Q1.

A sinusoidal wave with a speed of 22.4 m/s is travelling on a string of linear density 15.0 g/m. If the maximum transverse speed of a particle of the string is 7.05 m/s, then the average power transmitted by this wave is:

A) 8.35 W
B) 4.62 W
C) 5.21 W
D) 1.30 W
E) 9.62 W

Ans:

$$P_{av} = \frac{1}{2}\mu\omega^2 v {y_m}^2 = \frac{1}{2}\mu v(\omega y_m)^2$$
$$= \frac{1}{2} \times 15.0 \times 10^{-3} \times 22.4 \times (7.05)^2 = 8.35 \text{ W}$$

Q2.

A car, travelling with a speed of 30.0 m/s, follows a police car travelling at 50.0 m/s. The siren of the police car emits sound with a frequency of 500 Hz. What frequency is heard by the driver of the car? The speed of sound is 340 m/s.

A) 474 Hz
B) 527 Hz
C) 397 Hz
D) 534 Hz
E) 468 Hz

Ans:

Speed of car = x ; speed of police car = y

$$f' = f_0 \cdot \frac{v + v_0}{v + v_s} = f_0 \cdot \frac{v + x}{v + y} = (500) \cdot \frac{340 + 30}{340 + 50} = 474 \text{ Hz}$$

Q3.

For an ideal gas, which of the following statements is **CORRECT**?

A) In an isothermal expansion: $W = Q$. ✓ $\Delta_{Eint} = 0$ for isothermal
B) In an isothermal expansion: $W = \Delta E_{int}$. ✗
C) In an isothermal expansion: $Q = \Delta E_{int}$. ✗
D) In an isochoric process: $W = \Delta E_{int}$. ✗ $W = 0$ for isochoric
E) In an isochoric process: $W = Q$. ✗

Ans:

A

Q4.

Two moles of an ideal gas are in a 6.0 L container at a pressure of 5.0×10^5 Pa. Find the average translational kinetic energy of a single molecule.

A) 3.7×10^{-21} J
B) 1.2×10^{-21} J
C) 7.5×10^{-21} J
D) 1.9×10^{-21} J
E) 9.3×10^{-21} J

Ans:

$$K_{avg} = \frac{3}{2}kT = \frac{3k}{2}.\frac{pV}{nR}$$

$$= \frac{3}{2} \times 1.38 \times 10^{-23} \times \frac{5.0 \times 10^5 \times 6.0 \times 10^{-3}}{2 \times 8.31} = 3.7 \times 10^{-21}\ \mathrm{J}$$

Q5.

Five moles of an ideal monatomic gas are allowed to expand isobarically from 40.0 cm^3 to 100 cm^3. What is the change of entropy of the gas in this process?

A) + 95.2 J/K
B) + 57.1 J/K
C) – 95.2 J/K
D) – 57.1 J/K
E) + 19.1 J/K

Ans:

$$\Delta S = \int \frac{dQ}{T} = \int \frac{nC_p dT}{T} = n.C_p.\ln\left(\frac{T_f}{T_i}\right) = n.C_p.\ln\left(\frac{V_f}{V_i}\right)$$

$$= 5 \times \frac{5}{2} \times 8.31 \times \ln\left(\frac{100}{40.0}\right) = +95.2\ \mathrm{J/K}$$

Q6.

Two positive point charges are fixed on the x-axis as follows: q_1 = 12 μC at the origin, and q_2 = 3.0 μC at x = + 3.0 m. At what coordinate, on the x-axis, is the electric field due to q_1 and q_2 zero?

