

ESE GATE

MADE EASY WORKBOOK 2026



**Detailed Explanations of
Try Yourself *Questions***

Electrical Engineering
Electromagnetic Theory



1

Vector Analysis

T1. (d)

$$\vec{B} = -\rho \hat{a}_\phi + z \hat{a}_z$$

$$\rho = \sqrt{x^2 + y^2}$$

$$z = z$$

$$\begin{bmatrix} \hat{a}_\phi \\ \hat{a}_\phi \\ \hat{a}_z \end{bmatrix} = \begin{bmatrix} \cos\phi & \sin\phi & 0 \\ -\sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \hat{a}_x \\ \hat{a}_y \\ \hat{a}_z \end{bmatrix}$$

$\Rightarrow$

$$\hat{a}_\phi = -\sin\phi \hat{a}_x + \cos\phi \hat{a}_y$$

$$\tan\phi = \frac{y}{x}$$

$$\vec{B} = -\sqrt{x^2 + y^2} \{-\sin\phi \hat{a}_x + \cos\phi \hat{a}_y\} + z \hat{a}_z$$

$$= -\sqrt{x^2 + y^2} \left\{ \frac{-y}{\sqrt{x^2 + y^2}} \hat{a}_x + \frac{x}{\sqrt{x^2 + y^2}} \hat{a}_y \right\} + z \hat{a}_z$$

$$= y \hat{a}_x - x \hat{a}_y + z \hat{a}_z$$

T2. (-3)

As

$$\int_C \vec{F} \cdot d\vec{l} = \int y dx - \int x dy$$

So,

$$y = x^2 \Rightarrow dy = 2x dx$$

$$\int_C \vec{F} \cdot d\vec{l} = \int x^2 dx - \int x \cdot 2x dx$$

$$= \int (x^2 - 2x^2) dx = - \int_{x=-1}^2 x^2 dx$$

$$= - \frac{x^3}{3} \Big|_{-1}^2 = - \left[\frac{8}{3} + \frac{1}{3} \right] = -3$$

T3. (224)

$$\vec{A} = \nabla f = 4xyz\hat{a}_x + 2x^2z\hat{a}_y + 2x^2y\hat{a}_z$$

$$(0,0,0) \xrightarrow{dx\hat{a}_x} (2,0,0) \xrightarrow{dy\hat{a}_y} (2,7,0) \xrightarrow{dz\hat{a}_z} (2,7,4)$$

$$\begin{aligned} \therefore \int \vec{A} \cdot d\vec{l} &= \int 4xyz dx \text{ (at } y=0 \text{ and } z=0) + \int 2x^2z dy \text{ (at } z=0 \text{ and } x=2) + \int_{z=0}^4 2x^2y dz \text{ (at } x=2 \text{ and } y=7) \\ &= 224 \end{aligned}$$

T4.

$$\begin{aligned} \oint \vec{D} \cdot d\vec{S} &= \int \frac{5r^2}{4} \cdot r^2 \sin\theta d\theta d\phi \quad \left(\text{at } \theta = 0, \frac{\pi}{4}, \phi = 0, 2\pi\right) \\ &= 589.1 \text{ C} \end{aligned}$$

$$\int (\nabla \cdot \vec{D}) dV = \int (5r) \cdot r^2 \sin\theta d\theta d\phi dr = 589.1 \text{ C}$$

T5. (d)

$$\begin{aligned} \nabla \cdot \vec{F} &= \frac{1}{\rho} \frac{\partial}{\partial \rho} (\rho \rho) + \frac{1}{\rho} \frac{\partial}{\partial \phi} [\rho (\sin^2 \phi)] + \frac{\partial}{\partial z} (-z) \\ &= 2 + 2 \sin \phi \cos \phi - 1 = 1 + \sin 2\phi \end{aligned}$$

T6. Sol.

