Magnetic Field JEE Main PYQ - 1

Total Time: 1 Hour **Total Marks:** 100

Instructions

Instructions

1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Magnetic Field

1. For full scale deflection of total 50 divisions, 50 mV voltage is required in galvanometer. The resistance of galvanometer if its current sensitivity is 2 div/mA will be : (+4, -1)

a. 1 Ω

b. 2 Ω

c. 4 Ω

d. 5 Ω

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2. A coaxial cable consists of an inner wire of radius 'a' surrounded by an outer shell of inner and outer radii 'b' and 'c' respectively. The inner wire carries an electric current i_0, which is distributed uniformly across cross-sectional area. The outer shell carries an equal current in opposite direction and distributed uniformly. What will be the ratio of the magnetic field at a distance x from the axis when (i) x $<$ a and (ii) a $<$ x $<$ b? (+4, -1)

a. $\frac{x^2}{a^2}$

b. $\frac{a^2}{x^2}$

c. $\frac{x^2}{b^2-a^2}$

d. $\frac{b^2-a^2}{x^2}$

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3. An electron with mass m with an initial velocity $(t=0)\,\vec{v}=\vec{v_0}\,(v_0>0)$ enters a magnetic field $\vec{B}=B\hat{j}$. If the initial de-Broglie wavelength at $t=0$ is λ_0, then its value after time t would be: (+4, -1)

a. $\frac{\lambda_0}{\sqrt{1-\frac{e^2B^2t^2}{m^2}}}$

b. $\frac{\lambda_0}{\sqrt{1+\frac{e^2B^2t^2}{m^2}}}$

c. $\lambda_0\sqrt{1+\frac{e^2B^2t^2}{m^2}}$

d. λ_0

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4. The magnetic field inside a 200 turns solenoid of radius 10 cm is 2.9×10^{-4} Tesla. If the solenoid carries a current of 0.29 A, then the length of the solenoid is: (+4, -1)

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5. A solid sphere is rolling without slipping on a horizontal plane. The ratio of the linear kinetic energy of the centre of mass of the sphere and rotational kinetic energy is: (+4, -1)

a. $\frac{4}{3}$

b. $\frac{3}{4}$

c. $\frac{2}{5}$

d. $\frac{5}{2}$

---

6. Consider a long thin conducting wire carrying a uniform current I. A particle having mass M and charge q is released at a distance a from the wire with a speed v_0 along the direction of current in the wire. The particle gets attracted to the wire due to magnetic force. The particle turns round when it is at distance x from the wire. The value of x is: (+4, -1)

a. $\frac{a}{2}$

b. $a\left(1-\frac{mv_0}{q\mu_0 I}\right)$

c. $ae\left(-4\frac{mv_0}{q\mu_0 I}\right)$

d. $a\left[1-\frac{mv_0}{2q\mu_0 I}\right]$

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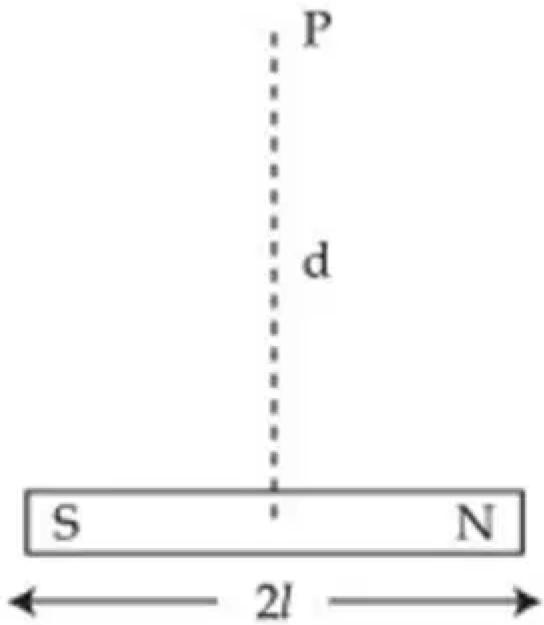
7. A bar magnet has total length $2l = 20$ units and the field point P is at a distance $d = 10$ units from the centre of the magnet. If the relative uncertainty of length measurement is 1%, then the uncertainty of the magnetic field at point P is: (+4, -1)



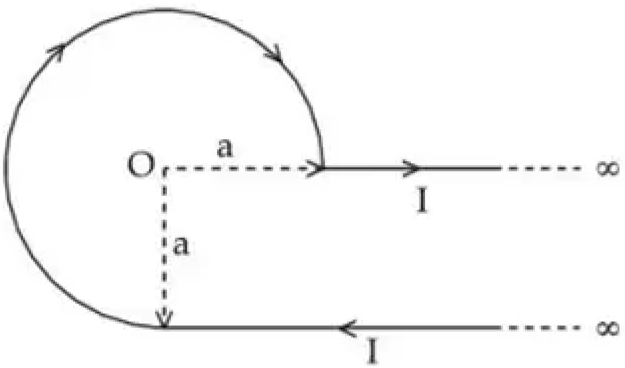
a. 10%

b. 4%

c. 5%

d. 3%

8. An infinite wire has a circular bend of radius a, and carrying a current I as shown in the figure. The magnitude of the magnetic field at the origin O of the arc is given by: (+4, -1)



