Q1.

A sinusoidal wave traveling on a string in the negative x direction has an amplitude of 0.10 m, a wavelength of 0.1 m and a frequency of 20 Hz. A particle at x = 0 and t = 0 has a displacement of +0.10 m. Choose the correct equation of the displacement of the particles as a function of x and t, where x is in meter and t in second.

A) y (x,t) = (0.10 m) sin(20πx+40πt+π/2)
B) y (x,t) = (0.10 m) sin(20πx+40πt)
C) y (x,t) = (0.10 m) sin(20πx − 40πt)
D) y (x,t) = (0.10 m) sin(40πx+20πt + π/2)
E) y (x,t) = (0.10 m) sin(20πx − 40πt + π/2)

Ans:

$$y = y_m \sin(kx \pm \omega t + \phi)$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.1} = 20\pi\ m^{-1}$$

$$\omega = 2\pi f = 2\pi \times 20 = 40\pi\ rad/s$$

$$y_m = 0.1\ m$$

$$y(0,0) = y_m \sin\phi = y_m \Rightarrow \sin\phi = 1 \Rightarrow \phi = \frac{\pi}{2}$$

$$y(x,t) = 0.1 \sin(2\pi t + 40\pi t + \frac{\pi}{2})$$

Q2.

A tube open at one end has a length of 50 cm. Calculate the speed of sound in air if the fifth harmonic in this tube is 850 Hz.

A) 340 m/s
B) 348 m/s
C) 343 m/s
D) 338 m/s
E) 345 m/s

Ans:

$$f_n = \frac{nv}{4L} \quad n = 1, 3, 5, \ldots$$

$$\text{Fifth harmonic} \Rightarrow n = 5 \Rightarrow f_5 = \frac{5v}{4\,L}$$

$$850 = \frac{5 \times v}{4 \times 0.5} \quad \Rightarrow v = 340\ m/s$$

Q3.

How much mass of aluminum initially at 150 ^{0}C must be added to 500 g of water, in a container, initially at 20.0 ^{0}C to make the final equilibrium temperature 50.0 ^{0}C? (neglect the heat capacity of the container) Specific heat of aluminum = 0.215 cal/g^{0}C and specific heat of water = 1.00 cal/g^{0}C.

A) 700 g
B) 500 g
C) 833 g
D) 150 g
E) 950 g

Ans:

$$m_w c_w(T_f - T_i) = m_{Al} c_{Al}(T_i - T_f)$$

$$500 \times 1 \times (50 - 20) = m_{Al} \times 0.215 \times (150 - 50)$$

$$m_{Al} = 700 \text{ g}$$

Q4.

An ideal monatomic gas (γ = 1.67) occupies a volume of 4.3 L at a pressure of 1.2 atm. It is compressed adiabatically to a volume of 2.1 L. Determine the final pressure of the gas.

A) 4.0 atm
B) 2.3 atm
C) 0.36 atm
D) 6.9 atm
E) 1.1 atm

Ans:

$$P_i V_i^{\gamma} = P_f V_f^{\gamma}$$

$$P_f = P_i \left(\frac{V_i}{V_f}\right)^{\gamma} = 1.2 \left(\frac{4.3}{2.1}\right)^{1.67} = 4.0 \text{ atm}$$

Q5.

When the temperature of a metal sphere is raised by 75 C^0, the sphere's volume increases by 6.9×10^{-5} m^3. If the original volume is 1.8×10^{-2} m^3, find the coefficient of linear expansion of the metal.

A) 1.7×10^{-5} / C^0
B) 2.5×10^{-5} / C^0
C) 5.1×10^{-5} / C^0
D) 0.87×10^{-5} / C^0
E) 0.45×10^{-5} / C^0

Ans:

$$\Delta V = 3\alpha V \Delta T$$

$$\alpha = \frac{\Delta V}{3V\Delta T} = \frac{6.9 \times 10^{-5}}{3 \times 1.8 \times 10^{-2} \times 75} = 1.7 \times 10^{-5} / \text{C}^{\circ}$$

Q6.

