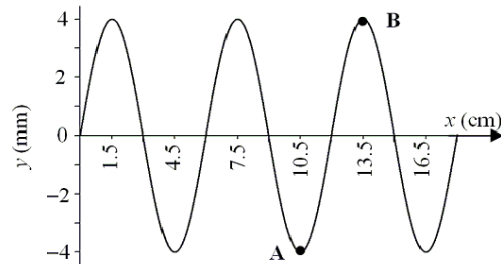


**Q1.**

The displacement of a vibrating string versus position along the string is shown in **Figure 1**. The speed of the wave is 10 cm/s. What is the phase difference between the points A and B on the string?

- A)  $\pi$  radians
- B)  $\pi/2$  radians
- C)  $\pi/4$  radians
- D)  $3\pi/4$  radians
- E)  $2\pi$  radians

Figure 1



**Ans:**

$$\lambda \rightarrow 2\pi$$

$$\therefore \frac{\lambda}{2} \rightarrow \pi$$

**Q2.**

You were using an instrument to measure the sound level of a point source located at a distance  $R_1$ . When you moved away from the source to a distance  $R_2$  the sound level decreased by 20 dB. Find the ratio  $R_2/R_1$ .

- A) 10
- B) 100
- C) 1000
- D) 2
- E) 5

**Ans:**

$$\beta = 10 \log \left( \frac{I}{I_0} \right) \text{ and } I = \frac{P_s}{4\pi r^2}$$

$$\Rightarrow \Delta\beta = \beta_2 - \beta_1 = 10 \log \left( \frac{I_2}{I_1} \right) = 20 \log \left( \frac{r_1}{r_2} \right)$$

$$-20$$

$$\Rightarrow \frac{r_1}{r_2} = 10^{-1} \Rightarrow \frac{r_2}{r_1} = 10$$

**Q3.**

An ideal gas can expand from state I to state F along three possible paths, as indicated in **Figure 2**. The work (in kJ) done by the gas along the paths IAF, IF, and IBF, respectively are:

- A) 8, 5, 2
- B) 8, 5, 8
- C) 2, 2, 2
- D) 6, 3, 0
- E) 8, 6, 2

**Ans:**

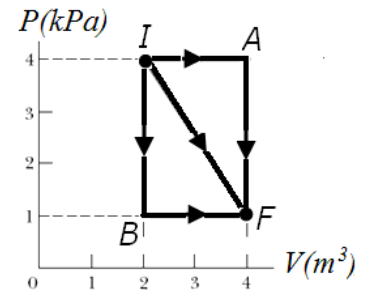
$$W = \int Pdv = \text{Area under } P \text{ vs } V \text{ curve}$$

$$\Rightarrow W_{IAF} = 4 \times 2 = 8 \text{ kJ}$$

$$W_{IF} = \frac{1}{2} \times 3 \times 2 + 1 \times 2 = 5 \text{ kJ}$$

$$W_{BF} = 1 \times 2 = 2 \text{ kJ}$$

Figure 2



**Q4.**

A gas mixture consists of two different gases, A and B with molar masses  $M_A = 2.0$  g/mol and  $M_B = 32$  g/mol. Find the ratio of their rms speeds  $V_{A-rms}/V_{B-rms}$ .

- A) 4.0
- B) 16
- C) 0.25
- D) 12
- E) 1.0

**Ans:**

$$V_{rms} = \sqrt{\frac{3RT}{M}} \propto \sqrt{\frac{1}{M}} \text{ at constant } T$$

$$\Rightarrow \frac{V_{A-rms}}{V_{B-rms}} = \sqrt{\frac{M_B}{M_A}} = 4.0$$

**Q5.**

For many solids at very low temperatures ( $T$ ), the molar specific heat  $c = AT^3$ , where the constant  $A$  depends on the material. For aluminum,  $A = 3 \times 10^{-5} \text{ J.mole}^{-1}.\text{K}^{-4}$ . Find the change in entropy for 3 moles of aluminum when its temperature is decreased from 8 to 5 K.

