

Q1.

A string fixed at both ends has successive resonances with wavelengths of 0.540 m for the n th harmonic and 0.480 m for the $(n+1)$ th harmonic. What is the length of the string?

- A) 2.16 m
- B) 1.02 m
- C) 3.59 m
- D) 2.94 m
- E) 4.22 m

Ans:

$$\lambda_n = \frac{2L}{n}; \lambda_{n+1} = \frac{2L}{n+1}$$

$$\frac{1}{\lambda_{n+1}} - \frac{1}{\lambda_n} = \frac{n+1}{2L} - \frac{n}{2L} = \frac{1}{2L}$$

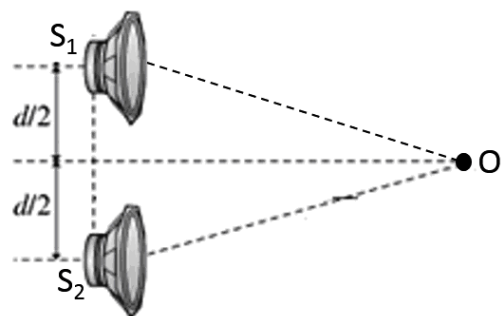
$$\frac{1}{0.48} - \frac{1}{0.54} = \frac{1}{2L}$$

$$L = 2.16 \text{ m}$$

Q2.

Two identical sound sources S_1 and S_2 are placed along a vertical line, as shown in **FIGURE 1** and are connected to the same oscillator. When only speaker 1 is ON the intensity of the sound recorded at O is I . If you switch on both speakers what will be the new intensity of the sound at O .

Figure 1



- A) 4 I
- B) 2 I
- C) I
- D) 8 I
- E) 3 I

Ans:

$$I \propto A^2 \Rightarrow I = KA^2$$

$$I' = K(2A)^2$$

$$I' = K(4A^2)$$

$$I' = 4I$$

Q3.

An ideal gas that initially occupies a volume of 0.240 m^3 at a pressure of $1.01 \times 10^5 \text{ Pa}$ is compressed isothermally to a pressure of $2.20 \times 10^5 \text{ Pa}$. How much energy is transferred as heat during the compression?

- A) **-18.9 kJ**
- B) +18.9 kJ
- C) -12.7 kJ
- D) +21.2 kJ
- E) -16.9 kJ

Ans:

$$W = nRT \ln \frac{V_f}{V_i} = P_1 V_1 \ln \frac{P_i}{P_f}$$

$$W = 1.01 \times 10^5 \times 0.24 \ln \left(\frac{1.01 \times 10^5}{2.2 \times 10^5} \right)$$

$$W = -18871 \text{ J}$$

For isotherm Process $W = Q$

$$\Rightarrow Q = -18.9 \text{ kJ}$$

Q4.

When 20.9 J was added as heat to a particular ideal gas, the volume of the gas changed from 50.0 cm^3 to 100 cm^3 while the pressure remained at 1.00 atm, find C_v of the gas.

- A) **26.1 J/mol.K**
- B) 36.2 J/mol.K
- C) 12.9 J/mol.K
- D) 42.0 J/mol.K
- E) 29.7 J/mol.K

Ans:

$$Q = nC_p \Delta T = C_p n \Delta T$$

$$Q = C_p \cdot \frac{P \Delta V}{R}$$

$$20.9 = C_p \cdot \frac{1.01 \times 10^5 \times 50 \times 10^{-6}}{8.31}$$

$$C_p = 34.39$$

$$C_p - C_v = R$$

$$C_v = 34.39 - 8.31 = 26.08$$

Q5.

A heat engine absorbs 100 J of heat from the hot reservoir and releases 60 J of heat to the cold reservoir during each cycle. If each cycle takes 0.50 s, find the power output of this engine.