A) + 2.0 m
B) – 1.5 m
C) + 3.0 m
D) + 1.0 m
E) – 1.0 m

Ans:

The requested point is between the two charges, a distance x from q_1.

magnitude: $E_1 = E_2$

$$\frac{kq_1}{x^2} = \frac{kq_2}{(3-x)^2}$$

$$\left(\frac{3-x}{x}\right)^2 = \frac{q_2}{q_1} = \frac{3}{12} = \frac{1}{4}$$

$$\frac{3-x}{x} = \frac{1}{2} \Rightarrow \frac{3}{x} - 1 = \frac{1}{2}$$

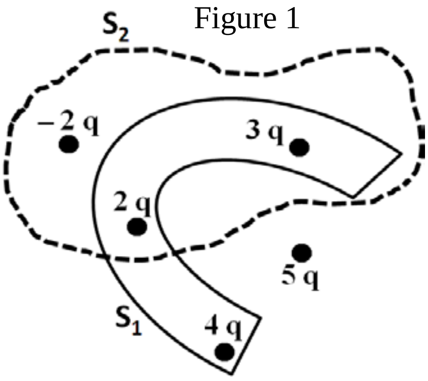
$$\Rightarrow \frac{3}{x} = \frac{3}{2} \Rightarrow x = +2.0 \text{ m}$$

Q7.

In **Figure** 1, what is the ratio of the electric flux that penetrates surface S_1 to the flux that penetrates surface S_2?

A) 3
B) 0
C) 2
D) 1
E) 1/3

Figure 1



Ans:

$$\Phi_1 = \frac{q_{enc}}{\varepsilon_0} = \frac{3q + 2q + 4q}{\varepsilon_0} = \frac{9q}{\varepsilon_0}$$

$$\Phi_2 = \frac{q_{enc}}{\varepsilon_0} = \frac{3q - 2q + 2q}{\varepsilon_0} = \frac{3q}{\varepsilon_0}$$

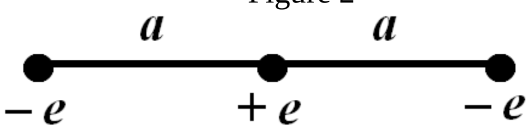
$$\frac{\Phi_1}{\Phi_2} = \frac{9q}{3q} = 3$$

Q8.

Three charges are arranged as shown in **Figure** 2. Calculate the work required by an external agent to remove the negative charge (– e) on the right end to infinity.

A) 3.8×10^{-19} J
B) 7.7×10^{-19} J
C) 1.5×10^{-18} J
D) 1.9×10^{-19} J
E) 1.3×10^{-19} J

Figure 2



$a = 3.0 \times 10^{-10}$ m , $e = 1.6 \times 10^{-19}$ C

Ans:

$$U_i = -\frac{ke^2}{a} + \frac{ke^2}{2a} - \frac{ke^2}{a} = -\frac{2ke^2}{a} + \frac{ke^2}{2a} = -\frac{3ke^2}{2a}$$

$$U_f = -\frac{ke^2}{a}$$

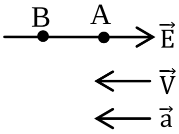
$$W_{ext} = \Delta U = U_f - U_i = -\frac{ke^2}{a} + \frac{3ke^2}{2a} = \frac{ke^2}{2a} = +3.8 \times 10^{-19}\ \mathrm{J}$$

Q9.

A particle (m = 2.0×10^{-9} kg, q = – 5.0 μC) has a speed of 30 m/s at point A and moves, under the effect of an electric field opposite to its velocity, to point B where its speed becomes 80 m/s. What is the potential difference $V_B - V_A$?

A) + 1.1 V
B) + 3.5 V
C) + 6.3 V
D) – 2.4 V
E) zero

Ans:



$$U_i + K_i = U_f + K_f$$

$$qV_A + \frac{1}{2}mv_A{}^2 = qV_B + \frac{1}{2}mv_B{}^2$$

$$\Rightarrow V_B - V_A = \frac{m}{2q}(v_A{}^2 - v_B{}^2)$$

$$V_B - V_A = \frac{2.0 \times 10^{-9}}{-1.0 \times 10^{-5}}.(900 - 6400)$$

$$= +1.1\ \mathrm{V}$$

Q10.

