Q1.

A sinusoidal wave travels along a stretched string. A particle on the string has a maximum transverse speed of 2.0 m/s and a maximum transverse acceleration of 2.0×10^2 m/s^2. What is the frequency of the wave?

A) 16 Hz
B) 32 Hz
C) 8.0 Hz
D) 64 Hz
E) 12 Hz

Ans:

$$|v_{max}| = \omega x_m \,, \qquad |a_{max}| = \omega^2 x_m$$

$$\omega = \frac{|a_{max}|}{|v_{max}|} = \frac{2\times10^2}{2} = 100 \text{ Hz}$$

$$\Rightarrow \quad f = \frac{\omega}{2\pi} = 15.9 \text{ Hz}$$

Q2.

A cord of mass 0.65 kg is stretched between two supports 28 m apart. The tension in the cord is 1.5×10^2 N. How long will it take a pulse to travel from one support to the other?

A) 0.35 s
B) 0.21 s
C) 0.14 s
D) 0.42 s
E) 0.57 s

Ans:

$$v = \sqrt{\frac{\tau}{\mu}} = \sqrt{\frac{T}{m/l}} = \sqrt{\frac{1.5\times 10^2}{(0.65/28)}} = 80.4 \text{ m/s}$$

$$t = \frac{L}{v} = 0.35 \text{ s}$$

Q3.

The average power output of a sound point source is 2.5 mW. What is the sound level at a distance of 5.0 m from the source?

A) 69 dB
B) 76 dB
C) 56 dB
D) 86 dB
E) 45 dB

Ans:

$$I = \frac{P}{A} = \frac{P}{4\pi r^2} = 7.96 \times 10^{-6}\ \mathrm{W/m^2}$$

$$\beta = 10 \log\left(\frac{I}{I_0}\right) = 69\ \mathrm{dB}$$

Q4.

A pipe 0.60 m long and closed at one end is filled with an unknown gas. The third lowest harmonic frequency for the pipe is 750 Hz. Find the fundamental frequency for this pipe filled with the unknown gas.

A) 150 Hz
B) 250 Hz
C) 100 Hz
D) 120 Hz
E) 130 Hz

Ans:

$$\text{third lowest} \Rightarrow n = 5$$

$$f_1 = \frac{v}{4L}\ ;\ f_5 = \frac{5v}{4L} = 750 = 5f_1 \implies f_1 = 150\ \mathrm{Hz}$$

Q5.

A 2.0 kg ice cube, initially at a temperature of $-20\ ^{o}\mathrm{C}$, absorbs heat at a rate of 22 kJ/min. How much time is needed to just melt the cube? (c_{ice} = 2220 J/kg.K)

A) 34 min
B) 57 min
C) 17 min
D) 20 min
E) 44 min

Ans:

$$Q_{tot} = mC\Delta T + mL_f = 754800\ \mathrm{J}$$

$$t = 34.3\ \mathrm{min}$$

Q6.

A cylinder contains 23 moles of a monatomic ideal gas at a temperature of 300 K. The gas is compressed at constant pressure until the final volume equals 0.43 times the initial volume. The heat transferred from the gas in this process is

A) 82 kJ
B) 94 kJ
C) 130 kJ
D) 64 kJ
E) 33 kJ

Ans:

$$nRT_1 = P_1V_1$$

$$nRT_2 = P_1V_2$$

$$\frac{T_2}{T_1} = \frac{V_2}{V_1} = 0.43 \Rightarrow T_2 = 0.43T_1 = 129\text{ K}$$

$$Q = nC_p\Delta T$$

$$= 23 \times \frac{5}{2} R\,(129 - 300) = -81.7\text{ kJ}$$

Q7.

An ideal gas in a cylinder is thermally insulated from all sides except from one side where it is in thermal contact with a heat reservoir at a temperature *T*. A force *F* compresses the gas from a volume V_i to a volume V_f. Which one of the following statements is **TRUE**?

A) The work done on the gas is equal to the heat transferred from the gas.
B) The work done by the gas is positive.
C) Heat flows into the gas.
D) The pressure of the gas will decrease.
E) The molar specific heat is decreased

Ans:

A

Q8.

Consider the following processes: The temperature of two identical ideal gases having the same number of moles is increased from the same initial temperature to the same final temperature. Reversible processes are used. For gas A the process is carried out at constant volume while for gas B it is carried out at constant pressure. The change in the entropy of gas A is

A) less than that of B
B) greater than that of B
C) equal to that of B
D) twice that of B
E) three times that of B

Ans:

$$\Delta S_A = nC_v \ln\left(\frac{T_f}{T_i}\right)$$

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

$$C_v < C_p \Rightarrow \Delta S_A < \Delta S_B$$

Q9.