- A) -0.01 J/K
- B) -0.02 J/K
- C) +0.02 J/K
- D) +0.03 J/K
- E) -0.03 J/K

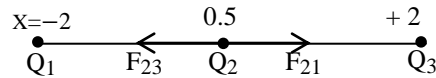
**Ans:**

$$\Delta S = \int \frac{dQ}{T} = \int \frac{ncdT}{T} = nA \int_8^5 \frac{T^3}{T} dT = nA \left[ \frac{T^3}{3} \right]_8^5 = -0.01 \text{ J/K}$$

**Q6.**

Three charged particles are fixed on an  $x$ -axis as follows:  $Q_1$  at  $x = -2.0$  cm,  $Q_2$  at  $x = 0.50$  cm, and  $Q_3$  at  $x = 2.0$  cm. If the net electrostatic force on  $Q_2$  is zero, find the ratio  $Q_1/Q_3$ .

- A) 2.8
- B) 0.36
- C) 1.0
- D) 0.60
- E) 1.7



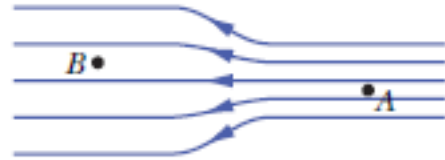
**Ans:**

$$F_{21} = F_{23} \Rightarrow \frac{KQ_1Q_2}{(2.5)^2} = \frac{KQ_3Q_2}{(1.5)^2} \Rightarrow \frac{Q_1}{Q_3} = 2.8$$

**Q7.**

In **Figure 3**, the electric field lines on the left have twice the separation of those on the right. If the magnitude of the electric field at **A** is 40 N/C, what is the magnitude of the electric field at **B**?

Figure 3



- A) 20 N/C
- B) 40 N/C
- C) 80 N/C
- D) 10 N/C
- E) 30 N/C

**Ans:**

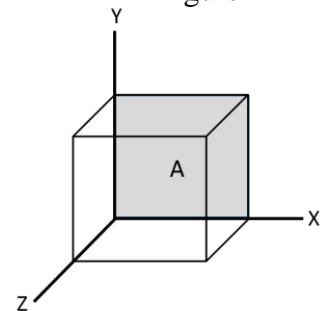
$$E \propto \frac{1}{\text{separation of field lines}}$$

$$\Rightarrow \frac{E_B}{E_A} = \frac{1}{2}$$

**Q8.**

**Figure 4** shows a cube of side length 4.0 cm placed in a non-uniform electric field given by  $\vec{E} = (3.0x \hat{i} + 4.0 \hat{j})$  N/C. What is the electric flux through the rear face (that lie in the xy-plane) of the cube?

Figure 4



- A) Zero
- B)  $4.8 \times 10^{-3} \text{ Nm}^2/\text{C}$
- C)  $6.4 \times 10^{-3} \text{ Nm}^2/\text{C}$
- D)  $8.0 \times 10^{-3} \text{ Nm}^2/\text{C}$
- E)  $1.1 \times 10^{-2} \text{ Nm}^2/\text{C}$

**Ans:**

$$\Phi = \int \vec{E} \cdot d\vec{A}$$

But  $d\vec{A}$  is parallel to  $-\hat{k}$

$$\therefore \int \vec{E} \cdot d\vec{A} = 0 \Rightarrow \Phi = 0$$

$$(\because \hat{i} \cdot \hat{k} = 0 \text{ and } \hat{j} \cdot \hat{k} = 0)$$

**Q9.**

Three charged particles are placed as follows:  $-16 \text{ pC}$  at  $(0, 0)$ ,  $-11 \text{ pC}$  at  $(4.0 \text{ cm}, 0)$ , and  $+11 \text{ pC}$  at  $(0, 4.0 \text{ cm})$ . Determine the electric potential at the mid-point on the line connecting the  $+11 \text{ pC}$  and  $-11 \text{ pC}$  charges. Assume  $V = 0$  at infinity.