$$\begin{aligned} \nabla \cdot \vec{A} &= \frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{1}{r} \right) + \frac{1}{r \sin \theta} \frac{\partial}{\partial \theta} (-r^2 \sin \theta \sin \theta) + \frac{1}{r \sin \theta} \frac{\partial}{\partial \phi} (10 \cos \phi) \\ &= \frac{1}{r^2} - 2r \cos \theta - \frac{10 \sin \phi}{r \sin \theta} \\ \nabla \cdot \vec{A} \text{ at } \left(2, \frac{\pi}{4}, \frac{\pi}{2} \right) &= \frac{1}{4} - 4 \times \frac{1}{\sqrt{2}} - \frac{10}{2 \times \frac{1}{\sqrt{2}}} = \frac{1}{4} - 7\sqrt{2} = -9.65 \end{aligned}$$

T7. (b)

$$\nabla \cdot \vec{A} = \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 \cdot K r^n) = \frac{1}{r^2} K(n+2) r^{n+1}$$

$$\nabla \times \vec{A} = 0$$

Hence, for $n = -2$ given vector is solenoidal and always irrotational.

T8. (d)

$$\oint \vec{A} \cdot d\vec{l} = \left[\int_A^B + \int_B^C + \int_C^A \right] \vec{A} \cdot d\vec{l}$$

$$\left. \begin{aligned} \vec{A} &= 3x^2y^3\hat{a}_x - x^3y^2\hat{a}_y \\ d\vec{l} &= dx\hat{a}_x + dy\hat{a}_y \end{aligned} \right\} \vec{A} \cdot d\vec{l} = 3x^2y^3dx - x^3y^2dy$$

$$\vec{A} \cdot d\vec{l} = 3x^2y^3dx - x^3y^2dy$$

Path AB :

$$y = x \Rightarrow dy = dx$$

$$\int \vec{A} \cdot d\vec{l} = \int 3x^2y^3dx - x^3y^2dy = \int 3x^5 - x^5dx = \int_{x=1}^2 2x^5dx = 2 \cdot \frac{x^6}{6} \Big|_1^2 = 21$$

Path CA :

$$x = 2 \Rightarrow dx = 0$$

Path CA :

$$y = 1 \Rightarrow dy = 0$$

$$\int \vec{A} \cdot d\vec{l} = \int 3x^2y^3dx = 3y^3 \int_{x=2}^1 x^2dx \text{ at } y=1 = 3 \cdot \frac{x^3}{3} \Big|_2^1 = -7$$

Path BC :

$$x = 2 \Rightarrow dx = 0$$

∴

$$\oint \vec{A} \cdot d\vec{l} = 21 + \frac{56}{3} - 7 = \frac{98}{3}$$

$$\begin{aligned} \int \vec{A} \cdot d\vec{l} &= - \int_2^1 x^3y^2dy \text{ at } x=2 \\ &= \frac{56}{3} \end{aligned}$$

$$\oint \vec{A} \cdot d\vec{l} = 21 + \frac{56}{3} - 7 = \frac{98}{3}$$

$\int (\nabla \times \vec{A}) \cdot d\vec{S}$:

$$\nabla \times \vec{A} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 3x^2y^3 & -x^3y^2 & 0 \end{vmatrix} = -12x^2y^2\hat{a}_z$$

$$d\vec{S} = dxdy(-\hat{a}_z)$$

(using RH curl)

$$\begin{aligned} \therefore \int \nabla \times \vec{A} \cdot d\vec{S} &= 12 \int_{x=1}^2 x^2dx \int_{y=1}^x y^2dy = 12 \int_{x=1}^2 x^2dx \frac{y^3}{3} \Big|_{y=2}^x = \frac{12}{3} \int_{x=1}^2 x^2dx (x^3 - 1) \\ &= 4 \left[\int_1^2 x^5dx - \int_1^2 x^2dx \right] = \frac{98}{3} \end{aligned}$$

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3

Electrostatics

T1. Sol.