The space between the plates of an isolated parallel-plate capacitor is filled with plastic of dielectric constant κ_1 = 2.10. The potential difference between the plates is 600 V. The plastic is replaced with glass whose dielectric constant is κ_2 = 3.40. What is the potential difference between the plates after inserting the glass?

A) 371 V
B) 247 V
C) 325 V
D) 199 V
E) 462 V

Ans:

$$Q_i = C_1.V_1 = (k_1.C_0)(600) = 1260\ C_0$$

$$Q_f = C_2.V_2 = (k_1.C_0)(V_f) = 3.40\ C_0V_f$$

$$\text{isolated: } Q_i = Q_f \Rightarrow 1260C_0 = 3.40C_0V_f \Rightarrow V_f = 371\text{ V}$$

Q11.

Two resistors, A and B, are made of the same material of cylindrical wires having the same length. When a potential difference of 110 V is applied to each wire, the powers dissipated in A and B are 400 W and 100 W, respectively. Ignoring the variation of resistance with temperature, the ratio of the diameter of A to that of B is:

A) 2
B) 1
C) 1/2
D) 1/4
E) 4

Ans:

$$R = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2} = \frac{\rho L}{\pi (D/2)^2} = \frac{4\rho L}{\pi D^2}$$

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$$

$$\frac{4\rho L}{\pi D^2} = \frac{V^2}{P} \Rightarrow D^2 = \frac{4\rho LP}{\pi V^2}$$

$$\Rightarrow D = K.\sqrt{P}\ (K = \text{constant})$$

$$\Rightarrow \frac{D_A}{D_B} = \sqrt{\frac{P_A}{P_B}} = \sqrt{\frac{400}{100}} = 2$$

Q12.

A light bulb has a tungsten filament with a resistance of 18.0 Ω at 20.0 °C. It is connected to a 120 V source. When operational, it dissipates a power of 100 W. What is the operational temperature of the filament? Assume that the dimensions of the filament do not change. The temperature coefficient of resistivity of tungsten is $4.50 \times 10^{-3}\ (^{o}C)^{-1}$.

A) 1850 K
B) 2880 K
C) 1110 K
D) 1280 K
E) 2930 K

Ans:

$$R_f = \frac{V^2}{P} = \frac{(120)^2}{100} = 144\ \Omega$$

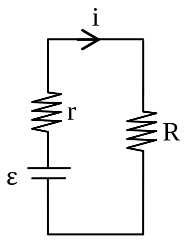
$$\Delta R = \alpha . R_0 . \Delta T \Rightarrow \Delta T = \frac{\Delta R}{\alpha . R_0} = \frac{144 - 18}{4.5 \times 10^{-3} \times 18} = 1555.56\ K$$

$$T_f = T_o + \Delta T = 293.15 + 1555.56 = 1848.71 \rightarrow 1850\ K$$

Q13.

A 45 Ω resistor is connected across the terminals of a 10 V battery. If a current of 0.20 A flows through the 45 Ω resistor, what is the internal resistance of the battery?

A) 5 Ω
B) 3 Ω
C) 9 Ω
D) 8 Ω
E) 7 Ω



Ans:

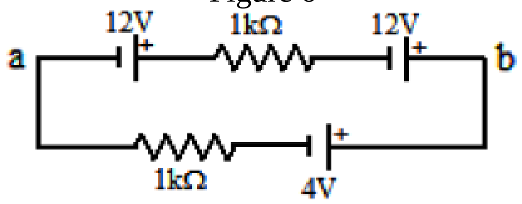
$$i = \frac{\varepsilon}{r + R} \Rightarrow r + R = \frac{\varepsilon}{i} = \frac{10}{0.20} = 50\ \Omega$$

$$r = 50 - R = 50 - 45 = 5\ \Omega$$

Q14.