You mix two samples of water, A and B. Sample A is 0.100 kg at 293 K and sample B is also 0.100 kg but at 353 K. Calculate the change in entropy of sample B.

A) −37.2 J/K
B) +37.2 J/K
C) −197 J/K
D) +197 J/K
E) Zero

Ans: $T_i = 353$ k
$T_f = 323$ k

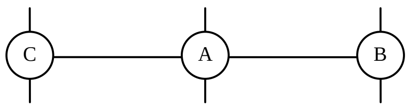
$$\Delta S_B = mc\, ln\left(\frac{T_f}{T_i}\right)$$

$$= 0.1 \times 4190 \times ln\left(\frac{323}{353}\right) = -37.2 \text{ J/K}$$

Q7.

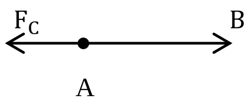
A charged particle, labeled A, is located at the midpoint between two other charged particles, labeled B and C, as shown in Figure 1. The sign of the charges on all three particles is the same. When particle A is released, it starts moving toward B. What can be concluded from this behavior?

Figure 1



A) The charge on C is greater than the charge on B.
B) The charge on B is greater than the charge on A.
C) The charge on A is greater than the charge on B.
D) The charge on B is greater than the charge on C.
E) The charge on A is greater than the charge on C.

Ans:



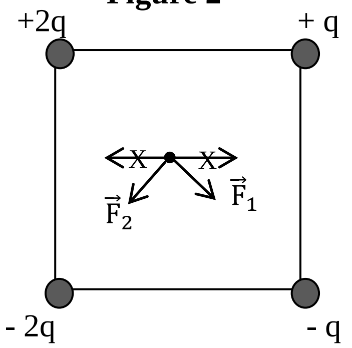
$F_2 > F_1$

Charge on C is larger than the charge on B

Q8.

Four charges are located at the corners of a square as shown in Figure 2. What is the direction of the net electric field at the center of the square labeled point P?

Figure 2



A) Vertically down.
B) To the Left.
C) There is no direction. The electric field at P is zero.
D) To the Right.
E) Vertically up.

Ans:

$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$

$F_x = F_{1x} - F_{2x} = 0$

$F_y = F_{1y} + F_{2y} \neq 0$

net force is vertically down

Q9.

A point charge q is located at the center of a Gaussian surface in the form of a cube. The electric flux through one face of the cube is:

A) $q/6\varepsilon_0$
B) $q/3\varepsilon_0$
C) $6q/\varepsilon_0$
D) $3q/\varepsilon_0$
E) q/ε_0

Ans:

$$\phi_{Total} = \frac{q}{\varepsilon_0} \text{, one side } \phi = \frac{\phi_{Total}}{6} = \frac{q}{6\varepsilon_0}$$

Q10.

A conducting spherical shell of radius 5.0 cm carries a charge of 7.0×10^{-8} C. What is the electric potential at the center of the sphere? Take the potential at infinity to be zero.

A) $+ 1.3 \times 10^4$ V
B) $- 1.3 \times 10^4$ V
C) $+ 7.0 \times 10^4$ V
D) $- 7.0 \times 10^4$ V
E) Zero

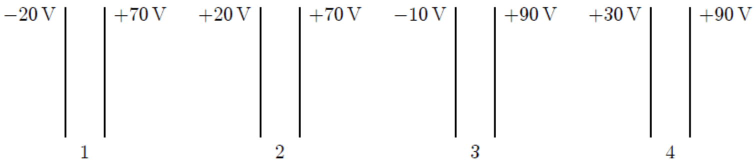
Ans:

$$V = \frac{kQ}{R} = \frac{9 \times 10^9 \times 7 \times 10^{-8}}{0.05} = 1.3 \times 10^4 \text{ V}$$

Q11.

Figure 3 shows four pairs of large parallel conducting plates with the same separation. The value of the electric potential is given for each plate. The electric field between the plates is uniform and perpendicular to the plates. Rank the pairs according to the magnitude of the electric field between the plates, **least to greatest**.