⇒

$$\psi = Q_{\text{enc}} = \int P_v dv = \int (\nabla \cdot \bar{D}) dv$$

$$\psi = \int_V (y + x + z) dx dy dz$$

$$= \int_{y=-2}^2 y dy \int_{x=1}^4 dx \int_{z=-1}^2 dz + \int_{z=-1}^2 z dz \int_{x=1}^4 dx \int_{y=-2}^2 dy$$

⇒

$$\psi = \frac{y^2}{2} \Big|_{-2}^2 \cdot x \Big|_1^4 \cdot z \Big|_{-1}^2 + \frac{z^2}{2} \Big|_{-1}^2 \cdot y \Big|_{-2}^2 \cdot x \Big|_1^4 + \frac{z^2}{2} \Big|_{-1}^2 \cdot x \Big|_1^4 \cdot y \Big|_{-2}^2$$

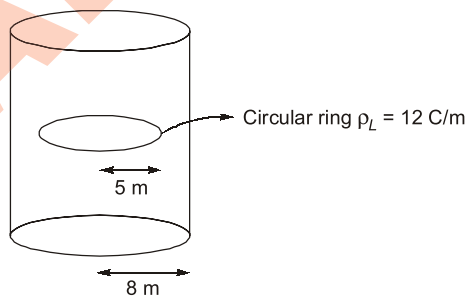
⇒

$$\psi = 0 + \frac{15}{2} \cdot 4 \cdot 3 + \frac{3}{2} \cdot 3 \cdot 4 = 90 + 18 = 108C$$

T2. (b)

$$\nabla \cdot D = \frac{1}{\rho} \left[\frac{\partial}{\partial \rho} (\rho 20\rho) + \frac{\partial}{\partial \rho} \left(\rho \frac{\rho^2}{3} \right) \right] = \frac{20 \times 2\rho}{\rho} + \frac{1}{3} \cdot \frac{3\rho^2}{\rho} = 40 + \rho$$

T3. Sol.



$$\text{Total charge enclosed} = \rho_L \times 2\pi R = 12 \times 2\pi \times 5 = 120\pi \text{ C}$$

T4. (c, d)

T5. (d)

Calculate the distance of the charges from the centre of the sphere and identify whether the charge is inside or outside the sphere.

For 2 C, $r_1 = \sqrt{4^2 + 8^2 + 3^2} = 9.43 \rightarrow$ Outside the sphere

For 8 C, $r_2 = \sqrt{2^2 + 1^2 + 3^2} = 3.74 \rightarrow$ Inside the sphere

For -12 C, $r_3 = \sqrt{4^2 + 0^2 + 1^2} = 4.123 \rightarrow$ Inside the sphere

Flux leaving the surface = $8 - 12 = -4$ C

T6. (c)

1 nC and 3 nC.

T7. (a)

$$\begin{aligned}\text{Charge enclosed} &= \rho_L \times \text{length}_{\text{enclosed}} \\ &= 15 \times 10 = 150 \text{ nC}\end{aligned}$$

T8. (5.903)

$$\vec{D} = \frac{\rho_L}{2\pi\epsilon_0} \hat{a}_p$$

$$d\vec{s} = dydz\hat{a}_x$$

$\therefore$

$$\phi = \int \vec{D} \cdot d\vec{s} = \frac{\rho_L}{2\pi\epsilon_0} dydz \hat{a}_p \cdot \hat{a}_x$$

$\therefore$

$$\rho = \sqrt{x^2 + y^2}; \hat{a}_p \cdot \hat{a}_x = \cos\phi$$

$\therefore$

$$\phi = \int \frac{\rho_L}{2\pi\sqrt{x^2 + y^2}} dydz \cdot \cos\phi$$

$\therefore$

$$\tan\phi = \frac{y}{x}$$

$\therefore$

$$\cos\phi = \frac{x}{\sqrt{x^2 + y^2}}$$

Hence,

$$\phi = \int \frac{\rho_L}{2\pi\sqrt{x^2 + y^2}} dy dz \cdot \frac{x}{\sqrt{x^2 + y^2}}$$

