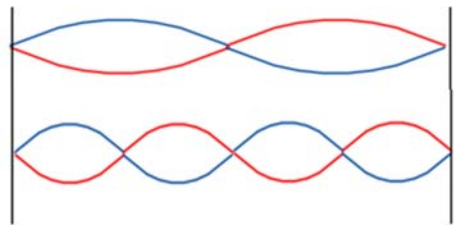
Q1.

A standing wave having three nodes is set up in a string fixed at both ends. If the frequency of the wave is doubled, how many antinodes will there be?

A) 4
B) 3
C) 2
D) 5
E) 6



Ans:

A

Q2.

A stationary motion detector sends sound waves of frequency 0.120 MHz towards a truck approaching (the detector) at a speed of 50.0 m/s. What is the frequency of the waves reflected back to the detector? [Speed of sound = 343 m/s]

A) 0.161 MHz
B) 0.103 MHz
C) 0.140 MHz
D) 0.234 MHz
E) 0.186 MHz

Ans:

$$\mathrm{f}' = f\frac{V + V_t}{V - V_t}$$

$$\mathrm{f}' = 0.12\frac{343 + 50}{343 - 50}$$

$$\mathrm{f}' = 0.12\frac{393}{293}$$

$$\mathrm{f}' = 0.12\frac{393}{293} = 0.16095 \approx 0.161\ MHz$$

Q3.

A box with a total surface area of 1.20 m^2 and a wall thickness of 4.00 cm is made of an insulating material. A 10.0 W electric heater inside the box maintains the inside temperature at 15.0 ^oC above the outside temperature. Find the thermal conductivity of the insulating material.

A) 0.022 W/m.K
B) 2.20 W/m.K
C) 0.034 W/m.K
D) 0.016 W/m.K
E) 1.23 W/m.K

Ans:

$$P = kA\frac{\Delta T}{\Delta x}$$

$$10 = k \times 1.2 \times \frac{15}{4 \times 10^{-2}}$$

$$k = \frac{10 \times 4 \times 10^{-2}}{1.2 \times 15} = 0.0222\ W/m.K$$

Q4.

An ideal gas initially at 330 K is compressed at a constant pressure of 25.0 N/m^2 from a volume of 3.0 m^3 to a volume of 1.00 m^3. In the process, 75.0 J is lost by the gas as heat. What is the change in internal energy of the gas?

A) −25.0 J
B) −125 J
C) +50.0 J
D) +65.0 J
E) –75.0 J

Ans:

$$\Delta W = P\Delta V = 25(1-3) = -50\ \text{J}$$

$$\Delta E = \Delta Q - \Delta W = -75 - (-50) = -25\,\text{J}$$

Q5.

A Carnot engine has an efficiency of ε when operating between T_H = 400 °C and T_L = 200 °C. What will be the efficiency of the same Carnot engine when operating between T_H = 800 °C and T_L = 400 °C.

A) 1.25ε
B) 2.0ε
C) 0.50ε
D) 1.5ε
E) 0.77ε

Ans:

$$\varepsilon = 1 - \frac{200 + 273}{400 + 273} = 0.29718$$

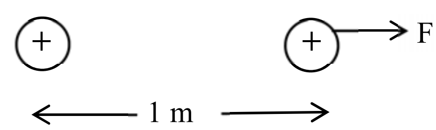
$$\varepsilon' = 1 - \frac{400 + 273}{800 + 273} = 0.3728$$

$$\frac{\varepsilon'}{\varepsilon} = 1.2544 \Rightarrow \varepsilon' = 1.25\ \varepsilon$$

Q6.

Two identical 0.20 kg masses are placed 1.0 m apart (center to center) on a frictionless surface. Each has +10 μC of charge. What is the initial acceleration of one of the masses if it is released from rest and allowed to move?

A) 4.5 m/s²
B) 2.3 m/s²
C) 6.3 m/s²
D) 1.4 m/s²
E) 5.2 m/s²



Ans:

$$F = \frac{kq_1q_2}{r^2} = \frac{9 \times 10^9 (10 \times 10^{-6})^2}{1^2}$$

$$F = 0.9\ N$$

$$a = \frac{F}{m} = \frac{0.9}{0.2}$$

$$a = 4.5\ \mathrm{m/s^2}$$

Q7.