A charged particle (mass = 5.0 g and charge = 4.9 μC) is shot horizontally with an initial velocity $2.0\hat{i}$ km/s between two plates where the electric field is $\vec{E} = 1.0\times10^4\ \hat{j}$ N/C (vertical). What will be the velocity of the particle after moving for two seconds between the plates?

A) $2.0\hat{i}$ km/s
B) $2.0\hat{j}$ km/s
C) $2.0\hat{i} + 2.0\hat{j}$ km/s
D) 0
E) $2.0\hat{i} - 2.0\hat{j}$ km/s

Ans:

$$F_{net} = qE - mg$$

$$= 4.9 \times 10^{-6} \times 1 \times 10^{4} - \frac{5}{1000} \times 9.8 = 0$$

No change in the velocity of the particle.

Q10.

A spherical conducting shell has a net charge of −10 μC. When a charge Q is placed at its center, the charge on the outer surface of the shell becomes −14 μC. Find Q.

A) − 4.0 μC
B) + 4.0 μC
C) + 14 μC
D) – 14 μC
E) − 24 μC

Ans:

$$q_{net} = q_{in} + q_{out} = -10\ \mu C$$

$$q_{in} = q_{net} - q_{out} = -10 - (-14) = 4\mu C$$

$$\Rightarrow Q = -4\mu C\ (E = 0 \text{ inside the shell})$$

Q11.

A charge Q is uniformly distributed through the volume of a non-conducting solid sphere of radius 10 cm. If the electric field 5.0 cm from the center of the sphere is 3.0×10^3 N/C and is directed radially inward, find the charge Q on the sphere.

A) – 6.7 nC
B) + 6.7 nC
C) + 3.7 nC
D) – 3.7 nC
E) + 2.3 nC

Ans:

$$E = \frac{kQ_r}{R^3} \Rightarrow Q = E = \frac{R^3}{kr} = 6.67 \times 10^{-9}\ C$$

Negative sign becaue E is directed inward

Q12.

Point A with coordinates (2,3) and point B with coordinates (1,4) are in a region where there is a uniform electric field $\vec{E} = 3\hat{i} + 2\hat{j} + 5\hat{k}$ N/C. Find $V_A - V_B$.

A) – 1 V
B) + 5 V
C) + 1 V
D) – 5 V
E) + 3 V

Ans:

$$V_A - V_B = -\int_B^A E.ds = -\vec{E}\ [(2-1)\hat{\imath} + (3-4)\hat{\jmath}] = -[3-2] = -1\ V$$

Q13.

Two capacitors C_1 = 10 μF and C_2 = 50 μF are connected in series. The maximum potential difference that can be applied to each capacitor without failure is 200 V. What is the maximum energy that can be stored in the combination?

A) 0.24 J
B) 0.45 J
C) 0.32 J
D) 3.0 J
E) 1.5 J

Ans:

Charge is same on both so $C_1V_1 = C_2V_2$

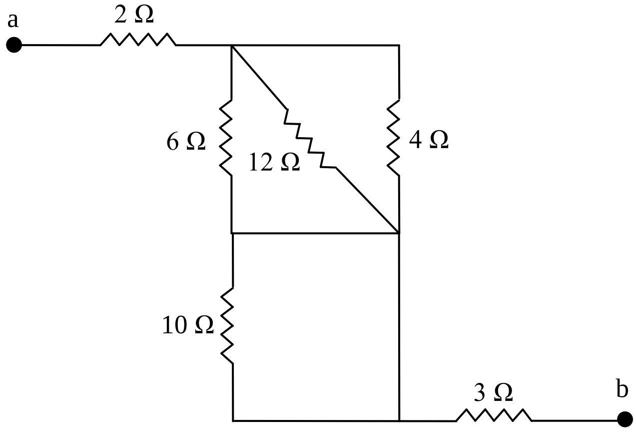
Maximum possible voltage is $V_1 = 200\text{ V} \Rightarrow V_2 = 40\text{ V}$

$\Rightarrow E = \frac{1}{2}C_1{V_1}^2 + \frac{1}{2}C_2{V_2}^2 = 0.24\text{ J}$

Q14.

Find the equivalent resistance between points a and b in Figure 1.