$$= \int \frac{\rho_L x}{2\pi\sqrt{x^2 + y^2}} dy dz$$

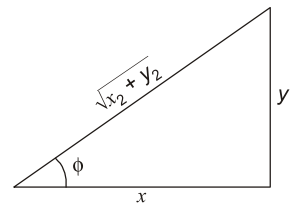
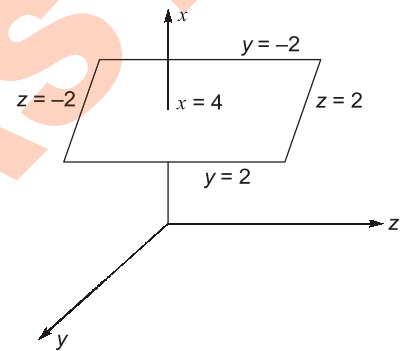
As $x = 4$, $y \in (-2, 2)$, $z \in (-2, 2)$

$\therefore$

$$\phi = \int \frac{\rho_L \cdot 4}{2\pi(16 + y^2)} dy dz$$

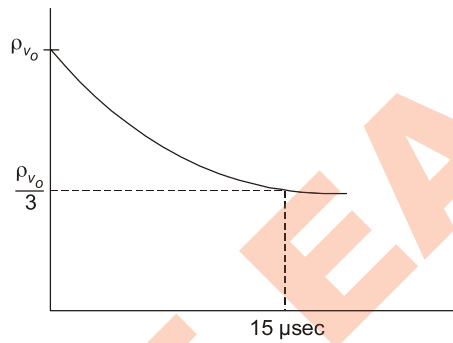
$$= \frac{\rho_L}{2\pi} \int_{-2}^2 \frac{4dy}{16 + y^2} \Big|_{-2}^2$$

$$= \frac{4\rho_L}{2\pi} \cdot \int_{-2}^2 \frac{4}{(4)^2 + y^2} dy$$



$$\begin{aligned}
 &= \frac{2\rho_L}{2\pi} \cdot 4 \cdot \int_{-2}^2 \frac{1}{(4)^2 + y^2} dy \\
 &= \frac{8\rho_L}{\pi} \cdot \frac{\tan^{-1}\left(\frac{1}{2}\right)}{4} \\
 &= \frac{2\rho_L}{\pi} \tan^{-1}\left(\frac{1}{2}\right) \cdot 2 \\
 &= \frac{4\rho_L}{\pi} \tan^{-1}\left(\frac{1}{2}\right) \\
 &= 5.903 \text{ nC}
 \end{aligned}$$

T9. (b)



$$\rho_v = \rho_{v0} e^{-t/T_r}; T_r = \frac{\epsilon}{\sigma}$$

$\therefore$

$$\frac{\rho_{v0}}{3} = \rho_{v0} e^{-t/T_r}$$

$$\frac{t}{T_r} = 1.0986$$

$$T_r = \frac{15 \times 10^{-6}}{1.0986} = 1.4 \times 10^{-5}$$

$$\begin{aligned}
 \epsilon_r &= \frac{1.4 \times 10^{-5} \times 2 \times 10^{-4}}{8.85 \times 10^{-12}} \\
 &= 308.56
 \end{aligned}$$

T10* (d)

$$\vec{E} = -\left[\frac{\partial V}{\partial x} \hat{a}_x + \frac{\partial V}{\partial y} \hat{a}_y + \frac{\partial V}{\partial z} \hat{a}_z \right]$$

$$\frac{\partial V}{\partial x} = 2y^3 - 3yz^2$$

$\Rightarrow$

$$V = 2y^3x - 3xyz^2 + f(y, z)$$

...(1)

$$\frac{\partial V}{\partial y} = 6xy^2 - 3xz^2$$

$$\Rightarrow V = 2xy^3 - 3xyz^2 + f(x, z) \quad \dots(2)$$

$$\frac{\partial V}{\partial z} = -6xyz$$

$$\Rightarrow V = -3xyz^2 + f(x, y) \quad \dots(3)$$

Equating equation (1), (2) and (3)

$$V = 2xy^3 - 3xyz^2$$

T11. Sol.

$$V = 100(x^2 - y^2)$$

At (2, 1, 1), $V = 100(4 - 1) = 300$

So, $100(x^2 - y^2) = 300$

$$\Rightarrow x^2 - y^2 = 3$$

T12. Sol.