- A) 80 W
- B) 40 W
- C) 60 W
- D) 20 W
- E) 50 W

Ans:

$$Q_H = Q_L + W$$

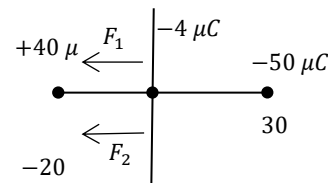
$$W = 100 - 60 = 40 \text{ J}$$

$$P = \frac{W}{t} = \frac{40}{0.5} = 80 \text{ W}$$

Q6.

A particle (charge = $+40 \mu\text{C}$) is located on the x axis at $x = -20$ cm, and a second particle (charge = $-50 \mu\text{C}$) is placed on the x axis at $x = +30$ cm. What is the magnitude of the total electrostatic force on a third particle (charge = $-4.0 \mu\text{C}$) placed at the origin ($x = 0$)?

- A) 56 N
- B) 41 N
- C) 16 N
- D) 35 N
- E) 72 N



Ans:

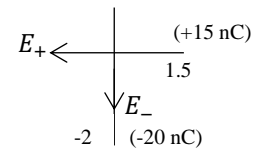
$$F_T = \frac{K(40 \mu)(4 \mu)}{(0.2)^2} + \frac{K(50 \mu)(4 \mu)}{(0.3)^2}$$

$$F_T = 9 \times 10^9 \times 4 \times 10^{-6} \left[\frac{40 \times 10^{-6}}{(0.2)^2} + \frac{50 \times 10^{-6}}{(0.3)^2} \right] = 56 \text{ N}$$

Q7.

A $+15.0 \text{ nC}$ point charge is placed on the x-axis at $x = +1.50 \text{ m}$, and a -20.0 nC charge is placed on the y-axis at $y = -2.00 \text{ m}$. What is the magnitude of the electric field at the origin?

- A) 75.0 N/C**
- B) 105 N/C
- C) 15.0 N/C
- D) 45.0 N/C
- E) 60.0 N/C



Ans:

$$E_+ = \frac{9 \times 10^9 \times 15 \times 10^{-9}}{(1.5)^2}; E_- = \frac{9 \times 10^9 \times 20 \times 10^{-9}}{2^2}$$

$$E_+ = 60 \text{ N/C}; E_- = 45 \text{ N/C}$$

$$E = \sqrt{E_+^2 + E_-^2} = \sqrt{60^2 + 45^2} = 75.0 \text{ N/C}$$

Q8.

A point charge is placed at the center of an imaginary cube that has 20-cm-long edges. The electric flux out of one of the cube's sides is $-2.5 \text{ kN}\cdot\text{m}^2/\text{C}$. How much charge is at the center?

- A) $-1.3 \times 10^{-7} \text{ C}$**
- B) $-2.2 \times 10^{-8} \text{ C}$
- C) $+1.3 \times 10^{-7} \text{ C}$
- D) $+2.2 \times 10^{-7} \text{ C}$
- E) $-6.6 \times 10^{-8} \text{ C}$

Ans:

$$\phi_t = \frac{1}{\epsilon_0} q_{enc}$$

$$6 \times (-2.5 \times 10^3) = \frac{1}{\epsilon_0} q_{enc}$$

$$q_{enc} = -1.327 \times 10^{-7} \text{ C}$$

Q9.

The electric potential at points in an xy plane is given by

$V = (1.2x^2 - 7.2x - 4.5y^2 + 18y) \text{ V}$. Find the coordinates of the point where the electric field is zero.

- A) (3.0, 2.0)
- B) (0, 0)
- C) (1.2, 4.5)
- D) (7.2, 2.0)
- E) (3.0, 7.0)

Ans:

$$E_x = -\frac{\partial v}{\partial x} = -[1.2(2x) - 7.2]$$

$$0 = -2.4x + 7.2 \Rightarrow x = 3$$

$$E_y = -\frac{\partial v}{\partial y} = -[-4.5(2y) + 18]$$

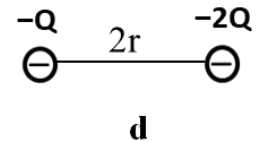
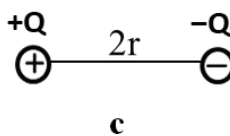
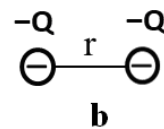
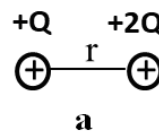
$$0 = 9y - 18 \Rightarrow y = 2$$

Q10.