Two point charges q_1= +15 μC and q_2 = −10 μC are placed in xy plane. If q_1 is placed at (20 cm, 0) and q_2 is placed at (0, 10 cm), find the resultant electric field at the origin.

A) $(-3.38\times10^6\hat{i}+9.00\times10^6\hat{j})N/C$
B) $(3.38\times10^6\hat{i}+9.00\times10^6\hat{j})N/C$
C) $(-3.38\times10^6\hat{i}-9.00\times10^6\hat{j})N/C$
D) $(-9.00\times10^6\hat{i}+3.38\times10^6\hat{j})N/C$
E) $(9.00\times10^6\hat{i}+3.38\times10^6\hat{j})N/C$

Ans:

$$\boldsymbol{E}_1=\frac{kq_1}{r^2}(-\hat{\imath})=\frac{9\times10^9(15\times10^{-6})}{0.2^2}(-\hat{\imath})=(-3.38\times10^6\hat{\imath})\text{N/C}$$

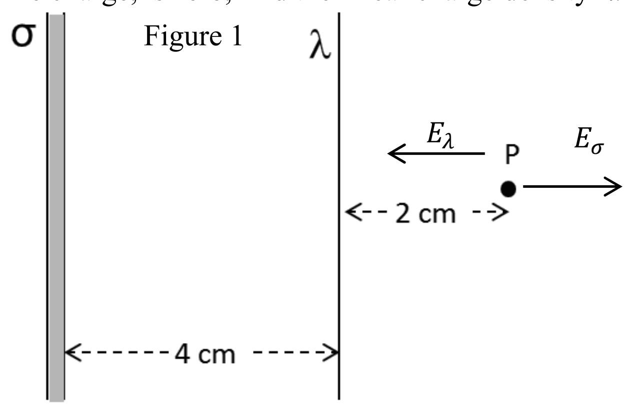
$$\boldsymbol{E}_2=\frac{kq_2}{r^2}(\hat{\jmath})=\frac{9\times10^9(10\times10^{-6})}{0.1^2}(\hat{\jmath})=(9.00\times10^6\hat{\jmath})\text{N/C}$$

$$\boldsymbol{E_{net}}=\boldsymbol{E}_1+\boldsymbol{E_2}$$

Q8.

FIGURE 1 shows portions of a large non-conducting sheet placed in parallel with long line of charge having a uniform charge per unit length λ. The surface charge density of the non-conducting sheet is $\sigma=+4.0\mu C/m^2$. If the electric field intensity at point P, 2.0 cm on right of the line charge, is zero, find the linear charge density λ.

A) −0.25 μC/m
B) +0.25 μC/m
C) +0.38 μC/m
D) −0.38 μC/m
E) −0.63 μC/m



Ans:

λ must be − ve

$$|E_\lambda|=|E_\sigma|$$

$$\frac{2K\lambda}{r}=\frac{\sigma}{2\varepsilon_0}$$

$$\lambda=\frac{\sigma\times r}{4\varepsilon_0 K}=\frac{4\times10^{-6}\times2\times10^{-2}}{4\times8.85\times10^{-12}\times9\times10^9}=2.51\times10^{-7}C/m\approx0.25\,\mu C/m$$

Q9.

A thick spherical conducting shell of outer radius 5.0 cm has a net charge Q = +10 μC. A point charge of −3.0 μC is placed at its center. Find the surface charge density on the ***outer surface*** of the shell.

A) 223 μC/m²
B) 414 μC/m²
C) 318 μC/m²
D) 203 μC/m²
E) 196 μC/m²

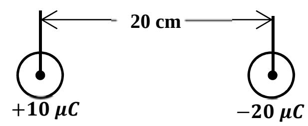
Ans:

$$\sigma = \frac{Q_T}{A} = \frac{+7\times10^{-6}}{4\pi(5\times10^{-2})^2} = 2.228\times10^{-4}\,C/m^2 \cong 223\mu\,C/m^2$$

Q10.