$$\nabla^2 V = 0$$

$$\Rightarrow \nabla^2 V = \frac{1}{h_1 h_2 h_3} \left[\frac{\partial}{\partial u} \left(\frac{h_2 h_3}{h_1} \frac{\partial V}{\partial u} \right) + \frac{\partial}{\partial v} \left(\frac{h_3 h_1}{h_2} \frac{\partial V}{\partial v} \right) + \frac{\partial}{\partial w} \left(\frac{h_1 h_2}{h_3} \frac{\partial V}{\partial w} \right) \right]$$

As $V = f(\phi)$

$$\Rightarrow \nabla^2 V = \frac{1}{\rho} \left[\frac{\partial}{\partial \phi} \left(\frac{1}{\rho} \frac{\partial V}{\partial \phi} \right) \right] = 0$$

$$\Rightarrow \frac{\partial^2 V}{\partial \phi^2} = 0 \Rightarrow \frac{\partial V}{\partial \phi} = A$$

$$\Rightarrow V = A\phi + B$$

At $\phi = 0^\circ$, $V = 10 \text{ V} \Rightarrow 10 = B$

At $\phi = \frac{\pi}{6}$, $V = 150 \text{ V}$

$$150 = \frac{A\pi}{6} + 10$$

$$\Rightarrow A = \frac{840}{\pi}$$

$$\therefore V = \left(\frac{840}{\pi} \phi + 10 \right) \text{ V}$$

As $\vec{E} = -\nabla V = \frac{-1}{\rho} \frac{\partial V}{\partial \phi} \hat{a}_\phi$

$$\Rightarrow \vec{E} = \left(\frac{-840}{\pi \rho} \hat{a}_\phi \right) \text{ V/m}$$

$$\therefore \vec{D} = \epsilon_o \vec{E} = \frac{-840}{\pi \rho} \epsilon_o \hat{a}_\phi$$

As the conductor is a plane surface.

$$\therefore \rho_s = |D|$$

$$\text{So, } \rho_s = \frac{840\epsilon_o}{\pi\rho}$$

$$\Rightarrow Q = \int \rho_s \vec{ds}$$

$$\vec{ds} = ds\hat{a}_\phi = \rho d\phi dz\hat{a}_\phi$$

$$\therefore Q = \int \frac{840\epsilon_o}{\pi\rho} \rho d\phi dz = \frac{840}{\pi} \epsilon_o \ln \rho \Big|_1^2 z \Big|_0^1$$

$$Q = \frac{840\epsilon_o}{\pi} \ln(2) \Rightarrow Q = 1.64 \text{ nC}$$

T13. Sol.

$$Q = C_o V_o = C_{eq} V'$$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = 1.6$$

$$V' = \frac{24}{1.6} = 15 \text{ V}$$

T14. (c)

For air filled parallel plate capacitor

$$C_o = \frac{\epsilon_o A}{d}$$

$$Q = C_o V$$

The equivalent arrangement is parallel capacitor

$$C_{eq} = \frac{4\epsilon_o A}{2d} + \frac{\epsilon_o A}{2d} = \frac{5\epsilon_o A}{2d} = \frac{5}{2} C_o$$

$$Q_T = C_{eq} V'$$

$$2.5Q = 2.5C_o V'$$

$$Q = C_o V'$$

$$Q = C_o V$$

$$V' = V$$

But

$\therefore$

T15. Sol.

$$C_1 = \frac{\epsilon_1 A/2}{d}$$

$$C_2 = \frac{\epsilon_2 A/2}{d}$$

$$W_E = \frac{1}{2} CV^2$$

$$\frac{W_{E_1}}{W_{E_2}} = \frac{1}{2} = 0.5$$

T16. (b)

Concept : Method of images

For $\vec{F}_1$:

$$\vec{r} = \vec{r}_f - \vec{r}_i = (1, 0, 1) - (1, 0, -1) = 2\hat{a}_z$$

$\therefore$

$$\hat{a}_r = \frac{\vec{r}}{|\vec{r}|} = \frac{2\hat{a}_z}{2} = \hat{a}_z$$

$\therefore$

$$\vec{F}_1 = \frac{-Q^2}{4\pi\epsilon_0(r)} \hat{a}_z = \frac{-Q^2}{16\pi\epsilon_0} \hat{a}_z$$