Figure 3



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

Ans:

1) $|\Delta V| = 90\text{ V}$

2) $|\Delta V| = 50\text{ V}$

3) $|\Delta V| = 100\text{ V}$

4) $|\Delta V| = 60\text{ V}$

d is the same for all plates

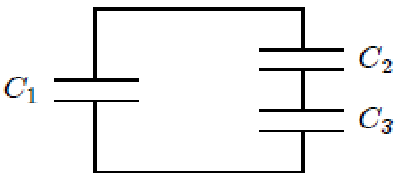
$$|E| = \frac{|\Delta V|}{d}$$

$2 < 4 < 1 < 3$

Q12.

Capacitor C_1 is connected to a battery and charged until the magnitude of the charge on each plate is 10 nC. Then, it is removed from the battery and connected to two other capacitors C_2 and C_3, as shown in Figure 4. The charge on capacitor C_1 is then 4.0 nC. The charges on capacitors C_2 and C_3 are:

Figure 4



A) $q_2 = 6.0$ nC and $q_3 = 6.0$ nC
B) $q_2 = 10$ nC and $q_3 = 10$ nC
C) $q_2 = 14$ nC and $q_3 = 14$ nC
D) $q_2 = 20$ nC and $q_3 = 20$ nC
E) $q_2 = 4.0$ nC and $q_3 = 4.0$ nC

Ans:

Before $Q_1 = 10\text{ nC}$

After $Q_1 = 4\text{ nC}$

$\Rightarrow\ Q_2 = Q_3 = 6\text{ nC}$

Q13.

A 100-W and a 60-W light bulbs are designed for use with the same voltage. What is the ratio of the resistance of the 100-W bulb to the resistance of the 60-W bulb?

A) 0.60
B) 1.7
C) 0.40
D) 2.5
E) 1.0

Ans:

$$100\text{ W} \Rightarrow P_1 = \frac{V^2}{R_1} \Rightarrow R_1 = \frac{V^2}{P_1}$$

$$60\text{ W} \Rightarrow P_2 = \frac{V^2}{R_2} \Rightarrow R_2 = \frac{V^2}{P_2}$$

$$\Rightarrow \frac{R_1}{R_2} = \frac{P_2}{P_1} = \frac{60}{100} = 0.60$$

Q14.

If the terminals of an ideal battery are connected across two identical resistors connected in series, the total power delivered by the battery is 8.0 W. If the same battery is connected to the same two resistors which are now connected in parallel, what is the total power delivered by the battery?

A) 32 W
B) 16 W
C) 8.0 W
D) 4.0 W
E) 2.0 W

Ans:

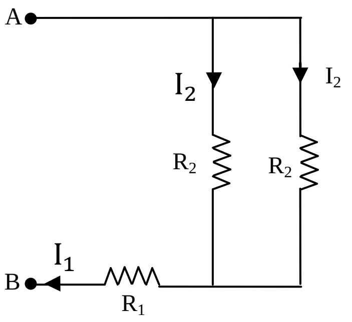
$$P_1 = \frac{V^2}{R_{eq}} = \frac{V^2}{2R} = 8\text{ W}$$

$$P_2 = \frac{V^2}{R_{eq}} = 2\left(\frac{V^2}{R}\right) = 4\left(\frac{V^2}{2R}\right) = 4\,P_1 = 32\text{ W}$$

Q15.

In Figure 5, I_2 = 0.30 A, R_1 = 5.0 Ω and R_2 = 8.0 Ω. Calculate the potential difference $V_A - V_B$.

Figure 5



A) 5.4 V
B) 3.9 V
C) 2.4 V
D) 1.5 V
E) 6.5 V

Ans:

$$I_1 = 2I_2 = 0.6\ \text{A}$$

$$V_A - V_B = R_1I_1 + R_2I_2$$

$$= 5 \times 0.6 + 8 \times 0.3 = 5.4\ \text{V}$$

Q16.

An un-charged 5.0 μF capacitor and a 1.0 MΩ resistor are connected in series to a battery. At what time, after the battery is connected, is the potential difference across the capacitor 60% of the value of the potential difference across the battery?