- A)  $-5.1 \text{ V}$
- B)  $-12 \text{ V}$
- C)  $-6.4 \text{ V}$
- D)  $+12 \text{ V}$
- E)  $+5.1 \text{ V}$

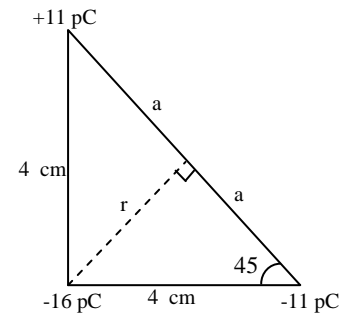
**Ans:**

$$V_A = K \left( \frac{-16 \times 10^{-12}}{r} + \frac{11 \times 10^{-12}}{a} - \frac{11 \times 10^{-12}}{a} \right)$$

$$r = 4 \sin 45^\circ \text{ cm}$$

$$K = 9 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2$$

$$\Rightarrow V_A = -5.1 \text{ V}$$



**Q10.**

A  $100 \text{ pF}$  capacitor is charged to a potential difference of  $50 \text{ V}$ , and the charging battery is disconnected. The capacitor is then connected across a second (initially uncharged) capacitor. If the potential difference across the  $1^{\text{st}}$  capacitor drops to  $40 \text{ V}$ , what is the capacitance of the  $2^{\text{nd}}$  capacitor?

- A)  $25 \text{ pF}$
- B)  $43 \text{ pF}$
- C)  $50 \text{ pF}$
- D)  $12 \text{ pF}$
- E)  $67 \text{ pF}$

**Ans:**

$$Q_i = C_1 V_i = 100 \times 50 \text{ pC}$$

$$C_{\text{eq}} = C_1 + C_2$$

$$\therefore Q_f = (C_1 + C_2) v_f = (100 + C_2) \times 40 \text{ pC}$$

$$Q_i = Q_f \Rightarrow C_2 = 25 \text{ pF}$$

**Q11.**

A wire with a resistance of  $6.0 \Omega$  is stretched so that its new length is twice its original length. Determine the resistance of the stretched wire, taking into consideration that the density and resistivity of the material are unchanged.

- A)  $24 \Omega$
- B)  $6.0 \Omega$
- C)  $3.0 \Omega$
- D)  $12 \Omega$
- E)  $1.5 \Omega$

**Ans:**

$$\text{Constant Volume} \Rightarrow A_i L_i = A_f L_f \Rightarrow A_f = A_i/2$$

$$R_f = \frac{\rho L_f}{A_f} = \frac{\rho(2L_i)}{(A_i/2)} = 4R_i = 24 \Omega$$

---

**Q12.**

A circuit with an ideal battery and one resistor of resistance  $R$  carries a current of  $6 \text{ A}$ . When an additional resistance of  $2 \Omega$  is inserted in series with  $R$ , the current drops to  $4 \text{ A}$ . Determine  $R$ .

- A)  $4 \Omega$
- B)  $0.5 \Omega$
- C)  $8 \Omega$
- D)  $1 \Omega$
- E)  $2 \Omega$

**Ans:**

$$\varepsilon = 6 R$$

$$R_{\text{eq}} = R + 2$$

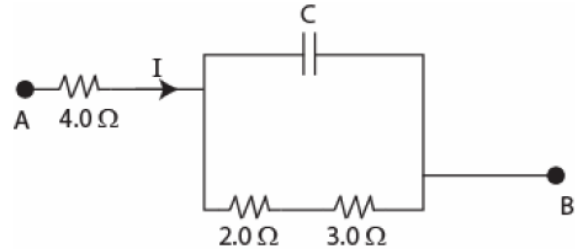
$$i = \frac{\varepsilon}{R_{\text{eq}}} \Rightarrow 4 = \frac{6 R}{R + 2} \Rightarrow R = 4 \Omega$$

**Q13.**

In **Figure 5**,  $C = 5.0 \mu\text{F}$ , and  $I = 3.0 \text{ A}$  when the capacitor is fully charged. Find the charge on the capacitor.