The absolute value of the potential difference between points ***a*** and ***b*** in the **Figure 6** is:

Figure 6



A) 14 V
B) 21 V
C) 41 V
D) 11 V
E) 19 V

Ans:

$R_{eq} = 2\ k\Omega$

$\varepsilon_{net} = 12 + 12 - 4 = 20\ V$

$i = \frac{\varepsilon_{net}}{R_{eq}} = \frac{20}{2 \times 10^3} = 1 \times 10^{-2} A$

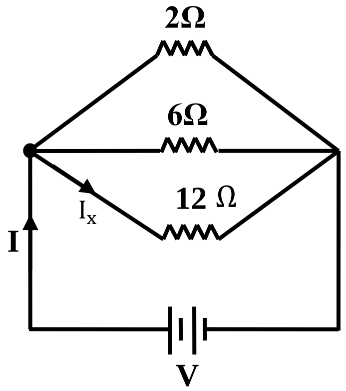
$V_a + 12 - (1 \times 10^3 \times 1 \times 10^{-2}) + 12 = V_b \Rightarrow V_a - V_b = -24 + 10 = -14\ V$

$|V_a - V_b| = 14\ V$

Q15.

Three resistors of resistances 2 Ω, 6 Ω and 12 Ω are connected to a battery, as shown in **Figure 7**. If the total current through the circuit is *I* = 5 A, what is the current through the 12 Ω resistor?

Figure 7



A) 0.6 A
B) 0.3 A
C) 0.1 A
D) 0.2 A
E) 0.9 A

Ans:

$$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{6} + \frac{1}{12} = \frac{6+2+1}{12} = \frac{9}{12}$$

$$\Rightarrow R_{eq} = \frac{12}{9} = \frac{4}{3}\ \Omega$$

$$\varepsilon = I.R_{eq} = \frac{5 \times 4}{3} = \frac{20}{3}\ V$$

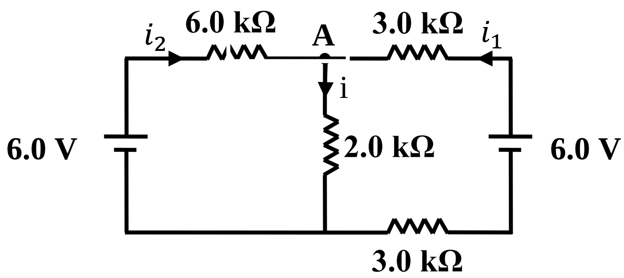
Now, consider the loop containing 12 Ω and ε:

$$+\varepsilon - 12\ I_x = 0 \Rightarrow I_x = \frac{\varepsilon}{12} = \frac{1}{12} \times \frac{20}{3} = \frac{20}{36} = 0.555\ A \Rightarrow 0.6\ A$$

Q16.

In the multi-loop circuit shown in **Figure 8**, the current through the 2.0 kΩ resistor is:

Figure 8



A) 1.2 mA
B) 3.1 mA
C) 1.9 mA
D) 0.7 mA
E) 2.5 mA

Ans:

Take the big outer loop:

$$+6.0 - 600\mathrm{i}_2 + 6000\mathrm{i}_1 - 6.0 = 0 \implies \mathrm{i}_1 = \mathrm{i}_2$$

$$\text{At junction A: } \mathrm{i} = \mathrm{i}_1 + \mathrm{i}_2 = 2\mathrm{i}_2 \implies \mathrm{i}_2 = \frac{\mathrm{i}}{2}$$

Now, take the left loop:

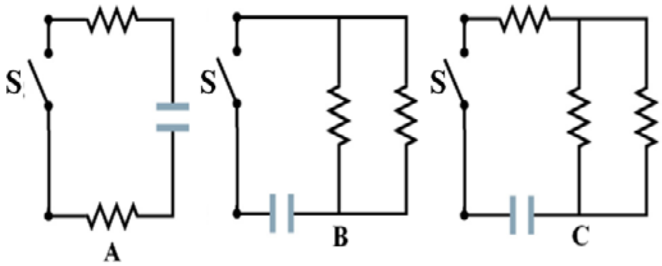
$$6 - 6000\,\mathrm{i}_2 - 2000\,\mathrm{i} = 0$$
$$6 - 3000\,\mathrm{i} - 2000\,\mathrm{i} = 0$$

$$\Rightarrow \mathrm{i} = \frac{6}{5000} = 1.2 \times 10^{-3}\mathrm{A}$$

Q17.