Rank the potential energies of the four systems of particles shown in **FIGURE 2**, **GREATEST POSITIVE FIRST**.

Figure 2

- A) a, (b and d tie), c
- B) a, d, c, b
- C) (a and d tie), b, c
- D) a, (b and c tie), d
- E) c, a, b, d



Ans:

A

Q11.

Five identical capacitors of capacitance $C_0 = 6.0 \mu\text{F}$ are connected in a so-called bridge network, as shown in **FIGURE 3**. What is the equivalent capacitance between points a and b?

- A) $12 \mu\text{F}$
- B) $30 \mu\text{F}$
- C) $15 \mu\text{F}$
- D) $10 \mu\text{F}$
- E) $21 \mu\text{F}$

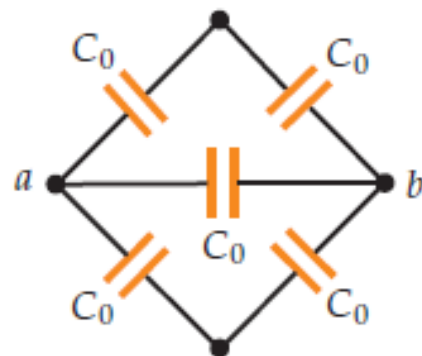
Ans:

$$\frac{1}{C_{top}} = \frac{1}{C_0} + \frac{1}{C_0} = \frac{2}{C_0}$$

$$C_{top} = C_{bot} = \frac{C_0}{2}$$

$$C_{tot} = \frac{C_0}{2} + \frac{C_0}{2} + C_0 = 2C_0 = 2 \times 6 = 12 \mu\text{F}$$

Figure 3



Q12.

A cylindrical resistor of radius 5.0 mm and length 2.0 cm is made of a material that has a resistivity of $3.5 \times 10^{-5} \Omega\text{-m}$. What is the potential difference across the resistor when the energy dissipation in the resistor is 3.0 W?

- A) **0.16 V**
- B) 0.035 V
- C) 1.2 V
- D) 0.29 V
- E) 0.092 V

Ans:

$$P = \frac{V^2}{R} = \frac{V^2}{\rho \frac{l}{A}} = \frac{V^2 A}{\rho l}$$

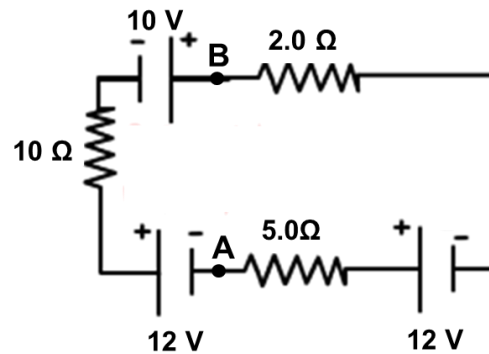
$$3 = \frac{V^2 (\pi (5 \times 10^{-3})^2)}{3.5 \times 10^{-5} \times 0.02} \Rightarrow V = \sqrt{\frac{3 \times 7 \times 10^{-7}}{\pi \times (5 \times 10^{-3})^2}} = 0.163 \text{ V}$$

Q13.

Three ideal batteries are connected in the circuit shown in **FIGURE 4**. If the potential of point **A** is 10 V, find the potential of point **B**.

