Q1.

For the wave described by $y = 0.02 \sin(kx)$ at $t = 0$ s, the first maximum displacement at a positive x coordinate occurs at $x = 4$ m. Where on the positive x axis does the second maximum displacement occur? (x and y are measured in m)

A) 12 m
B) 20 m
C) 34 m
D) 48 m
E) 59 m

Ans:

$$y = 0.02\ (kx)$$

$$For\ first\ max, \qquad \sin kx = 1 \Rightarrow kx = \frac{\pi}{2} \Longrightarrow \frac{2\pi}{\lambda} \cdot 4 = \frac{\pi}{2} \Longrightarrow \lambda = 16\ m$$

2nd Maximum Displacement will occur at $(4+\lambda/2)$m = (4+8) m = 12 m

---

Q2.

The sound intensity 5.00 m from a point source is 0.500 W/m^2. The power output of the source is:

A) 157 W
B) 391 W
C) 710 W
D) 235 W
E) 458 W

Ans:

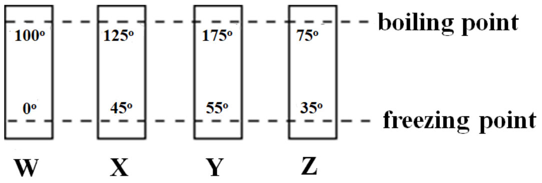
$$I = \frac{P}{A} \Rightarrow P = IA = I4\pi R^2$$

$$\therefore P = 0.5 \times 4 \times \pi \times 5^2 = 157\ \text{W}$$

Q3.

Figure 1 shows four vertical thermometers, labeled W, X, Y, and Z. The freezing and boiling points of water are indicated. Rank the 65 degree temperatures on different scale from **highest to lowest**.

Figure 1



A) 65°Z, 65°W, 65°X, 65°Y
B) 65°Z , 65°X, 65°W, 65°Y
C) 65°W, 65°X, 65°Y, 65°Z
D) 65°Y, 65°W, 65°X, 65°Z
E) 65°X, 65°Y, 65°Z, 65°W

Ans:

$$\frac{W-0}{100} = \left(\frac{65-45}{125-45}\right)X = \frac{20}{80}X$$

$$65X = 25\,W$$

$$\frac{W}{100} = \left(\frac{65-55}{175-55}\right)Y = \frac{10}{120} \Rightarrow 65Y = 8.3W$$

$$\frac{W}{100} = \left(\frac{65-35}{75-35}\right)Z = \frac{30}{40}$$

$$65Z = 75\,W$$

$$\therefore 65\mathrm{Z}, 65\ \mathrm{W}, 65\ \mathrm{X}\ \mathrm{and}\ 65\ \mathrm{Y}$$

Q4.

The approximate number of air molecules in a 1.00 m^3 volume at room temperature (300 K) and atmospheric pressure is: (Assume air to be an ideal gas)

A) 2.44×10^{25}
B) 3.30×10^{25}
C) 1.63×10^{25}
D) 4.71×10^{25}
E) 5.49×10^{25}

Ans:

$$PV = \frac{NRT}{N_A} \Rightarrow \frac{PVN_A}{RT} = N$$

$$\Rightarrow N = \frac{1.01 \times 10^5 \times 1}{8.31 \times 300} \times 6.0\,Z \times 10^{23} = 2.439 \times 10^{25}$$

Q5.

A certain heat engine draws 500 cal/s from a water bath at 27 °C and transfers 400 cal/s to a reservoir at a lower temperature. The efficiency of this engine is:

A) 20%
B) 7.5%
C) 55%
D) 35%
E) 10%

Ans:

$$\varepsilon = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{400}{500} = \frac{1}{5} = 0.2 = 20\%$$

Q6.

A particle with a charge of 5×10^{-6} C and a mass of 2.0×10^{-2} kg moves with a constant speed of 7.0 m/s in a circular orbit around a stationary particle with a charge of -5×10^{-6} C. The radius of the orbit is:

A) 0.23 m
B) 0.16 m
C) 0.52 m
D) 0.65 m
E) 0.84 m

Ans:

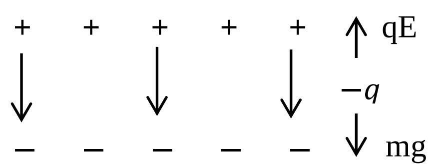
$$\frac{mv^2}{r} = \frac{kq^2}{r^2} \Rightarrow r = \frac{kq^2}{mv^2}$$

$$r = \frac{9 \times 10^9 \times (5 \times 10^{-6})^2}{2 \times 10^{-2} \times 7^2} = 0.23 \text{ m}$$

Q7.

