Q1.

A string of length *L* is fixed at both ends. Which one of the following is **NOT** a possible wavelength for standing waves on this string?

A) 4L
B) L
C) 2L
D) L/2
E) 2L/3

Ans:

$$\lambda_n = \frac{2L}{n} = \begin{cases} 2L \\ L \\ 2L/3 \\ L/2 \\ . \\ . \\ . \end{cases}$$

Q2.

A point source emits 30.0 W of sound isotropically. A detector has an area of 0.800 cm^2, and is at a distance of 20.0 m from the source. Calculate the power intercepted by the detector.

A) 4.77×10^{-7} W
B) 5.97×10^{-4} W
C) 7.46×10^{-7} W
D) 9.60×10^{-4} W
E) 3.95×10^{-4} W

Ans:

$d \rightarrow$ detector, $s \rightarrow$ source

$$I_d = \frac{P_s}{4\pi r^2}$$

$$P_d = I_d . A_d = \frac{P_s . A_d}{4\pi r^2} = \frac{30 \times 8 \times 10^{-5}}{4\pi \times 400} = 4.77 \times 10^{-7} W$$

Q3.

Two blocks, A and B, have identical masses, but are made of different substances. The specific heats of the blocks are c_A = 440 J/(kgK) and c_B = 160 J/(kgK). The blocks are initially at 21.0 °C; and the same quantity of heat is added to each block. If the final temperature of block A is 72.0 °C, what is the final temperature of block B?

A) 161 °C
B) 72.0 °C
C) 198 °C
D) 21.0 °C
E) 119 °C

Ans:

$$Q_A = Q_B$$

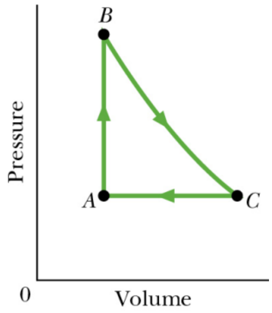
$$m_A c_A . \Delta T_A = m_B c_B . \Delta T_B$$

$$\Rightarrow \Delta T_B = \frac{c_A}{c_B} . \Delta T_A = \frac{440}{160} \times (72 - 21) = 140\ °C$$

$$\Rightarrow T_{Bf} = 140 + 21 = 161\ °C$$

Q4.

Gas within a chamber passes through the cycle shown in **Figure 1**. The heat added during process AB (Q_{AB}) is 20 J, and no heat is transferred during process BC. The net work done during the cycle is 15 J. Determine the heat transferred during process CA (Q_{CA}).



A) -5.0 J
B) -35 J
C) +35 J
D) +5.0 J
E) -20 J

Ans:

$$Q_{AB} = +20\ J$$

$$Q_{BC} = 0$$

$$W_{net} = 15\ J$$

Cyclic process: $\Delta E_{int} = 0$

$$\Rightarrow W_{net} = Q_{net}$$

$$15 = 20 + 0 + Q_{CA}$$

$$\Rightarrow Q_{CA} = -5.0\ J$$

Q5.

One mole of a monatomic ideal gas at 400.0 K is taken to half of its original volume by an isobaric process. How much work is done in the process?

A) 1662 J on the gas
B) 3324 J on the gas
C) 8300 J on the gas
D) 1662 J by the gas
E) 3324 J by the gas

Ans:

$$p_f v_f = nRT_f$$

$$p_i v_i = nRT_i$$

$$\frac{T_f}{T_i} = \frac{v_f}{v_i} = \frac{1}{2}$$

$$\Rightarrow T_f = \frac{T_i}{2}$$

$$W = p\Delta V = nR\Delta T$$

$$= nR\left(\frac{T_i}{2} - T_i\right) = -nR\frac{T_i}{2}$$

$$= -\frac{1 \times 8.31 \times 400}{2} = -1662 \text{ J}$$

Q6.

A Carnot heat engine operates between two reservoirs at temperatures of 300 K and 500 K. The work done in one cycle is 1200 J. What is the change in the entropy of the hot reservoir?

