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Magnetic Effects of Current and Magnetism — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · PHYSICS · PATTERN OF JEE (MAIN)

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	100	25 (20 + 5)	

GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Take $\mu_0 = 4\pi \times 10^{-7}$ T m/A, $e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg and $m_p = 1.67 \times 10^{-27}$ kg unless stated otherwise. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

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Topics covered: Biot–Savart law · Ampere's circuital law and its applications · Force on a moving charge · Force on a current-carrying conductor · Force between two parallel currents · Torque on a current loop · Moving coil galvanometer · Current loop as a magnetic dipole · Bar magnet and its magnetic field · Torque on a magnetic dipole · Magnetic materials · Effect of temperature on magnetic properties

SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

1. The magnetic field at the centre of a circular loop of radius R carrying a steady current is B. The magnetic field at a point on the axis of the loop at a distance R from its centre is

(1) B/2

(2) B/√2

(3) B/4

(4) B/(2√2)

2. A long wire carrying current I is bent into a hairpin: two long straight parallel parts joined by a semicircle of radius R. The magnitude of the magnetic field at the centre of the semicircle is

(1) $\mu_0 I/(4R)$

(2) $\mu_0 I(\pi + 1)/(4\pi R)$

(3) $\mu_0 I(\pi + 2)/(4\pi R)$

(4) $\mu_0 I/(2\pi R)$

3. A long hollow cylindrical conductor of inner radius a and outer radius 2a carries a current spread uniformly over its cross-section. The ratio of the magnetic field at a distance 1.5a from the axis to that at a distance 3a from the axis is

(1) 5 : 6

(2) 1 : 2

(3) 3 : 4

(4) 2 : 3

4. A solenoid 40 cm long has 800 turns and carries a current of 1.5 A. It is filled with a core of relative permeability 500. The magnetic field inside it, well away from the ends, is about

(1) 0.94 T

(2) 1.9 T

(3) 3.8 mT

(4) 3.8 T

5. A proton and an alpha particle are accelerated from rest through the same potential difference and then enter the same uniform magnetic field at right angles to it. The ratio of the radius of the proton's path to that of the alpha particle's path is

(1) 1 : 2

(2) 1 : √2

(3) √2 : 1

(4) 2 : 1

6. Electrons pass undeflected through a region where a uniform electric field of 3×10^4 V/m and a uniform magnetic field of 0.02 T are perpendicular to each other and to the beam. Their speed, and the radius of their path if the electric field is switched off, are

(1) 1.5×10^6 m/s and 4.3 cm

(2) 6.7×10^5 m/s and 0.43 mm

(3) 1.5×10^6 m/s and 4.3 m

(4) 1.5×10^6 m/s and 0.43 mm

7. A charged particle enters a uniform magnetic field with its velocity at 60° to the field. The ratio of the pitch of its helical path to the radius of the helix is

(1) $2\pi\sqrt{3}$

(2) $\pi/\sqrt{3}$

(3) $2\pi/\sqrt{3}$

(4) $\sqrt{3}\pi$

8. A wire bent into a semicircle of radius R carries a current I and lies in a plane perpendicular to a uniform magnetic field B. The magnitude of the net magnetic force on the wire is

(1) 2BIR

(2) πBIR

(3) BIR

(4) zero

9. Two long straight parallel wires 10 cm apart carry currents of 5 A and 8 A in opposite directions. The force per unit length on each wire is

(1) 8×10^{-5} N/m, repulsive

(2) 8×10^{-5} N/m, attractive

(3) 4×10^{-5} N/m, repulsive

(4) 1.6×10^{-4} N/m, attractive

10. A circular coil of 100 turns and radius 5 cm carries a current of 2 A in a uniform magnetic field of 0.4 T. The plane of the coil makes an angle of 30° with the field. The torque on the coil is about

(1) 0.31 N m

(2) 0.63 N m

(3) 0.54 N m

(4) 0.27 N m

11. A galvanometer of resistance 50 Ω gives a full-scale deflection for a current of 5 mA. To convert it into an ammeter of range 0–1 A and, separately, into a voltmeter of range 0–10 V, one needs respectively