A charged oil drop with a mass of 2.00×10^{-4} kg is held in equilibrium in air by a downward electric field of 300 N/C. The charge on the drop is:

A) -6.53×10^{-6} C
B) -1.50×10^{-6} C
C) $+6.53 \times 10^{-6}$ C
D) $+1.50 \times 10^{-6}$ C
E) $+3.57 \times 10^{-6}$ C



Ans:

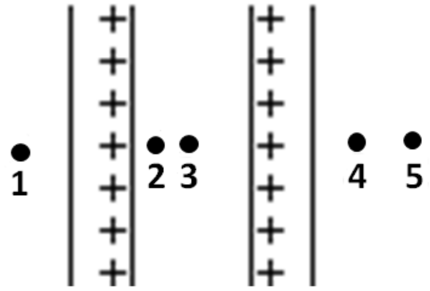
$$qE = mg$$

$$q = \frac{mg}{E} = \frac{2 \times 10^4 \times 9.8}{300} = -6.53 \times 10^{-6} \text{ C}$$

Q8.

Two identical large insulating parallel plates carry positive charge of equal magnitude that is distributed uniformly over their inner surfaces as shown in **Figure 2**. Rank the points 1 through 5 according to the magnitude of the electric field at these points, **least to greatest**.

Figure 2



A) (2 and 3) tie, then (1 and 4 and 5) tie
B) 1, 2, 3, 4, 5
C) 5, 4, 3, 2, 1
D) (1 and 4 and 5) tie, then (2 and 3) tie
E) (2 and 3) tie, then (1 and 4) tie, then 5

Ans:

A

Q9.

An isolated solid metal sphere of radius R carries a charge of 3.0 nC. How much charge remains in the sphere of radius R, when it is connected to another uncharged metallic sphere of radius 2R with a thin metallic wire? (Assume no charge remains on the wire and the spheres are far away from each other)

A) 1.0 nC
B) 2.0 nC
C) 6.0 nC
D) 1.5 nC
E) 3.0 nC

Ans:

$$V_R = V_{2R} \Rightarrow \frac{kq}{K} = \frac{k(3-q)}{2R}$$

$$2q = 3 - q \Rightarrow 3q = 3$$

$$q = 1\text{nc}$$

Q10.

Copper contains 8.4×10^{28} free electrons per cubic meter. A copper wire of radius 5.0×10^{-4} m carries a current of 1.0 A. The electron drift speed is:

A) 9.5×10^{-5} m/s
B) 1.0×10^{-5} m/s
C) 6.5×10^{-5} m/s
D) 3.0×10^{-5} m/s
E) 5.0×10^{-5} m/s

Ans:

$$i = nev_d A$$

$$\Rightarrow v_d = \frac{i}{neA} = \frac{1}{8.4 \times 10^{28} \times 1.6 \times 10^{-19} \times \pi \times (5 \times 10^{-4})^2} = 9.5 \times 10^{-5}\ \text{m/s}$$

Q11.

A particle with a charge $q_1 = 5.5 \times 10^{-8}$ C is fixed at the origin. Another particle with a charge $q_2 = -2.3 \times 10^{-8}$ C is moved from position x = 3.5 cm on the x axis to position y = 4.3 cm on the y axis. Find the amount of work required to move the charge.

A) $+6.0 \times 10^{-5}$ J
B) $+3.1 \times 10^{-5}$ J
C) -6.0×10^{-5} J
D) -3.1×10^{-5} J
E) $+2.7 \times 10^{-5}$ J

Ans:

$$W_a = \Delta V = U - U_0 = kq_1q_2\left(\frac{1}{r} - \frac{1}{r_0}\right)$$

$$= 9 \times 10^9 \times (5.5 \times 10^{-8})(-2.3 \times 10^{-8}) \times 100\left(\frac{1}{4.3} - \frac{1}{3.5}\right)$$

$$= 6 \times 10^{-5}\text{J}$$

Q12.

A parallel-plate capacitor has a plate area of 0.30 m^2 and a plate separation of 0.10 mm. If the charge on each plate has a magnitude of 5.0×10^{-6} C, what is the energy density in its electric field?

A) 16 J/m^3
B) 35 J/m^3
C) 78 J/m^3
D) 21 J/m^3
E) 54 J/m^3

Ans:

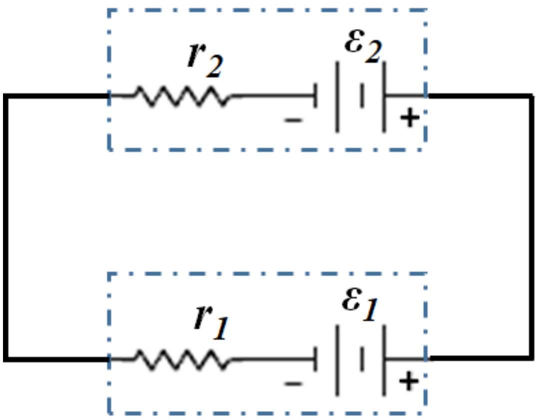
$$u = \frac{U}{Volume} = \frac{\frac{1}{2}CV^2}{Ad} = \frac{\frac{1}{2}Cq^2}{AdC^2} = \frac{q^2}{2ACd} = \frac{q^2}{2A\frac{\varepsilon_0 A}{d}d} = \frac{q^2}{2\varepsilon_0 A^2}$$

$$= \frac{(5\times10^{-6})^2}{2\times 8.85\times10^{-12}\times 0.3^2} = 15.7\,\mathrm{J/m^3}$$

Q13.