A) –6.0 J/K
B) +6.0 J/K
C) –10 J/K
D) +10 J/K
E) –0.96 J/K

Ans:

$$\varepsilon = 1 - \frac{T_L}{T_H} = 1 - \frac{300}{500} = 0.4$$

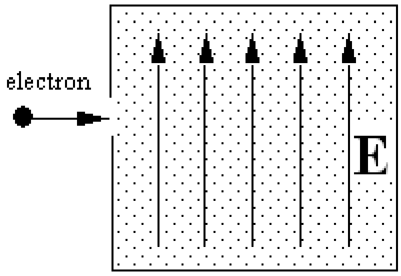
$$\varepsilon = \frac{W}{Q_H} \to Q_H = \frac{W}{\varepsilon} = \frac{1200}{0.4} = 3000 \text{ J}$$

$$\Delta s_H = -\frac{Q_H}{T_H} = -\frac{3000}{500} = -6.0 \frac{\text{J}}{\text{K}}$$

Q7.

An electron traveling horizontally enters a region where a uniform electric field is directed upward, as shown in **Figure 2**. What is the direction of the electric force exerted on the electron once it has entered the field?

A) downward
B) upward
C) to the left
D) to the right
E) out of the page



Ans:

$$\vec{F} = q\vec{E} = (-e)\vec{E} = -e\vec{E}$$

$\Longrightarrow \vec{F}$ is opposite to $\vec{E}$

Q8.

A solid non-conducting sphere of radius R carries a uniform charge density. At a radial distance $r_1 = R/4$, the electric field has a magnitude of E_o. What is the magnitude of the electric field at a radial distance $r_2 = 2R$? Radial distances are measured from the center of the sphere.

A) E_o
B) $E_o/2$
C) $E_o/4$
D) zero
E) $2E_o$

Ans:

$$E_0 = \frac{kQ}{R^3}.\frac{R}{4} = \frac{kQ}{4R^2} \Rightarrow 4R^2 = \frac{kQ}{E_0} \Rightarrow \frac{1}{4R^2} = \frac{E_0}{kQ}$$

$$E = \frac{kQ}{4R^2} = kQ.\frac{E_0}{kQ} = E_0$$

Q9.

Two point charges are fixed along the *x* axis as follows: q_1 = +2.0μC at x_1 =0, and q_2 = -5.0 μC at x_2 = 1.0 m. At which of the following values of *x* is the electric potential equal to zero? Take the electric potential to be zero at infinity.

A) +0.29 m
B) +0.05 m
C) +0.54 m
D) +0.45 m
E) +0.71 m

Ans:

∗ All the given answers are (+).

∗ The point must be between the charges.

∗ Let it be a distance x from the origin.

$$V = k\left[\frac{2}{x} - \frac{5}{1-x}\right] \times 10^{-6} = 0$$

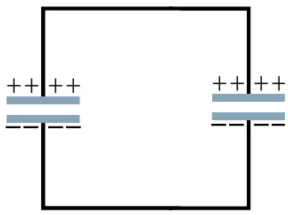
$$\Rightarrow \frac{2}{x} = \frac{5}{1-x}$$

$$2 - 2x = 5x \Rightarrow 7x = 2 \Rightarrow x = \frac{2}{7} = 0.29 \text{ m}$$

Q10.

A 10-μF capacitor is charged so that the potential difference between its plates is 10 V. A 5.0-μF capacitor is charged so that the potential difference between its plates is 5.0 V. The two charged capacitors are then connected as shown in **Figure 3**. What is the final charge on the 10-μF capacitor?