A) 4.6 s
B) 3.0 s
C) 2.4 s
D) 7.2 s
E) 1.9 s

Ans:

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

$$0.6\not\varepsilon = \not\varepsilon\left(1 - e^{-t/RC}\right)$$

$$0.4 = e^{-\frac{t}{RC}}$$

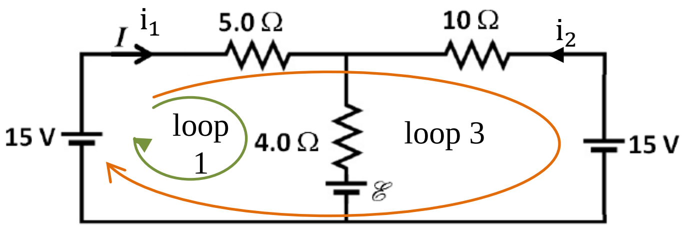
$$ln(0.4) - t/RC$$

$$t = -RC\ ln(0.4) = 4.6\ s$$

Q17.

Find the value of the emf (E) of the battery shown in Figure 6, if the current I = 1.2 A.

Figure 6



A) 1.8 V
B) 7.5 V
C) 3.8 V
D) 3.2 V
E) 4.3 V

Ans:

loop 3

$15 - 5 \times 1.2 + 10i_2 - 15 = 0 \Rightarrow i_2 = 0.6\ \text{A}$

$i_3 = i_1 + i_2 = 1.8\ \text{A}$

loop 1

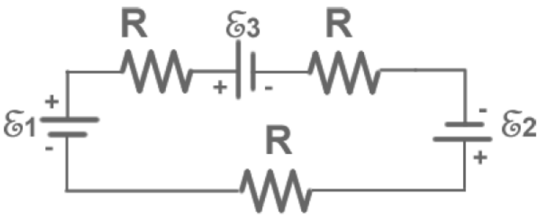
$15 - 5 \times 1.2 - 4 \times 1.8 - \varepsilon = 0$

$\varepsilon = 1.8\ \text{V}$

Q18.

In the circuit shown in Figure 7, what should be the ratio E_3/E_1 if $E_1 = E_2$ and the electric current in the circuit equal to zero?

Figure 7



A) 2.0
B) 0.50
C) 1.0
D) 4.0
E) 0.25

Ans:

$i = 0 \Rightarrow \varepsilon_1 - \varepsilon_3 + \varepsilon_2 = 0$

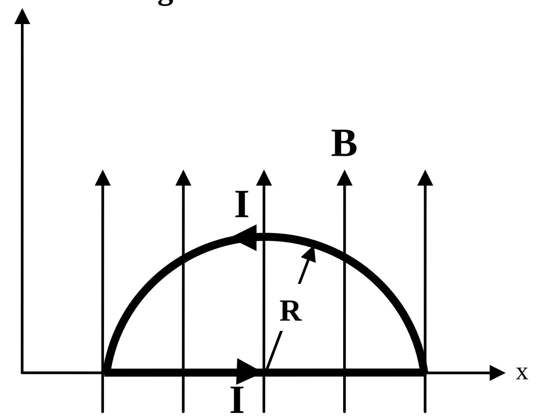
$\varepsilon_1 = \varepsilon_2 \Rightarrow 2\varepsilon_1 - \varepsilon_3 = 0$

$\frac{\varepsilon_3}{\varepsilon_1} = 2$

Q19.

A wire bent into a semicircle of radius R forms a closed loop and carries a current I, as shown in Figure 8. The wire lies in the xy plane, and a uniform magnetic field is directed along the positive y axis. What is the magnetic force on the curved portion of the wire?

Figure 8



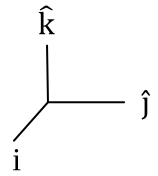
A) $-2IRB\ \hat{\mathbf{k}}$
B) $+2IRB\ \hat{\mathbf{k}}$
C) $-\pi IRB\ \hat{\mathbf{k}}$
D) $+\pi IRB\ \hat{\mathbf{k}}$
E) zero

Ans:

closed wire $\vec{F}_{net} = 0$

$\vec{F}_{straight} + \vec{F}_{curved} = 0$

$\vec{F}_{curved} = -\vec{F}_{straight} = -I(2R)B\,\hat{k}$



Q20.