In **Figure 3** a battery with an emf ε_1 = 12 V and an internal resistance of r_1= 1.0 Ω is used to charge a battery with an emf ε_2 = 7.0 V and an internal resistance of r_2 =1.0 Ω. The current in the circuit is:

Figure 3



A) 2.5 A
B) 1.0 A
C) 3.0 A
D) 4.1 A
E) 7.5 A

Ans:

$$\varepsilon_1 - \varepsilon_2 - ir_1 - ir_2 = 0$$

$$i = \frac{\varepsilon_1 - \varepsilon_2}{r_1 + r_2} = \frac{12-7}{2} = \frac{5}{2} = 2.5\text{ A}$$

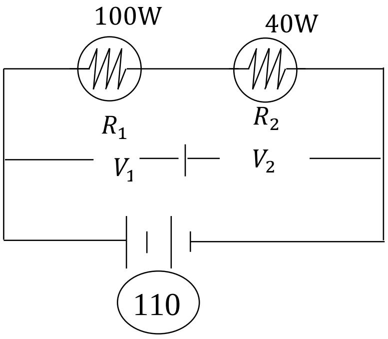
Q14.

Two light bulbs, with power ratings 40 W and 100 W, are connected in series to a 110 V source. Then which of the following statements is **TRUE**?

A) the current in the 100 W bulb is same as that in the 40 W bulb
B) the current in the 100 W bulb is less than that in the 40 W bulb
C) the voltage drop across the 100 W bulb is same as that in the 40 W bulb
D) both bulbs have same energy dissipation rate
E) the current in the 100 W bulb is greater than that in the 40 W bulb

Ans:

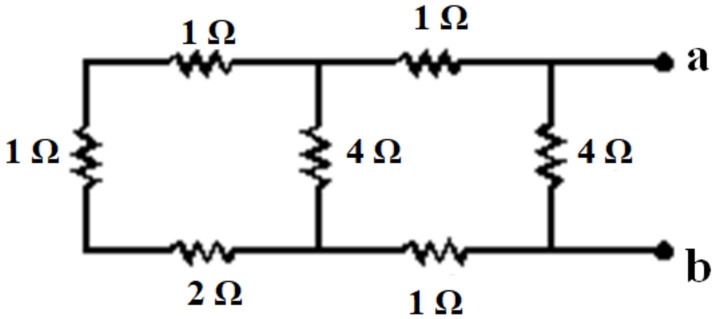
A



Q15.

Find the equivalent resistance across points a and b in the circuit shown in **Figure 4.**

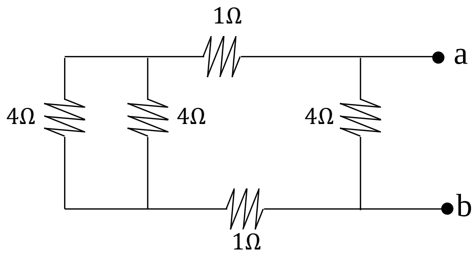
Figure 4

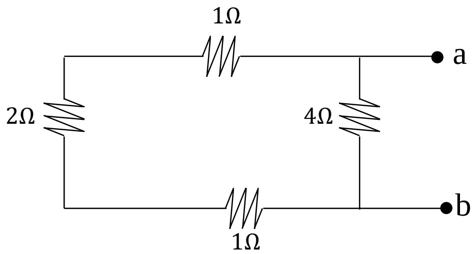


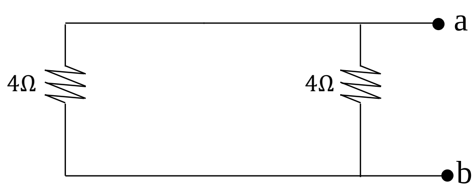
A) 2 Ω
B) 4 Ω
C) 1 Ω
D) 6 Ω
E) 3 Ω

Ans:

A





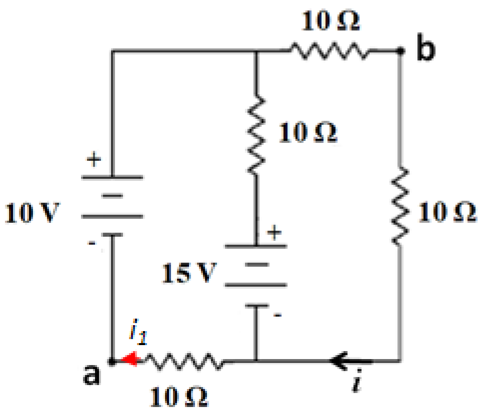


$= 2\Omega$

Q16.