- A) 75  $\mu\text{C}$
- B) 60  $\mu\text{C}$
- C) 15  $\mu\text{C}$
- D) 25  $\mu\text{C}$
- E) 12  $\mu\text{C}$

Figure 5



**Ans:**

Current through C is zero when it is fully charged.

$$\therefore V_c = I(2 + 3) = 3 \times 5 = 15 \text{ V}$$

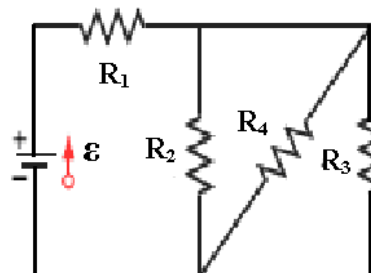
$$\therefore Q = C \cdot V_c = 75 \mu\text{C}$$

**Q14.**

In **Figure 6**,  $R_1 = 100 \Omega$ ,  $R_2 = R_3 = R_4 = 75 \Omega$ , and the ideal battery has emf  $\mathcal{E} = 6.0 \text{ V}$ . What is the current in  $R_1$ ?

- A) 48 mA
- B) 24 mA
- C) 34 mA
- D) 60 mA
- E) 18 mA

Figure 6



**Ans:**

$R_2, R_3$  and  $R_4$  are in parallel

$$\therefore R_{eq} = \frac{75}{3} = 25 \Omega$$

$R_1$  is in series with  $R_{eq}$

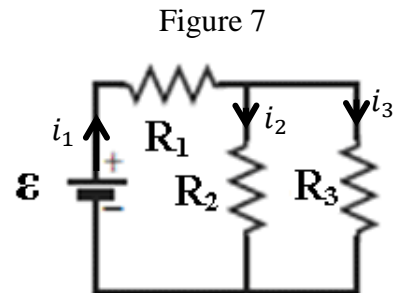
$$\therefore R'_{eq} = R_{eq} + R_1 = 125 \Omega$$

$$\therefore i = \frac{\mathcal{E}}{R'_{eq}} = 48 \text{ mA}$$

**Q15.**

In **Figure 7**,  $R_2 = 200 \Omega$ ,  $R_3 = 400 \Omega$ , and the power dissipated in  $R_3$  is 100 W. What is the current in  $R_1$ ?

- A) 1.5 A
- B) 0.50 A
- C) 0.75 A
- D) 1.0 A
- E) 0.25 A



**Ans:**

$$P_3 = i_3^2 R_3 \Rightarrow i_3 = \frac{1}{2} A$$

$$V_{R_3} = V_{R_2} \Rightarrow i_2 = \frac{R_3}{R_2} i_3 = 1 A$$

$$\therefore i_1 = i_2 + i_3 = 1.5 A$$

**Q16.**

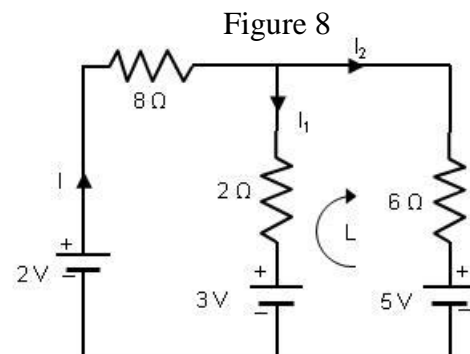
Applying Kirchhoff's rule to loop L in **Figure 8** (with ideal batteries) results in the following equation:

- A)  $3I_2 - I_1 + 1 = 0$
- B)  $3I_2 - I_1 + 8 = 0$
- C)  $3I_2 - I_1 - 8 = 0$
- D)  $3I_2 + I_1 + 1 = 0$
- E)  $3I_2 - I_1 - 1 = 0$

**Ans:**

$$3 + 2I_1 - 6I_2 - 5 = 0$$

$$\Rightarrow 3I_2 - I_1 + 1 = 0$$



**Q17.**

Four current-carrying coils (1, 2, 3, and 4) with given magnetic dipole moments (in mJ/T) of  $\vec{\mu}_1 = 10 \hat{j}$ ,  $\vec{\mu}_2 = -10 \hat{j}$ ,  $\vec{\mu}_3 = 10 \hat{i}$ , and  $\vec{\mu}_4 = -10 \hat{i}$  are placed in a uniform magnetic field  $\vec{B} = 20 \hat{j}$  mT. Rank the coils according to their potential (orientation) energies, greatest first.

