Moving Charges and Magnetism JEE Main PYQ - 1

Total Time: 50 Minute **Total Marks:** 80

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.

Moving Charges and Magnetism

1. A circular coil of radius R carries current such that magnetic field at its centre is 16μT. Find the magnetic field on the axis at a distance of $\sqrt{3}R$ from the centre of coil. (+4, -1)

 a. 2μT

 b. 4μT

 c. 3μT

 d. 5μT

 e. None of these

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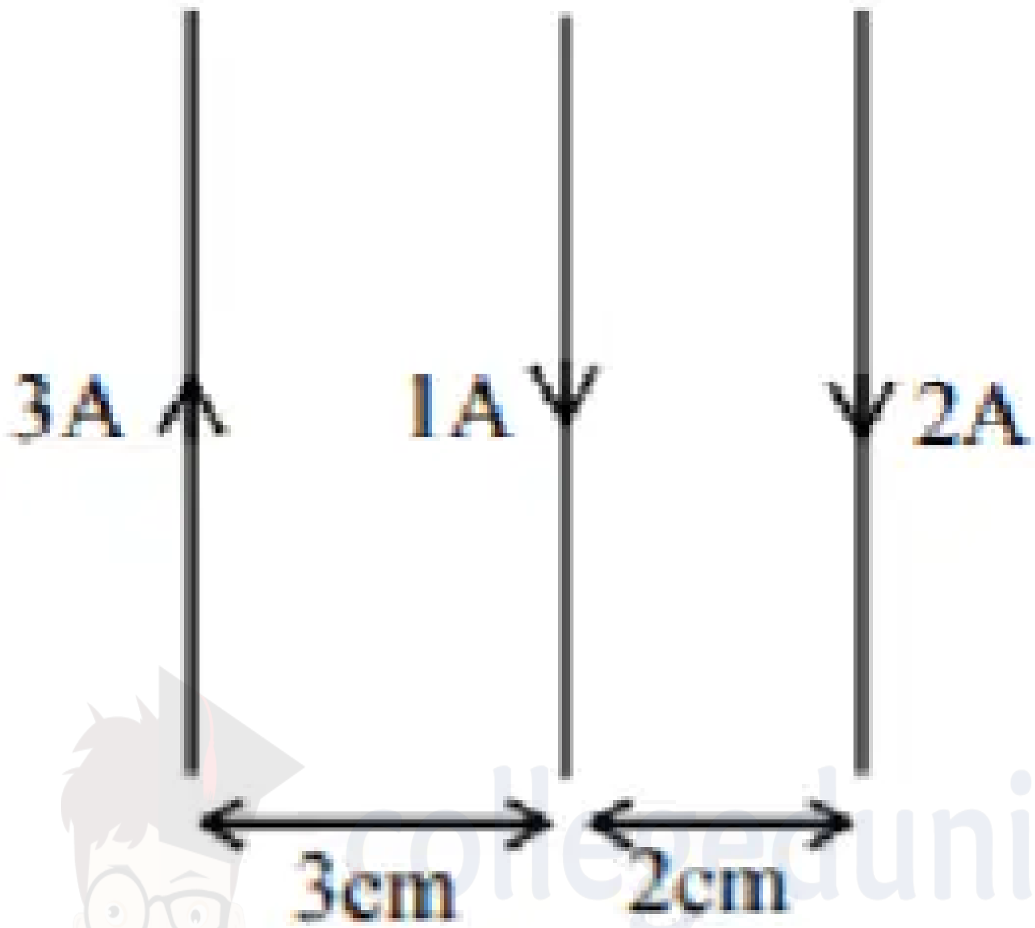
2. Three very long parallel wires carrying current as shown. Find the force acting at 15 cm length of middle wire : (+4, -1)



a. 1 μN

b. 6 μN

c. 7 μN

d. 5 μN

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3. For a circular coil of radius R, magnetic field at the center is $B_0 = 16\ \mu\text{T}$. What will be the magnetic field on the axis at a distance $x = \sqrt{3}R$ from the center? (+4, -1)

a. $\frac{1}{4}\ \mu\text{T}$

b. $\frac{1}{2}\ \mu\text{T}$

c. $4\ \mu\text{T}$

d. $2\ \mu\text{T}$

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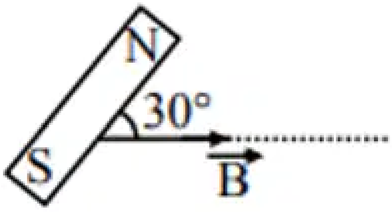
4. A bar magnet is kept such that it is making an angle of 30° with the magnetic field. The torque acting on the magnet is 0.016 N-m. Find the amount of work done by external agent in rotating the magnet from most stable position to most unstable position. (+4, -1)



a. 0.064 J

b. 0.020 J

c. 0.034 J

d. 0.055 J

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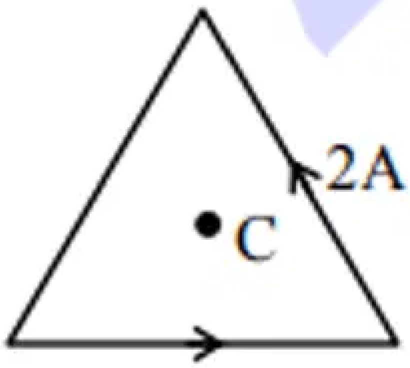
5. The equilateral triangular frame has current 2A. The side of frame is $4\sqrt{3}$ cm. Magnetic field at center C is: (+4, -1)