Figure 4

- A) 12 V
- B) 22 V
- C) 2.0 V
- D) 14 V
- E) 20 V



Ans:

Current in the loop

$$I = \frac{34}{17} = 2A$$

$$V_A + 12 - 20 + 10 = V_B$$

$$10 + 22 - 20 = V_B$$

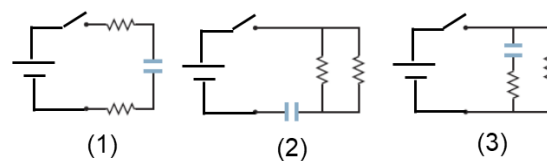
$$12 V = V_B$$

Q14.

FIGURE 5 shows three circuits where all batteries, resistors and capacitors are identical. Rank the circuits according to the charging *time constant* (RC) of the circuits. **GREATEST FIRST.**

- A) 1, 3, 2
- B) 1, 2, 3
- C) 3, 2, 1
- D) 2, 1, 3
- E) 1, (2 and 3 tie)

Figure 5



Ans:

A

Q15.

Two ideal batteries are connected across a set of resistors shown in **FIGURE 6**. If the current $i = 0.50 \text{ A}$, at what rate is the battery of emf 15 V providing energy to the circuit shown?

- A) 7.5 W
- B) 12 W
- C) 15 W
- D) 5.8 W
- E) 1.7 W

Ans:

$$V_{AB} = 20 \times 0.5 = 10 \text{ V}$$

$$V_A - 10I - 15 = V_B$$

$$V_A - V_B = 15 + 10 I$$

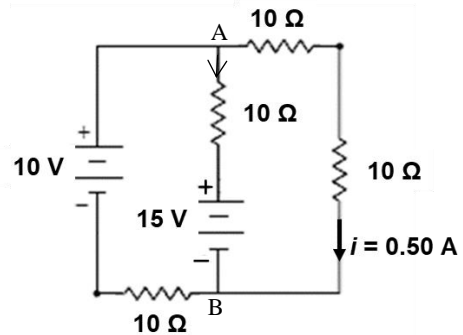
$$10 - 15 = 10 I$$

$$-\frac{5}{10} = I$$

$$I = -0.5 \text{ A}$$

$$P = \varepsilon I = 15(0.5) = 7.5 \text{ W}$$

Figure 6



Q16.

An ideal battery of emf ξ is connected in the circuit as shown in **FIGURE 7**. If the current through 10Ω resistor 1.0 A , find the emf ξ of the battery.

- A) 26 V
- B) 10 V
- C) 20 V
- D) 16 V
- E) 38 V

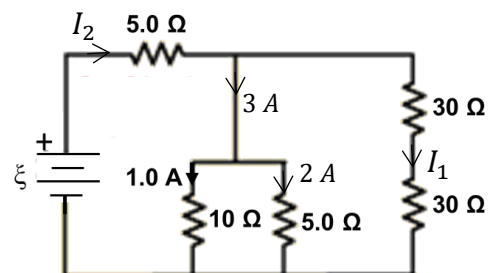
Ans:

$$I_1 = \frac{V}{R} = \frac{10}{60} = \frac{1}{6} \text{ A}$$

$$I_2 = I_t = 3 + \frac{1}{6} = \frac{19}{6} \text{ A}$$

$$\varepsilon = 10 + \frac{19}{6} (5) = 10 + \frac{95.0}{6} = 25.83 \text{ V}$$

Figure 7



Q17.

In **FIGURE 8** all the batteries are ideal. Find the current through 6.0Ω resistor.

- A) 0.91 A
- B) 0.73 A
- C) 0.50 A
- D) 1.3 A
- E) 0.65 A

Ans:

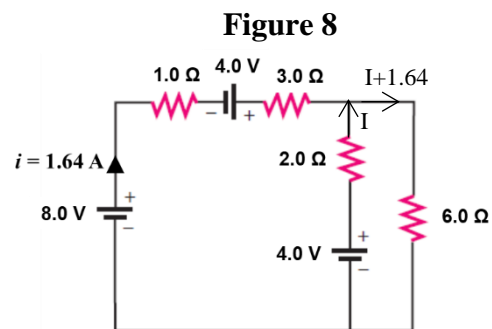
$$4 - 2I - 6(I + 1.64) = 0$$

$$4 - 2I - 6I - 9.84 = 0$$

$$-8I = 5.84$$

$$I = -0.73 \text{ A}$$

$$\therefore I_{6-\Omega} = -0.73 + 1.64 = 0.91 \text{ A}$$



Q18.