In the circuits shown in **Figure 9**, all the capacitors have the same capacitance and initial charge, and all the resistors have the same resistance. At time t = 0, switch S is closed such that each capacitor discharges through its resistors network. Rank the time taken for discharging the capacitor to have its initial charge, **shortest** time first.

Figure 9



A) B, C, A
B) C, B, A
C) A, C, B
D) C, A, B
E) B, A, C

Ans:

$$\tau = RC \longrightarrow \text{shortest } \tau \Rightarrow \text{smallest R}$$

$$\left.\begin{aligned} &A: R = 2R \\ &B: R = \frac{R}{2} \\ &C: R = \frac{3R}{2} \end{aligned}\right\} \therefore \text{B has the shortest time then C then A}$$

Q18.

A particle (mass = 6.0 $\times 10^{-6}$ kg) moves in the xy plane with a speed of 4.0 km/s in a direction that makes an angle of 37^{o} above the positive *x* axis. At the instant it enters a magnetic field of $(5.0\hat{i})$ mT, it experiences an acceleration of $(8.0\hat{k})$ m/s^2. What is the charge of the particle? Ignore the gravitational force on the particle.

A) – 4.0 μC
B) – 4.8 μC
C) + 4.0 μC
D) + 4.8 μC
E) – 5.0 μC

Ans:

$$\vec{F} = m\vec{a} = 6.0 \times 10^{-6} \times 8.0\,\hat{k} = 48 \times 10^{-6}\hat{k}\ (N)$$

$$\vec{v} \times \vec{B} = -(4.0 \times 10^{3} \times 5.0 \times 10^{-3} \times \sin 37°)\hat{k} = -12\,\hat{k}\ (N)$$

$\vec{F} = q\,(\vec{v} \times \vec{B})$: thus q = (48×10^{-6}) / (– 12) = – 4.0 μC

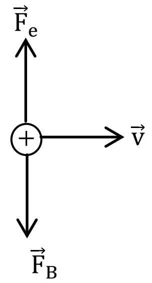
Q19.

A region of space contains perpendicular uniform electric and magnetic fields, with the electric field pointing in the positive y direction. In this region, a proton travels in the positive *x* direction with constant velocity. What is the direction of the magnetic field?

A) + *z* direction
B) – *z* direction
C) + *y* direction
D) – *y* direction
E) – *x* direction

Ans:

A



Q20.

A proton moves around a circular path (radius = 2.0 mm) in a uniform 0.25 T magnetic field. What total distance does this proton travel during a 1.0-s time interval?

A) 48 km
B) 82 km
C) 71 km
D) 59 km
E) 7.5 km

Ans:

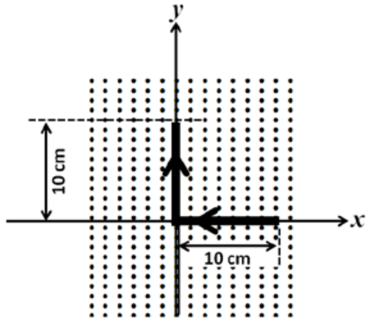
$$qvB = \frac{mv^2}{R} \Rightarrow v = \frac{qBR}{m}$$

$$S = v.t = \frac{qBRt}{m} = \frac{1.6 \times 10^{-19} \times 0.25 \times 2.0 \times 10^{-3} \times 1.0}{1.67 \times 10^{-2}} = 48\ km$$

Q21.