In the circuit diagram of **Figure 5**, if the current i = 0.5 A, find the potential difference
$V_b - V_a$.

Figure 5



A) 5.0 V
B) 4.0 V
C) 1.0 V
) 2.0 V
E) 8.0 V

Ans:

$$V_a + i_1 10 + i10 = V_b$$

$$V_b - V_a = 10i_1 + 10\,i$$

$$15 + 10i_1 - 10i - 10i - 10\,i = 0$$

$$15 + 10i_1 - 30i = 0$$

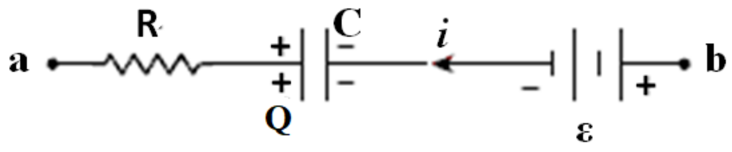
$$i_1 = (15 - 15)/10 = 0$$

$$\therefore V_b - V_a = 10 \times \frac{1}{2} = 5\text{V}$$

Q17.

A segment of a circuit diagram is shown in **Figure 6**. At a particular instant, if R = 2.0 kΩ, C = 4.0 mF, ε = 8.0 V, Q = 20 mC, and i = 3.0 mA, what is the potential difference $V_a - V_b$?

Figure 6



A) –9.0 V
B) +7.0 V
C) –7.0 V
D) +5.0 V
E) +9.0 V

Ans:

$$V_b - \varepsilon + \frac{Q}{C} - iR = V_a$$

$$-8 + \frac{20 \times 10^{-3}}{4 \times 10^{-3}} - 3 \times 10^{-3} \times 2 \times 10^{+3} = V_a - V_b$$

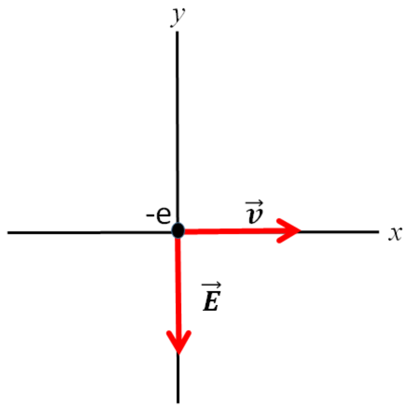
$$-8 + 5 - 6 = V_a - V_b$$

$$V_a - V_b = -9 \text{ V}$$

Q18.

An electron is travelling with constant velocity $\vec{v}$ in a region of uniform electric field $\vec{E}$ and the uniform magnetic field $\vec{B}$, as shown in **Figure 7. F**ind the direction of the magnetic field $\vec{B}$.

Figure 7



A) the negative z direction (into the page)
B) the negative *y* direction
C) the positive *y* direction
D) the positive z direction (out of the page)
E) the negative *x* direction

Ans:

$$F_B = -e(\vec{v} \times \vec{B})$$

The electric force qE is +y direction. So, F_b must be in –y direction.

$$-\hat{j} = -(\hat{\imath} \times -\hat{k})$$

$$B \rightarrow (-\hat{k})$$

Q19.

An electron has a velocity of 6.0×10^6 m/s in the positive x direction at a point where the magnetic field has components $B_x = 3.0$ T, $B_y = 1.5$ T, and $B_z = 2.0$ T. What is the magnitude of the acceleration of the electron at this point?

A) 2.6×10^{18} m/s^2
B) 3.4×10^{18} m/s^2
C) 6.0×10^{18} m/s^2
D) 1.2×10^{18} m/s^2
E) 5.8×10^{18} m/s^2

Ans:

$$m_e a = -e(\vec{v} \times \vec{B})$$

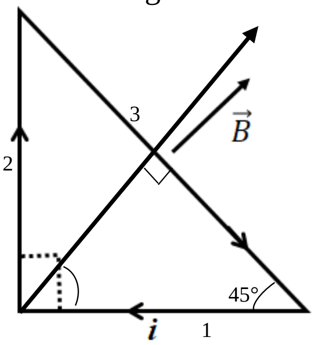
$$a = -\frac{e}{m_e}\left(6 \times 10^6 \hat{\imath} \times (3\hat{\imath} + 1.5\hat{\jmath} + 2\hat{k})\right)$$
$$= -\frac{1.6 \times 10^{-19}}{9.1 \times 10^{-31}}\left(6 \times 10^6 \times (1.5\hat{k} - 2\hat{\jmath})\right)$$

$$= \frac{1.6 \times 10^{-19}}{9.1 \times 10^{-31}} \times 6 \times 10^6 \sqrt{1.5^2 + 2^2} = 2.6 \times 10^{18}$$

Q20.