A) 83 μC
B) 67 μC
C) 33 μC
D) zero
E) 17 μC



Ans:

$$\left.\begin{array}{r} q_{1i} = 10 \times 10 = 100\mu c \\ q_{2i} = 5 \times 5 = 25\mu c \end{array}\right\} Q_i = q_{1i} + q_{2i} = 125\ \mu C$$

$$\left.\begin{array}{r} q_{1f} = c_1 v \\ q_{2f} = c_2 v \end{array}\right\} Q_f = (C_1 + C_2)V$$

$$Q_i = (C_1 + C_2)V \leftarrow \text{Charge Conservation}$$

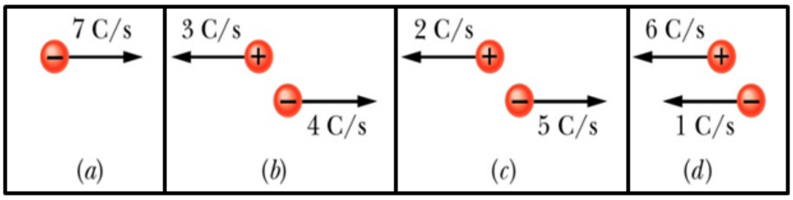
$$\Rightarrow V = \frac{Q_i}{C_1 + C_2} = \frac{125}{15} = 8.3 \text{ V}$$

$$\Rightarrow q_{1f} = 10 \times 8.3 = 83\ \mu C$$

Q11.

Figure 5 shows four situations in which positive and negative charges move horizontally, and gives the rate at which each charge moves. Rank the situations according to the net current through the regions, greatest first.

Fig # 5



A) **a** and **b** and **c** tie, then **d**
B) **a**, then **d**, then **c**, then **b**
C) **a**, then **d**, then **b**, then **c**
D) **a**, then **c**, then **d**, then **b**
E) **a**, then **c**, then **b**, then **d**

Ans:

$a = 7A$

$b = 3 + 4 = 7A$

$c = 2 + 5 = 7A$

$d = 6 - 1 = 5A$

Q12.

A flashlight bulb, made of a thin tungsten wire, is rated at 0.300 A / 3.00 V (the values of the current and voltage under operating conditions). If the resistance of the wire at room temperature (20.0 ^oC) is 1.00 Ω, what is its temperature when the bulb is turned ON? The temperature coefficient of resistivity of tungsten is 0.00450 $^oC^{-1}$. Assume the dimensions of the wire do not change.

A) 2020 ^oC
B) 1980 ^oC
C) 2000 ^oC
D) 1080 ^oC
E) 1820 ^oC

Ans:

$$R_f = \frac{V}{i} = \frac{3}{0.3} = 10\Omega$$

$$\Delta R = R_f - R_i = 10 - 1 = 9\ \Omega$$

$$\Delta R = \alpha R_i \Delta T$$

$$\Rightarrow \Delta T = \frac{\Delta R}{\alpha R_i} = \frac{9}{4.5 \times 10^{-3} \times 1} = 2000\ °C$$

$$\Rightarrow T_f = T_i + \Delta T = 2020\ °C$$

Q13.

A heating element is operated by maintaining a voltage of 110 V across the length of a wire whose cross sectional area is 8.0×10^{-7} m^2. The resistivity of the wire's material is 5.0×10^{-7} Ω m. If the element dissipates 5.0 kW, what is its length?

A) 3.9 m
B) 2.0 m
C) 1.2 m
D) 5.8 m
E) 4.1 m

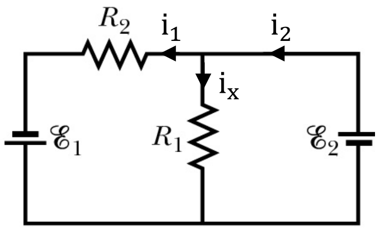
Ans:

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{(110)^2}{5000} = 2.42\ \Omega$$

$$R = \frac{\rho L}{A} \Rightarrow L = \frac{RA}{\rho} = \frac{2.42 \times 8 \times 10^{-7}}{5 \times 10^{-7}} = 3.9\ \text{m}$$

Q14.

