

Practice Set-1 Solutions

Magnetostatics

1. The magnetic field at a distance R from a long straight wire carrying a steady current I is proportional to [NET 2012]

- A.** IR **B.** I/R^2
C. I^2/R^2 **D.** I/R

Solution: The correct option is **(d)**

2. The vector potential \vec{A} due to a magnetic moment \vec{m} at a point \vec{r} is given by $\vec{A} = \frac{\vec{m} \times \vec{r}}{r^3}$. If \vec{m} is directed along the positive z-axis, the x - component of the magnetic field, at the point \vec{r} , is

- A.** $\frac{3myz}{r^5}$ **B.** $-\frac{3mxy}{r^5}$
- C.** $\frac{3mxz}{r^5}$ **D.** $\frac{3m(z^2 - xy)}{r^5}$

Solution:

$$\vec{m} = m\hat{z}$$

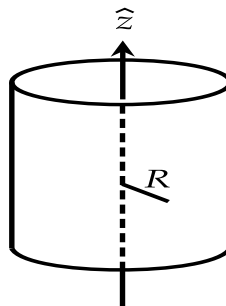
and

$$\vec{B} = \vec{\nabla} \times \vec{A} = \frac{m}{r^3} (2 \cos \theta \hat{r} + \sin \theta \hat{\theta}) = \frac{1}{r^3} [3(\vec{m} \cdot \hat{r})\hat{r} - \vec{m}]$$

$$\vec{B} = \frac{1}{r^3} \left[3m\hat{z} \cdot \left(\frac{x\hat{x} + y\hat{y} + z\hat{z}}{r} \right) \frac{\vec{r}}{r} - m\hat{z} \right]$$

$$B_x = \frac{3mxz}{r^5}$$

3. An infinite solenoid with its axis of symmetry along the z -direction carries a steady current I . The vector potential \vec{A} at a distance R from the axis



- A.** is constant inside and varies as R outside the solenoid
- B.** varies as R inside and is constant outside the solenoid
- C.** varies as $\frac{1}{R}$ inside and as R outside the solenoid
- D.** varies as R inside and as $\frac{1}{R}$ outside the solenoid

Pitch of the helix $l = v_{\parallel} T = v_{\parallel} \frac{2\pi R}{v_{\perp}}$

$$\frac{l}{R} = 4\pi$$

7. A proton moves with a speed of 300 m/s in a circular orbit in the xy -plan in a magnetic field 1 tesla along the positive z -direction. When an electric field of 1 V/m is applied along the positive y -direction, the center of the circular orbit

[NET 2014]

- A.** remains stationary
B. moves at 1 m/s along the negative x -direction
C. moves at 1 m/s along the positive z - direction
D. moves at 1 m/s along the positive x - direction

Solution: Change particle will deflect in $+x$ -direction with

$$v = \frac{E}{B} = \frac{1}{1} = 1 \text{ m/s.}$$

The correct option is **(d)**

8. Given a uniform magnetic field $B = B_0 \hat{k}$ (where B_0 is a constant), a possible choice for the magnetic vector potential A is

[NET 2015]

- A.** $B_0 y \hat{i}$ **B.** $-B_0 y \hat{i}$
C. $B_0 (x \hat{j} + y \hat{i})$ **D.** $B_0 (x \hat{i} + y \hat{j})$

Solution: (a) $\vec{\nabla} \times \vec{A} = -B_0 \hat{k}$

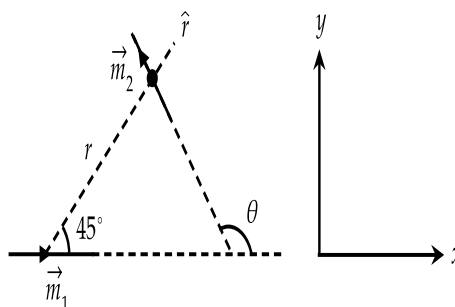
- (b) $\vec{\nabla} \times \vec{A} = B_0 \hat{k}$
 (c) $\vec{\nabla} \times \vec{A} = 0$
 (d) $\vec{\nabla} \times \vec{A} = 0$

The correct option is **(b)**

9. A small magnetic needle is kept at $(0,0)$ with its moment along the x -axis. Another small magnetic needle is at the point $(1,1)$ and is free to rotate in the xy - plane. In equilibrium the angle θ between their magnetic moments is such that

[NET 2015]

- A.** $\tan \theta = \frac{1}{3}$
- B.** $\tan \theta = 0$
- C.** $\tan \theta = 3$
- D.** $\tan \theta = 1$