a. $\frac{\mu_0 I}{4\pi a}\left(\frac{3\pi}{2}+2\right)$

b. $\frac{\mu_0 I}{2\pi a}\left(\frac{\pi}{2}+2\right)$

c. $\frac{\mu_0 I}{4\pi a}\left(\frac{3\pi}{2}\right)$

d. $\frac{\mu_0 I}{2\pi a}\left(\frac{3\pi}{2}+1\right)$

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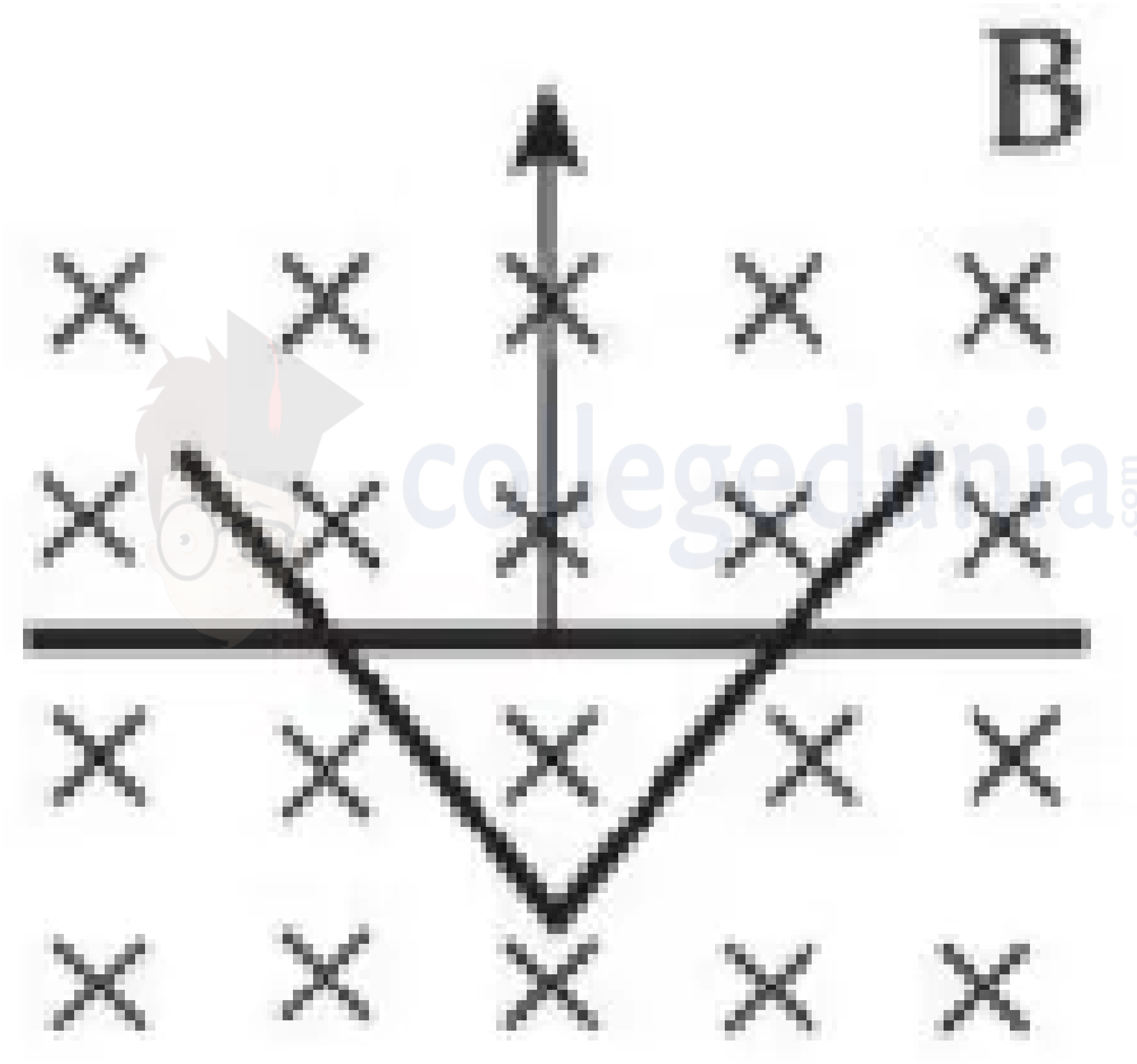
9. A conducting bar moves on two conducting rails as shown in the figure. A constant magnetic field B exists into the page. The bar starts to move from the vertex at time $t = 0$ with a constant velocity. If the induced EMF is $E \propto t^n$, then the value of n is _____. (+4, -1)



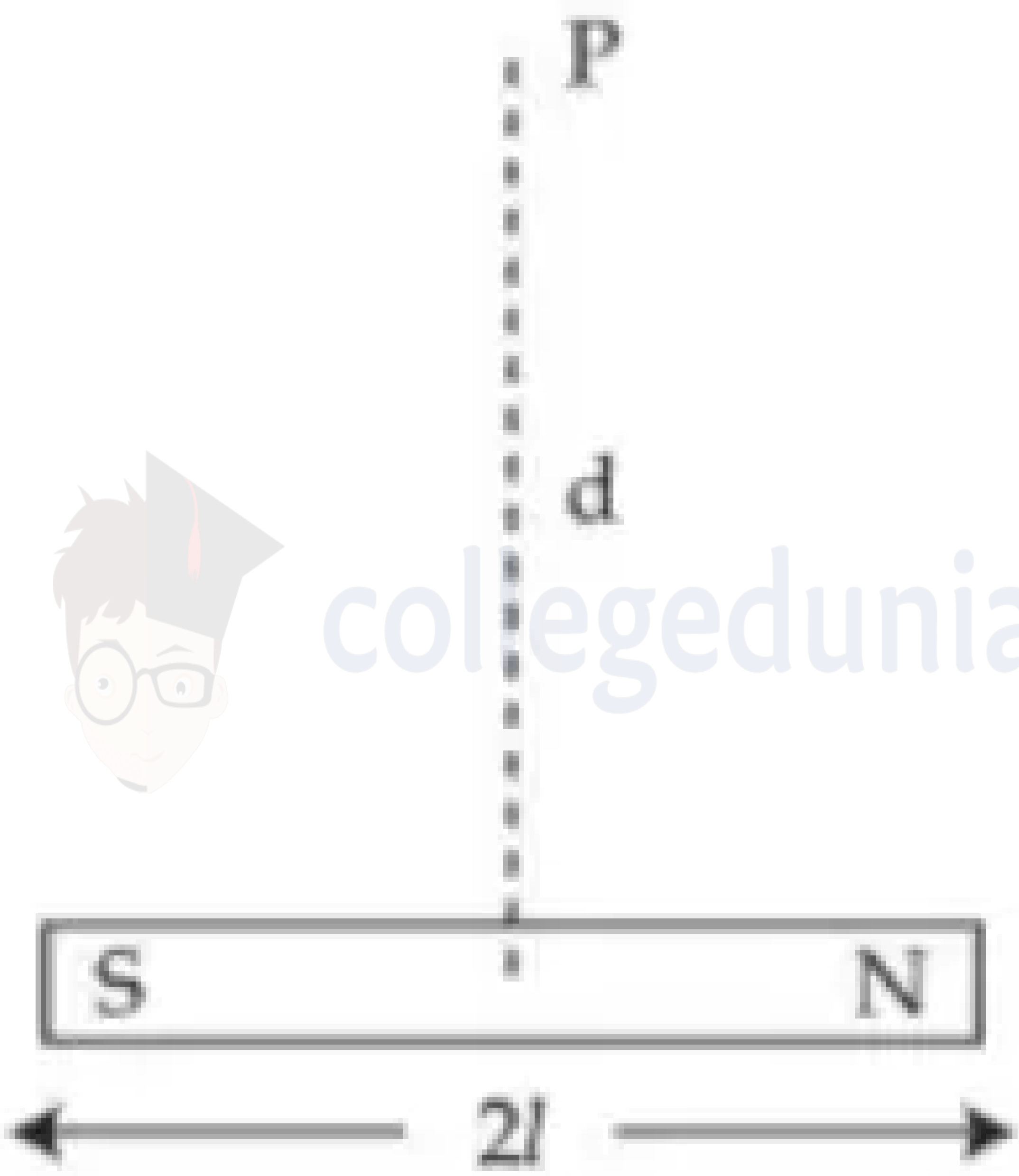
a. 1

b. 2

c. 3

d. 4

10. A bar magnet has total length $2l = 20$ units and the field point P is at a distance $d = 10$ units from the centre of the magnet. If the relative uncertainty of length measurement is 1\%, then the uncertainty of the magnetic field at point P is: (+4, -1)



a. 10\%

b. 4\%

c. 5\%

d. 3\%

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11. A 400 g solid cube having an edge of length 10 cm floats in water. How much volume of the cube is outside the water? (Given: density of water = $1000 kg/m^3$) (+4, -1)

a. $600 cm^3$

b. $4000 cm^3$

c. $1400 cm^3$

d. $400 cm^3$

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12. Which of the following phenomena cannot be explained by the wave theory of light? (+4, -1)

a. Reflection of light

b. Diffraction of light

c. Refraction of light

d. Compton effect

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13. A uniform magnetic field of 0.4 T acts perpendicular to a circular copper disc 20 cm in radius. The disc is having a uniform angular velocity of 10π rad/s about an axis through its center and perpendicular to the disc. What is the potential difference developed between the axis of the disc and the rim? ($\pi = 3.14$) (+4, -1)

