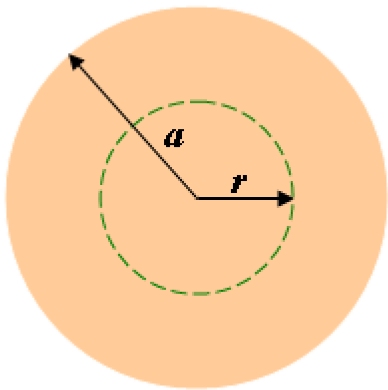
$$7.54 \times 10^{-7} = 4\pi \times 10^{-7}(-4.09 + I_3)$$

$$I_3 = 4.09 + \frac{7.54}{4\pi} = 4.69\ A$$

Q25.

Figure 12 shows a cross section of a long cylindrical conducting wire of radius ***a*** = 2.00 cm carrying a uniform current I. If the magnitude of the magnetic field due to current in the wire at radial distance ***r*** = 1.00 cm from the wire center is 9.00×10^{-4} T, find the magnitude of the total current I in the wire.

Figure 12



A) 1.80×10^2 A
B) 1.55×10^2 A
C) 1.00×10^2 A
D) 2.32×10^2 A
E) 1.11×10^2 A

Ans:

$$B(r) = \mu_0 \frac{I}{2\pi R^2} \times r$$

$$I = \frac{B(r) \times 2\pi R^2}{\mu_0 \times r} = \frac{B(r) \times 2\pi R^2}{4\pi \times 10^{-7} \times r}$$

$$I = \frac{B(r) \times R^2}{2r \times 10^{-3}} = \frac{9 \times 10^{-4} \times (0.02)^2}{2 \times (0.01) \times 10^{-3}} = 180\ A$$

Q26.

A long solenoid has 150 turns/cm and carries a current I = 0.150 A. An electron moves at a constant speed within the solenoid in a circle of radius 2.70 cm perpendicular to the solenoid axis. Calculate the speed of the electron.

A) 1.34×10^7 m/s
B) 1.00×10^7 m/s
C) 2.11×10^7 m/s
D) 2.55×10^7 m/s
E) 3.12×10^7 m/s

Ans:

$$B = \mu_0 ni$$

$$qvB = \frac{\mathrm{mv}^2}{R} \Rightarrow v = \frac{qR}{m}B = \frac{qR}{m}\mu_0 ni$$

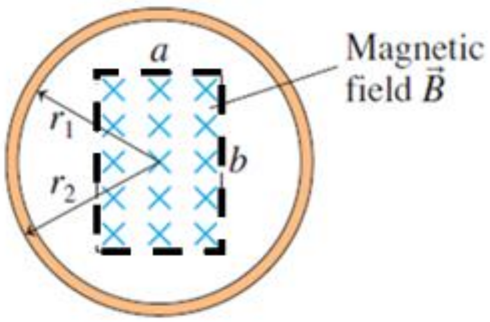
$$v = \frac{qR}{m}\mu_0 ni = \frac{1.6 \times 10^{-19} \times 0.027}{9.11 \times 10^{-31}} \times (4\pi \times 10^{-7} \times 1.5 \times 10^4 \times 0.15)$$

$$v = 1.34 \times 10^7 \text{ m/s}$$

Q27.

What is the magnitude of the magnetic flux through the circular loop shown in **Figure 13,** containing a uniform magnetic field $\vec{\mathbf{B}}$ (into the page) within a region of an area ***ab,*** shown by dotted lines? The inner and outer radii of the loop are r_1 and r_2, respectively.

Figure 13



A) Bab
B) $\pi B r_1^2$
C) $\pi B r_2^2$
D) Bb/a
E) Ba/b

Ans:

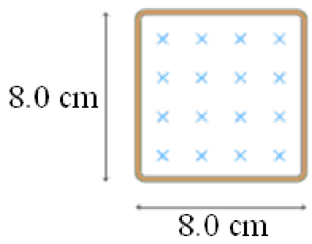
$$\Phi = \int \vec{B} \cdot d\vec{A} = BA$$

$$\Phi = Bab \quad (A = ab)$$

Q28.

The resistance of the square loop in **Figure 14** is 0.200 Ω. If the magnetic field is increasing at a rate of 4.69 T/s, find the magnitude and direction of the induced current in the loop.

Figure 14



A) 0.150 A , counter clockwise
B) 0.277 A , clockwise
C) 0.100 A , counter clockwise
D) 0.306 A , clockwise
E) 0.550 A , counter clockwise

Ans:

$$\varepsilon = \frac{d\phi}{dt} = A\,\frac{dB}{dt}$$

$$\varepsilon = (0.08)^2 \times 4.69 = 0.03\ \text{V}$$

$$\text{i} = \frac{\varepsilon}{R} = 0.150\ \text{A}$$

Q29.

A coil formed by wrapping 25 turns of wire in the shape of a square is placed in a magnetic field so that the normal to the plane of the coil makes an angle of 30° with the fixed direction of the field. When the magnitude of the magnetic field is increased uniformly from 0.20 T to 0.60 T in 0.40 s, an emf of magnitude 80 mV is induced in the coil. What is the area of the coil?

A) 3.7×10^{-3} m^2
B) 1.1×10^{-3} m^2
C) 1.8×10^{-3} m^2
D) 2.5×10^{-3} m^2
E) 2.3×10^{-3} m^2

Ans:

$$|\varepsilon| = \frac{d}{dt}(NBAcos\theta) = NAcos\theta\,\frac{dB}{dt}$$

$$80 \times 10^{-3} = 25 \times \text{A} \times \cos 30 \times \left(\frac{0.6 - 0.2}{0.4}\right) = 25 \times A \times \cos 30$$

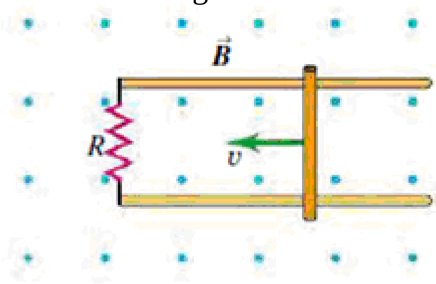
$$A = \frac{80 \times 10^{-3}}{25 \times \cos 30} = 3.695 \times 10^{-3} m^2$$

Q30.

Consider the circuit shown in **Figure 15** with the bar moving to the left on conducting rails at a constant speed v = 20 m/s in a uniform magnetic field *B* = 0.80T. The bar has a length of 0.50 m and the circuit resistance is *R* = 50 Ω. Determine the magnitude of the induced current in the 50 Ω resistor.

A) 0.16 A
B) 0.05 A
C) 0.29 A
D) 0.35 A
E) 0.46 A

Figure 14



Ans:

$\varepsilon = Blv$

$$i = \frac{|\varepsilon|}{R} = \frac{Blv}{R} = \frac{0.8 \times 0.5 \times 20}{50}$$

$= 0.16\ A$