a. $30\sqrt{3}\,\mu T$

b. $10\sqrt{3}\,\mu T$

c. $3\sqrt{10}\,\mu T$

d. $10\sqrt{10}\,\mu T$

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6. An ideal solenoid is kept with its axis vertical. Current I_0 is flowing in the solenoid. A charge Q is thrown downward inside the solenoid. The acceleration of the charged particle is then (+4, -1)

a. $a > g$

b. $a = g$

c. $a < g$

d. $a = 0$

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7. A proton and an α-particle enter into a magnetic field at right angles. The ratio of the radii of trajectory of proton to that of α-particle is 2 : 1. The ratio of $K_p : K_\alpha$ is: (+4, -1)

a. 1 : 4

b. 4 : 1

c. 8 : 1

d. 1 : 8

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8. A proton, a deuteron and an α particle are moving with same momentum in a uniform magnetic field. The ratio of magnetic forces acting on them is __________ and their speed is __________, in the ratio. (+4, -1)

a. 4 : 2 : 1 and 2 : 1 : 1

b. 2 : 1 : 1 and 4 : 2 : 1

c. 1 : 2 : 4 and 1 : 1 : 2

d. 1 : 2 : 4 and 2 : 1 : 1

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9. The fractional change in the magnetic field intensity at a distance 'r' from centre on the axis of current carrying coil of radius 'a' to the magnetic field intensity at the centre of the same coil is : (Take $r \ll a$) (+4, -1)

a. $\frac{3}{2}\frac{a^2}{r^2}$

b. $\frac{2}{3}\frac{a^2}{r^2}$

c. $\frac{2}{3}\frac{r^2}{a^2}$

d. $\frac{3}{2}\frac{r^2}{a^2}$

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10. A coil in the shape of an equilateral triangle of side 10 cm lies in a vertical plane between the pole pieces of permanent magnet producing a horizontal magnetic field 20 mT. The torque acting on the coil when a current of 0.2 A is passed through it and its plane becomes parallel to the magnetic field will be $\sqrt{x} \times 10^{-5}$ Nm. The value of x is ___________. (+4, -1)

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11. If the maximum value of accelerating potential provided by a radio frequency oscillator is 12 kV. The number of revolution made by a proton in a cyclotron to achieve one sixth of the speed of light is ___________. (+4, -1)
[m_p = 1.67×10^{-27} kg, e = 1.6×10^{-19} C, Speed of light = 3×10^{8} m/s]

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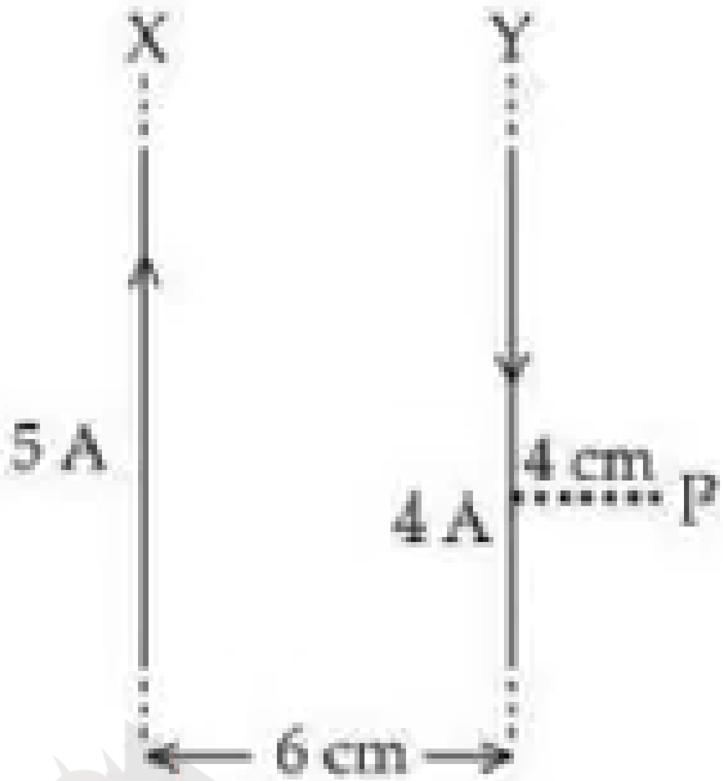
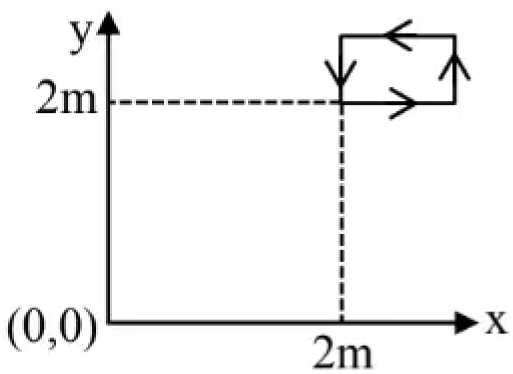
12. Two long parallel wires X and Y, separated by a distance of 6 cm, carry currents of 5 A and 4 A, respectively, in opposite directions as shown in the figure. Magnitude of the resultant magnetic field at point P at a distance of 4 cm from wire Y is 3×10^{-5} T. The value of x, which represents the distance of point P from wire X, is_____ cm. (Take permeability of free space as $\mu_0 = 4\pi \times 10^{-7}$ SI units.) (+4, -1)