An electron has a velocity of $6.0 \times 10^6 \text{ m/s}$ in the positive x direction at a point where the magnetic field has the components $B_y = 1.5 \text{ T}$, and $B_z = 2.0 \text{ T}$. What is the magnitude of the acceleration of the electron at this point?

- A) $2.6 \times 10^{18} \text{ m/s}^2$
- B) $2.1 \times 10^{18} \text{ m/s}^2$
- C) $1.6 \times 10^{18} \text{ m/s}^2$
- D) $3.2 \times 10^{18} \text{ m/s}^2$
- E) $3.7 \times 10^{18} \text{ m/s}^2$

Ans:

$$F = e (\vec{V} \times \vec{B})$$

$$= 1.6 \times 10^{-19} [6 \times 10^6 \hat{i} (1.5 \hat{j} + 2 \hat{k})]$$

$$F = 9.6 \times 10^{-13} [1.5 \hat{k} - 2 \hat{j}]$$

$$\vec{a} = \frac{\vec{F}}{m} = \frac{9.6 \times 10^{-13}}{9.11 \times 10^{-31}} (1.5 \hat{k} - 2 \hat{j})$$

$$\vec{a} = 1.0537 \times 10^{18} (1.5 \hat{k} - 2 \hat{j})$$

$$|\vec{a}| = 2.634 \times 10^{18} \text{ m/s}^2$$

Q19.

A proton travels through uniform magnetic and electric fields. The magnetic field is $\vec{B} = -2.5\hat{i} \text{ mT}$. At one instant the velocity of the proton is $\vec{v} = 2000\hat{j} \text{ m/s}$. At that instant (in unit vector notation), what is the net force acting on the proton if the electric field is $-4.00\hat{k} \text{ V/m}$?

- A) $+1.6 \times 10^{-19} \hat{k} \text{ N}$
- B) $-1.6 \times 10^{-19} \hat{k} \text{ N}$
- C) $+14 \times 10^{-19} \hat{k} \text{ N}$
- D) $-14 \times 10^{-19} \hat{k} \text{ N}$
- E) $-8.0 \times 10^{-19} \hat{k} \text{ N}$

Ans:

$$\begin{aligned} F_{net} &= \vec{F}_E + \vec{F}_B \\ &= q\vec{E} + q(\vec{v} \times \vec{B}) \\ &= 1.6 \times 10^{-19} [-4 \hat{k} + (2000 \hat{j}) \times (-2.5) \times 10^{-3} \hat{i}] \\ &= 1.6 \times 10^{-19} [-4 \hat{k} - 5(-\hat{k})] = 1.6 \times 10^{-19} [\hat{k}] \end{aligned}$$

Q20.

A straight horizontal copper wire of mass 90 g and length 3.0 m has a current $i = 30 \text{ A}$ through it. What is magnitude of the minimum magnetic field needed to suspend the wire in air?

- A) 9.8 mT
- B) 29 mT
- C) 13 mT
- D) 4.7 mT
- E) 21 mT

Ans:

$$\begin{aligned} mg &= ilB \\ 90 \times 10^{-3} \times 9.8 &= 30 \times 3 \cdot B \\ B &= 9.8 \times 10^{-3} \text{ T} \end{aligned}$$

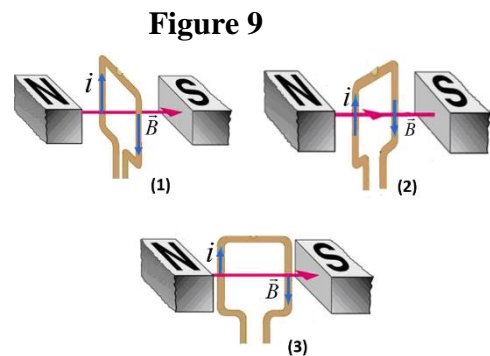
Q21.