a. 0.5024 V

b. 0.2512 V

c. 0.0628 V

d. 0.1256 V

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14. A uniform rod of mass 250 g having length 100 cm is balanced on a sharp edge at the 40 cm mark. A mass of 400 g is suspended at the 10 cm mark. To maintain the balance of the rod, the mass to be suspended at the 90 cm mark is: (+4, -1)

a. 300 g

b. 200 g

c. 290 g

d. 190 g

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15. The frequency of revolution of the electron in Bohr's orbit varies with n, the principal quantum number as: (+4, -1)

a. $\frac{1}{n^3}$

b. $\frac{1}{n^4}$

c. $\frac{1}{n}$

d. $\frac{1}{n^2}$

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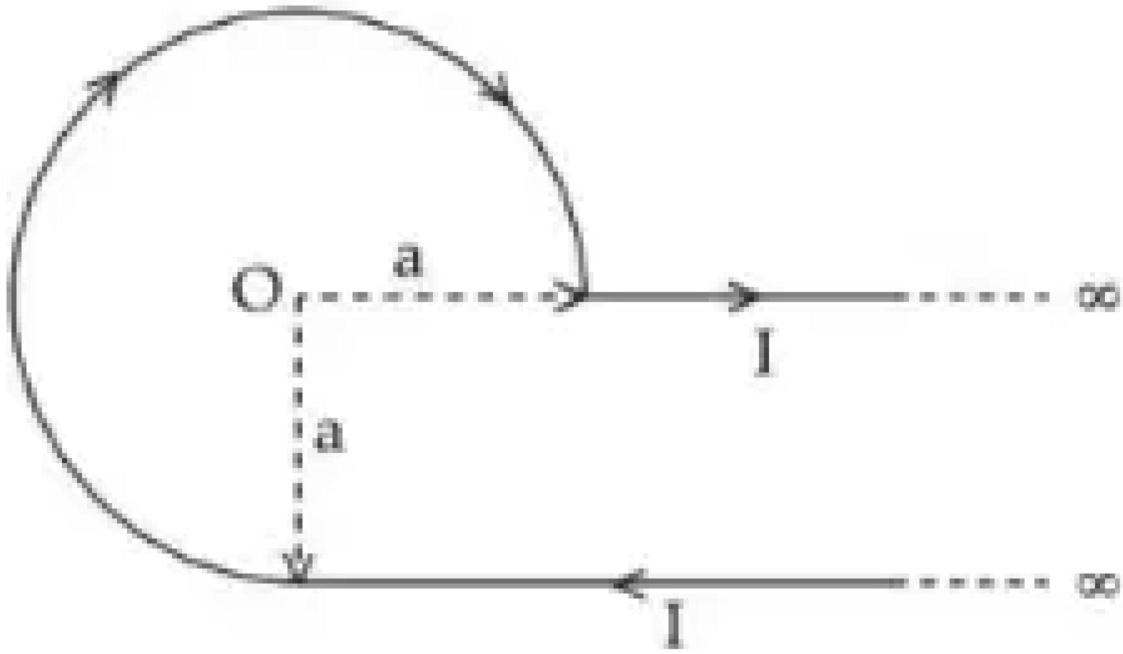
16. An infinite wire has a circular bend of radius a, and carrying a current I as shown in the figure. The magnitude of the magnetic field at the origin O of the arc is given by: (+4, -1)



a. $\frac{\mu_0 I}{4\pi a}\left(\frac{3\pi}{2}+2\right)$

b. $\frac{\mu_0 I}{2\pi a}\left(\frac{\pi}{2}+2\right)$

c. $\frac{\mu_0 I}{4\pi a}\left(\frac{3\pi}{2}\right)$

d. $\frac{\mu_0 I}{2\pi a}\left(\frac{3\pi}{2}+1\right)$

17. The magnetic field of an E.M. wave is given by: (+4, -1)

$$\vec{B}=\left(\frac{\sqrt{3}}{2}\hat{i}+\frac{1}{2}\hat{j}\right)30\sin\left(\omega\left(t-\frac{z}{c}\right)\right)$$

The corresponding electric field in S.I. units is:

a. $\vec{E}=\left(\frac{1}{2}\hat{i}+\frac{\sqrt{3}}{2}\hat{j}\right)30c\sin\left(\omega\left(t+\frac{z}{c}\right)\right)$

b. $\vec{E}=\left(\frac{3}{4}\hat{i}+\frac{1}{4}\hat{j}\right)30c\cos\left(\omega\left(t-\frac{z}{c}\right)\right)$

c. $\vec{E}=\left(\frac{\sqrt{3}}{2}\hat{i}-\frac{1}{2}\hat{j}\right)30c\sin\left(\omega\left(t+\frac{z}{c}\right)\right)$

d. $\vec{E}=\left(\frac{1}{2}\hat{i}-\frac{\sqrt{3}}{2}\hat{j}\right)30c\sin\left(\omega\left(t-\frac{z}{c}\right)\right)$

18. A solid sphere is rolling without slipping on a horizontal plane. The ratio of the linear kinetic energy of the centre of mass of the sphere and rotational kinetic energy is: (+4, -1)

a. $\frac{4}{3}$

b. $\frac{3}{4}$

c. $\frac{2}{5}$

d. $\frac{5}{2}$

---

19. A coil of area A and N turns is rotating with angular velocity ω in a uniform magnetic field $\mathbf{B}$ about an axis perpendicular to $\mathbf{B}$. Magnetic flux ϕ and induced emf ε across it, at an instant when $\mathbf{B}$ is parallel to the plane of the coil, are: (+4, -1)

a. $\phi = AB,\ \varepsilon = 0$

b. $\phi = 0,\ \varepsilon = 0$

c. $\phi = 0,\ \varepsilon = NAB\omega$

d. $\phi = AB,\ \varepsilon = NAB\omega$

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20. Consider a long thin conducting wire carrying a uniform current I. A particle having mass M and charge q is released at a distance a from the wire with a speed v_0 along the direction of current in the wire. The particle gets attracted to the wire due to magnetic force. The particle turns round when it is at distance x from the wire. The value of x is: (+4, -1)