In the circuit shown in **Figure 4**, $\boldsymbol{E_1}$ = 6.0 V, $\boldsymbol{E_2}$ = 12 V, R_1 = 200 Ω, and R_2 = 100 Ω. Determine the current passing through R_2.



A) 180 mA to the left
B) 180 mA to the right
C) 120 mA to the left
D) 120 mA to the right
E) 60 mA to the right

Ans:

$$\varepsilon_2 = i_x R_1 \Rightarrow i_x = \frac{\varepsilon_2}{R_1} = \frac{12}{200} = 0.06\ \text{A}$$

$$\varepsilon_1 + i_x R_1 - i_1 R_2 = 0$$

$$\Rightarrow i_1 = \frac{\varepsilon_1 + i_x R_1}{R_2} = \frac{6 + 12}{100} = 180\ \text{mA}$$

Q15.

A 1.0 μF capacitor with an initial stored energy of 0.50 J is discharged through a 1.0 M Ω resistor. Find the current through the resistor when the discharge starts.

A) 1.0 mA τ
B) 2.5 mA
C) 3.2 mA
D) 0.50 mA
E) 0 mA

Ans:

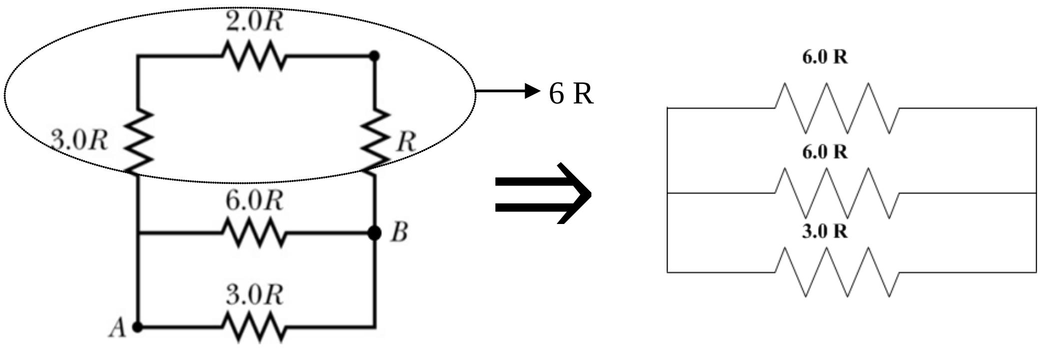
$$U_0{}^2 = \frac{q_0{}^2}{2C} \Rightarrow q_0 = \sqrt{2cU_0} = \sqrt{2 \times 10^{-6} \times 0.5} = 10^{-3}C$$

$$i = (q_0)\left(-\frac{1}{RC}\right)e^{-\tau/RC} \Rightarrow i_0 = \frac{q_0}{\tau} = \frac{q_0}{RC}$$

$$\therefore i_0 = \frac{10^{-3}}{1.0} = 1.0\ \text{mA}$$

Q16.

Consider the five resistors connected as shown in **Figure 6**. Find the equivalent resistance between the points A and B.



A) $3R/2$
B) $3R$
C) $15R$
D) $6R$
E) $36R/5$

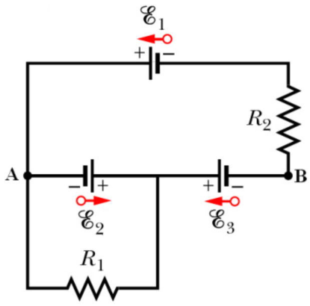
Ans:

$$\frac{1}{R_P} = \frac{1}{6R} + \frac{1}{6R} + \frac{1}{3R} = \frac{4}{6R}$$

$$\Rightarrow R_P = \frac{6R}{4} = \frac{3R}{2}$$

Q17.

In the circuit shown in **Figure 7**, R_1 = 100 Ω, R_2 = 50 Ω, and the ideal batteries have emfs $\mathbf{E}_1$ = 6.0 V, $\mathbf{E}_2$ = 5.0 V, and $\mathbf{E}_3$ = 4.0 V. Find the potential difference $V_B - V_A$.