Figure # 1



A) 7.0 Ω
B) 6.3 Ω
C) 13 Ω
D) 2.5 Ω
E) 3.0 Ω

Ans:

The resistors 6 Ω, 12 Ω and 4 Ω are in parallel.

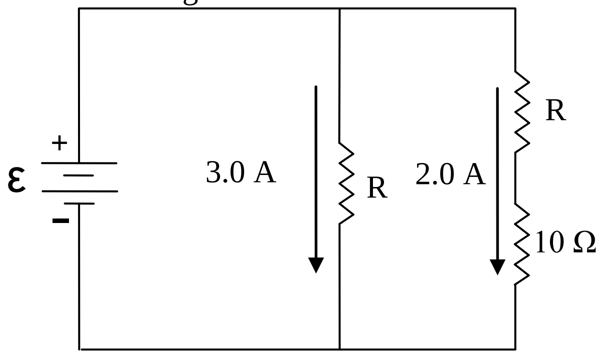
The 10 Ω will not contribute.

$$R_{eq} = 2 + \left(\frac{1}{6} + \frac{1}{12} + \frac{1}{4}\right)^{-1} + 3 = 7\Omega$$

Q15.

What are the resistance R and the emf ε of the battery in Figure 2.

Figure # 2



A) R= 20 Ω, ε = 60 V
B) R= 10 Ω, ε = 60 V
C) R= 10 Ω, ε = 30 V
D) R= 20 Ω, ε = 50 V
E) R= 15 Ω, ε = 45 V

Ans:

$$3R - 2\,(R + 10) = 0$$

$$3R - 2R - 20 = 0 \Rightarrow R = 20\ \Omega$$

$$\varepsilon - 3R = 0 \Rightarrow \varepsilon = 3R = 60\ V$$

Q16.

A 1.0 μF capacitor with an initial stored energy of 0.50 J is discharged through 1.0 MΩ resistor. Find the charge on the capacitor at t = 0.40 s.

A) 6.7×10^{-4} C
B) 3.7×10^{-4} C
C) 1.3×10^{-4} C
D) 9.4×10^{-4} C
E) 7.3×10^{-4} C

Ans:

$$Q = Q_0\, e^{-t/RC}$$

$$U_0 = \frac{1}{2}\frac{Q_0^{\ 2}}{C} \Longrightarrow Q_0 = \sqrt{2CU_0}$$

$$Q = \sqrt{2CU_0}\, e^{-t/RC} = 6.7 \times 10^{-4}\ C$$

Q17.

For a capacitor which is being charged, which one of the following statements is **FALSE**?

A) Initially (at t = 0) the capacitor acts like a broken wire in the circuit.
B) Initially (at t = 0) the capacitor acts like ordinary conducting wire.
C) After a long time the potential across the capacitor is equal to the emf of the battery.
D) Initially the current through the capacitor is maximum.
E) Initially (at t = 0) the potential difference across the capacitor is equal to zero.

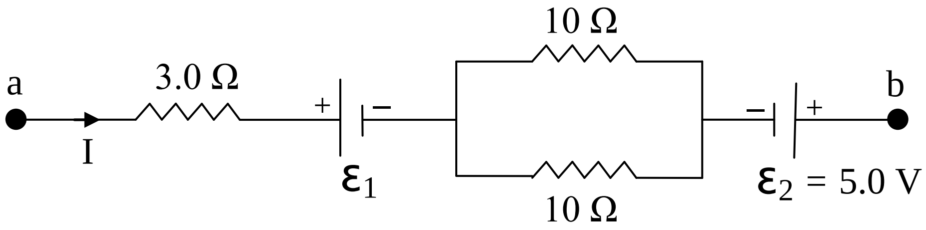
Ans:

A

Q18.

In Figure 3, the potential difference between points a and b is $(V_b - V_a) = -20$ V, the current I = 2.0 A, and $\varepsilon_2 = 5.0$ V. Find ε_1

Figure # 3



A) 9.0 V
B) 21 V
C) 1.0 V
D) 10 V
E) 15 V

Ans:

$$V_a - IR - \varepsilon_1 - 5I + 5 = V_b$$

$$V_b - V_a = -3I - \varepsilon_1 - 5I + 5 = -20$$

$$\varepsilon_1 = -8I + 5 + 20 = 9\text{ V}$$

Q19.