Three rectangular coils of same cross sectional areas are placed in a uniform horizontal magnetic \vec{B} , as shown in **FIGURE 9**. All coils carry the same current I . Rank the situation according to magnitude of the torque on the coils, **GREATEST FIRST**.

- A) 3, 2, 1
- B) 1, 2, 3
- C) 1, 3, 2
- D) 3, 1, 2
- E) 2, 1, 3

Ans:

A



Q22.

A circular coil with 150 turns and cross section area $4.0 \times 10^{-4} \text{ m}^2$ and carries a current of 0.20 mA. The coil is at rest in a uniform magnetic field of magnitude $B = 1.0 \text{ T}$, with its dipole moment $\vec{\mu}$ initially aligned with \vec{B} . Find the energy required to rotate the coil through an angle of 180° .

- A) $2.4 \times 10^{-5} \text{ J}$
- B) $1.4 \times 10^{-5} \text{ J}$
- C) $3.2 \times 10^{-5} \text{ J}$
- D) $4.3 \times 10^{-5} \text{ J}$
- E) $5.0 \times 10^{-5} \text{ J}$

Ans:

$$\begin{aligned}
 E_{req} &= U_f - U_i \\
 &= (-\vec{\mu} \cdot \vec{B})_f - (-\vec{\mu} \cdot \vec{B})_i \\
 &= -\mu B \cos(180) + \mu B \cos 0 = 2\mu B \\
 &= 2(NAi) \cdot B \\
 &= 2 \times (4 \times 10^{-4} \times 150 \times 0.2) \times 10^{-3} \\
 &= 2.4 \times 10^{-5} \text{ J}
 \end{aligned}$$

Q23.

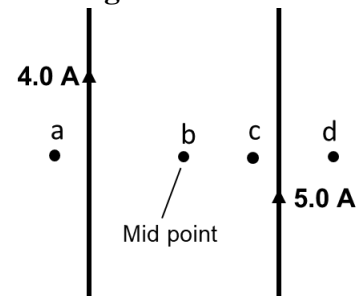
Two wires of infinite length are placed parallel to each other in the plane of the paper. One wire carries a current of 4.0 A and other carries a current of 5.0 A as shown in **FIGURE 10**. Four points are marked on the figure. At which of the point(s) the *direction of resultant magnetic field* is out of the page? (b is midpoint between the wires)

- A) a, b, and c
- B) a and c
- C) a only
- D) a and d
- E) b and c

Ans:

A

Figure 10



Q24.

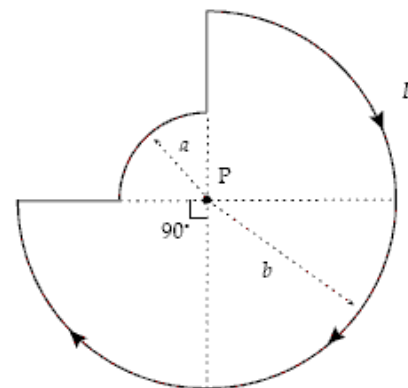
In the **FIGURE 11**, if $a = 2.0$ cm, $b = 4.0$ cm, and $I = 2.0$ A, what is the magnitude of the magnetic field at point P?