a. $\frac{a}{2}$

b. $a\left(1 - \frac{mv_0}{q\mu_0 I}\right)$

c. $ae\left(-4\frac{mv_0}{q\mu_0 I}\right)$

d. $a\left[1 - \frac{mv_0}{2q\mu_0 I}\right]$

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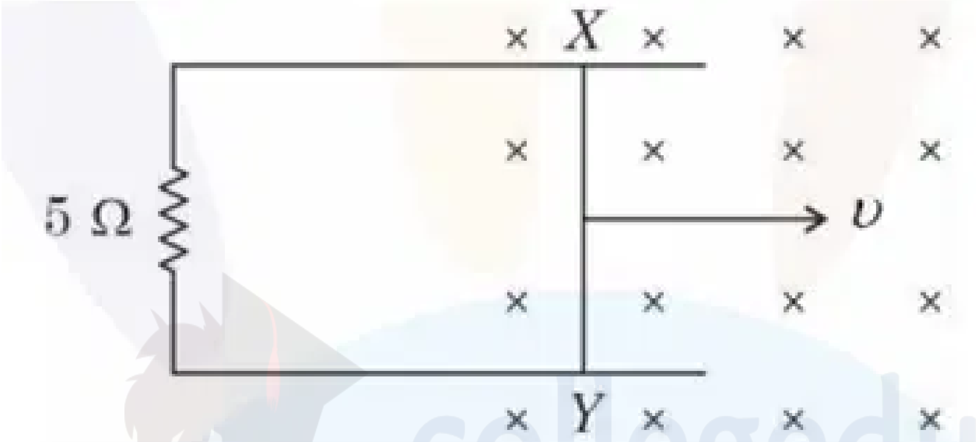
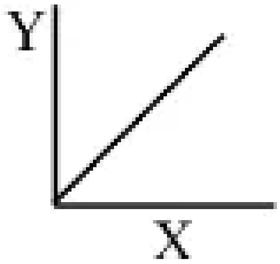
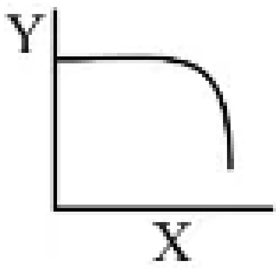
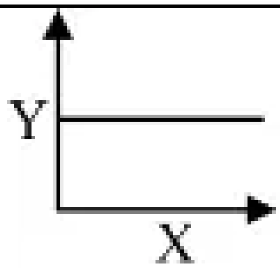
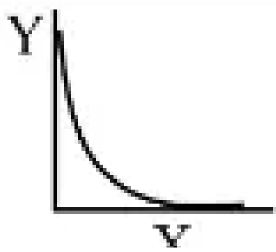
21. The current required to be passed through a solenoid of 15 cm length and 60 turns in order to demagnetize a bar magnet of magnetic intensity $2.4 \times 10^3 Am^{-1}$ is A. **(+4, -1)**

22. A 1 m long metal rod XY completes the circuit as shown in f igure. The plane of the circuit is perpendicular to the magnetic field of flux density 0.15 T. If the resistance of the circuit is 5ω, the force needed to move the rod in direction, as indicated, with a constant speed of 4 m/s will be ____10^{-3} N **(+4, -1)**



23. A coil having 100 turns, area of $5 \times 10^{-3}\,\mathrm{m}^2$, carrying current of $1\,\mathrm{mA}$ is placed in a uniform magnetic field of $0.20\,\mathrm{T}$ such a way that the plane of the coil is perpendicular to the magnetic field. **(+4, -1)**
The work done in turning the coil through 90° is ____ $\mu\mathrm{J}$.

24. Match List-I with List-II **(+4, -1)**

	List-I (Y vs X)		List-II (Shape of Graph)
(A)	Y = magnetic susceptibility X = magnetising field	(I)	
(B)	Y = magnetic field X = distance from centre of a current carrying wire for $x < a$ (where a=radius of wire)	(II)	
(C)	Y = magnetic field X = distance from centre of a current carrying wire for $x > a$ (where a = radius of wire)	(III)	
(D)	Y= magnetic field inside solenoid	(IV)	

	x = distance from center		^

Choose the correct answer from the options given below :

a. (A)-(III), (B)-(I), (C)-(IV), (D)-(II)

b. (A)-(I), (B)-(III), (C)-(II), (D)-(IV)

c. (A)-(IV), (B)-(I), (C)-(III), (D)-(II)

d. (A)-(III), (B)-(IV), (C)-(I), (D)-(II)

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25. A conducting circular loop is placed in a uniform magnetic field 0.04 T with its plane perpendicular to the magnetic field. Somehow, the radus of the loop starts expanding at a constant rate of 1 mm/s. The magnitude of induced emf in the loop at an instant when the radius of the loop is 2 cm will be ___μV **(+4, -1)**

Answers

1. Answer: b

Explanation:

Step 1: Understanding the Question:
We are given the voltage for full-scale deflection, the total number of divisions, and the current sensitivity of a galvanometer. We need to find the resistance of the galvanometer.
Step 2: Key Formula or Approach:
1. **Current for Full-Scale Deflection (I_g):** We can find this using the current sensitivity and the total number of divisions.
Current Sensitivity $= \frac{\text{Deflection (div)}}{\text{Current (mA)}}$
2. **Galvanometer Resistance (R_g):** We can find this using Ohm's law, $R_g = \frac{V_g}{I_g}$, where V_g is the voltage for full-scale deflection.
Step 3: Detailed Explanation:
Given values:
- Total divisions for full-scale deflection, $\theta_{\text{max}} = 50$ divisions.
- Voltage for full-scale deflection, $V_g = 50\,\text{mV} = 50 \times 10^{-3}\,\text{V}$.
- Current sensitivity, $S_i = 2\,\text{div/mA}$.
First, calculate the current required for full-scale deflection (I_g).
The sensitivity tells us that a current of 1 mA produces a deflection of 2 divisions.

$$I_g = \frac{\text{Total Divisions}}{\text{Current Sensitivity}} = \frac{50\,\text{div}}{2\,\text{div/mA}} = 25\,\text{mA}$$

Convert this current to Amperes:

$$I_g = 25 \times 10^{-3}\,\text{A}$$

Now, use Ohm's law to find the galvanometer resistance (R_g).

$$R_g = \frac{V_g}{I_g}$$

$$R_g = \frac{50 \times 10^{-3}\,\text{V}}{25 \times 10^{-3}\,\text{A}}$$

$$R_g = 2\,\Omega$$

Step 4: Final Answer:
The resistance of the galvanometer is 2 Ω.

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2. Answer: a

Explanation:

Step 1: Understanding the Question:
The question asks for the ratio of the magnetic field expressions in two different regions of a coaxial cable: inside the inner conductor ($x < a$) and between the inner and outer conductors ($a < x < b$). We will use Ampere's Law to find the magnetic field in each region.
Step 2: Key Formula or Approach:
Ampere's Circuital Law: The line integral of the magnetic field $\vec{B}$ around a closed loop is proportional to the total current I_{enc} enclosed by the loop.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enc}}$$

For a cylindrical wire, due to symmetry, this simplifies to $B(2\pi x) = \mu_0 I_{\text{enc}}$, where x is the radial distance from the axis.
Step 3: Detailed Explanation:
Case (i): Magnetic field at $x < a$ (inside the inner wire)
Let's call the magnetic field in this region B_1. We apply Ampere's law for a circular loop of radius x.
The current i_0 is distributed uniformly over the cross-sectional area πa^2. The current density is $J = \frac{i_0}{\pi a^2}$.
The current enclosed by the loop of radius x is:

$$I_{\text{enc}} = J \times (\text{Area of loop}) = \left(\frac{i_0}{\pi a^2}\right) \times (\pi x^2) = i_0 \frac{x^2}{a^2}$$

Applying Ampere's Law:
$B_1(2\pi x) = \mu_0 I_{\text{enc}} = \mu_0 \left(i_0 \frac{x^2}{a^2}\right)$

$$B_1 = \frac{\mu_0 i_0 x}{2\pi a^2}$$

Case (ii): Magnetic field at $a < x < b$ (between the conductors)
Let's call the magnetic field in this region B_2. We apply Ampere's law for a circular loop of radius x.