Figure 8 shows a loop of wire carrying a current $i = 2.0$ A is in the shape of a right triangle with two equal sides, each 15 cm long. A uniform magnetic field B = 0.7 T is in the plane of the triangle and is perpendicular to the hypotenuse. The resultant magnetic force on the two equal sides has a magnitude of:

Figure 8



A) 0.30 N
B) 0.21 N
C) 0.12 N
D) 0.45 N
E) 0.57 N

Ans:

$$F_1 = +ilB\sin 135° \,\hat{n}$$

$$F_2 = +ilB\sin 45° \,\hat{n}$$

$$F = F_1 + F_2$$

$$|F| = ilB[\sin 135° + Sin45°]$$

$$= 2 \times 0.15 \times 0.7[\sin 135° + Sin45°]$$

$$|F| = 0.297\ N$$

Q21.

A loop of current-carrying wire has a magnetic dipole moment of 5.0×10^{-4} A·m^2. The dipole moment is initially aligned with a 0.50 T magnetic field. To rotate the loop so that its dipole moment becomes perpendicular to the field, you must do work of:

A) $+2.5 \times 10^{-4}$ J
B) zero
C) -2.5×10^{-4} J
D) $+1.0 \times 10^{-3}$ J
E) -1.0×10^{-3} J

Ans:

$$W_a = \Delta U = U - U_0 = -\mu B(Cos\theta - Cos\theta_0)$$

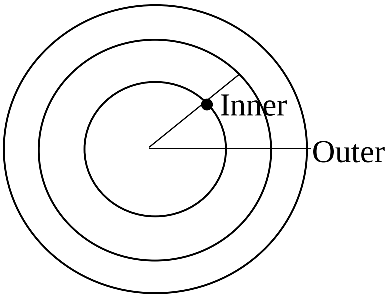
$$= -\mu B(Cos90° - Cos0°)$$

$$= \mu B = 5 \times 10^{-4} \times 0.5 = +2.5 \times 10^{-4} \text{ J}$$

Q22.

A long wire of radius R = 4.5 cm carries a uniform current throughout its cross-section. If the magnetic field inside the wire at 3.0 cm from the center is equal to three times the magnetic field at a distance r from the center, where $r > R$, calculate the distance r.

A) 20 cm
B) 35 cm
C) 13 cm
D) 46 cm
E) 54 cm



Ans:

$$\frac{\mu_0 i_{in}}{2\pi R_{in}} = \frac{3\mu_0 i}{2\pi r_{out}}$$

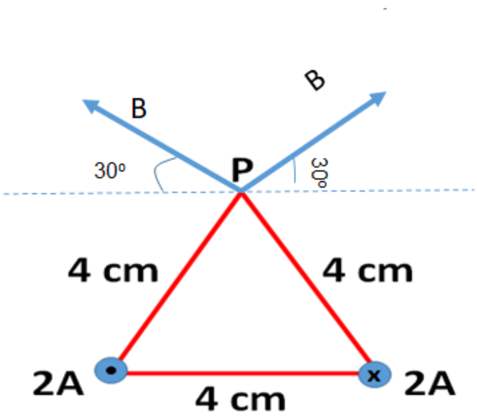
$$r = \frac{3i \times 3}{i_{in}} = \frac{3i \times 3}{J\pi 3^2} = \frac{i \times \pi \times 4.5^2}{i\pi} = 4.5^2 = 20.25 \text{ cm}$$

Q23.

Two long vertical wires pierce (penetrate) the horizontal plane of the paper at the vertices of an equilateral triangle, each carrying 2.0 A current, one out of the paper and the other into the paper, as shown in **Figure 9**. The magnetic field at point P has a magnitude of:

A) 1.0×10^{-5} T
B) 8.2×10^{-5} T
C) 1.7×10^{-5} T
D) 5.5×10^{-5} T
E) 2.9×10^{-5} T

Figure 9



Ans:

$$|B| = \frac{2\mu_0 i}{2\pi R} \sin 30°$$

$$= \frac{2 \times 4\pi \times 10^{-7} \times 2}{2 \times \pi \times 4 \times 10^{-2}} \times \frac{1}{2}$$
$$= 1 \times 10^{-5} \text{ T}$$

Q24.

Two long parallel wires X and Y are separated by 4.0 cm and carry currents 20 A and 30 A, respectively, along the same direction. Determine the magnitude of the magnetic force on a 2.0 m length of wire Y.