- A) 39 μ T
- B) 49 μ T
- C) 55 μ T
- D) 69 μ T
- E) 13 μ T

Ans:

$$\begin{aligned}
 B &= \frac{\mu_0 i}{4\pi a} \cdot \frac{\pi}{2} + \frac{\mu_0 i}{4\pi b} \cdot \frac{3\pi}{2} \\
 &= \frac{\mu_0 i \pi}{8\pi} \left(\frac{1}{a} + \frac{3}{b} \right) \\
 &= \frac{\mu_0 i}{8} \left(\frac{1}{0.02} + \frac{3}{0.04} \right) \\
 &= \frac{4\pi \times 10^{-7} (2)}{8} \left(\frac{1}{0.02} + \frac{3}{0.04} \right) \\
 &= 3.92 \times 10^{-5} T = 39.2 \times 10^{-6} T
 \end{aligned}$$

Figure 11

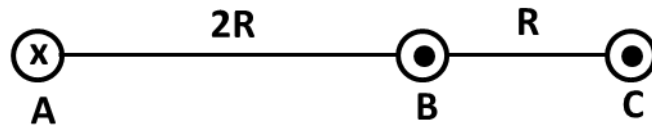


Q25.

FIGURE 12 shows a cross section of three long parallel wires each carrying a current of 24 A. The currents in wires B and C are out of the paper, while that in wire A is into the paper. If the distance $R = 5.0$ mm, what is the magnitude of the magnetic force on a 4.0 m length of wire A?

- A) 77 mN
- B) 15 mN
- C) 59 mN
- D) 12 mN
- E) 32 mN

Figure 12



Ans:

$$F = F_B + F_C$$

$$\frac{F}{l} = \frac{\mu_0 i_a i_b}{2\pi(2R)} + \frac{\mu_0 i_a i_c}{2\pi(3R)}$$

$$= \frac{\mu_0 (24)^2}{2\pi} \left[\frac{1}{2R} + \frac{1}{3R} \right]$$

$$= \frac{4\pi \times 10^{-7} (24)^2}{2\pi} \left[\frac{5}{6R} \right]$$

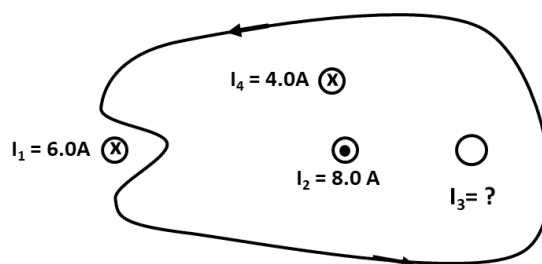
$$F = \left[4\pi \times 10^{-7} (24)^2 \left(\frac{5}{6 \times 5 \times 10^{-3}} \right) \right] \times 4 = 0.0768 \text{ N} \approx 77 \text{ mN}$$

Q26.

The value of the line integral $\oint \vec{B} \cdot d\vec{s}$ of \vec{B} around the closed path shown in **FIGURE 13** is 1.4×10^{-5} T.m. What are direction (into or out of the page) and magnitude of I_3 ?

- A) 7.1 A out of the page
- B) 5.1 A out of the page
- C) 4.0 A into the page
- D) 7.1 A into the page
- E) 5.1 A into the page

Figure 13



Ans:

$$\int B \cdot dl = \mu_0 (i_{enc})$$

$$1.4 \times 10^{-5} = \mu_0 (8 + I_3 - 4)$$

$$I_3 = \frac{1.4 \times 10^{-5}}{4\pi \times 10^{-7}} - 4 = 7.14 \text{ A}$$

Q27.

A circular loop of radius 15 cm carries a current of 15 A lies in a horizontal plane (x-y plane), shown in **FIGURE 14**. A flat coil of small radius 0.80 cm, having 50 turns and a current of 1.3 A, is concentric with the loop. The plane of loop is perpendicular to the plane of the coil. Assume the loop's magnetic field is uniform across the coil. What is the torque on the coil due to the loop?