Solution:

$$U = \frac{\mu_0}{4\pi r^3} [\vec{m}_1 \cdot \vec{m}_2 - 3(\vec{m}_1 \cdot \hat{r})(\vec{m}_2 \cdot \hat{r})]$$

$$U = \frac{\mu_0 m_1 m_2}{4\pi r^3} [\cos \theta - 3 \cos 45^\circ \cos (\theta - 45^\circ)]$$

For stable position energy is minimum i.e.

$$\frac{\partial U}{\partial \theta} = 0 \Rightarrow \frac{\mu_0 m_1 m_2}{4\pi r^3} \left[-\sin \theta + \frac{3}{\sqrt{2}} \sin (\theta - 45^\circ) \right] = 0$$

$$\Rightarrow \sin \theta = \frac{3}{\sqrt{2}} \left(\frac{\sin \theta}{\sqrt{2}} - \frac{\cos \theta}{\sqrt{2}} \right) \Rightarrow \tan \theta = 3$$

The correct option (c)

10. A dipole of moment \vec{p} , oscillating at frequency ω , radiates spherical waves. The vector potential at large distance is

$$\vec{A}(\vec{r}) = \frac{\mu_0}{4\pi} i\omega \frac{e^{ikr}}{r} \vec{p}$$

To order $\left(\frac{1}{r}\right)$ the magnetic field \vec{B} at a point $\vec{r} = r\hat{n}$ is

[NET 2015]

A. $-\frac{\mu_0}{4\pi} \frac{\omega^2}{c} (\hat{n} \cdot \vec{p}) \hat{n} \frac{e^{ikr}}{r}$

B. $-\frac{\mu_0}{4\pi} \frac{\omega^2}{c} (\hat{n} \times \vec{p}) \frac{e^{ikr}}{r}$

C. $-\frac{\mu_0}{4\pi} \omega^2 k (\hat{n} \cdot \vec{p}) \vec{p} \frac{e^{ikr}}{r}$

D. $-\frac{\pi_0}{4\pi} \frac{\omega^2}{c} \vec{p} \frac{e^{ikr}}{r}$

Solution:

$$\text{Let } \vec{p} = p\hat{z}$$

then, \vec{B} must be in $\hat{\phi}$ direction.

$$\hat{n} \times \vec{p} = \hat{r} \times \hat{z} = \hat{\phi}$$

The correct option is (b).

11. A loop of radius a , carrying a current I , is placed in a uniform magnetic field B . If the normal to the loop is denoted by \hat{n} , the force \vec{F} and the torque \vec{T} on the loop are

[NET 2015]

A. $\vec{F} = 0$ and $\vec{T} = \pi a^2 I \hat{n} \times B$

B. $\vec{F} = \frac{\mu_0}{4\pi} \vec{I} \times \vec{B}$

C. $\vec{F} = \frac{\mu_0}{4\pi} \vec{I} \times \vec{B}$ and $\vec{T} = I \hat{n} \times \vec{B}$

D. $\vec{F} = 0$ and $\vec{T} = \frac{1}{\mu_0 \epsilon_0} I \vec{B}$

Solution:

$$\text{In uniform field } \vec{F} = 0$$

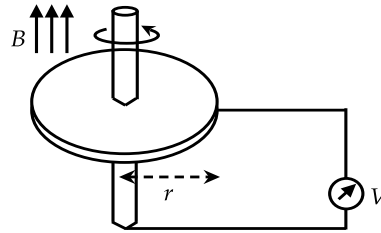
$$\text{Torque } \vec{T} = \vec{m} \times \vec{B}$$

$$= \pi a^2 I \hat{n} \times \vec{B}$$

The correct option is (a)

12. A conducting circular disc of radius r and resistivity ρ rotates with an angular velocity ω in a magnetic field B perpendicular to it. A voltmeter is connected as shown in the figure below. Assuming its internal resistance to be infinite, the reading on the voltmeter

[NET 2016]



- A. depends on ω, B, r and ρ
- B. depends on ω, B and r but not on ρ
- C. is zero because the flux through the loop is not changing
- D. is zero because a current the flows in the direction of B

Solution: Force experienced by charge is

$$\vec{F} = q(\vec{v} \times \vec{B}) \text{ and } v = r\omega$$

13. A set of N concentric circular loops of wire, each carrying a steady current I in the same direction, is arranged in a plane. The radius of the first loop is $r_1 = a$ and the radius of the n^{th} loop is given by $r_n = nr_{n-1}$. The magnitude B of the magnetic field at the centre of the circles in the limit $N \rightarrow \infty$, is

[NET 2016]

- A. $\mu_0 I (e^2 - 1) / 4\pi a$
- B. $\mu_0 I (e - 1) / \pi a$
- C. $\mu_0 I (e^2 - 1) / 8a$
- D. $\mu_0 I (e - 1) / 2a$