In this region, the loop encloses the entire current i_0 from the inner wire. The current from the outer shell is outside the loop, so it is not included in I_{enc}.

$$I_{\text{enc}} = i_0$$

Applying Ampere's Law:
$B_2(2\pi x) = \mu_0 i_0$

$$B_2 = \frac{\mu_0 i_0}{2\pi x}$$

Finding the Ratio:
The question asks for the ratio of the magnetic field at a distance x in case (i) to the magnetic field at a distance x in case (ii). Although a single value of x cannot be in both regions simultaneously, the question implies finding the ratio of the functional forms of the magnetic field expressions in the two regions.
Ratio = $\frac{B_1(x)}{B_2(x)}$

$$\text{Ratio} = \frac{\frac{\mu_0 i_0 x}{2\pi a^2}}{\frac{\mu_0 i_0}{2\pi x}}$$

$$\text{Ratio} = \left(\frac{\mu_0 i_0 x}{2\pi a^2}\right) \times \left(\frac{2\pi x}{\mu_0 i_0}\right)$$

The terms $\mu_0, i_0, 2\pi$ cancel out.

$$\text{Ratio} = \frac{x}{a^2} \times x = \frac{x^2}{a^2}$$

Step 4: Final Answer:
The ratio of the magnetic field expressions is $\frac{x^2}{a^2}$.

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3. Answer: d

Explanation:

Given: an electron (mass m, charge $-e$) enters a uniform magnetic field $\vec{B} = B\hat{j}$ with initial velocity $\vec{v} = \vec{v_0}$ (where $v_0 > 0$). The de-Broglie wavelength initially is λ_0. We need to find its wavelength after time t.

Concept Used:

The magnetic field exerts a force on the moving electron given by the Lorentz force:

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

This force changes the direction of velocity but not its magnitude (since the magnetic force is perpendicular to $\vec{v}$). Hence, the speed remains constant.

The de-Broglie wavelength is given by:

$$\lambda = \frac{h}{p} = \frac{h}{mv}.$$

Since v (the magnitude of velocity) is unchanged, the de-Broglie wavelength also remains constant in time.

Step-by-Step Solution:

Step 1: Write the equation of motion:

$$m\frac{d\vec{v}}{dt} = -e(\vec{v} \times \vec{B}).$$

The magnetic field causes circular motion with angular frequency (cyclotron frequency):

$$\omega = \frac{eB}{m}.$$

Step 2: The magnitude of velocity remains v_0, only its direction changes with time. Therefore, momentum magnitude $p = mv_0$ remains constant.

Step 3: Hence, the de-Broglie wavelength at time t is:

$$\lambda = \frac{h}{mv_0} = \lambda_0.$$

Final Computation & Result:

$$\boxed{\lambda(t) = \lambda_0.}$$

The de-Broglie wavelength of the electron remains unchanged with time.

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4. **Answer: 8 - 8**

Explanation:

Assuming a long solenoid, the magnetic field is given by the formula:

$$B = \mu_0 \frac{N}{l} I$$

Where:
- $B = 2.9 \times 10^{-4}\,\text{T}$,
- $N = 200$ turns,
- $I = 0.29\,\text{A}$,
- l is the length of the solenoid,
- $\mu_0 = 4\pi \times 10^{-7}\,\text{T m/A}$.

Now, solving for l:

$$l = \frac{\mu_0 N I}{B} = \frac{(4\pi \times 10^{-7})(200)(0.29)}{2.9 \times 10^{-4}}\,\text{m}$$

$$l = 8\,\text{m}$$

Thus, the length of the solenoid is 8 meters.

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5. **Answer: c**

Explanation:

When a solid sphere is rolling without slipping, the total kinetic energy K_{total} is the sum of the linear kinetic energy and rotational kinetic energy. - The linear kinetic energy of the centre of mass is given by:

$$K_{\text{linear}} = \frac{1}{2} m v^2,$$

where m is the mass of the sphere and v is the linear velocity of the centre of mass. - The rotational kinetic energy is given by:

$$K_{\text{rotational}} = \frac{1}{2} I \omega^2,$$

where I is the moment of inertia and ω is the angular velocity. For a solid sphere, the moment of inertia about the centre of mass is:

$$I = \frac{2}{5} m r^2,$$

where r is the radius of the sphere. Since the sphere is rolling without slipping, the relation between the linear velocity and angular velocity is $v = r\omega$. Therefore, the rotational kinetic energy becomes:

$$K_{\text{rotational}} = \frac{1}{2} \times \frac{2}{5}mr^2 \times \left(\frac{v}{r}\right)^2 = \frac{1}{5}mv^2.$$

Now, we find the ratio of the linear kinetic energy to the rotational kinetic energy:

$$\text{Ratio} = \frac{K_{\text{linear}}}{K_{\text{rotational}}} = \frac{\frac{1}{2}mv^2}{\frac{1}{5}mv^2} = \frac{5}{2}.$$

Final Answer: The ratio is $\frac{5}{2}$.

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6. Answer: d

Explanation:

To find the distance x, where the particle turns around, we need to consider the forces and energy involved in the system.

First, understand that a current-carrying wire generates a magnetic field around it, which is given by:

$B = \frac{\mu_0 I}{2\pi r}$ where r is the distance from the wire, and μ_0 is the permeability of free space.

The particle experiences a magnetic force, which affects its motion. This magnetic force F is perpendicular to the velocity of the particle and is given by:

$F = qvB$ where v is the velocity of the charged particle, and q is the charge.

Substituting the magnetic field B, we get:

$F = qv\left(\frac{\mu_0 I}{2\pi r}\right) = \frac{q\mu_0 I v}{2\pi r}$

The magnetic force acting as centripetal force changes the direction but not the magnitude of velocity.

Applying conservation of energy between the initial position a and the point of turn x:

Initial kinetic energy = Final kinetic energy

$\frac{1}{2}Mv_0^2 = \frac{1}{2}Mv^2$

Since the magnetic force doesn't do any work, it doesn't change the speed of the particle, only the direction. However, here, the turning involves an effective change due to motion constraints.

To solve for x, we consider the balance of the centripetal force at the turnaround:

$$M\frac{v_0^2}{a} = qv_0\frac{\mu_0 I}{2\pi x}$$

Rearranging gives us the value of x:

$x = a\left[1 - \frac{Mv_0}{2q\mu_0 I}\right]$

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7. **Answer: c**

Explanation:

The magnetic field at point P is proportional to $\frac{1}{d^3}$. Given the uncertainty in length measurement, the uncertainty in the magnetic field can be calculated using the propagation of errors. Since the relative uncertainty in length is 1%, the relative uncertainty in the magnetic field will be three times that:

$$\text{Uncertainty in } B = 3$$

Thus, the uncertainty in the magnetic field is 5%.

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8. **Answer: c**

Explanation:

Step 1: Magnetic Field Due to the Arc

For the arc with radius a and angle $\frac{3\pi}{2}$, the magnetic field at the origin is:

$$B_1 = \frac{\mu_0 I}{4\pi a}$$

Step 2: Magnetic Field Due to the Straight Segment

For the straight segment of the wire:

$$B_2 = \frac{\mu_0 I}{4\pi a}\left(\frac{3\pi}{2}\right)$$

Step 3: Magnetic Field Due to Other Segments

Since the magnetic field due to the straight segments at the origin is zero:

$$B_3 = 0$$

Step 4: Calculate the Total Magnetic Field

Thus, the total magnetic field at the origin is:

$$B = \frac{\mu_0 I}{4\pi a}\left(\frac{3\pi}{2}\right)$$

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9. **Answer: b**

Explanation:

The induced EMF in a moving conductor is given by:

$$E = B\frac{dA}{dt}$$

The area enclosed by the rails at any time t is:

$$A = \frac{1}{2}l^2$$

Since the length of the moving bar is proportional to time t, we assume:

$$l = vt$$

Then,

$$A = \frac{1}{2}(vt)^2 = \frac{1}{2}v^2t^2$$

Differentiating with respect to t:

$$\frac{dA}{dt} = v^2t$$

Thus, the induced EMF is:

$$E = Bv^2t$$

Comparing with $E \propto t^n$, we get $n = 2$.