(1) 0.25 Ω in series, and 1950 Ω in parallel

(2) 0.25 Ω in parallel, and 1950 Ω in series

(3) 0.25 Ω in parallel, and 2000 Ω in series

(4) 250 Ω in parallel, and 1950 Ω in series

12. The number of turns of the coil of a moving coil galvanometer is doubled, which also doubles the resistance of the coil; everything else is unchanged. Its current sensitivity and voltage sensitivity

(1) both double

(2) stay the same and halve, respectively

(3) both stay the same

(4) double and stay the same, respectively

13. A wire of length L carries a current I. The ratio of the magnetic dipole moment when it is bent into a single circular loop to that when it is bent into a single square loop is

(1) π/4

(2) 1

(3) 2/π

(4) 4/π

14. The magnetic field of a short bar magnet at a point on its axis at a distance d from its centre is equal in magnitude to its field at a point on its equatorial line at a distance x from its centre. Then x is

(1) d/2

(2) d/2^(1/3)

(3) 2^(1/3) d

(4) d/√2

15. A bar magnet of magnetic moment 2 A m² is free to turn in a horizontal plane in a uniform horizontal magnetic field of 0.3 T. It is released from rest with its axis at 60° to the field. Its kinetic energy as it passes through the direction of the field is

(1) 0.6 J

(2) 1.2 J

(3) 0.3 J

(4) 0.15 J

16. Which of the following lists contains only diamagnetic substances?

(1) bismuth, copper, water

(2) aluminium, sodium, oxygen

(3) iron, nickel, cobalt

(4) bismuth, aluminium, iron

17. The magnetic susceptibility of a paramagnetic salt is 1.2×10^{-5} at 300 K. Assuming Curie's law, its susceptibility at 200 K is

(1) 0.8×10^{-5}

(2) 1.2×10^{-5}

(3) 1.8×10^{-5}

(4) 2.7×10^{-5}

18. Which of the following statements about the magnetic field lines of a bar magnet is NOT correct?

(1) They form closed loops

(2) Outside the magnet they go from its north pole to its south pole

(3) Two field lines never cross each other

(4) Inside the magnet they go from its north pole to its south pole

19. A bar magnet of magnetic moment m is cut into two equal pieces along its length (parallel to its axis). The magnetic moment and pole strength of each piece, compared with those of the original magnet, are

(1) m/2, with the pole strength halved

(2) m/2, with the same pole strength

(3) m, with the pole strength halved

(4) m/4, with the pole strength halved

20. A proton moves with velocity 2×10^5 m/s along +x through a region with a uniform electric field of 4×10^5 V/m along +y and a uniform magnetic field of 0.5 T along +z. The net force on it is

(1) 8.0×10^{-14} N along +y

(2) 4.8×10^{-14} N along +y

(3) 4.8×10^{-14} N along −y

(4) 1.6×10^{-14} N along +y

SECTION B (Q21–25) · Numerical value · +4 / 0 / −1

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

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21. A square loop of side 10 cm carries a current of 5 A. The magnetic field (in μT) at its centre is _____ (to the nearest integer).

Answer: _____

22. A proton moves with a speed of 10^6 m/s at right angles to a uniform magnetic field of 0.5 T. The radius of its circular path (in mm) is _____ (to the nearest integer).

Answer: _____

23. Two long straight parallel wires 6 cm apart carry currents of 3 A and 6 A in the same direction. The magnetic field due to them is zero on the line, between the wires, at a distance (in cm) from the 3 A wire of _____.

Answer: _____

24. The coil of a moving coil galvanometer has 20 turns and an area of 5 cm × 4 cm, and lies in a radial magnetic field of 0.25 T. The torsion constant of the suspension is 1.0×10^{-4} N m per degree. A current of 0.5 A through the coil gives a steady deflection (in degrees) of _____.

Answer: _____

25. A circular coil of 50 turns and radius 10 cm carries a current of 0.5 A. The magnetic field (in μT) at a point on its axis $10\sqrt{3}$ cm from its centre is _____ (to the nearest integer).