Two conducting spherical shells of same outer radius r = 5.0 cm are placed at center to center distance of 20 cm. The charge of +10 μC and −20 μC is uniformly distributed over the outer surface of sphere 1 and 2, respectively, find the total potential at the center of sphere 1. (Assume potential is zero at infinity)

A) +900 kV
B) +270 kV
C) −900 kV
D) +450 kV
E) +600 kV



Ans:

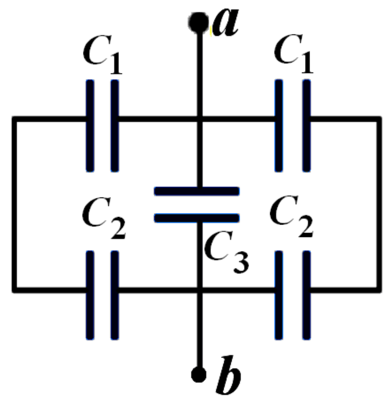
$$V = V_1 + V_2$$

$$V = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} = 9\times10^9\left(\frac{10\times10^{-6}}{0.05} + \frac{-20\times10^{-6}}{0.2}\right) = 900kV$$

Q11.

In **FIGURE 2** C_1 = 2.0 µF, C_2 = 4.0 µF, and C_3 = 6.0 µF. Find the equivalent capacitance between points a and b.

Figure 2



A) 8.7 µF
B) 18 µF
C) 9.8 µF
D) 12 µF
E) 2.0 µF

Ans:

C_1 and C_2 are in series

$$\frac{1}{C_{12}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{2} + \frac{1}{4} = \frac{3}{4}$$

$$C_{12} = \frac{4}{3}\mu F$$

Now required capacitance between points **a** and **b**

$$C_{ab} = C_{12} + C_{12} + C_3 = \frac{4}{3} + \frac{4}{3} + 6 = \frac{8+18}{3} = \frac{26}{3} = 8.66 \cong 8.7\ \mu F$$

Q12.

A current of 3.20 A exist in a copper wire whose diameter is 4.00 mm. The number of charge carrier per unit volume is 8.49×10^{28} m^{-3}. Assuming the current density is uniform, calculate the electron drift speed.

A) 1.87×10^{-5} m/s
B) 7.49×10^{-5} m/s
C) 4.25×10^{-6} m/s
D) 1.40×10^{-5} m/s
E) 3.23×10^{-5} m/s

Ans:

$$J = nev_d$$

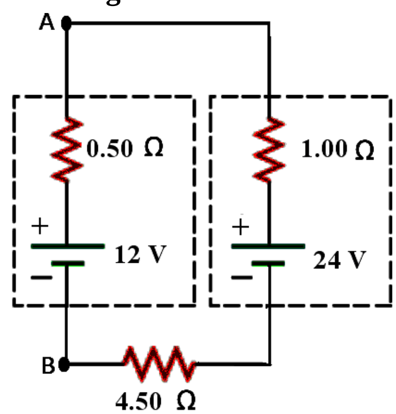
$$v_d = \frac{J}{ne} = \frac{I}{neA}$$

$$= \frac{3.2}{8.49 \times 10^{28} \times 1.6 \times 10^{-19} \times \pi(.002)^2} = 1.8746 \times 10^{-5} \cong 1.87 \times 10^{-5}\ m/s$$

Q13.

Two real batteries with some internal resistances are shown in **FIGURE 3**. Find the potential difference between points A and B ($V_A - V_B$).

Figure 3



A) 13.0 V
B) 23.5 V
C) 11.8 V
D) 24.5 V
E) 18.0 V

Ans:

$$\text{Current in Loop i} = \frac{12}{6} = 2 \text{ A}$$

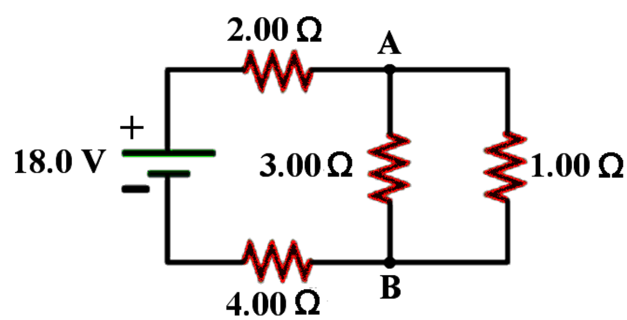
$$V_B + 12 + 2 \times 0.5 = V_A$$

$$V_A - V_B = 13 \text{ V}$$

Q14.