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10. **Answer: c**

Explanation:

The magnetic field at point P is proportional to $\frac{1}{d^3}$. Given the uncertainty in length measurement, the uncertainty in the magnetic field can be calculated using the propagation of errors. Since the relative uncertainty in length is 1%, the relative uncertainty in the magnetic field will be three times that:

$$UncertaintyinB = 3\% \times UncertaintyinLength$$

Thus, the uncertainty in the magnetic field is 5%.

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11. **Answer: d**

Explanation:

The total volume of the cube is:

$$V_{total} = (10cm)^3 = 1000cm^3$$

The mass of the cube is:

$$m = 400g = 0.4kg$$

The density of the cube is:

$$\rho_{cube} = \frac{m}{V_{total}} = \frac{0.4}{1000 \times 10^{-6}} = 400kg/m^3$$

Since the cube floats, the submerged volume is given by:

$$V_{submerged} = V_{total} \times \frac{\rho_{cube}}{\rho_{water}}$$

$$V_{submerged} = 1000 \times \frac{400}{1000} = 600cm^3$$

Thus, the volume outside the water is:

$$V_{outside} = V_{total} - V_{submerged}$$

$$V_{outside} = 1000 - 600 = 400cm^3$$

Thus, the correct answer is (4) 400 cm^3.

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12. **Answer: d**

Explanation:

The wave theory of light successfully explains phenomena such as:
- Reflection: Wavefront bending at an interface.
- Refraction: Change in speed and bending of light at different media.
- Diffraction: Spreading of waves when they encounter obstacles.
However, the Compton effect involves the scattering of photons by electrons, which requires the particle nature of light (photons) and cannot be explained by the wave theory.
Instead, it is explained using quantum mechanics.

---

13. **Answer: d**

Explanation:

The induced potential difference V in a rotating conducting disc is given by:

$$V = \frac{1}{2}B\omega R^2$$

where: - $B = 0.4$ T (magnetic field strength), - $\omega = 10\pi$ rad/s (angular velocity), - $R = 20$ cm $= 0.2$ m (radius of the disc). Substituting the values:

$$V = \frac{1}{2} \times 0.4 \times 10\pi \times (0.2)^2$$

$$V = \frac{1}{2} \times 0.4 \times 10\pi \times 0.04$$

$$V = \frac{1}{2} \times 0.4 \times 0.4\pi$$

$$V = \frac{1}{2} \times 0.16\pi$$

$$V = 0.08\pi$$

Since $\pi = 3.14$, we calculate:

$$V = 0.08 \times 3.14 = 0.2512V$$

Thus, the correct answer is (2) 0.2512 V.

---

14. Answer: d

Explanation:

The torque balance equation is:

$\tau_{Net} = 0 \quad \Rightarrow \quad (400g \times 30) = (250g \times 10) + (mg \times 50)$

Solving for m:

$$m = \frac{12000 - 2500}{50} = 190\,g$$

---

15. Answer: a

Explanation:

The frequency of revolution is inversely proportional to n^3, as the energy of the electron in Bohr's model depends on the quantum number n.

---

16. Answer: c

Explanation:

Let the magnetic fields due to different segments of the wire be B_1, B_2, and B_3. For the arc with radius a and angle $\frac{3\pi}{2}$, the magnetic field at the origin is:

$$B_1 = \frac{\mu_0 I}{4\pi a}$$

For the straight segment of the wire:

$$B_2 = \frac{\mu_0 I}{4\pi a}\left(\frac{3\pi}{2}\right)$$

Since the magnetic field due to the straight segments at the origin is zero:

$$B_3 = 0$$

Thus, the total magnetic field at the origin is:

$$B = \frac{\mu_0 I}{4\pi a}\left(\frac{3\pi}{2}\right)$$

---

17. **Answer: d**

Explanation:

We know that the relationship between the magnetic field $\vec{B}$ and electric field $\vec{E}$ in an electromagnetic wave is given by:

$$\vec{E} = \vec{B} \times \hat{c}$$

and $\vec{E} = B_0 c$, where c is the speed of light. We are given:

$$\vec{B} = \left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right) 30 \sin\left(\omega\left(t - \frac{z}{c}\right)\right)$$

We calculate $\vec{E}$ using the cross product and the fact that $\vec{E} = B_0 c$.

$$\vec{E} = \left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right) 30c \sin\left(\omega\left(t - \frac{z}{c}\right)\right)$$

---

18. **Answer: c**

Explanation:

When a solid sphere is rolling without slipping, the total kinetic energy K_{total} is the sum of the linear kinetic energy and rotational kinetic energy. - The linear kinetic energy of the centre of mass is given by:

$$K_{\text{linear}} = \frac{1}{2}mv^2,$$

where m is the mass of the sphere and v is the linear velocity of the centre of mass. - The rotational kinetic energy is given by:

$$K_{\text{rotational}} = \frac{1}{2}I\omega^2,$$

where I is the moment of inertia and ω is the angular velocity. For a solid sphere, the moment of inertia about the centre of mass is:

$$I = \frac{2}{5}mr^2,$$

where r is the radius of the sphere. Since the sphere is rolling without slipping, the relation between the linear velocity and angular velocity is $v = r\omega$. Therefore, the rotational kinetic energy becomes:

$$K_{\text{rotational}} = \frac{1}{2} \times \frac{2}{5}mr^2 \times \left(\frac{v}{r}\right)^2 = \frac{1}{5}mv^2.$$

Now, we find the ratio of the linear kinetic energy to the rotational kinetic energy:

$$\text{Ratio} = \frac{K_{\text{linear}}}{K_{\text{rotational}}} = \frac{\frac{1}{2}mv^2}{\frac{1}{5}mv^2} = \frac{5}{2}.$$

Final Answer: The ratio is $\frac{5}{2}$.

---

19. Answer: d

Explanation:

The magnetic flux ϕ is given by the product of the magnetic field $\mathbf{B}$, the area A of the coil, and the cosine of the angle between the magnetic field and the normal to the plane of the coil:

$$\phi = NBA\cos(\theta)$$

At the instant when $\mathbf{B}$ is parallel to the plane of the coil, the angle $\theta = 90^\circ$, so

$\cos(90^\circ) = 0$. Thus, the magnetic flux $\phi = AB$. The induced emf ε can be found using Faraday's Law of Induction, which states that the induced emf is equal to the rate of change of the magnetic flux:

$$\varepsilon = -\frac{d\phi}{dt}$$

Since the coil is rotating with angular velocity ω, the rate of change of the flux is $NAB\omega$, so the induced emf is $\varepsilon = NAB\omega$. Thus, the correct answer is $\phi = AB$ and $\varepsilon = NAB\omega$.

---

20. Answer: d

Explanation:

To find the value of x at which the particle turns round, we consider the magnetic force acting on the particle due to the current in the wire.