Solution:

$$B = \frac{\mu_0 I}{2} \left(\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \dots + \frac{1}{r_n} \right)$$

$$r_1 = a$$

$$r_n = nr_{n-1}$$

$$r_1 = r_0 = a, r_2 = 2r_1 = 2a, r_3 = 3r_2 = 3.2a \text{ and } r_4 = 4r_3 = 4.3.2a$$

$$\Rightarrow B = \frac{\mu_0 I}{2a} \left(1 + \frac{1}{2} + \frac{1}{3.2} + \frac{1}{4.3.2} + \dots \right)$$

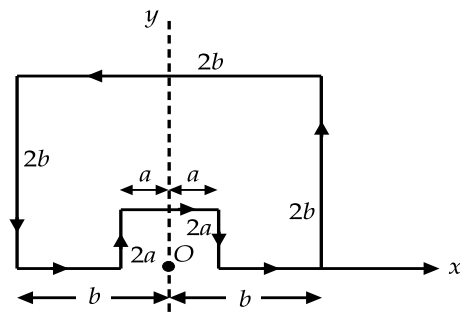
$$B = \frac{\mu_0 I}{2a} \left(\sum_{n=1}^N \frac{1}{n} \right)$$

$$e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!} \Rightarrow e = \sum_{n=0}^{\infty} \frac{1}{n!} = 1 + \sum_{n=1}^{\infty} \frac{1}{n!} \Rightarrow \sum_{n=1}^{\infty} \frac{1}{n!} = e - 1$$

$$\lim_{N \rightarrow \infty} \left(\sum_{n=1}^N \frac{1}{n} \right) = e - 1 \Rightarrow B = \frac{\mu_0 I}{2a} (e - 1)$$

The correct option is (d)

14. A constant current I is flowing in a piece of wire that is bent into a loop as shown in the figure.



The magnitude of the magnetic field at the point O is

[NET 2017]

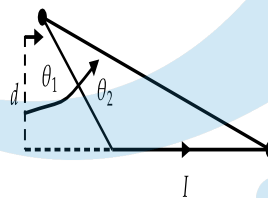
A. $\frac{\mu_0 I}{4\pi\sqrt{5}} \ln\left(\frac{a}{b}\right)$

B. $\frac{\mu_0 I}{4\pi\sqrt{5}} \left(\frac{1}{a} - \frac{1}{b}\right)$

C. $\frac{\mu_0 I}{4\pi\sqrt{5}} \left(\frac{1}{a}\right)$

D. $\frac{\mu_0 I}{4\pi\sqrt{5}} \left(\frac{1}{b}\right)$

Solution:



$$\vec{B} = \frac{\mu_0 I}{4\pi d} (\sin \theta_2 - \sin \theta_1) \hat{\phi}$$

Magnetic field due to left and right segment of $2a$

$$B_{2a} = \frac{\mu_0 I}{4\pi a} \left(\frac{2a}{\sqrt{5}a} \right) \otimes$$

Field due to upper segment of $2a$

$$= \frac{\mu_0 I}{4\pi(2a)} \times \left(\frac{a}{\sqrt{5}a} + \frac{a}{\sqrt{5}a} \right)$$

Net field

$$B_{2a} = 2 \times \frac{\mu_0 I}{4\pi a} \times \frac{2}{\sqrt{5}} + \frac{\mu_0 I}{4\pi a} \times \frac{1}{\sqrt{5}}$$

$$B_{2a} = \frac{\mu_0 I}{4\pi a} \sqrt{5} \otimes (\text{inward})$$

$$\text{similarly, } B_{2b} = \frac{\mu_0 I}{4\pi b} \sqrt{5} \odot (\text{outward})$$

Net field

$$B = B_{2a} - B_{2b} = \frac{\mu_0 I}{4\pi} \sqrt{5} \left(\frac{1}{a} - \frac{1}{b} \right)$$

The correct option is **(b)**

15. A circular current carrying loop of radius a carries a steady current. A constant electric charge is kept at the centre of the loop. The electric and magnetic fields, \vec{E} and \vec{B} respectively, at a distance d vertically above the centre of the loop satisfy

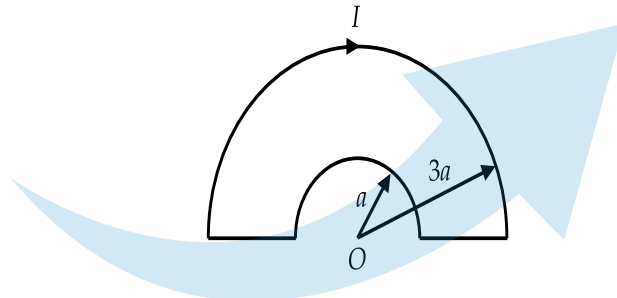
[NET 2017]