In a circuit shown in **FIGURE 4** if the potential of point **A** is zero find the potential of point **B**.

Figure 4



A) −2.0 V
B) +2.0 V
C) +6.0 V
D) −6.0 V
E) −4.0 V

Ans:

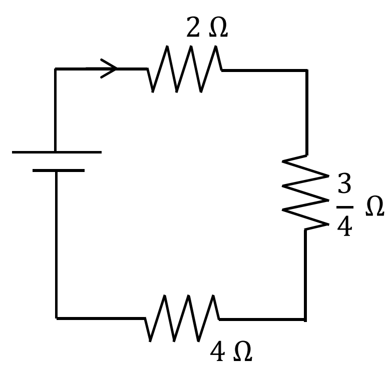
Two resistors on the right side are parallel

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

$$R = \frac{3}{4}\Omega$$

$$R_T = 2 + \frac{3}{4} + 4 = \frac{8 + 3 + 16}{4} = \frac{27}{4}\Omega$$

$$i = \frac{V}{R} = \frac{18}{\frac{27}{4}} = \frac{8}{3} A$$



$$V_{AB} = \frac{3}{4} \times \frac{8}{3} = 2V$$

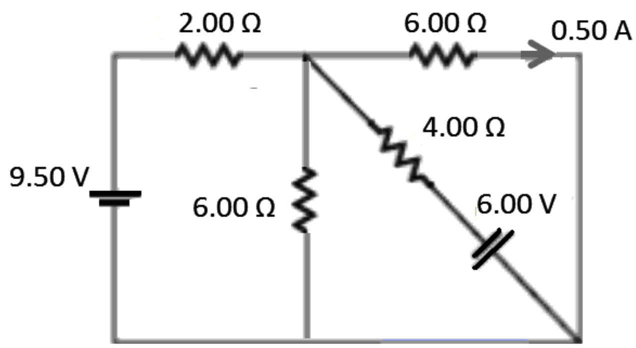
Potential of the point A is zero, Therefore $V_B = -2.0\ V$

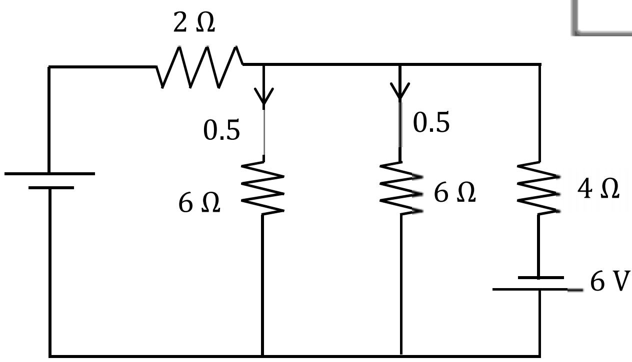
Q15.

For the circuit given in **FIGURE 5**, if the current through one of the 6.00 Ω is 0.500 A find the current through the 4.00 Ω resistor.

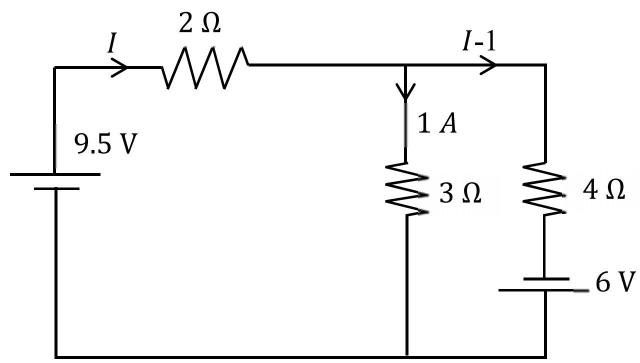
Figure 5

A) 2.25 A
B) 0.33 A
C) 3.50 A
D) 1.55 A
E) 0.50 A





Ans:



$$9.5 + 6 - 2I - 4(I - 1) = 0$$

$$15.5 - 2I - 4I + 4 = 0$$

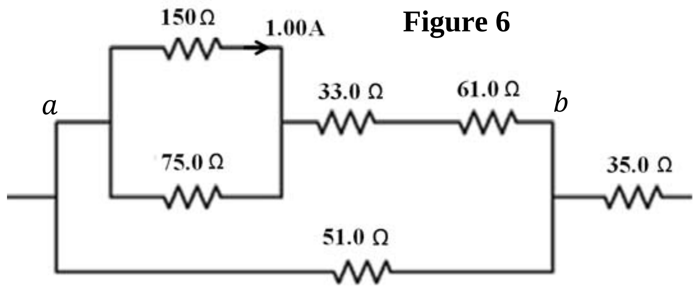
$$I = \frac{19.5}{6} = 3.25$$

∴ Current through 4Ω $3.25 - 1 = 2.25$ A

Q16.

If the current through the 150 Ω resistor is 1.00 A as shown in **FIGURE 6**, find the current through the 51.0 Ω resistor.

A) 8.47 A
B) 3.00 A
C) 5.42 A
D) 11.4 A
E) 6.45 A



Ans:

Current in 75Ω is 2A

∴ Current through 33Ω and 61Ω will be 3A

Therefore, the potential difference between points a and b

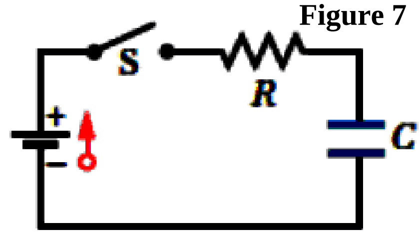
$$\therefore\ V_{ab} = 150 + 94(3) = 432\ V$$

$$\therefore \text{ Current through 51 } \Omega \text{ i} = \frac{432}{51} = 8.47 \text{ A}$$

Q17.

Switch S in **FIGURE 7** is closed at time t = 0, to begin charging an initially uncharged capacitor C = 15.0 µF through a resistor R = 20.0 Ω. At what time is the potential difference across the capacitor double to that across the resistor?

A) 3.30×10^{-4} s
B) 2.08×10^{-4} s
C) 1.25×10^{-4} s
D) 1.04×10^{-4} s
E) 0.52×10^{-4} s



Ans:

$$V_0\left(1 - e^{-t/RC}\right) = 2V_0 e^{-t/RC}$$

$$1 = 3e^{-t/RC}$$

$$e^{-t/RC} = \frac{1}{3}$$

$$\frac{-t}{RC} = ln\left(\frac{1}{3}\right)$$

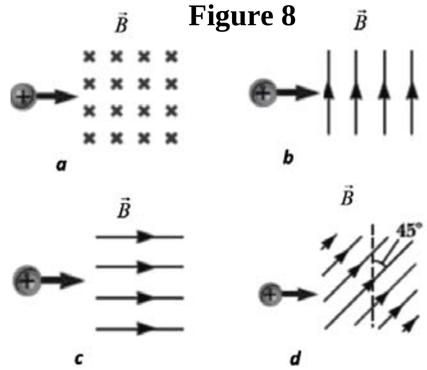
$$t = -RCln\left(\frac{1}{3}\right) = -20(15 \times 10^{-6})ln\left(\frac{1}{3}\right) = 3.2958 \times 10^{-4} \approx 3.30 \times 10^{-4}\ s$$

Q18.

A proton enters with the same speed in four regions of uniform magnetic fields of same magnitudes but in different directions, as shown in **FIGURE 8**. Rank regions according to magnitude of the force on the protons, **GREATEST FIRST.**

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

Figure 8



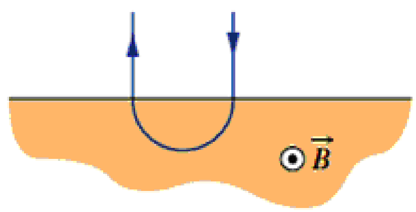
Ans:

A

Q19.

In **FIGURE 9** a charged particle electron or proton (you must decide which) moves in uniform magnetic field $\vec{B}$ (out of the page), goes through half circle, and then exits that region. The charged particle spends 240 ns in the region, find the magnitude of magnetic field.