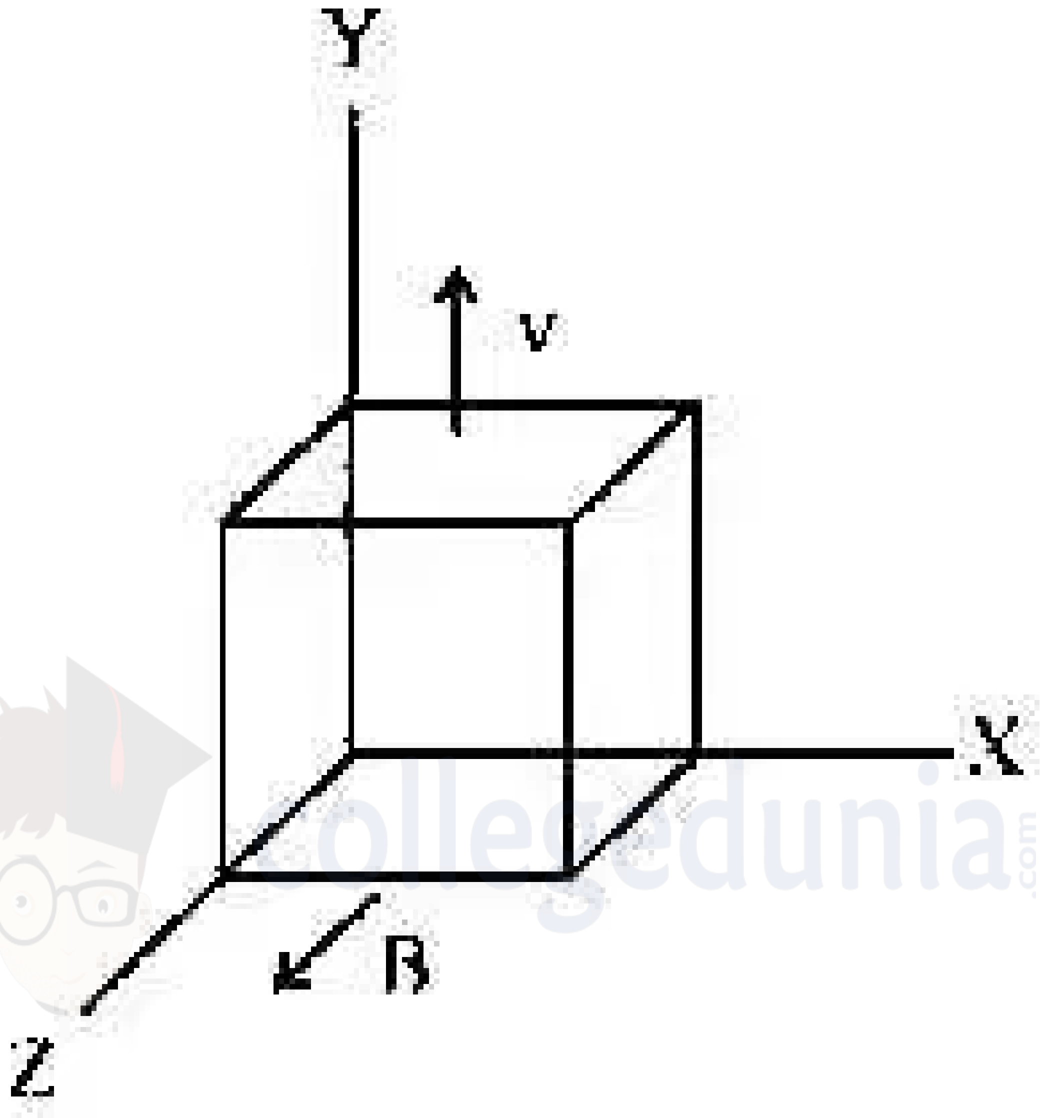
13. The magnetic field existing in a region is given by **(+4, -1)**

$$\vec{B} = 0.2(1 + 2x)\hat{k}\,\text{T}.$$

A square loop of edge $50\,\text{cm}$ carrying $0.5\,\text{A}$ current is placed in the x-y plane with its edges parallel to the x- and y-axes, as shown in the figure. The magnitude of the net magnetic force experienced by the loop is ______ mN.



14. A metallic cube of side 15 cm moving along y-axis at a uniform velocity of 2 ms^{-1}. In a region of uniform magnetic field of magnitude 0.5T directed along z-axis. In equilibrium the potential difference between the faces of higher and lower potential developed because of the motion through the field will be ___ mV. **(+4, -1)**



15. A long straight wire of circular cross-section (radius a) is carrying steady current I. The current I is uniformly distributed across this cross-section. The magnetic field is **(+4, -1)**

a. zero in the region $r < a$ and inversely proportional to r in the region $r > a$

b. inversely proportional to r in the region $r < a$ and uniform throughout in the region $r > a$

c. directly proportional to r in the region $r < a$ and inversely proportional to r in the region $r > a$

d. uniform in the region r < a and inversely proportional to distance r from the axis, in the region r > a

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16. A cyclotron is used to accelerate protons.If the operating magnetic field is 1.0 T and the radius of the cyclotron 'dees' is 60 cm,the kinetic energy of the accelerated protons in MeV will be **(+4, -1)**
$[Use\ m_p = 1.6 \times 10^{-27}\ kg, e = 1.6 \times 10^{-19} C]$

a. 12

b. 18

c. 16

d. 32

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17. A proton and an alpha particle of the same velocity enter in a uniform magnetic field which is acting perpendicular to their direction of motion. The ratio of the radii of the circular paths described by the alpha particle and proton is **(+4, -1)**

a. 1:4

b. 4:1

c. 2:1

d. 1:2

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18. Given below are two statements: **(+4, -1)**

Statement I: The electric force changes the speed of the charged particle and hence changes its kinetic energy; whereas the magnetic force does not change the kinetic energy of the charged particle.
Statement II: The electric force accelerates the positively charged particle perpendicular to the direction of electric field. The magnetic force accelerates the moving charged particle along the direction of magnetic

field.