- A) 2, then 3 and 4 tie, 1
- B) 1, 3, 2, 4
- C) 3 and 4 tie, then 1 and 2 tie
- D) 1, 2, 3, 4
- E) 1 and 2 tie, then 3 and 4 tie

**Ans:**

$$u = -\vec{\mu} \cdot \vec{B}$$



**Q18.**

A charge  $q$  travels along a straight line in a region of uniform magnetic and electric fields at constant velocity of  $\vec{v} = (2.0\hat{i} - 4.0\hat{j})$  m/s. If the magnetic field  $\vec{B} = (4.0\hat{j})$  T, find the electric field (in N/C).

- A)  $-8.0\hat{k}$
- B)  $8.0\hat{k}$
- C)  $16\hat{k}$
- D)  $8.0\hat{j}$
- E)  $-16\hat{j}$

**Ans:**

$$\begin{aligned}\vec{F}_e + \vec{F}_B &= m\vec{a} \\ &= 0 \\ \Rightarrow \vec{F}_e &= -\vec{F}_B \\ \Rightarrow q\vec{E} &= -q(\vec{v} \times \vec{B}) \\ \Rightarrow \vec{E} &= -(2\hat{i} - 4\hat{j}) \times 4\hat{j} = -8\hat{k}\end{aligned}$$

---

**Q19.**

An electron (e) and a proton (p) are moving in circular paths with the same speed in a plane that is perpendicular to a uniform magnetic field. What is the ratio of their periods,  $T_e/T_p$ ?

- A)  $5.5 \times 10^{-4}$
- B)  $1.8 \times 10^3$
- C)  $2.3 \times 10^{-4}$
- D)  $1.3 \times 10^3$
- E) 1.0

**Ans:**

$$\begin{aligned}T &= \frac{2\pi m}{qB} \\ \Rightarrow \frac{T_e}{T_p} &= \frac{m_e}{m_p} = 5.5 \times 10^{-4}\end{aligned}$$

**Q20.**

A 1.0 m long wire lying along an  $x$ -axis carries a current of 2.0 A in the positive  $x$  direction. The wire is in a uniform magnetic field of  $\vec{B} = (4.0\hat{i} - 3.0\hat{j})$  T . What is the magnetic force on the wire?

- A)  $-6.0\hat{k}$  N
- B)  $+6.0\hat{k}$  N
- C)  $-8.0\hat{k}$  N
- D)  $+8.0\hat{k}$  N
- E)  $-12\hat{k}$  N

**Ans:**

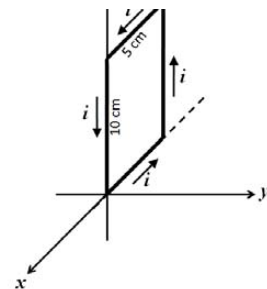
$$\vec{F} = I \vec{l} \times \vec{B} = 2.0 [1.0 \hat{i} \times (4.0 \hat{i} - 3.0 \hat{j})] = -6.0 \hat{k}$$

**Q21.**

**Figure 9** shows a 20-turn rectangular coil of dimensions 10 cm by 5 cm. It is hinged along one long side (z-axis), and carries a current  $i = 0.1$  A. A uniform magnetic field of  $\vec{B} = 0.5\hat{i}$  T is present in the region. What is the torque acting on the coil about the hinge line?

- A)  $-5 \times 10^{-3} \hat{k}$  Nm
- B)  $+5 \times 10^{-3} \hat{k}$  Nm
- C)  $-2 \times 10^{-3} \hat{j}$  Nm
- D)  $+2 \times 10^{-3} \hat{j}$  Nm
- E)  $-2 \times 10^{-3} \hat{k}$  Nm

Figure 9



**Ans:**

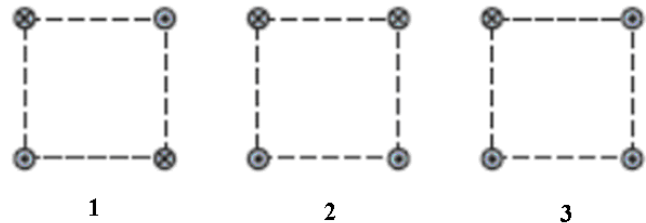
$$\vec{\mu} = Ni\vec{A} = 20 \times 0.1 \times 10 \times 10^{-2} \times 5 \times 10^{-2} \hat{j} = 10^{-2} \hat{j}$$

$$\vec{\tau} = \vec{\mu} \times \vec{B} = 10^{-2} \hat{j} \times 0.5 \hat{i} = -5 \times 10^{-3} \hat{k}$$

Q22.