Step 1: The magnetic force is given by the formula:

$$F_{\text{mag}} = \frac{\mu_0 I q}{2\pi x}$$

where μ_0 is the permeability of free space, I is the current, q is the charge of the particle, and x is the distance from the wire.

Step 2: The force provides the centripetal acceleration, so we use the centripetal force formula:

$$F_{\text{cent}} = \frac{Mv_0^2}{x}$$

Step 3: Set the magnetic force equal to the centripetal force:

$$\frac{\mu_0 I q}{2\pi x} = \frac{Mv_0^2}{x}$$

Step 4: Simplify and solve for x:

$$x = \frac{2\pi M v_0^2}{\mu_0 I q}$$

Final Conclusion: The value of x at which the particle turns round is given by $a\left[1 - \frac{mv_0}{2q\mu_0 I}\right]$, which corresponds to Option (4).

---

21. **Answer: 6 - 6**

Explanation:

Step 1: Formula for Magnetic Intensity

The magnetic intensity H inside a solenoid is given by:

$$H = \frac{NI}{l}$$

Where:

- N: Number of turns (60)
- I: Current in Amperes
- l: Length of the solenoid (15 cm = 0.15 m)

Step 2: Rearrange to Solve for I

Rearrange the formula to solve for I:

$$I = \frac{Hl}{N}$$

Step 3: Substitute the Values

Substitute $H = 2.4 \times 10^3\ \mathrm{A/m}$, $l = 0.15\,\mathrm{m}$, and $N = 60$:

$$I = \frac{(2.4 \times 10^3)(0.15)}{60}$$

Simplify the expression:

$$I = \frac{360}{60} = 6\,\mathrm{A}$$

Final Answer:

The current required to demagnetize the bar magnet is $6\,\mathrm{A}$.

---

22. **Answer: 18 - 18**

Explanation:

Step 1: Write the Force Equation

The force on a conductor in a magnetic field is given by:

$F = I\ell B$

Where:

- I: Current
- ℓ: Length of the conductor in the magnetic field
- B: Magnetic field strength

Step 2: Substitute I in Terms of $e, R,$ and v

The current I can be expressed as:

$I = \frac{e}{R}$

Substitute I into the force equation:

$$F = Bv\ell B \cdot \frac{\ell}{R}$$

Simplify:

$$F = \frac{B^2\ell^2 v}{R}$$

Step 3: Substitute Known Values

Given:

- $B = 15\,\text{T}$
- $\ell = 1\,\text{m}$
- $v = 4\,\text{m/s}$
- $R = 5\,\Omega$

Substitute these values into the equation:

$$F = \frac{(15)^2 \cdot (1)^2 \cdot 4}{5}$$

Simplify:

$$F = \frac{225 \cdot 4}{5} = 180\,\text{N}$$

Final Answer:

The magnetic force is $F = 18\,\text{N}$.

---

23. Answer: 100 - 100

Explanation:

The problem asks for the work done in rotating a current-carrying coil in a uniform magnetic field from an initial orientation to a final one. We are given the coil's properties, the current it carries, the strength of the magnetic field, and the angle of rotation.

Concept Used:

The work done in rotating a magnetic dipole (such as a current-carrying coil) in a uniform magnetic field is equal to the change in its potential energy. The potential energy U of a magnetic dipole in a magnetic field is given by the dot product of the magnetic moment and the magnetic field:

$$U = -\vec{\mu} \cdot \vec{B} = -\mu B \cos\theta$$

where μ is the magnitude of the magnetic dipole moment, B is the magnitude of the magnetic field, and θ is the angle between the magnetic moment vector $\vec{\mu}$ and the magnetic field vector $\vec{B}$.

The magnetic moment of a coil with N turns, area A, and carrying current I is:

$$\mu = NIA$$

The work done W in changing the orientation of the coil from an initial angle θ_i to a final angle θ_f is:

$$W = \Delta U = U_f - U_i = (-\mu B \cos\theta_f) - (-\mu B \cos\theta_i) = \mu B(\cos\theta_i - \cos\theta_f)$$

Step-by-Step Solution:

Step 1: Determine the initial and final angles (θ_i and θ_f).

The magnetic moment vector $\vec{\mu}$ is always perpendicular to the plane of the coil. The initial state is given as "the plane of the coil is perpendicular to the magnetic field". This means the magnetic moment vector $\vec{\mu}$ is parallel to the magnetic field vector $\vec{B}$. Therefore, the initial angle is:

$$\theta_i = 0^\circ$$

The coil is then turned through 90°. The final angle is:

$$\theta_f = \theta_i + 90^\circ = 0^\circ + 90^\circ = 90^\circ$$

Step 2: Calculate the magnitude of the magnetic dipole moment (μ).

We are given:

Number of turns, $N = 100$
Area, $A = 5 \times 10^{-3}\,\mathrm{m}^2$
Current, $I = 1\,\mathrm{mA} = 1 \times 10^{-3}\,\mathrm{A}$

Using the formula $\mu = NIA$:

$$\mu = (100) \times (1 \times 10^{-3}\,\mathrm{A}) \times (5 \times 10^{-3}\,\mathrm{m}^2)$$

$$\mu = 500 \times 10^{-6}\,\mathrm{A \cdot m^2} = 5 \times 10^{-4}\,\mathrm{A \cdot m^2}$$

Step 3: Calculate the work done using the formula.

The work done is $W = \mu B(\cos\theta_i - \cos\theta_f)$. We have:

$\mu = 5 \times 10^{-4}\,\mathrm{A \cdot m^2}$
Magnetic field, $B = 0.20\,\mathrm{T}$
$\cos\theta_i = \cos(0^\circ) = 1$
$\cos\theta_f = \cos(90^\circ) = 0$

Substituting these values:

$$W = (5 \times 10^{-4}) \times (0.20) \times (1 - 0)$$

$$W = 1 \times 10^{-4}\,\mathrm{J}$$

Step 4: Convert the work done to microjoules (μJ).

Since $1\,\mu\mathrm{J} = 10^{-6}\,\mathrm{J}$, we can convert the result:

$$W = 1 \times 10^{-4}\,\mathrm{J} = (1 \times 10^{-4}) \times 10^{6}\,\mu\mathrm{J} = 100\,\mu\mathrm{J}$$

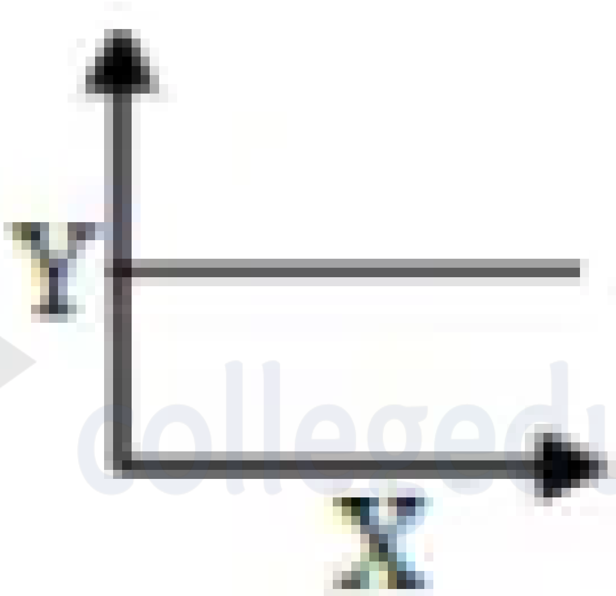
The work done in turning the coil is **100** μJ.