- A.** $\vec{E} \perp \vec{B}$
- B.** $\vec{E} = 0$
- C.** $\vec{\nabla}(\vec{E} \cdot \vec{B}) = 0$
- D.** $\vec{\nabla} \cdot (\vec{E} \times \vec{B}) = 0$

Solution: $\vec{E} \times \vec{B} = 0 \Rightarrow \vec{\nabla} \cdot (\vec{E} \times \vec{B}) = 0$

The correct option is **(c)**

16. The loop shown in the figure below carries a steady current I



The magnitude of the magnetic field at the point O is

[NET 2018]

- A.** $\frac{\mu_0 I}{2a}$ **B.** $\frac{\mu_0 I}{6a}$
C. $\frac{\mu_0 I}{4a}$ **D.** $\frac{\mu_0 I}{3a}$

Solution:

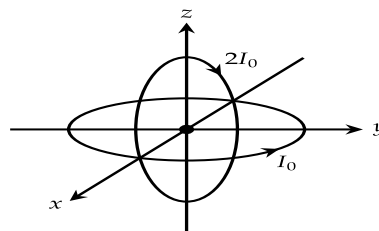
$$\begin{aligned} B_a &= \frac{1}{2} \frac{\mu_0 I}{2a} \odot, \\ B_{3a} &= \frac{1}{2} \frac{\mu_0 I}{2(3a)} \otimes \\ B &= B_a - B_{3a} = \frac{\mu_0 I}{4a} \left(1 - \frac{1}{3} \right) = \frac{\mu_0 I}{6a} \end{aligned}$$

The correct option is **(b)**

17. Two current-carrying circular loops, each of radius R , are placed perpendicular to each other, as shown in the figure.

The loop in the xy - plane carries a current I_0 while that in the xz -plane carries a current $2I_0$. The resulting magnetic field \vec{B} at the origin is

[NET 2018 dec]



A. $\frac{\mu_0 I_0}{2R} [2\hat{j} + \hat{k}]$

B. $\frac{\mu_0 I_0}{2R} [2\hat{j} - \hat{k}]$

C. $\frac{\mu_0 I_0}{2R} [-2\hat{j} + \hat{k}]$

D. $\frac{\mu_0 I_0}{2R} [-2\hat{j} - \hat{k}]$

Solution:

Field due to loop in xy plane is

$$\vec{B}_1 = \frac{\mu_0 I_0}{2R} \hat{z}$$

Field due to loop in xz plane is

$$\vec{B}_2 = \frac{\mu_0 (2I_0)}{2R} (-\hat{y})$$

Resultant field

$$\vec{B} = \vec{B}_1 + \vec{B}_2 = \frac{\mu_0 I_0}{2R} (-2\hat{y} + \hat{z})$$

The correct option is (c)



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Practice Set - 2 Solutions

Magnetostatics

1. Two magnetic dipoles of magnitude m each are placed in a plane as shown in figure. The energy of interaction is given by

[GATE 2010]

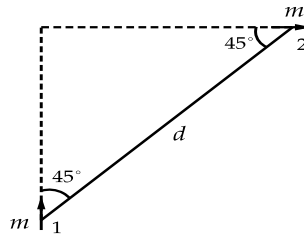


Figure 1

- A. Zero
 B. $\frac{\mu_0 m^2}{4\pi d^3}$
 C. $\frac{3\mu_0 m^2}{2\pi d^3}$
 D. $-\frac{3\mu_0 m^2}{8\pi d^3}$

Solution:

$$U = \frac{\mu_0}{4\pi r^3} [\vec{m}_1 \cdot \vec{m}_2 - 3(\vec{m}_1 \cdot \hat{r})(\vec{m}_2 \cdot \hat{r})]$$

$$\text{Since } \vec{m}_1 \perp \vec{m}_2 \Rightarrow \vec{m}_1 \cdot \vec{m}_2 = 0$$

$$U = \frac{\mu_0}{4\pi d^3} [-3 \times m \cos 45^\circ \times m \cos 45^\circ]$$

$$\Rightarrow U = -\frac{3\mu_0 m^2}{8\pi d^3}$$

The correct option is (d)

2. If a force \vec{F} is derivable from a potential function $V(r)$, where r is the distance from the origin of the coordinate system, it follows that

[GATE 2011]

- A. $\vec{\nabla} \times \vec{F} = 0$
 B. $\vec{\nabla} \cdot \vec{F} = 0$
 C. $\vec{\nabla} V = 0$
 D. $\nabla^2 V = 0$