For $\vec{F}_2$:

$$\vec{r} = \vec{r}_f - \vec{r}_i = (1, 0, 1) - (0, 0, -1) = \hat{a}_x + 2\hat{a}_z$$

$$|\vec{r}| = \sqrt{5}$$

$\therefore$

$$\hat{a}_r = \frac{\vec{r}}{|\vec{r}|} = \frac{\hat{a}_x + 2\hat{a}_z}{\sqrt{5}}$$

$\therefore$

$$\vec{F}_2 = \frac{Q^2}{4\pi\epsilon_0(5)} \cdot \frac{\hat{a}_x + 2\hat{a}_z}{\sqrt{5}}$$

For $\vec{F}_3$:

$$\vec{r} = \vec{r}_f - \vec{r}_i = (1, 0, 1) - (0, 0, 1) = \hat{a}_x$$

$$|\vec{r}| = 1$$

$\therefore$

$$\hat{a}_r = \frac{\hat{r}}{|\vec{r}|} = \hat{a}_x$$

$\therefore$

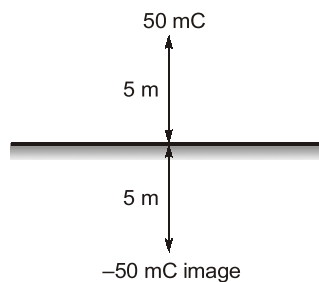
$$\vec{F}_3 = \frac{-Q^2}{4\pi\epsilon_0(1)} \hat{a}_x$$

Hence,

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 = -\frac{Q^2}{16\pi\epsilon} \hat{a}_z + \frac{Q^2}{4\pi\epsilon_0(5\sqrt{5})} (\hat{a}_x + 2\hat{a}_z) - \frac{Q^2}{4\pi\epsilon_0} \hat{a}_x$$

$$\vec{F} = \frac{Q^2}{4\pi\epsilon_0} \left[\frac{-\hat{a}_z}{4} + \frac{2\hat{a}_z}{5\sqrt{5}} + \frac{\hat{a}_x}{5\sqrt{5}} - \hat{a}_x \right]$$

$$\vec{F} = \frac{-Q^2}{4\pi\epsilon_0} [0.91\hat{a}_x + 0.071\hat{a}_z] \text{ N}$$

T17. Sol.

The induced surface charge density is the normal flux density at the point

$$D_{\text{normal}} = \rho_s$$

$$E \text{ due charge} = \frac{50 \times 10^{-3} \times 9 \times 10^9}{25} = 18 \times 10^6 \text{ V/m}$$

$$E \text{ due to image} = 18 \times 10^6 \text{ V/m (same direction)}$$

$$\text{Total } E = 36 \times 10^6$$

$$D = 36 \times 10^6 \times \frac{1}{36\pi \times 10^9} = \frac{1}{\pi} \text{ mC}$$

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MADE EASY

4

Magnetostatics

T1. Sol.

$$H \propto \frac{I}{d} \text{ for a square loop}$$

$$\frac{H_1}{H_2} = \frac{I_1}{I_2} \frac{d_2}{d_1} = \frac{20}{5} \frac{d}{d/3} = 12$$

T2. (b)

$$B \text{ at centre} = \frac{\mu_0 I}{2R} \left[1 - \frac{1}{2} + \frac{1}{4} \dots \right] \hat{a}_z$$

$$= \frac{\mu_0 I}{2R} \left[\frac{1}{1 - \left(-\frac{1}{2} \right)} \right] \hat{a}_z = \frac{\mu_0 I}{3R} \hat{a}_z$$