A) +1.0 V
B) –1.0 V
C) +9.0 V
D) –9.0 V
E) +15 V

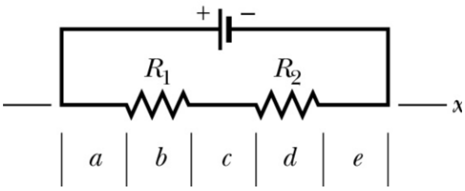
Ans:

$V_B = \epsilon_3 - \epsilon_2 = V_A$

$\Rightarrow V_B - V_A = \epsilon_2 - \epsilon_3 = 5 - 4 = +1.0\text{ V}$

Q18.

In the circuit shown in **Figure 8**, an ideal battery is connected to two resistors ($R_1 > R_2$). The section lying along an x axis is divided into five segments of equal length. Rank the segments according to the magnitude of the electric field in them, **greatest first**.



A) **b**, then **d**, then **a** and **c** and **e** tie
B) **d**, then **b**, then **a** and **c** and **e** tie
C) **a** and **c** and **e** tie, then **b**, then **d**
D) **a** and **c** and **e** tie, then **d**, then **b**
E) The electric field is the same in all segments.

Ans:

$V_R = iR$

$E = \frac{V_R}{L} = \frac{iR}{L}$

$\Rightarrow E \propto R\{i, L \rightarrow \text{same}\}$

Q19.

At one instant, a charged particle is moving with velocity $\vec{\mathbf{v}} = 2.0\hat{\mathbf{i}} + 3.0\hat{\mathbf{j}}$ (m/s) in a uniform external magnetic field $\vec{\mathbf{B}} = -3.0\hat{\mathbf{j}}$ (T). At that instant, the magnetic field produces a force $\vec{\mathbf{F}} = 5.8\times10^{-3}\hat{\mathbf{k}}$ (N) on the particle. What is the charge of the particle?

A) -9.7×10^{-4} C
B) $+9.7 \times 10^{-4}$ C
C) -6.4×10^{-4} C
D) $+6.4 \times 10^{-4}$ C
E) $+3.2 \times 10^{-4}$ C

Ans:

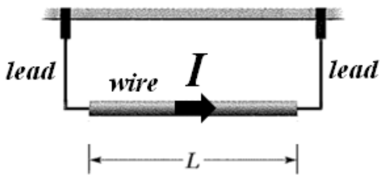
$$\vec{v} \times \vec{B} = (2\hat{\imath} + 3\hat{\jmath}) \times (-3\hat{\jmath}) = -6\,\hat{k}$$

$$\vec{F} = q\left(\vec{v} \times \vec{B}\right)$$

$$\Rightarrow q = \frac{\vec{F}}{\vec{v} \times \vec{B}} = \frac{5.8 \times 10^{-3}\hat{k}}{-6\hat{k}} = -9.7 \times 10^{-4}\text{C}$$

Q20.

A 10 g wire of length L = 70 cm is suspended by a pair of flexible leads, as shown **Figure 9**. The wire carries a current of 0.7 A that flows to the right. What is the minimum magnetic field needed to have zero tension in the leads?



A) 0.2 T, into the page
B) 0.2 T, out of the page
C) 0.2 T, upward
D) 0.2 T, downward
E) No magnetic field can balance the wire

Ans:

For minimum: $\vec{B} \perp \vec{L} \Rightarrow \vec{B}$ must be into the page

$$F_B = F_g : \ iLB = mg$$

$$\Rightarrow B = \frac{mg}{iL} = \frac{10^{-2} \times 9.8}{0.7 \times 0.7} = 0.2\text{ T}$$

check: $\vec{L} \rightarrow \hat{\imath}, \qquad \vec{B} \rightarrow -\hat{k}$

$$\vec{L} \times \vec{B} = \hat{\imath} \times \left(-\hat{k}\right) = +\hat{\jmath}$$

Q21.