A) 6.0×10^{-3} N
B) 4.0×10^{-3} N
C) 2.0×10^{-3} N
D) 3.0×10^{-3} N
E) 7.0×10^{-3} N

Ans:

$$F = i_y L_y \frac{\mu_0 i_x}{2\pi R}$$

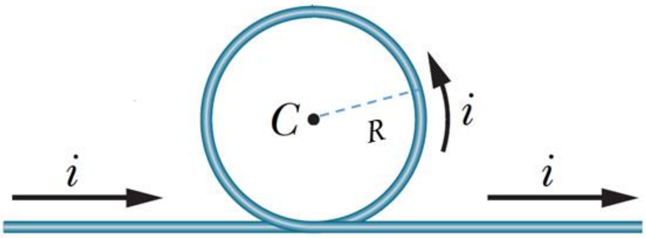
$$F = \frac{4\pi \times 10^{-7} \times 30 \times 20 \times 2}{2\pi \times 4 \times 10^{-2}} = 6 \times 10^{-3}\text{N}$$

Q25.

In **Figure 10**, part of a long insulated wire carrying current i = 5.0 A is bent into a circular section of radius R = 0.1 m. What is the magnetic field at the center C of the circular section?

A) 4.1×10^{-5} T out of the page
B) 4.1×10^{-5} T into the page
C) 5.5×10^{-5} T into the page
D) 5.5×10^{-5} T out of the page
E) 3.7×10^{-5} T out of the page

Figure 10



Ans:

$$\frac{\mu_0 i}{2\pi R}\hat{k} + \frac{\mu_0\, i 2\pi}{4\pi R}\hat{k}$$

$$\frac{\mu_0 i}{R}\left(\frac{1}{2\pi} + \frac{1}{2}\right)\hat{k}$$

$$= \frac{4\pi \times 10^{-7} \times 5}{0.1}\left(\frac{1}{2\pi} + \frac{1}{2}\right)\hat{k}$$

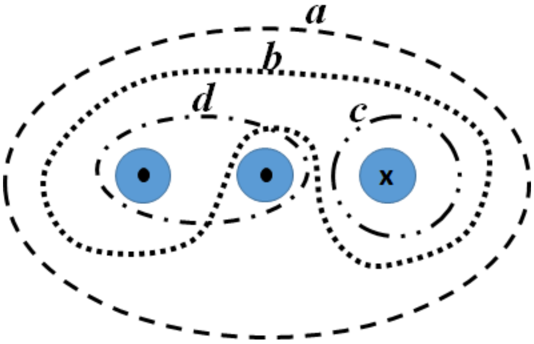
$$= 4.1 \times 10^{-5}\text{T out of the Page}$$

Q26.

Figure 11 shows the cross-sectional view of three wires carrying identical currents i and four Amperian loops (a through d) encircling them. Rank the loops according to the magnitude of $\oint \vec{B}.d\vec{s}$ along each, **greatest first**.

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

Figure 11



Ans:

$$\oint_a \vec{B}\cdot\overrightarrow{ds} = 2i - i = i$$

$$\oint_b \vec{B}\cdot\overrightarrow{ds} = i - i = 0$$

$$\oint_c \vec{B}\cdot\overrightarrow{ds} = i$$

$$\oint_d \vec{B}\cdot\overrightarrow{ds} = 2i$$

Q27.

A square loop (length along one side = 20 cm) rotates in a constant magnetic field which has a magnitude of 2.0 T. At an instant when the angle between the magnetic field and the normal to the plane of the loop is equal to 20° and increasing at a rate of 0.18 rad/s, what is the magnitude of the induced emf in the loop?

A) 4.9 mV
B) 1.3 mV
C) 3.5 mV
D) 2.1 mV
E) 5.2 mV

Ans:

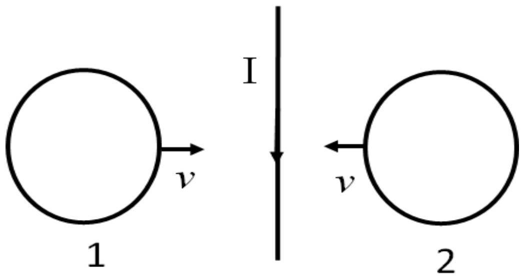
$$|\varepsilon| = \left|-\frac{d(BAcos\theta)}{dt}\right| = BA\frac{dcos\theta}{d\theta}\frac{d\theta}{dt} = BA\omega sin\theta$$

$$= 2 \times 0.2 \times 0.2 \times 0.18\, sin(20°) = 4.9\, mV$$

Q28.

A long straight wire is in the plane of two circular conducting loops. The straight wire carries a constant current I in the direction shown in **Figure 12**. The circular loop 1 is moved to the right while the loop 2 is moved to the left with the same speed, v. The direction of the induced current in the circular loops 1 and 2 are respectively:

Figure 12



A) counter-clockwise , clockwise
B) counter-clockwise , counter-clockwise
C) clockwise , clockwise
D) clockwise , counter-clockwise
E) no direction because induced current is zero

Ans:

A

Q29.