A straight 20-cm wire is bent at its midpoint so as to form an angle of 90^o, as shown in **Figure 10**, and carries a current of 10 A. It lies in the *xy* plane in a region where the magnetic field is in the positive *z* direction and has a constant magnitude of 3.0 mT. What is the magnitude of the total magnetic force on this wire?

Figure 10



A) 4.2×10^{-3} N
B) 3.2×10^{-3} N
C) 5.3×10^{-3} N
D) 2.1×10^{-3} N
E) 6.0×10^{-3} N

Ans:

Portion on the x − axis:

$$\vec{F}_1 = (iL_1B)\hat{j} = 10 \times 0.1 \times 3.0 \times 10^{-3}\hat{j} = 3.0 \times 10^{-3}\hat{j}\ (N)$$

Portion on the y − axis:

$$\vec{F}_2 = (iL_2B)\hat{i} = 3.0 \times 10^{-3}\hat{i}\ (N)$$

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 = (\hat{i} + \hat{j}) \times 3.0 \times 10^{-3}\ (N)$$

$$F_{net} = \sqrt{1+1} \times 3.0 \times 10^{-3} = 4.2 \times 10^{-3}\ N$$

Q22.

A loop of radius *r* = 5.00 cm, carrying a current *I* = 0.200 A, is placed inside a magnetic field $\vec{B} = 0.300\hat{i}$ (T). The normal to the loop is parallel to a unit vector $\hat{n} = -0.600\hat{i} - 0.800\hat{j}$. Calculate the magnitude of the torque on the loop.

A) 3.78×10^{-4} N.m
B) 1.13×10^{-4} N.m
C) 0.600×10^{-4} N.m
D) 4.72×10^{-4} N.m
E) Zero

Ans:

$$\vec{\mu} = N\ iA\hat{n} = N\ i\pi r^2\hat{n} = 1 \times 0.200 \times \pi \times 25 \times 10^{-4} \times (-0.6\hat{i} - 0.80\hat{j})$$

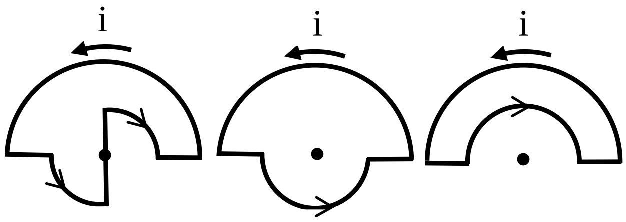
$$= -9.42 \times 10^{-4}\hat{i} - 1.26 \times 10^{-3}\hat{j}\ (A.m^2)$$

$$\vec{\tau} = \vec{\mu} \times \vec{B} = +3.78 \times 10^{-4}\ \hat{k}\ (N.m)$$

Q23.

Figure 11 shows three circuits consisting of straight radial lengths and concentric circular arcs (either half- or quarter-circles of radii *r* or *2r*). The circuits carry the same current in the indicated direction. Rank the circuits according to the magnitude of the magnetic field produced at the center of curvature (the dot), greatest first.

Figure 11



A) B2, B1, B3
B) B1, B2, B3
C) B3, B2, B1
D) B2, B3, B1
E) B1, B3, B2

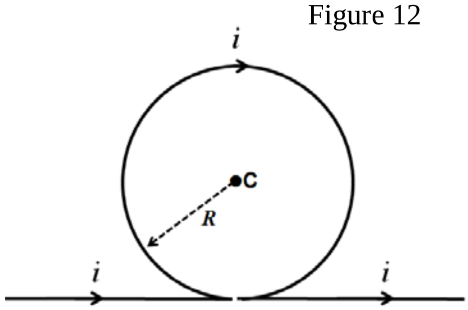
Ans:

1: Contribution from the big circle only
2: Contribution from both circles
3. Inner circle cancels some of the outer

Q24.