A proton moves with a velocity of 1.0×10^{7} m/s in the positive z direction in a uniform magnetic field of magnitude 21×10^{-3} T in the negative y direction. Determine the acceleration (in m/s^2) of the proton.

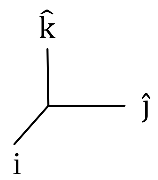
A) 2.0×10^{13} in the positive x direction
B) 2.0×10^{13} in the negative x direction
C) 3.3×10^{13} in the positive x direction
D) 3.3×10^{13} in the negative x direction
E) 5.0×10^{13} in the positive x direction

Ans:

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

$\vec{a} = \frac{q}{m}\left(\vec{v} \times \vec{B}\right)$

$= \frac{1.6 \times 10^{-19}}{1.67 \times 10^{-27}}\left(1 \times 10^{7}\,\hat{k} - 21 \times 10^{-3}\,\hat{j}\right) = 2.0 \times 10^{13}\,\hat{\imath}$



Q21.

An electron and a proton are travelling in the same direction with the same speed. They are injected into a uniform magnetic field with their velocities perpendicular to the field. Once, they are in the field, which of the following statements is CORRECT?

A) They will experience the same magnitude of force.
B) They will have the same radius of revolution.
C) They will have the same period of revolution.
D) They will travel in the same direction.
E) They will travel with different speeds.

Ans:

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

same $q, \vec{v}$ and $\vec{B}$ $\Rightarrow$ same magnitude of the force

---

Q22.

A current of 15 mA is maintained in a 50-turn circular coil of radius 5.0 cm. A uniform magnetic field of magnitude 0.80 T is directed parallel to the plane of the coil. What is the magnitude of the torque exerted by the magnetic field on the coil?

A) 4.7×10^{-3} N.m
B) 1.2×10^{-4} N.m
C) 2.1×10^{-5} N.m
D) 3.1×10^{-2} N.m
E) zero

Ans:

$$\tau = NiAB = 50 \times 15 \times 10^{-3} \times \pi(0.05)^2 \times 0.8$$

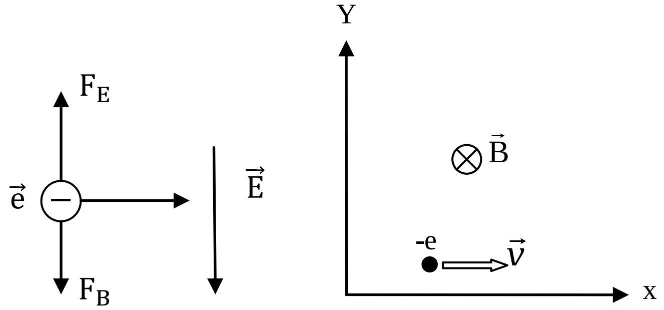
$$= 4.7 \times 10^{-3}\ \text{N.m}$$

Q23.

In Figure 9, an electron moves at a constant speed of 230 m/s along an *x* axis through uniform magnetic and electric fields undeflected. The magnetic field is directed into the page and has a magnitude of 5.0 mT. What is the electric field (in units of V/m)?

Figure 9

A) $-1.2\ \hat{j}$
B) $+1.2\ \hat{j}$
C) $-2.7\ \hat{j}$
D) $+2.7\ \hat{j}$
E) $+4.6\ \hat{j}$



Ans:

$qvB = qE$

magnitude $E = vB = 230 \times 5 \times 10^{-3} = 1.2\ \text{V/m}$

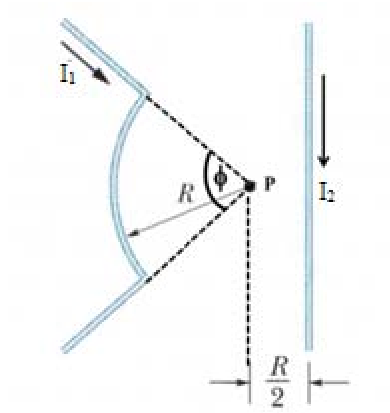
direction : $-y$ axis

Q24.