Solution: The correct option is (a)

3. A uniform surface current is flowing in the positive y -direction over an infinite sheet lying in $x-y$ plane. The direction of the magnetic field is

[GATE 2011]

- A. along \hat{i} for $z > 0$ and along $-\hat{i}$ for $z < 0$
 B. along \hat{k} for $z > 0$ and along $-\hat{k}$ for $z < 0$
 C. along $-\hat{i}$ for $z > 0$ and along \hat{i} for $z < 0$
 D. along $-\hat{k}$ for $z > 0$ and along \hat{k} for $z < 0$

Solution: The correct option is (a)

4. A magnetic dipole of dipole moment \vec{m} is placed in a non-uniform magnetic field \vec{B} . If the position vector of the dipole is \vec{r} , the torque acting on the dipole about the origin is

[GATE 2011]

A. $\vec{r} \times (\vec{m} \times \vec{B})$

B. $\vec{r} \times \vec{\nabla}(\vec{m} \cdot \vec{B})$

C. $\vec{m} \times \vec{B}$

D. $\vec{m} \times \vec{B} + \vec{r} \times \nabla(\vec{m} \cdot \vec{B})$

Solution: The correct option is (c)

5. Which of the following expressions for a vector potential \vec{A} DOES NOT represent a uniform magnetic field of magnitude B_0 along the z-direction?

[GATE 2011]

A. $\vec{A} = (0, B_0 x, 0)$

B. $\vec{A} = (-B_0 y, 0, 0)$

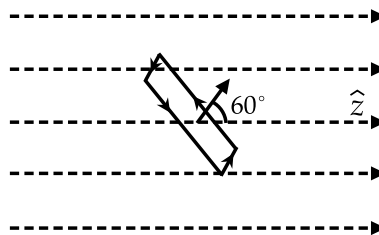
C. $\vec{A} = \left(\frac{B_0 x}{2}, \frac{B_0 y}{2}, 0 \right)$

D. $\vec{A} = \left(-\frac{B_0 y}{2}, \frac{B_0 x}{2}, 0 \right)$

Solution: $\vec{B} \neq \vec{\nabla} \times \vec{A}$

The correct option is (c)

6. In a constant magnetic field of 0.6 Tesla along the z direction, find the value of the path integral $\oint \vec{A} \cdot d\vec{l}$ in the units of (Tesla m^2) on a square loop of side length $(1/\sqrt{2})$ meters. The normal to the loop makes an angle of 60° to the z-axis, as shown in the figure.



The answer should be up to two decimal places.

[GATE]

Solution:

$$\begin{aligned} \oint \vec{A} \cdot d\vec{l} &= \int_S (\vec{\nabla} \times \vec{A}) d\vec{a} \\ &= \int_S \vec{B} \cdot d\vec{a} \\ &= BA \cos 60^\circ \\ &= 0.6 \times \left(\frac{1}{\sqrt{2}} \right)^2 \times \frac{1}{2} \\ &= 0.15 T \cdot m^2 \end{aligned}$$

7. The value of the magnetic field required to maintain non-relativistic protons of energy 1 MeV in a circular orbit of radius 100 mm is Tesla

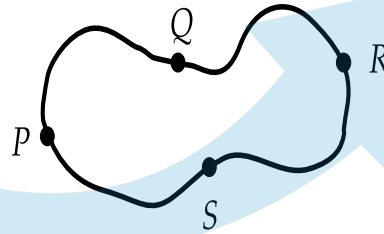
[GATE 2014]

Solution:

$$\begin{aligned}
 E &= \frac{q^2 B^2 R^2}{2m_p} \Rightarrow 1.6 \times 10^{-13} = \frac{(1.6 \times 10^{-19})^2 B^2 (0.1)^2}{2(1.67 \times 10^{-27})} \\
 \Rightarrow B^2 &= \frac{1.6 \times 10^{-13} \times 2(1.67 \times 10^{-27})}{(1.6 \times 10^{-19})^2 (0.1)^2} \\
 \Rightarrow B^2 &= \frac{10^{-13} \times 2(1.67 \times 10^{-27})}{(1.6 \times 10^{-38})(0.01)} = \frac{3.34 \times 10^{-40}}{1.6 \times 10^{-40}} = 2.08 \\
 \Rightarrow B &= \sqrt{2.08} \text{ Tesla} = 1.44 \text{ Tesla}
 \end{aligned}$$

8. Given that the magnetic flux through the closed loop $PQRSP$ is ϕ . If $\int_P^R \vec{A} \cdot d\vec{l} = \phi_1$ along PQR , the value of $\int_P^R \vec{A} \cdot d\vec{l}$ along PSR is