Figure 9



A) 0.137 T
B) 0.298 T
C) 1.49×10^{-4} T
D) 3.72×10^{-4} T
E) 0.579 T

Ans:

The direction of force implies the particel is a proton

$$\frac{mV^2}{r} = qVB \Rightarrow V = \frac{qBr}{m}$$

$$T = \frac{2\pi r}{V} = \frac{2\pi m}{qB}$$

$$B = \frac{2\pi m}{qT} = \frac{2\pi \times 1.67 \times 10^{-27}}{1.6 \times 10^{-19} \times 2(240 \times 10^{-9})} = 0.13662 \cong 0.137 \text{ T}$$

Q20.

An 80.0 cm long wire, laying along the positive x axis (with one end at the origin), carries a current of 0.80 A in the negative x direction and placed in a magnetic field. $\vec{B} = 4.0\hat{i} + 12\hat{j}$, where x in meters and B in mT. Find, in unit vector notation, the magnetic force on the wire?

A) $(-7.68\times10^{-3}\,\hat{k})N$
B) $(+2.62\ \times10^{-3}\ \ \hat{k})N$
C) $(-2.62\times10^{-3}\,\hat{k})N$
D) $(+5.62\ \times10^{-3}\,\hat{j})N$
E) $(-4.72\times10^{-3}\,\hat{i})N$

Ans:

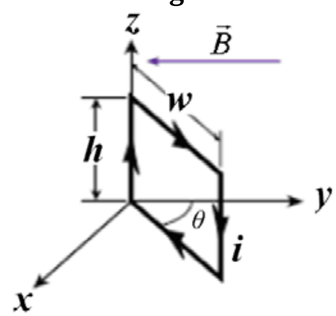
$$\vec{F} = I\left(\bar{l}\times\bar{B}\right) = 0.8[0.8(-\hat{\imath})\times(4\hat{\imath}+12\hat{\jmath})\times10^{-3}]$$

$$= 0.8[-0.8\times10^{-3}(12)\times\hat{\imath}\times\hat{\jmath}] = -7.68\times10^{-3}\hat{k}\ N$$

Q21.

A rectangular loop with height h = 6.50 cm and width w = 5.40 cm is in a uniform magnetic field of magnitude B = 0.250 T, which points in negative y direction as shown in **FIGURE 10**. The loop makes an angle of θ = 30º with the y axis and carries a current of 9.00 A in the direction indicated. What is the magnitude of the torque on the loop?

Figure 10



A) 6.84×10^{-3} N.m
B) 9.56×10^{-3} N.m
C) 7.62×10^{-3} N.m
D) 3.95×10^{-3} N.m
E) 4.32×10^{-3} N.m

Ans:

$$\vec{\tau} = \vec{\mu}\times\vec{B} = \mu B sin\theta = iA\cdot Bsin60$$

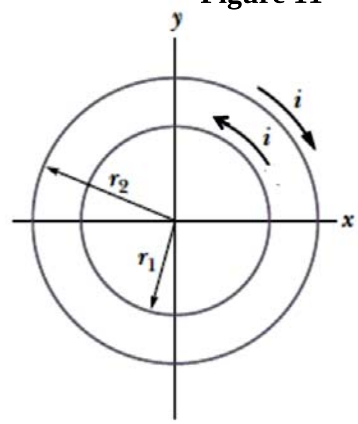
$$= 9\times(0.065\times0.054)0.25sin60$$

$$= 6.8394\times10^{-3}\ N\cdot m \cong 6.84\times10^{-3} N\cdot m$$

Q22.

Two concentric circular loops of radii r_1 = 20.0 cm and r_2 = 30.0 cm are located in xy plane; each carries current of same magnitude i = 7.00 A but in opposite direction as shown in **FIGURE 11**. Find the net magnetic dipole moment of the loops.