In the light of the above statements, choose the most appropriate answer from the options given below:

a. Both statement I and statement II are correct

b. Both statement I and statement II are incorrect

c. Statement I is correct but statement II is incorrect

d. Statement I is incorrect but statement II is correct

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19. Two long current carrying conductors are placed parallel to each other at a distance of 8 cm between them. The magnitude of magnetic field produced at mid-point between the two conductors due to current flowing in them is 30 μT. The equal current flowing in the two conductors is: **(+4, -1)**

a. 30 A in the same direction

b. 30 A in the opposite direction

c. 60 A in the opposite direction

d. 300 A in the opposite direction

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20. A singly ionized magnesium atom (A=24) ion is accelerated to kinetic energy 5keV and is projected perpendicularly into a magnetic field *B* of the magnitude 0.5 T. The radius of path formed will be ________ cm. **(+4, -1)**

Answers

1. Answer: a

Explanation:

Step 1: Understanding the Concept:
The magnetic field of a current loop decreases as we move along its central axis away from the center.
Step 2: Key Formula or Approach:
Field at center: $B_c = \frac{\mu_0 I}{2R}$.
Field on axis at distance x: $B_a = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$.
Ratio: $\frac{B_a}{B_c} = \left(\frac{R^2}{R^2+x^2}\right)^{3/2}$.
Step 3: Detailed Explanation:
Given $x = \sqrt{3}R$.

$$\frac{B_a}{B_c} = \left(\frac{R^2}{R^2+(\sqrt{3}R)^2}\right)^{3/2} = \left(\frac{R^2}{R^2+3R^2}\right)^{3/2}$$

$$\frac{B_a}{B_c} = \left(\frac{R^2}{4R^2}\right)^{3/2} = \left(\frac{1}{4}\right)^{3/2} = \frac{1}{(4^{1/2})^3} = \frac{1}{2^3} = \frac{1}{8}$$

Given $B_c = 16\ \mu\text{T}$:

$$B_a = \frac{B_c}{8} = \frac{16}{8} = 2\ \mu\text{T}$$

Step 4: Final Answer:
The magnetic field at the given axial point is 2 μT.

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2. Answer: b

Explanation:

Step 1: Understanding the Concept:
Parallel wires carrying currents in the same direction attract each other.

Parallel wires carrying currents in opposite directions repel each other.

Step 2: Key Formula or Approach:

The magnetic force per unit length between two wires is:

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

Force on length L: $F = \frac{\mu_0 I_1 I_2 L}{2\pi r}$.

Step 3: Detailed Explanation:

Let the wires be A (3A), B (1A), and C (2A). We need the force on wire B.

Distance $AB = 3 \text{ cm} = 0.03 \text{ m}$.

Distance $BC = 2 \text{ cm} = 0.02 \text{ m}$.

Length $L = 15 \text{ cm} = 0.15 \text{ m}$.

1. Force on B due to A (F_{BA}): Currents are opposite (3A up, 1A down), so it is repulsive. Wire B is pushed to the right by wire A.

$$F_{BA} = \frac{2 \times 10^{-7} \times 3 \times 1 \times 0.15}{0.03} = \frac{0.9 \times 10^{-7}}{0.03} = 30 \times 10^{-7} = 3\ \mu\text{N (Right)}$$

2. Force on B due to C (F_{BC}): Currents are in the same direction (1A down, 2A down), so it is attractive.

Wire B is pulled to the right by wire C.

$$F_{BC} = \frac{2 \times 10^{-7} \times 1 \times 2 \times 0.15}{0.02} = \frac{0.6 \times 10^{-7}}{0.02} = 30 \times 10^{-7} = 3\ \mu\text{N (Right)}$$

Since both forces act to the right, the net force is:

$$F_{net} = 3\ \mu\text{N} + 3\ \mu\text{N} = 6\ \mu\text{N}$$

Step 4: Final Answer:

The net force acting on the 15 cm length of the middle wire is 6 μN.

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3. Answer: d

Explanation:

Concept: The magnetic field on the axis of a circular current-carrying coil at a distance x from its center is given by:

$$B = \frac{B_0}{\left(1 + \frac{x^2}{R^2}\right)^{3/2}}$$

where:

B_0 is the magnetic field at the center of the coil,
R is the radius of the coil,
x is the axial distance from the center.
Step 1: Substitute the given values.

$$B_0 = 16\ \mu\text{T}, \quad x = \sqrt{3}R$$

$$\frac{x^2}{R^2} = \frac{(\sqrt{3}R)^2}{R^2} = 3$$

Step 2: Calculate the magnetic field at the given point.

$$B = \frac{16}{(1+3)^{3/2}} = \frac{16}{4^{3/2}}$$

$$4^{3/2} = (\sqrt{4})^3 = 2^3 = 8$$

$$B = \frac{16}{8} = 2\ \mu\text{T}$$

Conclusion:

$$\boxed{B = 2\ \mu\text{T}}$$

Hence, the correct answer is **(4)**.

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4. Answer: a

Explanation:

Step 1: Understanding the Question:
A bar magnet experiences a torque when placed in a uniform magnetic field at a

given angle. We need to use this information to find the magnetic moment or the product μB (or MB). Then, we must calculate the work done to rotate the magnet from its most stable equilibrium to its most unstable equilibrium.