[GATE 2015]



- A. (a) $\phi - \phi_1$
C. $-\phi_1$

- B. $\phi_1 - \phi$
D. ϕ_1

Solution:

$$\begin{aligned}
 \phi &= \int_s \vec{B} \cdot d\vec{a} \\
 &= \oint \vec{A} \cdot d\vec{l} \\
 &= \int_P^R \vec{A} \cdot d\vec{l} + \int_R^P \vec{A} \cdot d\vec{l} \\
 \phi &= \phi_1 - \int_P^R \vec{A} \cdot d\vec{l} \\
 \int_P^R \vec{A} \cdot d\vec{l} &= \phi_1 - \phi
 \end{aligned}$$

The correct option is (b)

9. Which of the following magnetic vector potentials gives rise to a uniform magnetic field $B_0 \hat{k}$?

[GATE 2016]

A. $B_0 z \hat{k}$

B. $-B_0 x \hat{j}$

C. $\frac{B_0}{2}(-y\hat{i} + x\hat{j})$

D. $\frac{B_0}{2}(y\hat{i} + x\hat{j})$

Solution: (a) $\vec{\nabla} \times \vec{A} = 0$
 (b) $\vec{\nabla} \times \vec{A} = -B_0 \hat{k}$
 (c) $\vec{\nabla} \times \vec{A} = B_0 \hat{k}$

$$(d) \vec{\nabla} \times \vec{A} = 0$$

The correct option is (c)

10. The magnitude of the magnetic dipole moment associated with a square shaped loop carrying a steady current I is m . If this loop is changed to a circular shape with the same current I passing through it, the magnetic dipole moment becomes $\frac{pm}{\pi}$. The value of p is

[GATE 2016]

Solution: Magnetic dipole moment associated with a square shaped loop (let side is a) carrying a steady current I is $m = Ia^2$.

Magnetic dipole moment associated with a circular shaped loop (let radius is r) carrying a steady current I is $m' = I\pi r^2$. Here,

$$\begin{aligned} 4a &= 2\pi r \\ r &= \frac{2a}{\pi} \\ m' &= I\pi r^2 = I\pi \left(\frac{2a}{\pi}\right)^2 \\ &= \frac{4Ia^2}{\pi} = \frac{4m}{\pi} \end{aligned}$$

11. An infinite solenoid carries a time varying current $I(t) = At^2$, with $A \neq 0$. The axis of the solenoid is along the \hat{z} direction. \hat{r} and $\hat{\theta}$ are the usual radial and polar directions in cylindrical polar coordinates. $\vec{B} = B_r\hat{r} + B_\theta\hat{\theta} + B_z\hat{z}$ is the magnetic field at a point outside the solenoid. Which one of the following statements is true?

[GATE 2017]

A. $B_r = 0, B_\theta = 0, B_z = 0$

B. $B_r \neq 0, B_\theta \neq 0, B_z = 0$

C. $B_r \neq 0, B_\theta \neq 0, B_z \neq 0$

D. $B_r = 0, B_\theta = 0, B_z \neq 0$

Solution: The correct option is (d)

12. An infinitely long straight wire is carrying a steady current I . The ratio of magnetic energy density at distance r_1 to that at $r_2 (= 2r_1)$ from the wire is

[GATE 2018]

Solution:

$$u_B = \frac{B^2}{2\mu_0} \propto \frac{1}{r^2} \Rightarrow \frac{u_{B1}}{u_{B2}} = \frac{r_2^2}{r_1^2} = \frac{(2r_1)^2}{r_1^2} = 4$$

13. A constant and uniform magnetic field $\vec{B} = B_0\hat{k}$ pervades all space. Which one of the following is the correct choice for the vector potential in Coulomb gauge?

[GATE 2018]

A. $-B_0(x+y)\hat{i}$

B. $B_0(x+y)\hat{j}$

C. $B_0x\hat{j}$

D. $-\frac{1}{2}B_0(x\hat{i} - y\hat{j})$

Solution: Check option (c),

$$\vec{\nabla} \cdot \vec{A} = 0, \vec{B} = \vec{\nabla} \times \vec{A} = B_0\hat{k}$$

The correct option is (c)