Figure 11



A) 1.10 A.m^2 into the page
B) 2.86 A.m^2 into the page
C) 1.10 A.m^2 out of the page
D) 2.86 A.m^2 out of the page
E) 1.98 A.m^2 into the page

Ans:

$\mu_1 \rightarrow$ out of the page

$\mu_2 \rightarrow$ into the page

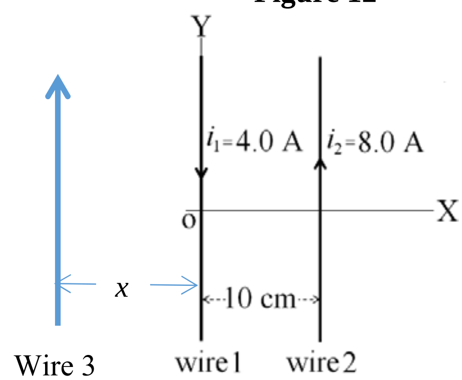
$\mu_{net} = \mu_2 - \mu_1 = iA_2 - iA_1 = i(A_2 - A_1)$

$\mu_{net} = 7[\pi(0.3)^2 - (0.2)^3] = 1.0995\ A \cdot m^2 = 1.10\ A \cdot m^2$

Q23.

Wire 1 and wire 2 placed parallel to y axis at x = 0 and x = 10 cm, respectively, and carries currents $i_1 = 4.0A$ and $i_2 = 8.0A$ in opposite directions as shown in **FIGURE 12**. A third wire carries current in positive y direction is to be placed parallel to wire 1 and wire 2 such that net force per unit length on wire 3 due to wire 1 and wire 2 is zero. Find the position x of wire 3.

Figure 12



A) −10 cm
B) +20 cm
C) +15 cm
D) −5.0 cm
E) −15 cm

Ans:

$|F_{31}| = |F_{32}|$

$$\frac{\mu_0 i_1 i_3}{2\pi x} = \frac{\mu_0 i_2 i_3}{2\pi(x + 0.1)}$$

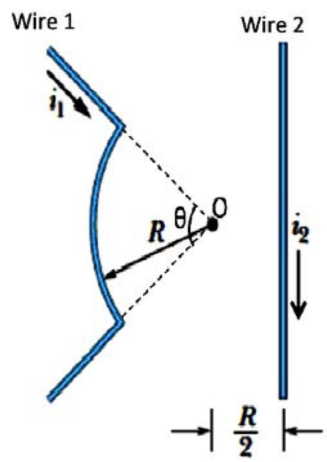
$$\frac{i_1}{x} = \frac{i_2}{x + 0.1}$$

$4(x + 0.1) = 8x \Rightarrow 0.4 = 4x \Rightarrow x = 0.1\ m = 10\ cm$

Q24.

In **FIGURE 13** wire 1 consist of a circular arc of radius R with central angle of θ = 120° and two radial lengths and carries current $i_1 = 2.00A$ in the direction indicated. Wire 2 is long and straight and it carries a current i_2 and placed at a distance of R/2 from the center of circular arc. If the net magnetic field at the center of the arc O is zero find the current i_2 .

Figure 13



A) 1.05 A
B) 2.75 A
C) 0.84 A
D) 1.34 A
E) 2.05 A

Ans:

$$|\vec{B}_{wire}| = |B_{arc}|$$

$$\frac{\mu_0 i_2}{2\pi\left(\frac{R}{2}\right)} = \frac{\mu_0 i_1}{4\pi R} \cdot \frac{2}{3}\pi$$

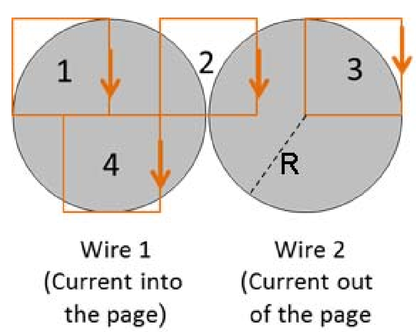
$$i_2 = \frac{i_1 \pi}{6}$$

$$i_2 = \frac{2 \times \pi}{6} = 1.04719 \approx 1.05\ A$$

Q25.

FIGURE 14 shows a cross section across the diameter of two long cylindrical conducting wires 1 and 2 of same radius R carrying same uniform current but in opposite directions. Four square paths (of side length R) of same dimensions are indicated for the line integral $\oint \vec{B}.d\vec{s}$. Rank the paths according to the magnitude of $\oint \vec{B}.d\vec{s}$ taken in the directions shown, **GREATESR FIRST**.