Step 2: Key Formula or Approach:

1. Torque on a magnetic dipole: $\tau = MB\sin\theta$, where M is the magnetic moment.
2. Potential energy of a magnetic dipole: $U = -MB\cos\theta$.
3. Most stable position is at $\theta_1 = 0^\circ$ (Minimum PE).
4. Most unstable position is at $\theta_2 = 180^\circ$ (Maximum PE).
5. Work done by external agent: $W_{ext} = \Delta U = U_f - U_i$.

Step 3: Detailed Explanation:

Given:

Initial angle, $\theta = 30^\circ$

Torque, $\tau = 0.016$ N-m

Using the torque formula to find MB:

$\tau = MB\sin 30^\circ$

$0.016 = MB \times \frac{1}{2}$

$MB = 0.032$ J

Now, calculate the work done to rotate the magnet from $\theta_1 = 0^\circ$ (most stable) to $\theta_2 = 180^\circ$ (most unstable).

$W = U_f - U_i = (-MB\cos 180^\circ) - (-MB\cos 0^\circ)$

Since $\cos 180^\circ = -1$ and $\cos 0^\circ = 1$:

$W = (-MB \times -1) - (-MB \times 1)$

$W = MB + MB = 2MB$

Substitute the value of MB:

$W = 2 \times 0.032$ J

$W = 0.064$ J

Step 4: Final Answer:

The amount of work done by the external agent is 0.064 J.

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5. **Answer: a**

Explanation:

Step 1: Understanding the Question:

We need to find the total magnetic field at the center (centroid) of an equilateral triangular loop carrying a current. The total field is the vector sum of the fields produced by the three straight wire segments of the triangle.

Step 2: Key Formula or Approach:

The magnetic field B at a perpendicular distance d from a finite straight wire carrying current I is given by:

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

where θ_1 and θ_2 are the angles subtended by the ends of the wire at the point.

Step 3: Detailed Explanation:

Part A: Geometric Parameters

- Side length of the equilateral triangle, $a = 4\sqrt{3}$ cm = $4\sqrt{3} \times 10^{-2}$ m.
- The center C is the centroid. The perpendicular distance d from the centroid to any side is given by $d = \frac{a}{2\sqrt{3}}$.

$$d = \frac{4\sqrt{3} \times 10^{-2}}{2\sqrt{3}} = 2 \times 10^{-2}\ \text{m}$$

- For an equilateral triangle, the angles subtended by the ends of any side at the centroid are $\theta_1 = 60^\circ$ and $\theta_2 = 60^\circ$.

Part B: Magnetic Field from One Side

Using the formula for a finite wire with $I = 2$ A:

$$B_{side} = \frac{\mu_0 I}{4\pi d}(\sin 60^\circ + \sin 60^\circ) = \frac{\mu_0 I}{4\pi d}(2\sin 60^\circ)$$

$$B_{side} = \frac{(4\pi \times 10^{-7}) \times 2}{4\pi \times (2 \times 10^{-2})}\left(2 \times \frac{\sqrt{3}}{2}\right)$$

$$B_{side} = \frac{2 \times 10^{-7}}{2 \times 10^{-2}} \times \sqrt{3} = 10^{-5}\sqrt{3}\ \text{T}$$

Part C: Total Magnetic Field

By the right-hand rule, the magnetic field from each of the three sides points in the same direction at the center (e.g., into the page). Therefore, the net magnetic field is the sum of the magnitudes of the fields from the three sides.

$$B_{net} = 3 \times B_{side} = 3 \times (10^{-5}\sqrt{3})\ \text{T} = 3\sqrt{3} \times 10^{-5}\ \text{T}$$

To express this in microteslas (μT), we multiply by 10^6.

$$B_{net} = (3\sqrt{3} \times 10^{-5}) \times 10^6\ \mu T = 30\sqrt{3}\ \mu T$$

Step 4: Final Answer:

The magnetic field at the center C is $30\sqrt{3}\ \mu T$.

6. **Answer: b**

Explanation:

Concept: An ideal solenoid produces a uniform magnetic field inside it, directed along its axis. A magnetic field exerts a force on a moving charged particle only if the velocity of the particle has a component perpendicular to the magnetic field. The magnetic force on a charge is given by:

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

Step 1: Direction of magnetic field and velocity Inside an ideal solenoid, the magnetic field $\vec{B}$ is along the axis of the solenoid. Since the solenoid's axis is vertical, $\vec{B}$ is vertical. The charged particle is thrown downward, so its velocity $\vec{v}$ is also vertical.
Step 2: Magnetic force on the charged particle

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

Because $\vec{v}$ is parallel to $\vec{B}$,

$$\vec{v} \times \vec{B} = 0$$

Hence, the magnetic force acting on the charge is zero.
Step 3: Net force and acceleration Since no magnetic force acts on the particle, the only force acting on it is gravity:

$$F = mg$$

Therefore, the acceleration of the particle is:

$$a = g$$

Conclusion: The acceleration of the charged particle remains equal to gravitational acceleration.

$$\boxed{a = g}$$

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7. **Answer: b**

Explanation:

Step 1: The formula for radius r in a magnetic field is $r = \frac{\sqrt{2mK}}{qB}$.
Step 2: Express Kinetic Energy K: $K \propto \frac{q^2r^2}{m}$ (since B is constant).
Step 3: Let proton have $m_p = m, q_p = e$ and α-particle have $m_\alpha = 4m, q_\alpha = 2e$.
Step 4: Calculate the ratio:

$$\frac{K_p}{K_\alpha} = \left(\frac{q_p}{q_\alpha}\right)^2 \times \left(\frac{r_p}{r_\alpha}\right)^2 \times \left(\frac{m_\alpha}{m_p}\right)$$

$$\frac{K_p}{K_\alpha} = \left(\frac{e}{2e}\right)^2 \times \left(\frac{2}{1}\right)^2 \times \left(\frac{4m}{m}\right) = \frac{1}{4} \times 4 \times 4 = 4$$

The ratio is 4 : 1.