A 26-turn rectangular coil of wire carrying a current of 0.25 A is placed in a uniform magnetic field of magnitude 0.050 T. The coil is 2.5 cm long and has width *w*. The torque acting on the coil is 2.3×10^{-4} N.m. If the angle between the magnetic field and the plane of the coil is 55^o, then the width *w* of the coil is:

A) 4.9 cm
B) 0.050 cm
C) 1.3 cm
D) 0.030 cm
E) 3.5 cm

Ans:

$$\tau = \mu B \text{Sin}\theta = \text{NiAB}\text{Sin}\theta = \text{NiLw}\sin\theta$$

$$\Rightarrow w = \frac{\tau}{\text{NiLB}\sin\theta} = \frac{2.3 \times 10^{-4}}{26 \times 0.25 \times 0.025 \times 0.05 \times \sin 35°}$$

$$= 4.9 \text{ cm}$$

Q22.

An electron is accelerated from rest by a potential difference of 350 V. It then enters a uniform magnetic field of magnitude 2.00 mT with its velocity perpendicular to the magnetic field. The radius of the circular path of the electron in the magnetic field is:

A) 3.16 cm
B) 2.58 cm
C) 4.71 cm
D) 6.37 cm
E) 5.83 cm

Ans:

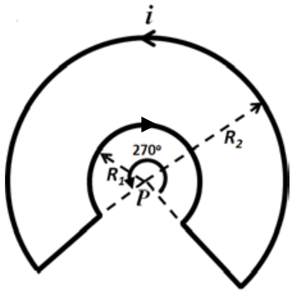
$$\frac{1}{2}\text{mv}^2 = \text{qV} \Rightarrow \text{v} = \sqrt{\frac{2\text{qV}}{\text{m}}}$$

$$\text{qVB} = \frac{\text{mv}^2}{\text{R}} \Rightarrow \text{R} = \frac{\text{mv}}{\text{qB}} = \frac{\text{m}}{\text{qB}} \cdot \sqrt{\frac{2\text{qV}}{\text{m}}} = \frac{1}{\text{B}} \cdot \sqrt{\frac{2\text{mV}}{\text{q}}}$$

$$\Rightarrow \text{R} = \frac{1}{0.002} \times \left[\frac{2 \times 9.11 \times 10^{-31} \times 350}{1.6 \times 10^{-19}}\right]^{\frac{1}{2}} = 3.16 \text{ cm}$$

Q23.

In **Figure 10**, a closed loop carries current i = 0.20 A. The loop consists of two straight wires and two concentric circular arcs of radii R_1 = 2.0 m and R_2 = 4.0 m. What is the magnetic field at the center P?



A) 2.4×10^{-8} T into the page
B) 2.4×10^{-8} T out of the page
C) 3.5×10^{-8} T into the page
D) 3.5×10^{-8} T out of the page
E) zero

Ans:

Net $\vec{B}$ is into the page

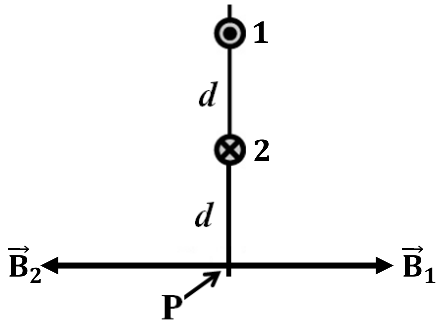
$$B_P = \frac{\mu_0 i \phi}{4\pi}\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$= \frac{4\pi \times 10^{-7} \times 0.2 \times \frac{3\pi}{2}}{4\pi}\left[\frac{1}{2} - \frac{1}{4}\right]$$

$$= 2.4 \times 10^{-8}\ \text{T}$$

Q24.

Two infinitely long wires carry currents in opposite directions, as shown in **Figure 11**. The current in each wire is 5.0 A, and the distance d = 1.0 m. What is the net magnetic field at point P?