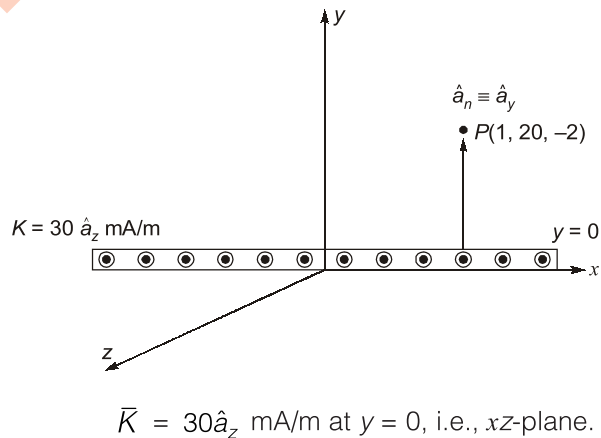
T3. (d)

$$\hat{a}_H = \hat{a}_L \times \hat{a}_r$$

1. For xy -plane wire : $\hat{a}_H = \hat{a}_x \times -\hat{a}_y = -\hat{a}_z$

2. For yz -plane wire : $\hat{a}_H = \hat{a}_y \times -\hat{a}_z = -\hat{a}_x$

T4. Sol.



$P(1, 20, -2)$ has $y = 20$ which lies above $y = 0$.

So, $\hat{a}_x \equiv \hat{a}_y$

Hence,
$$\begin{aligned}\vec{H} &= \frac{1}{2} \vec{K} \times \hat{a}_x \\ &= \frac{1}{2} \times 30 [\hat{a}_z \times \hat{a}_y] \\ &= -15 \hat{a}_x\end{aligned}$$

$\therefore \vec{H} = -15 \hat{i} \text{ mA/m}$

T5. Sol.

If flow direction = Vector potential direction

A direction at $\rho = \hat{a}_y$

B direction = $\hat{a}_y \times \hat{a}_x = -\hat{a}_z$

T6. Sol.

$\nabla^2 A = -\mu J$

$\nabla^2 z^2 \hat{a}_\rho + \nabla^2 2\rho^2 \cos\phi \hat{a}_\phi = -\mu J$

$$\nabla^2 z^2 = \frac{1}{\rho} \frac{\partial}{\partial \rho} \left(\rho \frac{\partial z^2}{\partial \rho} \right) + \frac{1}{\rho} \frac{\partial}{\partial \rho} \left(\frac{1}{\rho} \frac{\partial z^2}{\partial \phi} \right) + \frac{1}{\rho} \frac{\partial}{\partial z} \left(\rho \frac{\partial z^2}{\partial z} \right) = 2$$

$$\begin{aligned}\nabla^2 2\rho^2 \cos\phi &= \frac{1}{\rho} \frac{\partial}{\partial \rho} \left(\rho \frac{\partial}{\partial \rho} (2\rho^2 \cos\phi) \right) + \frac{1}{\rho} \frac{\partial}{\partial \phi} \left(\frac{1}{\rho} \frac{\partial}{\partial \phi} (2\rho^2 \cos\phi) \right) + \frac{1}{\rho} \frac{\partial}{\partial z} \left(\rho \frac{\partial}{\partial z} (2\rho^2 \cos\phi) \right) \\ &= \frac{1}{\rho} \cos\phi \cdot 4 \cdot 2 \cdot \rho - 2 \cos\phi = 6 \cos\phi\end{aligned}$$

At the origin,

$\nabla^2 A = 2\hat{a}_\rho + 6\hat{a}_\phi = -\mu J$

$J = \frac{-1}{\mu} (2\hat{a}_\rho + 6\hat{a}_\phi)$

T7. (a)

T8. Sol.