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8. **Answer: b**

Explanation:

Step 1: Force $F = qvB$. Since momentum $p = mv$ is same, $v = p/m$.
Step 2: $F = q(p/m)B = \frac{q}{m}(pB)$. Since p, B are constant, $F \propto q/m$.
Step 3: Ratio of q/m: Proton (e/m), Deuteron $(e/2m)$, α $(2e/4m = e/2m)$. Ratio F: $1 : 1/2 : 1/2 \Rightarrow 2 : 1 : 1$.
Step 4: Ratio of speeds $(v = p/m \propto 1/m)$: Proton $(1/m)$, Deuteron $(1/2m)$, α $(1/4m)$. Ratio v: $1 : 1/2 : 1/4 \Rightarrow 4 : 2 : 1$.

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9. **Answer: d**

Explanation:

Step 1: Understanding the Concept:
The magnetic field due to a circular coil at an axial point is compared with the field at the center. For points close to the center, we use a binomial approximation.
Step 2: Key Formula or Approach:
Magnetic field at axial distance r: $B = \frac{\mu_0 I a^2}{2(a^2+r^2)^{3/2}}$.
Field at center $(r = 0)$: $B_0 = \frac{\mu_0 I}{2a}$.
Step 3: Detailed Explanation:
Express B in terms of B_0:

$$B = B_0 \cdot \frac{a^3}{(a^2 + r^2)^{3/2}} = B_0 \left(1 + \frac{r^2}{a^2}\right)^{-3/2}$$

Since $r \ll a$, apply binomial expansion $(1 + x)^n \approx 1 + nx$:

$$B \approx B_0 \left(1 - \frac{3}{2}\frac{r^2}{a^2}\right)$$

Fractional change:

$$\frac{B_0 - B}{B_0} = 1 - \left(1 - \frac{3}{2}\frac{r^2}{a^2}\right) = \frac{3}{2}\frac{r^2}{a^2}$$

Step 4: Final Answer:

The fractional change is $\frac{3}{2}\frac{r^2}{a^2}$.

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10. Answer: 3 - 3

Explanation:

Step 1: Understanding the Question:

We need to find the torque on a triangular current-carrying coil placed in a magnetic field. The orientation is specified, which allows us to find the maximum torque.

Step 2: Key Formula or Approach:

1. The torque (τ) on a current loop in a uniform magnetic field (B) is given by $\vec{\tau} = \vec{M} \times \vec{B}$, where $\vec{M}$ is the magnetic dipole moment of the loop.

2. The magnitude of the torque is $\tau = MB\sin\theta$, where θ is the angle between $\vec{M}$ and $\vec{B}$.

3. The magnetic moment is given by $M = NIA$, where N is the number of turns (here N=1), I is the current, and A is the area of the loop.

4. Torque is maximum when $\sin\theta = 1$, which occurs when $\vec{M}$ is perpendicular to $\vec{B}$. The direction of $\vec{M}$ is normal to the plane of the coil. If the plane of the coil is parallel to $\vec{B}$, then its normal is perpendicular to $\vec{B}$, so $\theta = 90^\circ$.

Step 3: Detailed Explanation:

Given values:

Side of equilateral triangle, a = 10 cm = 0.1 m

Magnetic field, B = 20 mT = 20 $\times$ 10^{-3} T
Current, I = 0.2 A
Number of turns, N = 1
First, calculate the area (A) of the equilateral triangle coil:

$$A = \frac{\sqrt{3}}{4}a^2 = \frac{\sqrt{3}}{4}(0.1\ \mathrm{m})^2 = \frac{\sqrt{3}}{4}(0.01)\ \mathrm{m}^2$$

The plane of the coil is parallel to the magnetic field, so the angle θ between the magnetic moment (normal to the plane) and the magnetic field is 90°. Thus, the torque is maximum.

$$\tau = \tau_{max} = NIAB$$

Substitute the values:

$$\tau = (1) \times (0.2\ \mathrm{A}) \times \left(\frac{\sqrt{3}}{4} \times 0.01\ \mathrm{m}^2\right) \times (20 \times 10^{-3}\ \mathrm{T})$$

$$\tau = 0.2 \times \frac{\sqrt{3}}{4} \times 0.01 \times 20 \times 10^{-3}$$

$$\tau = (0.2 \times 20) \times \frac{\sqrt{3}}{4} \times 0.01 \times 10^{-3}$$

$$\tau = 4 \times \frac{\sqrt{3}}{4} \times 10^{-2} \times 10^{-3}$$

$$\tau = \sqrt{3} \times 10^{-5}\ \mathrm{Nm}$$

The problem states that the torque is $\sqrt{x} \times 10^{-5}$ Nm.
Comparing our result with the given expression:

$$\sqrt{3} \times 10^{-5} = \sqrt{x} \times 10^{-5}$$

$$\sqrt{3} = \sqrt{x} \implies x = 3$$

Step 4: Final Answer:
The value of x is 3.