A. $\alpha = \beta$

B. $\alpha = -\beta$

C. $\alpha = 2\beta$

D. $\alpha = \frac{\beta}{2}$

Solution:

$$\text{Solution: } \vec{B} = \vec{\nabla} \times \vec{A} = \frac{1}{r} \begin{vmatrix} \hat{r} & r\hat{\phi} & \hat{z} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ A_r & rA_\phi & 0 \end{vmatrix} = \mu_0 n I \hat{z}$$

$$\vec{B}' = \vec{\nabla} \times \vec{A}' = \frac{1}{r} \begin{vmatrix} \hat{r} & r\hat{\phi} & \hat{z} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ A_r & rA_\phi & 0 \end{vmatrix} = \mu_0 n I \left[(\alpha \cos \phi + 1) - \frac{\beta \cos \phi}{2} \right] \hat{z}$$

$$\text{Equate } \vec{B}' = \vec{B} \Rightarrow \left[(\alpha \cos \phi + 1) - \frac{\beta \cos \phi}{2} \right] = \mu_0 n I$$

$$\Rightarrow \alpha \cos \phi = \frac{\beta}{2} \cos \phi \Rightarrow \alpha = \frac{\beta}{2}$$

The correct option is (d)

17. A magnetic field $\vec{B} = B_0(\hat{i} + 2\hat{j} - 4\hat{k})$ exists at point. If a test charge moving with a velocity, $\vec{v} = v_0(3\hat{i} - \hat{j} + 2\hat{k})$ experiences no force at a certain point, the electric field at that point in SI units is

[JEST 2012]

A. $\vec{E} = -v_0 B_0(3\hat{i} - 2\hat{j} - 4\hat{k})$

B. $\vec{E} = -v_0 B_0(\hat{i} + \hat{j} + 7\hat{k})$

C. $\vec{E} = v_0 B_0(14\hat{j} + 7\hat{k})$

D. $\vec{E} = -v_0 B_0(14\hat{j} + 7\hat{k})$

Solution:

$$\begin{aligned} \vec{F} &= q[\vec{E} + \vec{v} \times \vec{B}] = 0 \Rightarrow \vec{E} = -(\vec{v} \times \vec{B}) \\ \Rightarrow \vec{E} &= -v_0 B_0 \{ (4 - 4)\hat{i} + (2 + 12)\hat{j} + (6 + 1)\hat{k} \} \\ &= -v_0 B_0(14\hat{j} + 7\hat{k}) \end{aligned}$$

18. A small magnet is dropped down a long vertical copper tube in a uniform gravitational field. After a long time, the magnet

[JEST 2012]

A. attains a constant velocity

B. moves with a constant acceleration

C. moves with a constant deceleration

D. executes simple harmonic motion

Solution: The correct option is (a)

19. A thin uniform ring carrying charge Q and mass M rotates about its axis. What is the gyromagnetic ratio (defined as ratio of magnetic dipole moment to the angular momentum) of this ring?

[JEST 2013]

A. $\frac{Q}{2\pi M}$

B. $\frac{Q}{M}$

C. $\frac{Q}{2M}$

D. $\frac{Q}{\pi M}$

Solution: Magnetic dipole moment $M' = IA = \frac{Q}{T} \pi r^2 \Rightarrow \frac{Q}{2\pi T} \times 2\pi \times \pi r^2 = \frac{Q\omega r^2}{2}$
 Angular momentum $J = Mr^2\omega \Rightarrow \frac{M'}{J} = \frac{Q}{2M}$

20. The electric and magnetic field caused by an accelerated charged particle are found to scale as $E \propto r^{-n}$ and $B \propto r^{-m}$ at large distances. What are the value of n and m ?

[JEST 2013]

A. $n = 1, m = 2$

B. $n = 2, m = 1$

C. $n = 1, m = 1$

D. $n = 2, m = 2$

Solution:

For large distance

$$F = \frac{qa \sin \theta}{r}$$

$$B = \frac{qa \sin \theta}{r}$$

$$\Rightarrow E \propto \frac{1}{r},$$

$$B \propto \frac{1}{r}$$

So $m = n = 1$

The correct option is (c)

21. A system of two circular co-axial coils carrying equal currents I along same direction having equal radius R and separated by a distance R (as shown in the figure below). The magnitude of magnetic field at the midpoint P is given by

[JEST 2014]

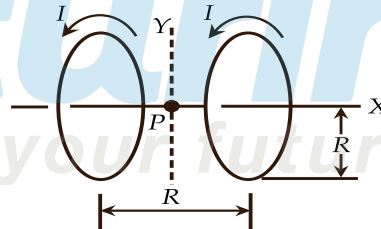


Figure 3

A. (a) $\frac{\mu_0 I}{2\sqrt{2}R}$

B. $\frac{4\mu_0 I}{5\sqrt{5}R}$

C. $\frac{8\mu_0 I}{5\sqrt{5}R}$

D. 0

Solution:

$$\therefore B = \frac{\mu_0 I R^2}{2(R^2 + d^2)^{\frac{3}{2}}}$$

$$B_1 = \frac{\mu_0 I R^2}{2\left(R^2 + \frac{R^2}{4}\right)^{\frac{3}{2}}}$$

$$B_2 = \frac{\mu_0 I R^2}{2\left(R^2 + \frac{R^2}{4}\right)^{\frac{3}{2}}} \because d = \frac{R}{2}$$

$$B = B_1 + B_2$$

$$= \frac{\mu_0 I \times 2}{2R \left(\frac{5}{4}\right)^{\frac{3}{2}}}$$

$$B = \frac{\mu_0 I 4^{\frac{3}{2}}}{R 5^{\frac{3}{2}}} = \frac{8\mu_0 I}{5\sqrt{5}R}$$