$f = \mu N = \mu_{mg} = 0.1 \times 1 \times 10 = 1 \text{ N}$

$\vec{F} = i\vec{l} \times \vec{B} = 10(0.5)\hat{a}_y \times -1\hat{a}_z \equiv -5\hat{a}_x \Rightarrow |\vec{F}| = 5$

$F_{\text{net}} = F - f = 5 - 1 = 4$

$F_{\text{net}} = ma$

Also,

$\therefore ma = 4 \Rightarrow a = \frac{4}{m} = \frac{4}{1} \equiv 4 \text{ m/s}^2$

Now,

$V^2 = u^2 + 2as$

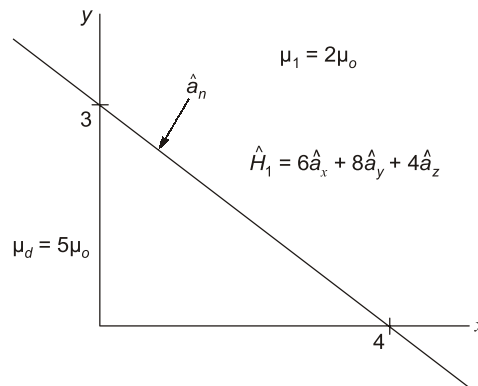
$\Rightarrow$

$V^2 = 2as$

$\Rightarrow$

$V = \sqrt{2as} \equiv \sqrt{2 \times 4 \times 1} \equiv \sqrt{8} \equiv 2.8 \text{ m/s}$

T9. (b)



$$3x + 4y = 12$$

At $x = 0$,

$$y = 3$$

At $y = 0$,

$$x = 4$$

As

$$\vec{H}_1 = 6\hat{a}_x + 8\hat{a}_y + 4\hat{a}_z$$

$\Rightarrow$

$$\begin{aligned}\vec{H}_{1n} &= (\vec{H}_1 \cdot \hat{a}_n) \hat{a}_n = \left\{ (6, 8, 4) \left(\frac{3, 4, 0}{5} \right) \right\} \left(\frac{3, 4, 0}{5} \right) \\ &= \left\{ \frac{18 + 32}{25} \right\} (3\hat{a}_x + 4\hat{a}_y) \equiv 6\hat{a}_x + 8\hat{a}_y\end{aligned}$$

$\therefore$

$$\vec{H}_{1t} = \vec{H}_1 - \vec{H}_{1n} = (6, 8, 4) - (6, 8, 0) \equiv 4\hat{a}_z$$

Now, at $\vec{K} = 0$,

$$\vec{H}_{1t} = \vec{H}_{2t} \Rightarrow \vec{H}_{2t} = 4\hat{a}_z$$

Also,

$$\vec{B}_{1n} = \vec{B}_{2n}$$

$\Rightarrow$

$$\mu_1 \vec{H}_{1n} = \mu_2 \vec{H}_{2n}$$

$\Rightarrow$

$$\vec{H}_{2n} = \frac{\mu_1}{\mu_2} \vec{H}_{1n} = \frac{2}{5} (6\hat{a}_x + 8\hat{a}_y) \equiv 2.4\hat{a}_x + 0.8\hat{a}_y$$

$\therefore$

$$\vec{H}_2 = \vec{H}_{2t} + \vec{H}_{2n} = 2.4\hat{a}_x + 0.8\hat{a}_y + 4\hat{a}_z \text{ A/m}$$

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5

Time Varying Fields

T1. (c)

T2. (d)

T3. (a, b, c)

Region has no charge, i.e., $\rho_v = 0$ and no current, i.e., $\vec{J} = 0$.

(a) $\nabla \cdot \vec{D} = \rho_v$

at $\rho_v = 0$, $\nabla \cdot \vec{D} = 0 \Rightarrow \nabla \cdot \vec{E} = 0$

(b) $\nabla \cdot \vec{B} = 0$

(c) $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$

(d) $\nabla \times \vec{H} = \vec{J}_c + \vec{J}_d = \vec{J}_d$

$\Rightarrow \nabla \times \frac{\vec{B}}{\mu} = \frac{\partial \vec{D}}{\partial t}$

$\Rightarrow \nabla \times \vec{B} = \mu \epsilon \frac{\partial \vec{E}}{\partial t}$

$\Rightarrow \nabla \times \vec{B} = \frac{1}{C^2} \cdot \frac{\partial \vec{E}}{\partial t}$

$\Rightarrow \nabla \times \vec{B} - \frac{1}{C^2} \cdot \frac{\partial \vec{E}}{\partial t} = 0$

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