**Figure 10** shows three arrangements in which long parallel wires carry equal currents directly into or out of the page at the corners of identical squares. Rank the arrangements according to the magnitude of the net magnetic field at the center of the square, greatest first.

Figure 10



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

Ans:

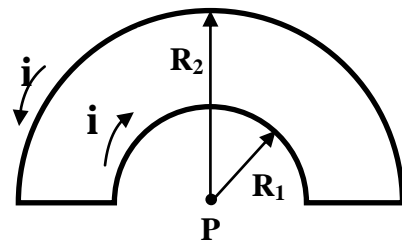
$$B = \frac{\mu_0 i}{2\pi r}$$

The direction of  $B$  is given by right hand rule.

Q23.

In **Figure 11**, a closed loop carries a current  $i = 0.40$  A. The loop consists of two straight wires and two concentric circular arcs of radii  $R_1 = 4.0$  m and  $R_2 = 8.0$  m. What is the magnetic field at the center P?

Figure 11



- A)  $1.6 \times 10^{-8}$  T, into the page
- B)  $1.6 \times 10^{-8}$  T, out of the page
- C)  $4.8 \times 10^{-8}$  T, into the page
- D)  $4.8 \times 10^{-8}$  T, out of the page
- E)  $3.2 \times 10^{-8}$  T, into the page

Ans:

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

$$\phi = \pi \text{ rad} \Rightarrow B_P = 1.6 \times 10^{-8} \text{ T}$$

**Q24.**

Two long parallel wires, separated by a distance of 5.0 cm, carry currents in the same direction. If  $I_1 = 5.0$  A and  $I_2 = 8.0$  A, the magnitude of the force per unit length exerted on each wire by the other is:

- A)  $1.6 \times 10^{-4}$  N/m
- B)  $3.2 \times 10^{-4}$  N/m
- C) Zero
- D)  $8.0 \times 10^{-4}$  N/m
- E)  $8.0 \times 10^{-6}$  N/m

**Ans:**

$$F = \frac{\mu_0 L I_1 I_2}{2\pi d} \Rightarrow \frac{F}{L} = 1.6 \times 10^{-4} \text{ N/m}$$

---

**Q25.**

A solenoid is 95 cm long and has a diameter of 4.0 cm and 1200 turns. It carries a current of 3.6 A. The magnitude of the magnetic field inside the solenoid at a distance 1.5 cm from its center is:

- A) 5.7 mT
- B) 2.8 mT
- C) 4.3 mT
- D) 1.4 mT
- E) 8.9 mT

**Ans:**

$$B = \mu_0 n i = \mu_0 \frac{N}{L} i = 5.7 \text{ mT}$$

---

**Q26.**

A long wire carrying 50 A is perpendicular to the magnetic field lines of a uniform magnetic field of magnitude 2.5 mT. The net magnetic field at a point is zero. Find the distance of the point from the wire.

- A)  $4.0 \times 10^{-3}$  m
- B)  $2.0 \times 10^{-3}$  m
- C)  $8.0 \times 10^{-3}$  m
- D)  $1.6 \times 10^{-3}$  m
- E)  $6.3 \times 10^{-3}$  m

**Ans:**

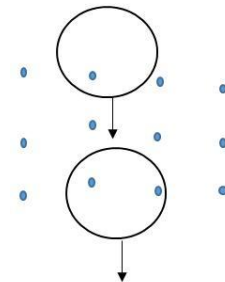
$$B = \frac{\mu_0 i}{2\pi d} \Rightarrow d = \frac{\mu_0 i}{2\pi B} = 4.0 \times 10^{-3} \text{ m}$$

Q27.

A conducting loop is moving into a uniform magnetic field  $\vec{B}$ , which is directly out of the page as shown in **Figure 12**. What are the directions of the induced electric current when it is entering and leaving the field, respectively?