A wire is bent as shown in **FIGURE 12**, and carries a current *i* = 15 mA along the indicated directions. What is the magnitude of the magnetic field at the center of the loop, C, if the radius of the loop is *R* = 5.0 cm?

Figure 12



A) 1.3×10^{-7} T
B) 3.3×10^{-6} T
C) 1.1×10^{-8} T
D) 3.1×10^{-7} T
E) 5.3×10^{-8} T

Ans:

$$\text{Straight: } B_1 = \frac{\mu_0 i}{2\pi R} = \frac{4\pi \times 10^{-7} \times 15 \times 10^{-3}}{2\pi \times 5.0 \times 10^{-2}} = 6.0 \times 10^{-8}\ \text{T}$$

→ Out of page

$$\text{Circle: } B_2 = \frac{\mu_0 i \phi}{4\pi R} = \frac{4\pi \times 10^{-7} \times 15 \times 10^{-3} \times 2\pi}{4\pi \times 5.0 \times 10^{-2}} = 18.8 \times 10^{-8}\ \text{T}$$

→ Into page

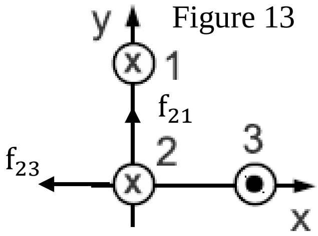
$B_c = B_2 - B_1 = 12.8 \times 10^{-8}$ T → into the page

Q25.

Three long wires have currents flowing perpendicular to the page with directions as indicated in **FIGURE 13**. Wire 1 is at y = 2.0 m on the y-axis, wire 2 is located at the origin, and wire 3 is at x = 2.0 m on the x-axis. If I_1 = 1.0 A, I_2 = 2.0 A, and I_3 = 3.0 A, what is the magnitude of the net force per unit length on wire 2 due to the other two wires?

A) 6.3×10^{-7} N/m
B) 5.3×10^{-5} N/m
C) 5.3×10^{-9} N/m
D) 3.6×10^{-7} N/m
E) 1.3×10^{-7} N/m

Figure 13



Ans:

f = force per unit lenght

$$f_{21} = \frac{\mu_0 I_1 I_2}{2\pi d} = \frac{4\pi \times 10^{-7} \times 1.0 \times 2.0}{2\pi \times 2.0} = 2.0 \times 10^{-7}\ \frac{N}{m}$$

$$f_{23} = \frac{\mu_0 I_2 I_3}{2\pi d} = \frac{4\pi \times 10^{-7} \times 2.0 \times 3.0}{2\pi \times 2.0} = 6.0 \times 10^{-7}\ \frac{N}{m}$$

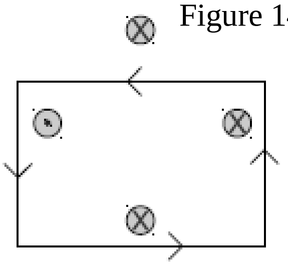
$$f_{2,net} = \sqrt{4.0 + 36} \times 10^{-7} = 6.3 \times 10^{-7}\ \frac{N}{m}$$

Q26.

Each of the four wires in **Figure 14** carries a 2.0 A current into or out of the page. What is the value of the line integral $\oint \vec{\mathbf{B}}.d\vec{\mathbf{s}}$ for the indicated path of integration?

A) -2.5×10^{-6} T.m
B) $+2.5 \times 10^{-6}$ T.m
C) -1.5×10^{-7} T.m
D) $+1.5 \times 10^{-7}$ T.m
E) $+5.5 \times 10^{-6}$ T.m

Figure 14



Ans:

$$i_{enc} = +2.0 - 2.0 - 2.0 = -2.0\ A$$

$$\oint \vec{B}.d\vec{s} = \mu_0.\ i_{enc} = -2.5 \times 10^{-6}\ (T.m)$$

Q27.

A solenoid with N turns carries a current of 12 A and has a length of 43 cm. If the magnitude of the magnetic field generated at the center of the solenoid is 90 mT, what is the value of *N*?