---

24. Answer: d

Explanation:

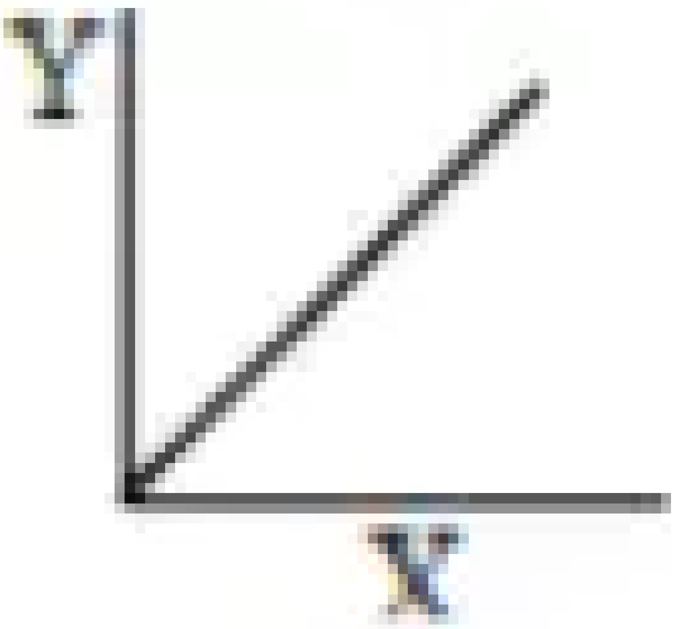
(A) The graph between magnetic susceptibility and magnetising field is as shown in (III).



(B) For $x < a$, the magnetic field due to a current-carrying wire is given by:

$$B = \frac{\mu_0 I x}{2\pi a^2},$$

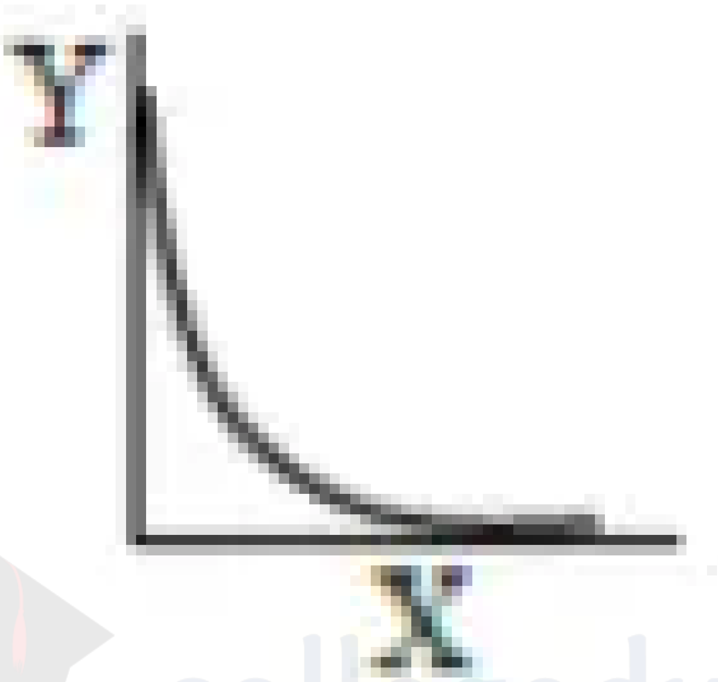
matching graph (IV).



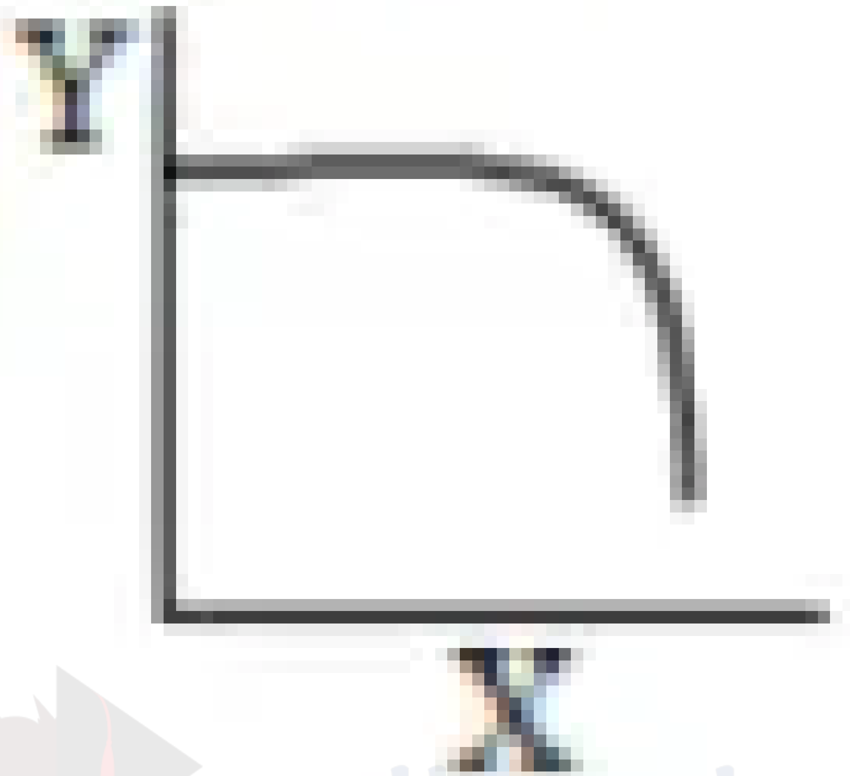
(C) For $x > a$, the magnetic field due to a current-carrying wire is given by:

$$B = \frac{\mu_0 I}{2\pi x},$$

matching graph (I).



(D) The magnetic field inside a solenoid varies with distance as shown in (II).



25. **Answer: 50 - 50**

Explanation:

Solution:
Given:

$B = 0.4$ T

$\frac{dr}{dt} = 1 \text{ mm/s} = 1 \times 10^{-3} \text{ m/s}$

$r = 2 \text{ cm} = 2 \times 10^{-2} \text{ m}$

$\theta = 0^\circ$ (plane perpendicular to the field)

The area of the loop is $A = \pi r^2$.
The magnetic flux is $\Phi = B\pi r^2 \cos 0^\circ = B\pi r^2$. Induced emf:

$$\varepsilon = -\frac{d(B\pi r^2)}{dt} = -B\pi \frac{d(r^2)}{dt} = -B\pi(2r\frac{dr}{dt}) = -2\pi Br\frac{dr}{dt}$$

Substituting the given values:

$$\varepsilon = -2\pi(0.4)(2 \times 10^{-2})(1 \times 10^{-3}) = -1.6\pi \times 10^{-5}\ \mathrm{V}$$

$$\varepsilon = -16\pi \times 10^{-6}\ \mathrm{V} = -16\pi\mu\mathrm{V}$$

Magnitude of the induced emf:

$$|\varepsilon| = 16\pi\mu\mathrm{V}$$

$$|\varepsilon| = 16 \times 3.14159\mu\mathrm{V} \approx 50.265\mu\mathrm{V}$$

Therefore, the magnitude of the induced emf in the loop is approximately 50.265 μV .

Answer: 50.265