A) 0.50 μT, to the left
B) 0.50 μT, to the right
C) 1.5 μT, to the left
D) 1.5 μT, to the right
E) zero

Ans:

$B_1 = \frac{\mu_0 i}{4\pi d}$, → To the right

$B_2 = \frac{\mu_0 i}{2\pi d}$ → To the Left

$$B_{net} = \frac{\mu_0 i}{2\pi d} - \frac{\mu_0 i}{4\pi d} = \frac{\mu_0 i}{4\pi d}$$

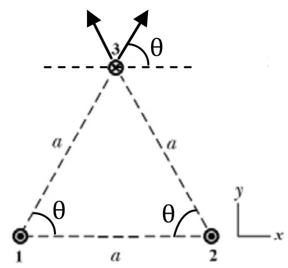
$$= \frac{4\pi \times 10^{-7} \times 5}{4\pi \times 1} = 5.0 \times 10^{-7}\ \text{T}$$

Since $B_2 > B_1 \Rightarrow B_{net}$ is to the left

Q25.

Figure 12 shows three long parallel wires at the vertices of an equilateral triangle of side a = 10 cm, and carrying the same current I = 5.0 A. The currents in wires 1 and 2 are out of the page, while in wire 3 the current is into the page. Calculate the net magnetic force per unit length on wire 3 due to wires 1 and 2.

A) $+8.7 \times 10^{-5}\ \hat{\mathbf{j}}$ N/m
B) $-8.7 \times 10^{-5}\ \hat{\mathbf{j}}$ N/m
C) $+3.1 \times 10^{-5}\ \hat{\mathbf{j}}$ N/m
D) $-3.1 \times 10^{-5}\ \hat{\mathbf{j}}$ N/m
E) $+9.8 \times 10^{-5}\ \hat{\mathbf{j}}$ N/m



Ans:

$$\vec{F} = 2.F_i.\sin\theta\hat{j}$$

$$\Rightarrow \frac{\vec{F}}{l} = \frac{2 \times \mu_0 i^2}{2\pi a} \times \sin 60^\circ\ \hat{j}$$

$$= \frac{8\pi \times 10^{-7} \times 25 \times \sin 60^\circ}{2\pi \times 0.1}\ \hat{j}$$

$$= 8.7 \times 10^{-5}\ \hat{j}\ \frac{N}{m}$$

Q26.

A long wire has a radius greater than 4.0 mm, and carries a current that is uniformly distributed over its cross section. The magnitude of the magnetic field due to this current is 0.28 mT at a point 4.0 mm from the axis of the wire, and 0.20 mT at a point 10 mm from the axis of the wire. What is the radius of the wire?

A) 5.3 mm
B) 6.0 mm
C) 7.5 mm
D) 8.0 mm
E) 4.6 mm

Ans:

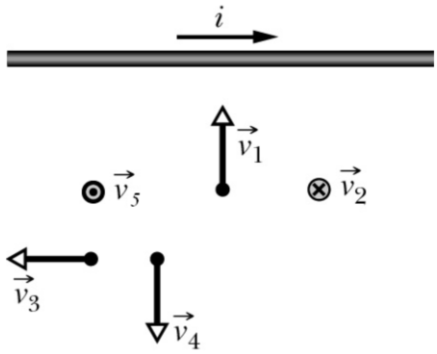
$$\left.\begin{array}{l} r_1 = 4.0\text{ mm},\ B_1 = 0.28\text{ mT} \\ r_2 = 10\text{ mm},\ B_2 = 0.20\text{ mT} \end{array}\right\} \begin{array}{c} \text{Since } B_2 < B_1 \\ \Rightarrow r_1 \text{is inside} \\ r_2 \text{is outside} \end{array}$$

$$\left.\begin{array}{l} B_1 = \dfrac{\mu_0 2 r_1}{2\pi R^2} \\ B_2 = \dfrac{\mu_0 i}{2\pi r^2} \end{array}\right\} \frac{B_2}{B_1} = \frac{R^2}{r_1 r_2} \rightarrow R = \sqrt{r_1 r_2 . \frac{B_2}{B_1}} = 5.3\text{ mm}$$

Q27.