- A) Clockwise, Counterclockwise
- B) Clockwise, Clockwise
- C) Counterclockwise, Counterclockwise
- D) Counterclockwise, Clockwise
- E) Induced current is zero in both cases

Figure 12



Ans:

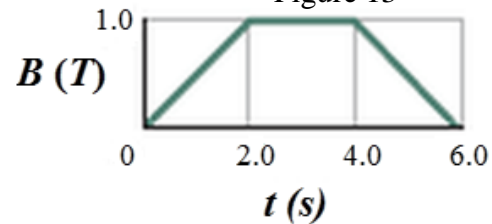
A (use Lenz law)

Q28.

A conducting loop of radius 12 cm is located in a uniform magnetic field  $\vec{B}$  that changes in magnitude as given in **Figure 13**. The loop's plane is perpendicular to the magnetic field. What emf is induced in the loop during the time interval 4.0 s to 6.0 s?

- A)  $+2.3 \times 10^{-2} \text{ V}$
- B)  $-2.3 \times 10^{-2} \text{ V}$
- C) +1.0 V
- D) -1.0 V
- E) +8.5 V

Figure 13



Ans:

$$\varepsilon_{ind} = - \frac{d\Phi}{dt} = - \frac{d(BA)}{dt} = -A \frac{dB}{dt}$$

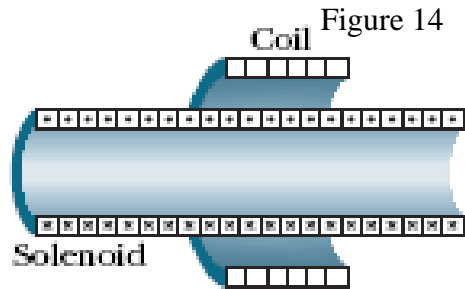
$$\frac{dB}{dt} = \frac{0 - 1}{6 - 4} = -0.5, A = \pi r^2$$

$$\Rightarrow \varepsilon_{ind} = 2.3 \times 10^{-2} \text{ V}$$

**Q29.**

In **Figure 14**, a 240-turn coil of radius 1.8 cm and resistance 5.3  $\Omega$  is coaxial with a solenoid of 220 turns/cm and radius 1.6 cm. The solenoid current drops from 3.0 A to zero at a steady rate in 50 ms. What current is induced in the coil during this time interval?

- A)  $6.0 \times 10^{-2}$  A
- B)  $2.5 \times 10^{-4}$  A
- C)  $2.5 \times 10^{-6}$  A
- D) Zero
- E)  $6.0 \times 10^{-5}$  A



**Ans:**

$$\varepsilon_{ind} = N_c \frac{d\Phi}{dt} = N_c \frac{d}{dt}(A_s B_s) = N_c A_s \frac{dB_s}{dt}$$

$$\frac{dB_s}{dt} = \frac{d}{dt}(\mu_0 n i) = \mu_0 n \frac{di}{dt}$$

$$\therefore \varepsilon_{ind} = N_c A_s \mu_0 n \frac{di}{dt}$$

$$= 240 \times (\pi \times 1.6^2 \times 10^{-4}) \times (4\pi \times 10^{-7}) \times (220 \times 100) \times \frac{3}{50 \times 10^{-3}}$$

$$\therefore i_{ind} = \frac{\varepsilon_{ind}}{R} = \frac{0.32}{5.3} = 6.0 \times 10^{-2} \text{ A}$$

**Q30.**

A conducting bar of 10.0 cm length and negligible resistance slides along horizontal, parallel, frictionless conducting rails connected to a resistor  $R = 2.00 \Omega$  as shown in **Figure 15**. A uniform magnetic field  $B = 3.00$  T is present perpendicular to the plane of the paper. What should be the speed of the bar such that the power dissipated in the resistor is 8.50 W?

- A) 13.7 m/s
- B) 18.9 m/s
- C) 25.5 m/s
- D) 2.55 m/s
- E) 5.10 m/s

**Ans:**

$$\varepsilon_{ind} = BLv$$

$$\therefore P = \frac{\varepsilon_{ind}^2}{R} = \frac{B^2 L^2 v^2}{R}$$

$$\Rightarrow v = \frac{\sqrt{PR}}{BL} = 13.7 \text{ m/s}$$