A long solenoid (n = 1500 turns/m) has a cross-sectional area of 0.40 m^2 and a current given by I = (4.0 + 3.0t^2) A, where t is in seconds. A flat circular coil (N = 300 turns) with a cross-sectional area of 0.15 m^2 is inside and coaxial with the solenoid. What is the magnitude of the emf induced in the coil at t = 2.0 s?

A) 1.0 V
B) 2.0 V
C) 1.5 V
D) 2.5 V
E) 3.5 V

Ans:

$$B = \mu_0 n i = 4\pi \times 10^7 \times 1500\, I$$

$$\varepsilon(t) = N \frac{d(BAcos0)}{dt} = A \frac{dB}{dt} N$$

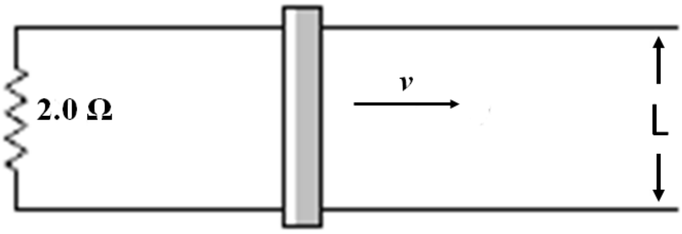
$$= 0.15 \times 4\pi \times 10^{-7} \times 1500 \frac{dI}{dt} \times 300$$

$$\varepsilon(2.0) = 0.15 \times 4\pi \times 10^{-7} \times 1500 \times 6 \times 2 \times 300 = 1.0 \text{ V}$$

Q30.

In the arrangement shown in **Figure 13**, a conducting bar of negligible resistance slides along horizontal, parallel, and frictionless conducting rails connected as shown to a 2.0 Ω resistor. A uniform 1.5 T magnetic field is perpendicular to the plane of the paper. If L = 60 cm, at what rate is thermal energy being generated in the resistor at the instant the speed of the bar *v* = 4.2 m/s?

Figure 13



A) 7.1 W
B) 2.6 W
C) 5.0 W
D) 1.2 W
E) 3.6 W

Ans:

$$\varepsilon = \frac{\partial(BA)}{\partial t}(cos0°) = BLv$$

$$P = \frac{\varepsilon^2}{R} = \frac{B^2L^2v^2}{R} = \frac{1.5^2 \times 0.6^2 \times 4.2^2}{2} = 7.1\ W$$

$v = \sqrt{\tau / \mu}$

$y = y_m \sin(kx - \omega t)$

$v = \sqrt{B / \rho}$

$s = s_m \cos(kx - \omega t)$

$I = \frac{P_s}{4\pi r^2}$

$P_{avg} = \frac{1}{2}\mu\omega^2 v y_m^2$

$\Delta P = \Delta P_m \sin(kx - \omega t)$

$\Delta P_m = \rho v \omega S_m$

$I = \frac{1}{2}\rho\left(\omega S_m\right)^2 v$

$\beta = 10 \log\frac{I}{I_0}$, $I_0 = 10^{-12} W/m^2$

$f' = f\left(\frac{v \pm v_D}{v \mp v_s}\right)$

$y = \left(2y_m \cos\frac{\phi}{2}\right)\sin\left(kx - \omega t - \frac{\phi}{2}\right)$

$\Delta L = \frac{\lambda}{2\pi}\varphi$

$\Delta L = m\lambda$, m = 0, 1, 2, 3, ...

$\Delta L = \left(m + \frac{1}{2}\right)\lambda$, m = 0, 1, 2, 3, ...

$y = 2y_m (\sin kx)(\cos \omega t)$

$f_n = \frac{nv}{2L}$, $n = 1, 2, 3, ...$

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

$\alpha = \frac{\Delta L}{L}\frac{1}{\Delta T}$, $\beta = \frac{\Delta V}{V}\frac{1}{\Delta T}$

$PV = nRT = NkT$

$W = \int P\, dV$

$W = n R T \ln(V_f / V_i)$

$v_{rms} = \sqrt{\frac{3RT}{M}}$, $\frac{1}{2}mv^2 = \frac{3}{2}kT$

$Q = mc\Delta T$, $Q = mL$

$\Delta E_{int} = Q - W$, $\Delta E_{int} = n C_v \Delta T$

$Q = nC_p\Delta T$, $Q = nC_v\Delta T$

$C_p - C_v = R$, $\gamma = Cp / Cv$

$P_{cond} = \frac{Q}{t} = \kappa A \frac{T_H - T_C}{L}$

$PV^\gamma = \text{constant}$, $TV^{\gamma-1} = \text{constant}$

$T_F = \frac{9}{5}T_C + 32$, $T_K = T_C + 273$

$W = Q_H - Q_L$, $\varepsilon = \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H}$