The correct option is (c)

22. A charged particle is released at time $t = 0$, from the origin in the presence of uniform static electric and magnetic fields given by $E = E_0 \hat{y}$ and $B = B_0 \hat{z}$ respectively. Which of the following statements is true for $t > 0$?

[JEST 2015]

- A. The particle moves along the x -axis. B. The particle moves in a circular orbit.
C. The particle moves in the (x, y) plane. D. Particle moves in the (y, z) plane

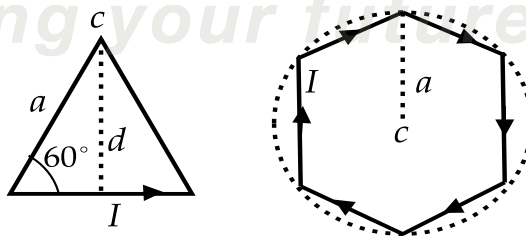
Solution: In a cycloid charged particle will be always confined in a plane perpendicular to B .
The correct option is (c)

23. The strength of magnetic field at the center of a regular hexagon with sides of length a carrying a steady current I is:

[JEST 2016]

- A. $\frac{\mu_0 I}{\sqrt{3}\pi a}$ B. $\frac{\sqrt{6}\mu_0 I}{\pi a}$
C. $\frac{3\mu_0 I}{\pi a}$ D. $\frac{\sqrt{3}\mu_0 I}{\pi a}$

Solution:



$$d = a \cos 30^\circ = \frac{\sqrt{3}}{2} a$$

$$\therefore B = \frac{\mu_0 I}{4\pi d} (\sin \theta_2 - \sin \theta_1)$$

$$\Rightarrow B_1 = \frac{\mu_0 I}{4\pi d} 2 \sin 30^\circ = \frac{\mu_0 I}{4\pi \frac{\sqrt{3}}{2} a} 2 \sin 30^\circ = \frac{\mu_0 I}{2\sqrt{3}\pi a}$$

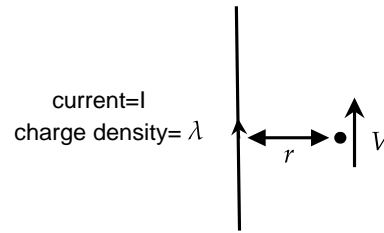
$$\Rightarrow B = 6B_1 = 6 \times \frac{\mu_0 I}{2\sqrt{3}\pi a}$$

$$= \frac{3\mu_0 I}{\sqrt{3}\pi a}$$

$$= \frac{\sqrt{3}\mu_0 I}{\pi a}$$

24. A wire with uniform line charge density λ per unit length carries a current I as shown in the figure. Take the permittivity and permeability of the medium to be $\epsilon_0 = \mu_0 = 1$. A particle of charge q is at a distance r and is travelling along a trajectory parallel to the wire. What is the speed of the charge?

[JEST 2019]

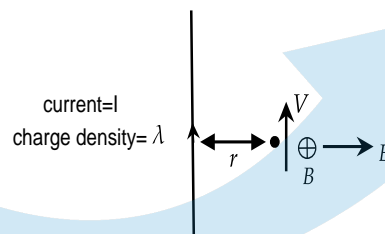


A. $\frac{\lambda}{I}$

B. $\frac{\lambda}{2I}$

C. $\frac{\lambda}{3I}$

D. $\frac{4\lambda}{I}$

Solution:

$$E = \frac{\lambda}{2\pi\epsilon_0 r} \text{ and } B = \frac{\mu_0 I}{2\pi r}$$

Net force on q is zero i.e.

$$\vec{F} = 0$$

$$\Rightarrow q[\vec{E} + (\vec{v} \times \vec{B})] = 0$$

$$E = vB \Rightarrow \frac{\lambda}{2\pi\epsilon_0 r} = v \frac{\mu_0 I}{2\pi r}$$

$$v = \frac{\lambda}{I} \quad \because \epsilon_0 = \mu_0 = 1$$

The correct option is (a)



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