A proton and an alpha particle (q = +2e, m = 4.0 u) both having the same kinetic energy enter a region of uniform magnetic field B, moving perpendicular to B. What is the ratio of the radius of the proton orbit to the radius of the alpha particle orbit? (u is the mass of the proton)

A) 1.0
B) 2.0
C) 0.50
D) 3.0
E) 2.5

Ans:

$$vB = \frac{mv^2}{r} \Rightarrow \frac{1}{2}mv^2 = K = q_v B_r$$

$$K = q_p v_p B r_p = q_a v_a B r_a \Rightarrow \frac{r_p}{r_a} = \frac{q_a v_a}{q_p v_p}$$

$$\frac{q_a}{q_p} = 2\,, \frac{v_a}{v_p} = \sqrt{\frac{m_p}{m_a}} = \frac{1}{2}$$

$$\Rightarrow \frac{r_p}{r_a} = 1$$

Q20.

At one instant an electron is moving in the xy plane, the components of its velocity being $v_x = 5.0\times10^5$ m/s and $v_y = 3.0\times10^5$ m/s. A magnetic field of 0.80 T is in the positive x direction. At that instant the magnitude of the magnetic force on the electron is:

A) 3.8×10^{-14} N
B) 2.6×10^{-14} N
C) 0
D) 6.4×10^{-14} N
E) 1.0×10^{-13} N

Ans:

$$\vec{v} = 5 \times 10^5\,\hat{\imath} + 3 \times 10^5\hat{\jmath}\,\frac{m}{s}, \qquad \vec{B} = 0.8\,\hat{\imath}$$

$$\vec{F} = q\vec{v} \times \vec{B}$$

$$= e\,(-0.8 \times 3 \times 10^5)\hat{k} = 3.84 \times 10^{-14}\ \text{N}\ \hat{k}$$

Q21.

A single square shape loop of wire having a side of 4.0 m lies in the x-z plane. The loop carries a current of 0.40 A in the counterclockwise direction. The loop is located in a magnetic field given by $\vec{B} = 0.25\,\hat{i} + 0.50\,\hat{j} - 0.80\,\hat{k}$ T. Find the torque on the loop.

A) $-5.1\,\hat{i} - 1.6\,\hat{k}$ N.m
B) $+4.3\,\hat{i} + 4.3\,\hat{j}$ N.m
C) $+1.4\,\hat{j} - 3.8\,\hat{k}$ N.m
D) $+2.1\,\hat{j} + 5.6\,\hat{k}$ N.m
E) $+8.2\,\hat{i} - 3.2\,\hat{k}$ N.m

Ans:

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

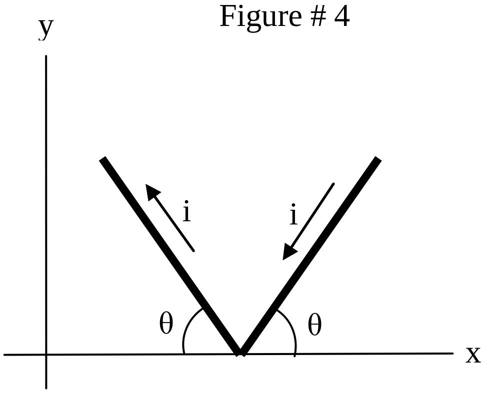
$\vec{\mu} = 6.4\,\hat{j}$

$\Rightarrow \tau = -5.1\hat{\imath} - 1.6\,\hat{k}$

Q22.

A wire is bent as shown in Figure 4. It lies in a uniform magnetic field $\vec{B} = 4.0\,\hat{k}$ T. Each wire section is 2.0 m long and makes an angle of $\theta = 60^o$ with the x-axis, and the wire carries a current of 2.0 A. What is the the net magnetic force on the wire? (the positive z-axis is out of the page).

Figure # 4



A) $+16\,\hat{j}$ N
B) $+28\,\hat{j}$ N
C) $-28\,\hat{i}$ N
D) $-16\,\hat{j}$ N
E) Zero

Ans:

$F = iL \times B$. On each segment, the force has two components. The horizontal components cancel out but the vertical components add up.

$\vec{F} = 2(iLB)\sin 30^\circ\ \hat{\jmath}$

$= 16\,\hat{\jmath}\,N$

Q23.

A proton accelerates from rest through a potential of 16.0 kV. It then enters a velocity selector, consisting of a parallel plate capacitor and a magnetic field. Between the capacitor plates the electric field is 3.10×10^5 N/C. What is the magnetic field needed so that the proton will pass through the region without deflection?