$\varepsilon_c = 1 - \frac{T_L}{T_H}$, $K_{Ref} = \frac{Q_L}{W}$, $K_{HP} = \frac{Q_H}{W}$,

$\Delta S = \int \frac{dQ}{T}$,

$\Delta S = nR\ln\frac{V_f}{V_i} + nC_V \ln\frac{T_f}{T_i}$

$F = \frac{kq_1q_2}{r^2}$, $F = qE$

$U = -\vec{p}.\vec{E}$, $\vec{\tau} = \vec{p}\times\vec{E}$

$\phi_c = \oint \vec{E}.d\vec{A} = \frac{q_{in}}{\varepsilon_0}$

$\phi = \int_{Surface} \vec{E} . d\vec{A}$, $E = \frac{kq}{r^2}$

$E = \frac{kQ}{R^3}r$, $E = \frac{2k\lambda}{r}$

$E = \frac{\sigma}{2\varepsilon_o}$, $E = \frac{\sigma}{\varepsilon_o}$

$\Delta V = V_B - V_A = -\int_A^B \vec{E}.d\vec{S} = \frac{\Delta U}{q_0}$

$V = \frac{kQ}{r}$, $U_{12} = \frac{kq_1q_2}{r_{12}}$

$E_x = -\frac{\partial V}{\partial x}$, $E_y = -\frac{\partial V}{\partial y}$, $E_z = -\frac{\partial V}{\partial z}$

$C = \frac{Q}{V}$, $C = \frac{\varepsilon_0 A}{d}$

$C = \frac{2\pi\varepsilon_0 L}{\ln(b/a)}$, $C = \frac{4\pi\varepsilon_0 ab}{b-a}$

$U = \frac{1}{2}CV^2$, $C_\kappa = \kappa C_{air}$

$I = \frac{dQ}{dt}$, $I = JA$, $J = nev_d$

$R = \frac{V}{I} = \rho\frac{L}{A}$, $J = \sigma E = E/\rho$

$\rho = \rho_0 [1 + \alpha(T - T_0)]$, $P = IV$

$q(t) = C\varepsilon[1 - e^{-t/RC}]$,

$i(t) = \frac{\varepsilon}{R}e^{-t/RC}$

$q(t) = q_o e^{-t/RC}$, $i(t) = \frac{q_o}{RC}e^{-t/RC}$

$\vec{F} = q(\vec{v}\times\vec{B})$, $\vec{F} = i(\vec{L}\times\vec{B})$

$\vec{\tau} = \vec{\mu}\times\vec{B}$, $\vec{\mu} = Ni\vec{A}$

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

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\, d\vec{s}\times\vec{r}}{r^3}$

$\oint \vec{B}.d\vec{s} = \mu_0 i_{enc}$

$B = \frac{\mu_0 i}{4\pi R}\varphi$, $B = \frac{\mu_0 i}{2\pi r}$

$F_{ba} = \frac{\mu_o L i_a i_b}{2\pi d}$,

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

$B_s = \mu_0 n i$

$\vec{B}(z) = \frac{\mu_0}{2\pi}\frac{\vec{\mu}}{z^3}$,

$\Phi_B = \int \vec{B}\cdot d\vec{A}$

$\varepsilon_{ind} = -\frac{d\Phi_B}{dt}$, $\varepsilon_{ind} = BLv$

$\varepsilon_o = 8.85 \times 10^{-12}\ C^2/N.m^2$

$k = 9.00 \times 10^9\ N.m^2/C^2$

$q_e = -e = -1.60 \times 10^{-19}$ C

$q_p = +e = +1.60 \times 10^{-19}$ C

$m_e = 9.11 \times 10^{-31}$ kg

$m_p = 1.67 \times 10^{-27}$ kg

μ = micro = 10^{-6}, n = nano = 10^{-9}

p = pico = 10^{-12}

$\mu_0 = 4\pi \times 10^{-7}$ Wb/A. m

$k_B = 1.38 \times 10^{-23}$ J/K

$N_A = 6.02 \times 10^{23}$ molecules/mole

1 atm = $1.01 \times 10^5\ N/m^2$

R = 8.31 J/mol. K

g = 9.8 m/s^2

1L = $10^{-3}\ m^3$

For water:

L_F = 333 kJ/kg

L_V = 2256 kJ/kg

c = 4190 J/kg.K

$\int x^n dx = \frac{x^{n+1}}{n+1}$

$\int \frac{dx}{x} = \ln x$

$v = v_o + at$

$v^2 = v_o^2 + 2a(x - x_o)$

$\Delta K = -\Delta U$

$\Delta U_g = mg\Delta y$