Figure 14



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

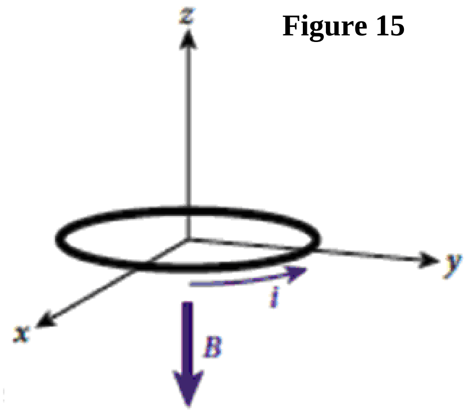
Ans:

A

Q26.

A circular wire loop has radius of 0.12 m and carries current $i = 0.10A$ placed in the xy plane in a uniform magnetic field $\vec{B} = -1.5\hat{k}\,T$, as shown in **FIGURE 15**. Find the potential energy of the loop in the position shown.

Figure 15



A) $+6.79 \times 10^{-3}$ J
B) -6.79×10^{-3} J
C) $+5.65 \times 10^{-2}$ J
D) 0
E) -5.65×10^{-2} J

Ans:

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

$$= -\left[iA(\hat{k})\cdot(-1.5\,\hat{k})\right]$$

$$= -\left[0.1\pi(0.12)^2(1.5)(-\hat{k}\cdot\hat{k})\right]$$

$$= 6.7858 \times 10^{-3}\text{ J}$$

$$\approx 6.79 \times 10^{-3}\text{ J}$$

Q27.

A solenoid has a length L = 1.55 m and an inner diameter d = 4.15 cm, and carries a current i = 4.80 A. The solenoid consists of six close-packed layers, each with 750 turns along length L. What is the magnitude of magnetic field at its center?

A) 17.5 mT
B) 23.8 mT
C) 5.65 mT
D) 13.5 mT
E) 19.8 mT

Ans:

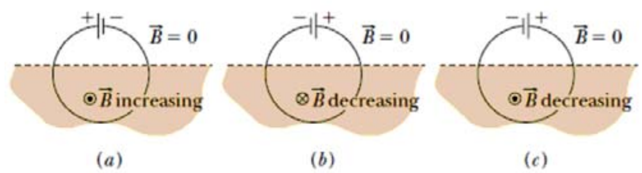
$$B = \mu_0 n_i = \mu_0 \frac{N}{l}\, i$$

$$B = 4\pi \times 10^{-7}\frac{750 \times 6}{1.55}(4.8) = 0.01751\,T = 17.5\,mT$$

Q28.

FIGURE 16 shows three situations in which a wire loop lies partially in a uniform magnetic field. The magnetic field is either increasing or decreasing, as indicated. In each situation, a battery is part of the loop. In which situation(s) is/are the induced emf and the battery emf in the same direction along the loop.

Figure 16



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

Ans:

A

Q29.

The magnetic flux through a loop increases according to the relation $\Phi_B = 6.0t^2 + 7.0t$, where Φ_B is in mT.m^2 and t is in seconds. What is the magnitude of the emf induced in the loop when t = 2.0 s?

A) 31 mV
B) 38 mV
C) 24 mV
D) 17 mV
E) 40 mV

Ans:

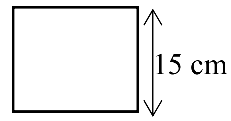
$$\varepsilon = -\frac{d\Phi}{dt}$$

$$\varepsilon = \frac{d}{dt}(6t^2 + 7t) = -(12\,t + 7) \times 10^{-3} = -(12 \times 2 + 7) \times 10^{-3} = 31\,mV$$

Q30.

A 60.0 cm copper wire is formed into a square loop and placed perpendicular to a uniform magnetic field that is increasing at the constant rate 12.0 mT/s. If the resistance of the loop is 20.0 Ω, at what rate is thermal energy generated in the loop?

A) 3.65×10^{-9} W
B) 2.70×10^{-9} W
C) 7.45×10^{-9} W
D) 1.35×10^{-9} W
E) 4.12×10^{-9} W



Ans:

$$P = \frac{\varepsilon^2}{R}$$

$$= \frac{1}{R}\left[\frac{d\varphi}{dt}\right]^2 = \frac{1}{R}\left[A \cdot \frac{dB}{dt}\right]^2 = \frac{1}{20}[0.15 \times 0.15 \times 0.12 \times 10^{-3}]^2 = 3.65 \times 10^{-9} W$$