Figure 10 shows two wires each carrying a current in the direction indicated in the figure. Wire 1, which consists of a circular arc of radius R and two radial lengths, carries a current I_1= 1.5 A. Wire 2 is long and straight; carries a current I_2= 0.4 A and is at a distance R/2 from the center of the arc. For what value of arc angle ϕ the net magnetic field B at point P due to the two currents is zero?

Figure 10

A) 61^0
B) 55^0
C) 75^0
D) 70^0
E) 51^0



Ans:

$\vec{B}_1$ is out of the page

$\vec{B}_2$ is into the page

$\vec{B}_{net} = 0 \Rightarrow B_1 = B_2$

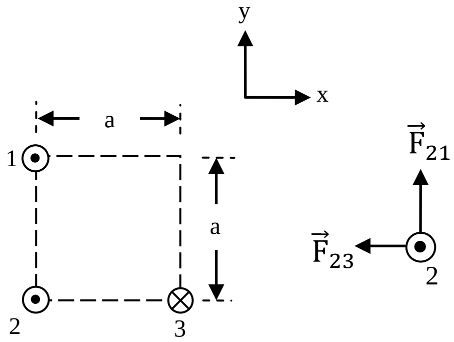
$$\frac{\mu_0 I_1}{4\pi R}\phi = \frac{\mu_0 I_2}{2\pi\left(\frac{R}{2}\right)}$$

$$\phi = \frac{4 I_2}{I_1} = 1.067\ \text{rad} = 61.1\ °$$

Q25.

Three long straight wires are perpendicular to the page. Each wire carries a current of 15 A and are arranged at the three corners of a square of edge length *a* = 1.0 cm, as shown in Figure 11. Find the magnitude of net magnetic force per unit length (in N/m) on wire 2 due to wires 1 and 3.

Figure 11



A) 6.4×10^{-3}
B) 4.6×10^{-3}
C) 3.4×10^{-2}
D) 4.3×10^{-2}
E) 5.1×10^{-3}

Ans:

$$\frac{F_{21}}{l} = \frac{\mu_0 I^2}{2\pi a} = \frac{F_{23}}{l}$$

$$= \frac{4\pi \times 10^{-7} \times (15)^2}{2\pi(0.01)} = 4.5 \times 10^{-3}$$

$$\frac{F_{net}}{l} = \frac{F_{21}}{l}\sqrt{2} = 6.4 \times 10^{-3}\ \text{N/m}$$

Q26.

A long, straight wire carries a 3.0 A current. This current creates a magnetic field of strength 1.0 T at the surface of the wire. If the wire has a radius R, where within the wire is the magnetic field strength 0.36 T? (Assume the current density is uniform throughout the wire)

A) 0.36 R
B) 0.18 R
C) 0.64 R
D) 0.72 R
E) 0.26 R

Ans:

$$B_{surface} = \frac{\mu_0 I}{2\pi R} \qquad B_{inside} = \frac{\mu_0 I}{2\pi R^2} r = B_{surface} \times \left(\frac{r}{R}\right)$$

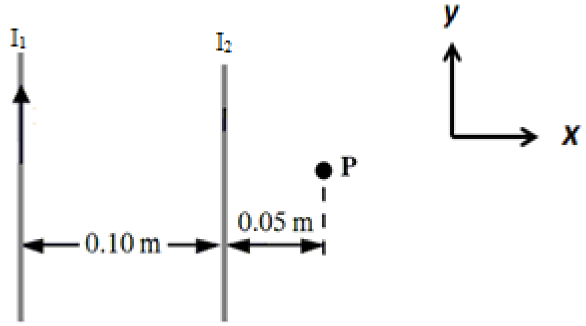
$$B_{inside} = B_{surface} \times \frac{r}{R} \Rightarrow 0.36 = 1 \times \frac{r}{R}$$

$$\Rightarrow r = 0.36\ R$$

Q27.