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11. Answer: 543 - 543

Explanation:

Step 1: Understanding the Question:
A proton in a cyclotron gains energy each time it crosses the gap between the dees. We are given the accelerating potential and the final desired speed. We need to find how many full revolutions it takes to reach that speed.
Step 2: Key Formula or Approach:
1. Calculate the final kinetic energy (K_f) of the proton using $K = \frac{1}{2}mv^2$.
2. In a cyclotron, the particle is accelerated twice in each revolution. The energy gained in one revolution is $\Delta K_{rev} = 2 \times qV_0$, where V_0 is the accelerating potential.
3. The total number of revolutions (N) is the total kinetic energy gained divided by the energy gained per revolution: $N = \frac{K_f}{\Delta K_{rev}}$.
Step 3: Detailed Explanation:
Given values:
Accelerating potential, V_0 = 12 kV = 12 $\times$ 10^3 V
Proton mass, m_p = 1.67 $\times$ 10^{-27} kg
Proton charge, e = 1.6 $\times$ 10^{-19} C
Speed of light, c = 3 $\times$ 10^8 m/s
Final speed, v_f = c/6 = (3 $\times$ 10^8) / 6 = 0.5 $\times$ 10^8 m/s
First, calculate the final kinetic energy (K_f) in Joules:

$$K_f = \frac{1}{2}m_p v_f^2 = \frac{1}{2}(1.67 \times 10^{-27})(0.5 \times 10^8)^2$$

$$K_f = \frac{1}{2}(1.67 \times 10^{-27})(0.25 \times 10^{16}) = 0.20875 \times 10^{-11} \text{ J}$$

Next, calculate the energy gained per revolution in Joules:

$$\Delta K_{rev} = 2eV_0 = 2 \times (1.6 \times 10^{-19} \text{ C}) \times (12 \times 10^3 \text{ V})$$

$$\Delta K_{rev} = 38.4 \times 10^{-16} \text{ J} = 3.84 \times 10^{-15} \text{ J}$$

Finally, calculate the number of revolutions (N):

$$N = \frac{K_f}{\Delta K_{rev}} = \frac{0.20875 \times 10^{-11} \text{ J}}{3.84 \times 10^{-15} \text{ J}}$$

$$N = \frac{0.20875}{3.84} \times 10^4 \approx 0.05436 \times 10^4 = 543.6$$

The number of revolutions must be an integer. Since the question asks for the number of revolutions to achieve the speed, we take the integer part.
Step 4: Final Answer:
The number of revolutions made by the proton is 543.

12. Answer: 1 - 1

Explanation:

To find the distance x of point P from wire X, we need to consider the magnetic fields produced by both wires at point P. The magnetic field due to a straight current-carrying wire at a distance r is given by:

$$B = \frac{\mu_0 I}{2\pi r}$$

For wire Y, at distance 4 cm:

$$B_Y = \frac{\mu_0 \times 4}{2\pi \times 0.04} = \frac{4\pi \times 10^{-7} \times 4}{2\pi \times 0.04} = 10^{-5}\,\mathrm{T}$$

For wire X, at distance x:

$$B_X = \frac{\mu_0 \times 5}{2\pi x} = \frac{4\pi \times 10^{-7} \times 5}{2\pi x} = \frac{10^{-6}}{x}\,\mathrm{T}$$

Since the currents are in opposite directions, their magnetic fields at point P are in opposite directions. Hence, the resultant magnetic field B is:

$$B = |B_X - B_Y| = 3 \times 10^{-5}\,\mathrm{T}$$

Substituting values:

$$\left|\frac{10^{-6}}{x} - 10^{-5}\right| = 3 \times 10^{-5}$$

Consider $\frac{10^{-6}}{x} > 10^{-5}$:

$$\frac{10^{-6}}{x} - 10^{-5} = 3 \times 10^{-5}$$

$$\frac{10^{-6}}{x} = 4 \times 10^{-5}$$

$$x = \frac{10^{-6}}{4 \times 10^{-5}} = \frac{1}{4} \times 10^{1} = 2.5\,\mathrm{cm}$$

---

13. Answer: 50 - 50

Explanation:

Magnetic Force on a Current-Carrying Wire in a Magnetic Field:
The magnetic force F on a segment of current-carrying wire in a magnetic field is given by:

$$F = ILB\sin\theta$$

where:
I is the current,
L is the length of the segment,
B is the magnetic field,
θ is the angle between the magnetic field and the current direction.

In this case, the loop lies in the $x-y$ plane with its edges parallel to the $x-$ and $y-$ axes. Since $\vec{B}$ varies with x, the magnetic force on each side of the loop depends on its position in the $x-y$ plane.

Calculate the Force on Each Side of the Loop:
For the left side at $x = 0$:

$$B_{\text{left}} = 0.2(1 + 2 \times 0) = 0.2\,\text{T}$$

Force on the left side:

$$F_{\text{left}} = ILB_{\text{left}} = 0.5 \times 0.5 \times 0.2 = 0.05\,\text{N}$$

For the right side at $x = 0.5\,\text{m}$:

$$B_{\text{right}} = 0.2(1 + 2 \times 0.5) = 0.2 \times 2 = 0.4\,\text{T}$$

Force on the right side:

$$F_{\text{right}} = ILB_{\text{right}} = 0.5 \times 0.5 \times 0.4 = 0.1\,\text{N}$$

Net Force on the Loop:
The forces on the top and bottom sides (parallel to the x-axis) will cancel each other out due to symmetry, as the magnetic field along these sides is the same. Therefore, the net force is due to the difference in the forces on the left and right sides:

$$F_{\text{net}} = F_{\text{right}} - F_{\text{left}} = 0.1 - 0.05 = 0.05\,\text{N}$$

Convert to mN:

$$F_{\text{net}} = 0.05\,\text{N} = 50\,\text{mN}$$

Conclusion:
The magnitude of the net magnetic force experienced by the loop is $50\,\text{mN}$.

