# Class 12 Physics · Chapter 5: Magnetism and Matter

**Answer key and marking scheme** · 20 marks · about 40 minutes · based on NCERT

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**1.** Which statement about the magnetic field lines of a bar magnet is NOT correct? [1]

(a) The tangent to a line at a point gives the direction of B there.
(b) They form continuous closed loops.
(c) They start at the north pole and end at the south pole.
(d) Two field lines never intersect.

**Answer: (c)** The lines of a magnet run outside from N to S and continue inside the magnet from S to N, forming closed loops; they do not begin or end anywhere. The other three are properties stated for field lines.

**2.** The field of a short bar magnet at a point on its axis at a distance r is B. At a point on its equatorial line at a distance 2r, the field has magnitude [1]

(a) B/2
(b) B/8
(c) B/32
(d) B/16

**Answer: (d)** Axial: $B = (\mu_0/4\pi)(2m/r^3)$. Equatorial at 2r: $(\mu_0/4\pi)\, m/(2r)^3 = (\mu_0/4\pi)\, m/8r^3 = B/16$. Forgetting the factor 2 of the axial field gives B/8; counting it twice gives B/32; ignoring the change of distance gives B/2.

**3.** The field of a short bar magnet at a point on its axis 10 cm from its centre is $4.0 \times 10^{-4}$ T. At a point on its equatorial line 20 cm from its centre, the field is [1]

(a) $1.0 \times 10^{-4}$ T
(b) $5.0 \times 10^{-5}$ T
(c) $2.5 \times 10^{-5}$ T
(d) $1.25 \times 10^{-5}$ T

**Answer: (c)** Halving for the equatorial position and dividing by $2^3 = 8$ for the doubled distance: $B = 4.0 \times 10^{-4} \times (1/2) \times (1/8) = 2.5 \times 10^{-5}$ T. Dropping the 1/2 gives $5.0 \times 10^{-5}$ T.

**4.** A long magnetised steel knitting needle is snapped into many short pieces. Each piece [1]

(a) is unmagnetised, except the two end pieces
(b) has only a north pole or only a south pole
(c) is a magnet with its own north and south pole
(d) is unmagnetised, since the poles stay with the end pieces

**Answer: (c)** Magnetic poles cannot be isolated: breaking a magnet gives smaller magnets, each with a north and a south pole. Isolated poles (monopoles) do not exist.

**5.** A bar magnet of moment 2.0 J $T^{-1}$ lies in a uniform field of 0.30 T, its moment making 120° with the field. Taking the energy as zero when the moment is perpendicular to the field, its potential energy is [1]

(a) −0.30 J
(b) 0.30 J
(c) 0.52 J
(d) −0.60 J

**Answer: (b)** $U = -mB\cos\theta = -2.0 \times 0.30 \times \cos 120° = -0.60 \times (-0.5) = +0.30$ J. The sign is positive because the moment points more against the field than along it.


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**6.** A short bar magnet produces a field of 3.2 μT at a point on its axis 50 cm from its centre. Find its magnetic moment, and the field it produces at a point on its equatorial line 50 cm from the centre, with direction. (Take $\mu_0/4\pi = 10^{-7}$ T m $A^{-1}$.) [2]

On the axis, $B = (\mu_0/4\pi)(2m/r^3)$, so $m = Br^3/(2 \times 10^{-7}) = 3.2 \times 10^{-6} \times (0.50)^3/(2 \times 10^{-7}) = 2.0$ A $m^2$. On the equatorial line at the same distance the field is half the axial value, $(\mu_0/4\pi)(m/r^3) = 1.6$ μT, directed opposite to m.

- m from the axial field: m = 2.0 A $m^2$ (1)
- equatorial field 1.6 μT, opposite to m (1)

**7.** A long solenoid carrying a fixed current is filled first with a diamagnetic liquid of $\chi = -1.0 \times 10^{-5}$, and then with a paramagnetic liquid of $\chi = +1.0 \times 10^{-5}$. Find the ratio of the field inside in the second case to that in the first, and comment on the size of the difference. [2]

$H = nI$ is the same in both cases, and $B = \mu_0(1 + \chi)H$. Ratio $= (1 + 1.0 \times 10^{-5})/(1 - 1.0 \times 10^{-5}) \approx 1 + 2.0 \times 10^{-5} = 1.00002$. The fields differ by only 2 parts in $10^5$: a minuscule difference in χ, yet one liquid is pushed out of strong-field regions and the other is drawn in.