Answer: _____

END OF THE QUESTION PAPER

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(4)	(3)	(1)	(2)	(2)	(4)	(3)	(1)	(1)	(3)

Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
(2)	(4)	(4)	(2)	(3)	(1)	(3)	(4)	(1)	(2)

Q21	Q22	Q23	Q24	Q25
57	21	2	50	20

WORKED SOLUTIONS

Q1. Answer (4). On the axis $B(x) = \mu_0 IR^2/[2(R^2 + x^2)^{(3/2)}]$; at the centre $B = \mu_0 I/(2R)$. At $x = R$: $\mu_0 IR^2/[2(2R^2)^{(3/2)}] = \mu_0 I/(2R \times 2\sqrt{2}) = B/(2\sqrt{2})$.

Q2. Answer (3). The semicircle gives $\mu_0 I/(4R)$. Each straight part is a semi-infinite wire ending level with the centre, at perpendicular distance R: $\mu_0 I/(4\pi R)$ each, in the same direction as the semicircle's field. Total $\mu_0 I/(4R) + 2\mu_0 I/(4\pi R) = \mu_0 I(\pi + 2)/(4\pi R)$.

Q3. Answer (1). Ampère's law: $B \times 2\pi r = \mu_0 \times$ (current enclosed). At 1.5a the enclosed current is $I(2.25a^2 - a^2)/(4a^2 - a^2) = 5I/12$, so $B = \mu_0(5I/12)/(2\pi \times 1.5a) = 5\mu_0 I/(36\pi a)$. At 3a, $B = \mu_0 I/(6\pi a)$. Ratio $(5/36)/(1/6) = 5 : 6$.

Q4. Answer (2). $n = 800/0.4 = 2000$ turns per metre. $B = \mu_r \mu_0 nI = 500 \times 4\pi \times 10^{-7} \times 2000 \times 1.5 \approx 1.9$ T. (3.8 mT is the field without the core.)

Q5. Answer (2). $qV = \tfrac{1}{2}mv^2$ gives $mv = \sqrt{(2mqV)}$, and $r = mv/(qB) = \sqrt{(2mV/q)}/B \propto \sqrt{(m/q)}$. Proton: $\sqrt{(1/1)}$; alpha: $\sqrt{(4/2)} = \sqrt{2}$. Ratio $1 : \sqrt{2}$.

Q6. Answer (4). Undeflected when $eE = evB$: $v = E/B = 3 \times 10^4/0.02 = 1.5 \times 10^6$ m/s. Then $r = mv/(eB) = 9.1 \times 10^{-31} \times 1.5 \times 10^6/(1.6 \times 10^{-19} \times 0.02) = 4.3 \times 10^{-4}$ m = 0.43 mm.

Q7. Answer (3). The perpendicular component $v \sin 60°$ gives circles of radius $r = mv \sin 60°/(qB)$ and period $T = 2\pi m/(qB)$. The pitch is $v \cos 60° \times T = 2\pi mv \cos 60°/(qB)$. Pitch/r $= 2\pi \cot 60° = 2\pi/\sqrt{3}$.

Q8. Answer (1). In a uniform field the force on any wire is BI times the straight line joining its ends (the sum of dl is that vector). The ends of a semicircle are 2R apart, so $F = 2BIR$. (πBIR wrongly adds the forces on all the elements without allowing for their directions.)

Q9. Answer (1). $F/L = \mu_0 I_1 I_2/(2\pi d) = 2 \times 10^{-7} \times 5 \times 8/0.1 = 8 \times 10^{-5}$ N/m. Antiparallel currents repel.

Q10. Answer (3). $\tau = NIAB \sin\theta$, where θ is the angle between the field and the normal to the coil: $\theta = 90° - 30° = 60°$. $\tau = 100 \times 2 \times \pi(0.05)^2 \times 0.4 \times \sin 60° = 0.628 \times 0.866 \approx 0.54$ N m. (0.31 N m wrongly uses 30°.)

Q11. Answer (2). Ammeter: a shunt in parallel takes the rest of the current: $S = I_g G/(I - I_g) = 0.005 \times 50/0.995 \approx 0.25\ \Omega$. Voltmeter: a resistance in series so that 10 V drives 5 mA: $R = 10/0.005 - 50 = 1950\ \Omega$. (2000 Ω forgets the galvanometer's own 50 Ω.)