---

14. Answer: 150 - 150

Explanation:

Given:

- Side of the cube (l) = $15\,\text{cm} = 0.15\,\text{m}$
- Velocity $(\vec{v})$ = $2\hat{j}\,\text{m/s}$
- Magnetic field $(\vec{B})$ = $0.5\hat{k}\,\text{T}$

Step 1: Formula for Induced EMF

The induced electromotive force (EMF) or potential difference (V) across the faces of the cube due to its motion in the magnetic field is given by:

$$V = Blv,$$

where:

- B: Magnetic field strength
- l: Length of the side of the cube perpendicular to both velocity and magnetic field
- v: Velocity of the cube

Step 2: Substitute the Given Values

Substitute $B = 0.5\,\text{T}$, $l = 0.15\,\text{m}$, and $v = 2\,\text{m/s}$ into the formula:

$$V = (0.5)(0.15)(2).$$

Simplify:

$$V = 0.15\,\text{V}.$$

Convert to millivolts:

$$V = 150\,\text{mV}.$$

Final Answer:

The potential difference developed between the faces is $150\,\mathrm{mV}$.

---

15. **Answer: c**

Explanation:

It is a case of solid infinite current carrying wire.
Using ampere circuital law,
CASE I: if r ≤ R $B = \mu\_0i/2\pi R\^2\ r$
CASE II: r>R $B = \mu 0i\ /2\pi$r

---

16. **Answer: b**

Explanation:

The correct answer is (B) : 18
$R = \frac{mv}{Bq} = \frac{\sqrt{2mk}}{Bq}$
$\Rightarrow K = \frac{B^2q^2R^2}{2m}$
$\Rightarrow \frac{(1.6\times10^{-19})^2\times0.6^2}{2\times1.6\times10^{-27}}\ J$
= 18MeV

Concepts:

1. Moving Charges and Magnetism:

Moving charges generate an electric field and the rate of flow of charge is known as current. This is the basic concept in Electrostatics. Another important concept related to moving electric charges is the magnetic effect of current. Magnetism is caused by the current.

Magnetism:

- The relationship between a Moving Charge and Magnetism is that Magnetism is produced by the movement of charges.

- And Magnetism is a property that is displayed by Magnets and produced by moving charges, which results in objects being attracted or pushed away.

Magnetic Field:

Region in space around a magnet where the Magnet has its Magnetic effect is called the Magnetic field of the Magnet. Let us suppose that there is a point charge q (moving with a velocity v and, located at r at a given time t) in presence of both the electric field E (r) and the magnetic field B (r). The force on an electric charge q due to both of them can be written as,

$$F = q\,[\,E\,(r) + v \times B\,(r)] \equiv E_{Electric} + F_{magnetic}$$

This force was based on the extensive experiments of Ampere and others. It is called the Lorentz force.

---

17. **Answer: c**

Explanation:

Radius, $R = \frac{mv}{qB}$

The ratio of the radii of the circular paths,

$$\frac{R_\alpha}{R_p} = \frac{\frac{m_\alpha}{q_\alpha}}{\frac{m_p}{q_q}}$$

$$\frac{R_\alpha}{R_p} = \frac{2}{1}$$

So, Answer is (C): $2 : 1$

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Magnetic Field:

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---

18. **Answer: c**

Explanation:

The correct answer is (C) : Statement I is correct but statement II is incorrect.
Electric field accelerates the particle in the direction of field
$\vec{F} = q\vec{E} = m\vec{a}$
and magnetic field accelerates the particle perpendicular to the field
$(\vec{F} = q\vec{v} \times \vec{B} = m\vec{a})$

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---

19. **Answer: b**

Explanation:

The correct answer is (B) : 30 A in the opposite direction
If currents are equal in both wires and field at mid-point is not zero, then the current is in opposite direction to sum up the fields at the point.

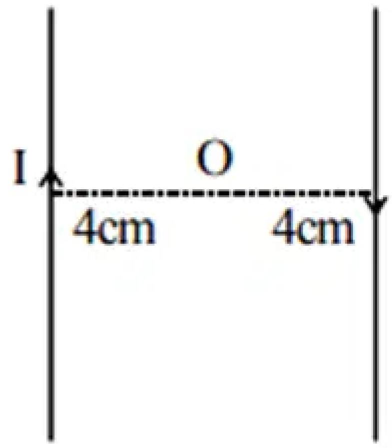

Fig.

As $B_{net} \neq 0$ that is the wires are carrying current in opposite direction.

$\frac{\mu_0 I \times 2}{2\pi(4\times10^{-2})} = 30 \times 10^{-6} T$

$\Rightarrow I = \frac{30 \times 10^{-6}}{10^{-6}} A = 30A$

in opposite direction.

Concepts:

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20. Answer: 10 - 10

Explanation:

The correct answer is 10

$R = \frac{mv}{qB}$

$R = \frac{\sqrt{2mKE}}{qB}$

$= \frac{\sqrt{2 \times 24 \times 1.67 \times 10^{-27} \times 5 \times 16 \times 10^{-16}}}{1.6 \times 10^{-19} \times 0.5}$

= 10.009

= 10 cm

∴ The radius of path formed will be 10 cm.

Concepts:

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