A) 2.6×10^3
B) 1.9×10^3
C) 2.2×10^3
D) 1.1×10^3
E) 1.7×10^3

Ans:

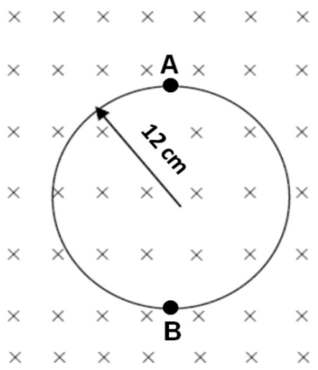
$$B = \mu_0 n i = \frac{\mu_0 N i}{L}$$

$$\Rightarrow N = \frac{BL}{\mu_0 i} = \frac{90 \times 10^{-3} \times 43 \times 10^{-2}}{4\pi \times 10^{-7} \times 12} = 2.6 \times 10^3$$

Q28.

A flexible loop has a radius of 12.0 cm and is placed with its plane perpendicular to a uniform magnetic field of magnitude 0.150 T, as shown in **Figure** 3. The loop is grasped at points A and B and stretched at constant rate until its area is zero. If it takes 0.300 s to stretch the loop, what is the magnitude of the induced emf during this time interval?

Figure 3



A) 22.6 mV
B) 6.31 mV
C) 2.76 mV
D) 63.1 mV
E) 16.3 mV

Ans:

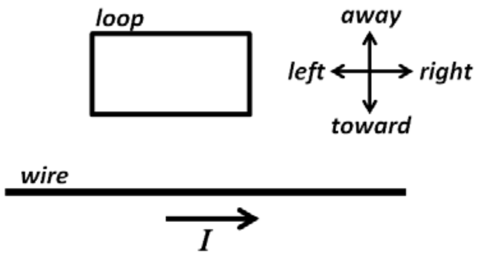
$$\varepsilon_{ind} = \frac{d\phi_B}{dt} = \frac{d}{dt}(BA) = B\frac{dA}{dt} = B.\frac{\Delta A}{\Delta t}$$

$$= \frac{(B)(\pi r^2)}{\Delta t} = \frac{0.150 \times \pi \times 144 \times 10^{-4}}{0.300} = 22.6 \text{ mV}$$

Q29.

A conducting loop is placed near a long straight wire carrying a constant current *I*, as shown in **Figure** 4. Which of the following actions will induce a counterclockwise current in the loop?

Figure 4



A) Moving it up away from the wire ✓
B) Moving it toward the wire clockwise
C) Moving it to the right (parallel to the wire) No change
D) Moving it to the left (parallel to the wire) No change
E) Rotating it through an axis that coincides with the wire No change

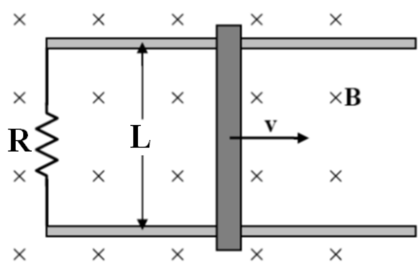
Ans:

A

Q30.

Figure 5 shows a metallic bar being moved to the right on two conducting parallel rails in a uniform magnetic field of magnitude 2.5 T, directed into the page. If *R* = 6.0 Ω, and *L* = 1.2 m, what is the magnitude of the applied force required to move the bar at a constant speed of 2.0 m/s?

Figure 5



A) 3.0 N
B) 5.0 N
C) 2.0 N
D) 4.0 N
E) 6.0 N

Ans:

$$\varepsilon_{ind} = BLv = 2.5 \times 1.2 \times 2.0 = 6.0\ V$$

$$i = \frac{\varepsilon_{ind}}{R} = \frac{6.0}{6.0} = 1.0\ A$$

$$F = iLB = 1.0 \times 1.2 \times 2.5 = 3.0\ N$$