Q12. Answer (4). Current sensitivity $\theta/I = NAB/k$ doubles with N. Voltage sensitivity $\theta/V = NAB/(kG)$: N and G both double, so it is unchanged.

Q13. Answer (4). $m = IA$. Circle: $r = L/(2\pi)$, $A = L^2/(4\pi)$. Square: side L/4, $A = L^2/16$. Ratio $(1/(4\pi))/(1/16) = 4/\pi$: of all shapes, the circle encloses the largest area.

Q14. Answer (2). Axial: $B = \mu_0(2m)/(4\pi d^3)$; equatorial: $B = \mu_0 m/(4\pi x^3)$. Equal when $2/d^3 = 1/x^3$, i.e. $x^3 = d^3/2$ and x = d/2^(1/3).

Q15. Answer (3). $U = -mB\cos\theta$. The loss in potential energy from 60° to 0° is $mB(1 - \cos 60°) = 2 \times 0.3 \times 0.5 = 0.3$ J, which becomes kinetic energy.

Q16. Answer (1). Bismuth, copper and water are diamagnetic (small negative susceptibility). Aluminium, sodium and oxygen are paramagnetic; iron, nickel and cobalt are ferromagnetic.

Q17. Answer (3). Curie's law: $\chi = C/T$, so $\chi \propto 1/T$. $\chi = 1.2 \times 10^{-5} \times 300/200 = 1.8 \times 10^{-5}$.

Q18. Answer (4). Magnetic field lines are closed loops (there are no isolated magnetic poles). Outside the magnet they run from N to S, so to close they must run from S to N inside it. Lines cannot cross, since B has one direction at a point.

Q19. Answer (1). m = (pole strength) × (length). Cutting along the length leaves the length unchanged but halves the pole strength (each pole face is halved), so each piece has m/2. (Cutting across the length would instead keep the pole strength and halve the length, again giving m/2.)

Q20. Answer (2). $F = q(E + v \times B)$. $v \times B = 2 \times 10^5 \times 0.5\,(\hat{x} \times \hat{z}) = -1 \times 10^5\,\hat{y}$ V/m. So $E + v \times B = 3 \times 10^5\,\hat{y}$ and $F = 1.6 \times 10^{-19} \times 3 \times 10^5 = 4.8 \times 10^{-14}$ N along +y.

Q21. Answer 57. Each side is a finite wire at distance a/2 = 5 cm from the centre, with its ends at 45°: $B = \mu_0 I/(4\pi \times a/2) \times 2\sin 45° = 10^{-7} \times 5/0.05 \times \sqrt{2} = 1.414 \times 10^{-5}$ T. Four sides: 5.66×10^{-5} T ≈ 57 μT.

Q22. Answer 21. $r = mv/(qB) = 1.67 \times 10^{-27} \times 10^6/(1.6 \times 10^{-19} \times 0.5) = 2.09 \times 10^{-2}$ m ≈ 21 mm.

Q23. Answer 2. Between wires with parallel currents the two fields are opposite. $B = \mu_0 I/(2\pi r)$: $3/x = 6/(6 - x)$, so $18 - 3x = 6x$ and x = 2 cm.

Q24. Answer 50. In a radial field the deflecting torque is $NIAB = 20 \times 0.5 \times 2 \times 10^{-3} \times 0.25 = 5 \times 10^{-3}$ N m at every angle. Equilibrium: $k\theta = NIAB$, $\theta = 5 \times 10^{-3}/10^{-4} = 50°$.

Q25. Answer 20. $B = \mu_0 NIR^2/[2(R^2 + x^2)^{(3/2)}]$ with $R^2 + x^2 = 0.04$ m², $(R^2 + x^2)^{(3/2)} = 0.008$ m³: $B = 4\pi \times 10^{-7} \times 50 \times 0.5 \times 0.01/(2 \times 0.008) = 1.96 \times 10^{-5}$ T ≈ 20 μT.

All questions are original and © Master Testing Agency. Free to download and use for personal practice; not for resale. Every answer in this paper was checked independently by computer: fields by summing the Biot–Savart law over small pieces of each wire, forces and torques by summing I dl × B, and the paths of charged particles by step-by-step integration of the Lorentz force.