A) 0.177 T
B) 0.500 T
C) 0.250 T
D) 0.635 T
E) 0.050 T

Ans:

$$v = \frac{E}{B} \Rightarrow B = \frac{E}{v}$$

$$\frac{1}{2}mv^2 = eV \Longrightarrow v = 1.75 \times 10^6 \text{ m/s}$$

$$B = \frac{E}{v} = 0.177 \text{ T}$$

Q24.

A long, straight, cylindrical conductor of radius R = 12.0 mm carries a current I uniformly distributed over its cross section. If the magnitude of the magnetic field produced at a distance r = 24.0 mm is 0.100 mT, then what is the magnitude of the magnetic field at a distance r = 6.00 mm?

A) 0.100 mT
B) 0.050 mT
C) 0.400 mT
D) 0.200 mT
E) 0.440 mT

Ans:

$$B_0 = \frac{\mu_0 i}{2\pi r}\text{, at r} = 24\text{ mm}; \quad B = 0.1\times10^{-3} = \frac{4\pi\times10^{-7}}{2\pi\left(\frac{24}{1000}\right)^2} \Rightarrow i = 12\text{ A}$$

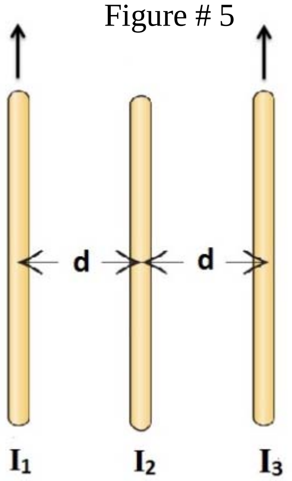
$$B_i = \frac{\mu_0 i}{2\pi R^2} r = \frac{4\pi\times10^{-7}\times12}{2\pi\left(\frac{12}{1000}\right)^2}\times\left(\frac{6}{1000}\right) = 1\times10^{-4} = 0.1\text{ mT}$$

Q25.

Figure 5 shows three parallel wires separated by a distance d = 0.44 m. The currents are I_1= 8.54 A and I_3= 6.51 A. Calculate the magnitude and the direction of the current I_2 such that the net force per unit length exerted by wire 1 and wire 2 on wire 3 is zero?

A) 4.27 A downward
B) 3.26 A downward
C) 2.81 A upward
D) 5.81 A downward
E) 7.54 A upward

Figure # 5



Ans:

$$\frac{F_{13}}{l} + \frac{F_{23}}{l} = 0$$

$$\Rightarrow \frac{\mu_0 I_1 I_s}{2\pi(2d)} + \frac{\mu_0 I_2 I_s}{2\pi d} = 0$$

$$\Rightarrow \frac{I_1}{2} = -I_2 \Rightarrow I_2 = 4.27\text{ A downward}$$

Q26.

Two long ideal solenoids with radii 20 mm and 30 mm have the same number of turns per unit length. The smaller solenoid is mounted inside the larger one, along a common axis. The net magnetic field within the inner solenoid is zero. The current in the inner solenoid must be:

A) the same as the current in the outer solenoid
B) one-third the current in the outer solenoid
C) twice the current in the outer solenoid
D) half the current in the outer solenoid
E) two-thirds the current in the outer solenoid

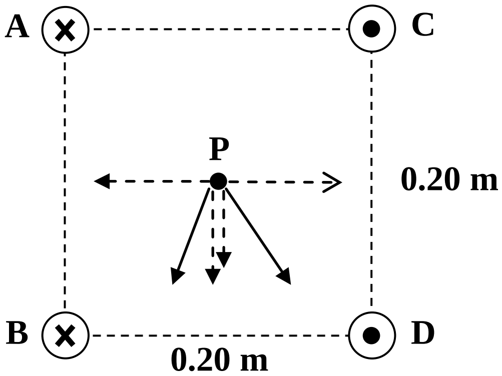
Ans:

A

Q27.

Four long, parallel wires carry equal currents I = 5.0 A as shown in Figure 6. Currents in wire A and wire B are directed into the page while currents in wire C and wire D are out of the page. Calculate the magnitude and direction of the net magnetic field at point P, located at the center of the square with edge of length 0.20 m.

Figure # 6



A) 20 μT toward the bottom of the page
B) 10 μT toward the left of the page
C) 30 μT toward the right of the page
D) 40 μT toward the top of the page
E) 0

Ans:

The horizontal components of the net magnetic field will cancel out the vertical components (downward) will add up.