- $H = nI$ unchanged; $B = \mu_0(1 + \chi)H$ (1)
- ratio ≈ 1.00002, a difference of 2 parts in $10^5$, though the behaviours are opposite (1)

**8.** A bar magnet of moment 2.5 A $m^2$ can turn freely in a uniform field of 0.040 T. (a) What is the largest torque it can experience, and in which orientation? (b) At what angles between its moment and the field is the torque half its largest value? Find its potential energy at each, taking the energy as zero when the moment is perpendicular to the field. [2]

(a) $\tau = mB \sin\theta$ is largest at $\theta = 90°$: $\tau_{max} = 2.5 \times 0.040 = 0.10$ N m, with the moment perpendicular to the field. (b) $\sin\theta = 1/2$, so $\theta = 30°$ or 150°. $U = -mB\cos\theta$: at 30°, $U = -0.10 \times 0.866 = -0.087$ J; at 150°, $U = +0.087$ J.

- $\tau_{max} = mB = 0.10$ N m at $\theta = 90°$ (1)
- $\theta = 30°$ or 150°, U = −0.087 J and +0.087 J (1)

**9.** The largest torque a bar magnet can experience in a uniform field of 0.30 T is 0.060 N m. Find (a) its magnetic moment, (b) the angle between its moment and the field at which its potential energy is −0.030 J (zero when the moment is perpendicular to the field), and the torque on it there, (c) the work needed to turn it slowly from that angle to its position of unstable equilibrium. [3]

(a) $\tau_{max} = mB$, so $m = 0.060/0.30 = 0.20$ A $m^2$. (b) $U = -mB\cos\theta = -0.060\cos\theta = -0.030$ J gives $\cos\theta = 0.5$, $\theta = 60°$; $\tau = mB\sin 60° = 0.060 \times 0.866 = 0.052$ N m. (c) The unstable equilibrium is $\theta = 180°$: $W = mB(\cos 60° - \cos 180°) = 0.060 \times 1.5 = 0.090$ J.

- $m = \tau_{max}/B = 0.20$ A $m^2$ (1)
- $\theta = 60°$, $\tau = 0.052$ N m (1)
- $W = mB(\cos 60° - \cos 180°) = 0.090$ J (1)

**10.** Using the analogy between an electric dipole and a magnetic dipole, write the magnetic counterparts of (a) $1/\varepsilon_0$ and the dipole moment p, (b) the torque $p \times E$ and the energy $-p \cdot E$, (c) the field on the axis of a short electric dipole, $2p/4\pi\varepsilon_0 r^3$. [3]

(a) $1/\varepsilon_0 \to \mu_0$ (equivalently $1/4\pi\varepsilon_0 \to \mu_0/4\pi$), $p \to m$. (b) Torque $m \times B$; energy $-m \cdot B$. (c) Axial field of a short bar magnet: $B_A = (\mu_0/4\pi)(2m/r^3)$, along m.

- $1/\varepsilon_0 \to \mu_0$ and $p \to m$ (1)
- torque $m \times B$ and energy $-m \cdot B$ (1)
- $B_A = \mu_0 2m/4\pi r^3$ (1)


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**11.** An iron nail is made of many magnetic domains, yet on its own it attracts nothing. (a) Explain why it shows no net magnetisation. (b) Explain how it becomes strongly magnetised when a magnet is brought near. (c) Why does it stay magnetised for only a short time after the magnet is removed, while a lodestone stays magnetised? [3]

(a) Within each domain the atomic dipoles are aligned, but the magnetisation varies randomly from domain to domain, so the moments cancel and there is no bulk magnetisation. (b) In the magnet's field the domains turn towards the field and those already along it grow, so the field lines are highly concentrated; in the non-uniform field it moves towards high field, that is, it is attracted. (c) The nail is soft iron, a soft ferromagnet whose magnetisation disappears when the field is removed; lodestone is a hard ferromagnet whose magnetisation persists.

- domains randomly oriented, so moments cancel (1)
- domains align and grow in the field; attracted towards high field (1)
- soft ferromagnet loses magnetisation; lodestone is a hard ferromagnet (1)


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