- A) $8.2 \times 10^{-7} \text{ N}\cdot\text{m}$
- B) 0
- C) $4.7 \times 10^{-7} \text{ N}\cdot\text{m}$
- D) $2.3 \times 10^{-7} \text{ N}\cdot\text{m}$
- E) $6.9 \times 10^{-7} \text{ N}\cdot\text{m}$

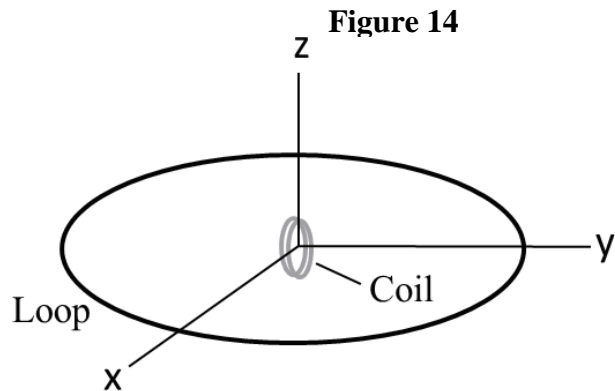
Ans:

$$\vec{\tau} = \vec{\mu} \times \vec{B} = \mu B \sin 90$$

$$= NiA \cdot \frac{\mu_0 i}{2r}$$

$$= 50 \times 1.3 \times \pi(0.8 \times 10^{-2})^2 \cdot \frac{4\pi \times 10 \times 15}{2 \times 0.15}$$

$$= (0.013069)(6.28 \times 10^{-5}) = 8.2 \times 10^{-7} \text{ N}\cdot\text{m}$$



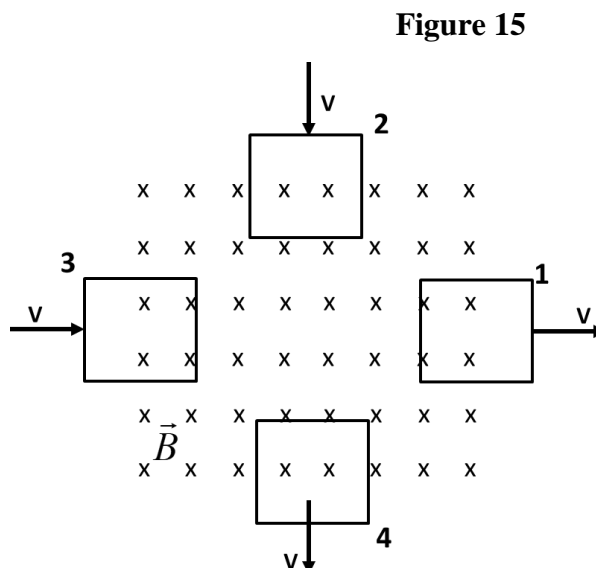
Q28.

FIGURE 15 shows four square loops moving *in or out* of the uniform magnetic field (directed into the page) at same constant speed \mathbf{V} . In which of the following situation(s) the induced current in the loop(s) is in clockwise direction. (ignore any interaction between the loops)

- A) 1 and 4
- B) 2 and 3
- C) 1 and 3
- D) 2 and 4
- E) All (1, 2, 3, and 4)

Ans:

A



Q29.

A square, single turn loop is placed with its plane perpendicular to a constant magnetic field. An emf of 20 mV is induced in the loop when the area of the loop decreases at a rate of $0.20 \text{ m}^2/\text{s}$. What is the magnitude of magnetic field?

- A) 0.10 T
- B) 0.20 T
- C) 0.29 T
- D) 0.37 T
- E) 0.15 T

Ans:

$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}BA$$

$$20 \times 10^{-3} = B \frac{dA}{dt}$$

$$20 \times 10^{-3} = B \cdot (0.2) = 0.10T$$

Q30.

FIGURE 16 shows a bar of length $L = 35 \text{ cm}$ moving to the right on two parallel rails at a constant speed of 5.0 m/s in a uniform magnetic field $B = 0.40 \text{ T}$. If the induced current in the circuit is 1.2 A , the power dissipated in the circuit is

- A) 0.84 W
- B) 0.58 W
- C) 6.0 W
- D) 0.70 W
- E) 2.4 W

Ans:

$$P = \varepsilon \cdot i = Blv$$

$$= 0.4 \times 0.35 \times 5 = 0.7 \text{ V}$$

$$P = 0.7 \times 1.2 = 0.84 \text{ W}$$