Figure 13 shows a snapshot of the velocity vectors of five electrons near a wire carrying current *i*. The five velocities have the same magnitude. Which electron experiences the largest magnetic force?

A) 1
B) 2
C) 3
D) 4
E) 5



Ans:

$\vec{v}_3$ and $\vec{v}_4$ are farther away from the wire.

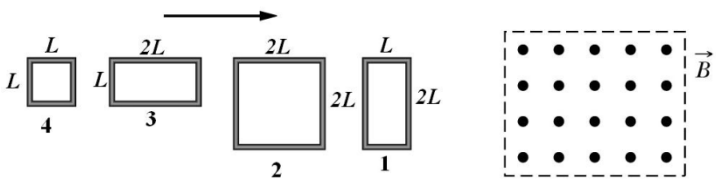
$\vec{v}_2$ and $\vec{v}_5$ will not experience a magnetic force because they are parallel to $\vec{B}$

$\Rightarrow \vec{v}_1$ experiences the largest magnetic force.

Q28.

Figure 14 shows four wire loops, with edge lengths of either *L* or *2L*. All four wires move toward a region of uniform magnetic field **B** (directed out the page) at the same constant velocity. As they enter the magnetic field, in which loop(s) is the greatest induced emf?

A) 1 and 2
B) 3 and 4
C) 3 only
D) 1 only
E) 2 only



Ans:

$\varepsilon_{ind} = B.L.v$

$\Rightarrow \varepsilon_{ind} \propto$ Length

$\Rightarrow (\epsilon_1 = \varepsilon_2) > (\epsilon_3 = \varepsilon 4_4)$

Q29.

A square loop of wire is held in a uniform 0.24 T magnetic field directed perpendicular to the plane of the loop. The length of each side of the loop is decreasing at a constant rate of 5.0 cm/s. What is the emf induced in the loop at the instant the length is 12 cm?

A) 2.9 mV
B) 1.2 mV
C) 3.5 mV
D) 12 mV
E) 5.0 mV

Ans:

$$\varepsilon = \frac{d\Phi_B}{dt} = \frac{d}{dt}(BA) = B\frac{dA}{dt} = B.\frac{d}{dt}(x^2)$$

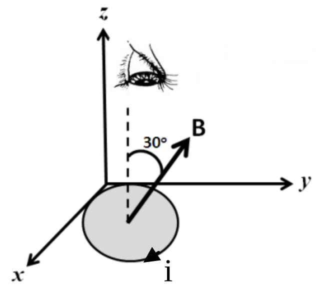
$$= 2Bx\frac{dx}{dt} = (2)(0.24)(0.12)(0.05)$$

= 2.9 mV

Q30.

A circular loop of wire of radius 14 cm is placed in the xy plane in a magnetic field that makes an angle of 30^o with the normal to the plane of the loop, as shown in **Figure 15**. The magnitude of this field increases at constant rate from 30 mT to 60 mT in 15 ms. If the loop has a resistance of 5.0 Ω, what is the current induced in the loop, looking from the top?

A) 21 mA, clockwise
B) 21 mA, counter clockwise
C) 10 mA, clockwise
D) 10 mA, counter clockwise
E) 32 mA, clockwise



Ans:

$$\epsilon = d\,\frac{d\phi_B}{dt} = \frac{d}{dt}(BA\cos\theta) = A\cos\theta\frac{dB}{dt}$$

$$i = \frac{\epsilon}{R} = \frac{A\cos\theta}{R}\frac{\Delta B}{\Delta t}$$

$$\Rightarrow i = \frac{\pi \times (0.14)^2 \times \cos 30^\circ}{5.0} \times \frac{30 \times 10^{-3}}{15 \times 10^{-3}}$$

= 21 mA