Two long, straight wires, separated by 0.10 m, carry currents I_1 and I_2 as shown in Figure 12. If current I_1=18 A and the resultant magnetic field due to these two current carrying wires at point P is zero, then the magnitude and direction of I_2 is:

Figure 12



A) 6.0 A, along the negative y-axis
B) 6.0 A, along the positive y-axis
C) 54 A, along the negative y-axis
D) 54 A, along the positive y-axis
E) 9.0 A, along the positive y-axis

Ans:

B_1 is inside, B_2 should be outside

$\Rightarrow i_2$ should be along the negative $y-$axis

$B_P = 0 = B_2 - B_1$

$\Rightarrow B_2 = B_1$

$$\frac{\mu_0 I_2}{2\pi r_2} = \frac{\mu_0 I_1}{2\pi r_1}$$

$$I_2 = I_1 \frac{r_2}{r_1} = 18 \times \frac{0.05}{0.15} = 6 \text{ A}$$

Q28.

A 10 m long conductor is formed into a single circular loop in the *xy*-plane. A uniform magnetic field, $\vec{B} = (4.0\hat{i} + 19.0\hat{j} + 24.0\hat{k})$ T, exists in the region of the conductor. Find the magnetic flux through the loop?

A) $191 \text{ T}\cdot\text{m}^2$
B) $609 \text{ T}\cdot\text{m}^2$
C) $152 \text{ T}\cdot\text{m}^2$
D) $253 \text{ T}\cdot\text{m}^2$
E) $334 \text{ T}\cdot\text{m}^2$

Ans:

$2\pi R = l$

$$R = \frac{l}{2\pi} = \frac{10}{2\pi} = 1.6 \text{ m} \;;\quad A = \pi R^2 = 7.95 \text{ m}^2$$

$$\phi = \vec{B}.\vec{A} = (4\,\hat{\imath} + 19\,\hat{\jmath} + 24\,\hat{k}).(7.96\,\hat{k}) = 191 \text{ T.m}^2$$

Q29.

A conducting loop has an area of 0.065 m^2 and is positioned such that a uniform magnetic field is perpendicular to the plane of the loop. When the magnitude of the magnetic field decreases to 0.300 T in 0.087 s, the average induced emf in the loop is 1.20 V. What is the initial value of the magnetic field?

A) 1.91 T
B) 0.750 T
C) 0.800 T
D) 1.20 T
E) 0.423 T

Ans:

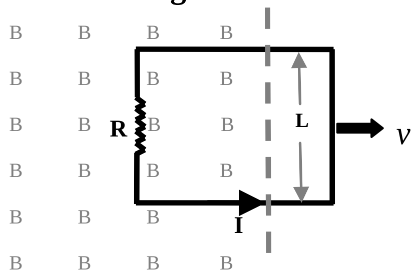
$$\varepsilon = -\frac{\Delta\phi}{\Delta t} = -A\frac{\Delta B}{\Delta t} = -\frac{A(B_f - B_i)}{\Delta t}$$

$$1.2 = -\frac{0.065}{0.087}(0.3 - B_i) \Rightarrow B_i = 1.9\ \mathrm{T}$$

Q30.

A circuit is pulled to the right at a constant speed v = 5.0 m/s in a uniform magnetic field B as shown in Figure 13. As the circuit moves, a 1.2 mA current flows through the resistor R= 4.0 Ω. If L= 12 cm, then magnitude and direction of the field B is:

Figure 13



A) 8.0 mT, directed out of the page
B) 8.0 mT, directed into the page
C) 20 mT, directed out of the page
D) 20 mT, directed into the page
E) 14 mT, directed out of the page.

Ans:

$$\varepsilon = BLv = IR$$

$$B = \frac{IR}{Lv} = \frac{1.2 \times 10^{-3} \times 4}{0.12 \times 5} = 8 \times 10^{-3}\ \mathrm{T}$$

Since A is decreasing $\vec{B}$ and $\vec{B}$ induced should have the same direction

$\vec{B}$ induced out of the page $\Rightarrow$ $\vec{B}$ is also out of the page

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