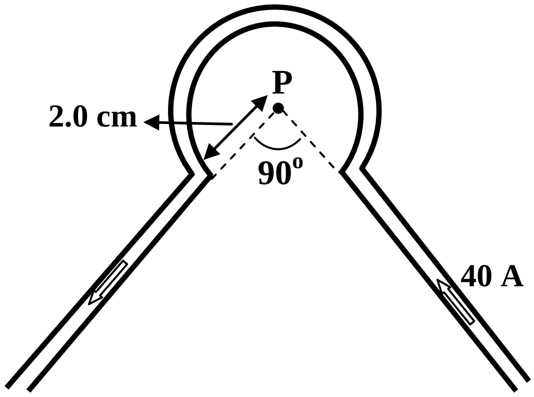
$$B = 4\left(\frac{\mu_0 i}{2\pi r}\right)\cos 45^\circ$$

$$= 4\left(\frac{4\pi \times 10^{-7} \times 5}{2\pi \times \sqrt{2}\,(0.1)}\right)\cos 45^\circ = 2 \times 10^{-5}\ \mathrm{T} = 20\mu\mathrm{T}$$

Q28.

The wire shown in Figure 7 carries a current of 40 A. Find both the magnitude and the direction of the magnetic field at point P.

Figure # 7



A) 0.94 mT out of the page
B) 0.94 mT into the page
C) 1.21 mT out of the page
D) 1.21 mT into the page
E) 0.51 mT into the page

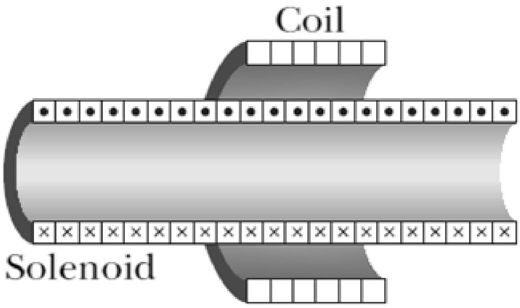
Ans:

$$B = \frac{\mu_0 i}{4\pi R}\varphi = \frac{(4\pi \times 10^{-7})(40)}{4\pi(0.02)}\frac{3\pi}{2} = 9.4 \times 10^{-4} = 0.94 \text{ mT out of the page}$$

Q29.

A 200 turn coil of radius 2.2 cm and resistance 5.5 Ω is coaxial with a solenoid of 300 turns/cm and radius 1.6 cm (see Figure 8). The solenoid current drops from 1.5 A to 0.50 A in 20 ms. What is the current induced in the coil during this time interval?

Figure # 8



A) 0.055 A
B) 0.024 A
C) 1.1 A
D) 0.92 A
E) 0.24 A

Ans:

$$\varepsilon = \frac{d\phi}{dt} = N_c A_s \mu_0 n \frac{dv}{dt}$$

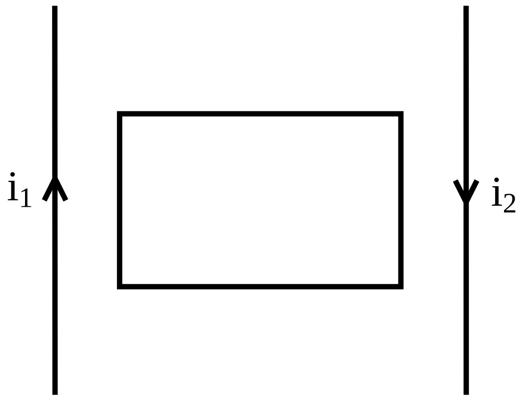
$$= 200 \times \pi \times \left(\frac{1.6}{100}\right)^2 \times 4\pi \times 10^{-7} \times (300 \times 100) \times \frac{1.5 - 0.5}{20 \times 10^{-3}} = 0.303 \text{ v}$$

$$\Rightarrow i = \frac{\varepsilon}{R} = 0.055 \text{ A}$$

Q30.

A rectangular loop of wire is placed midway between two long straight parallel conductors as in Figure 9. The conductors carry currents i_1 and i_2 which are antiparallel to each other. The magnitudes of the currents are increasing with time at the same rate. Which one of the following statements is **TRUE**?

Figure # 9



A) The net induced current in the loop is counterclockwise.
B) The net induced current in the loop is clockwise.
C) The net induced current in the loop is zero.
D) The net induced magnetic field in the loop is into the page
E) The net induced magnetic field in the loop is zero.

Ans:

A