ANSWER KEY & MARKING SCHEME · CBSE CLASS 12

Moving Charges and Magnetism

Physics · Chapter 4 · Use this with the Board Paper · Companion to Quick Drill

HOW TO USE

Attempt the Board Paper first (closed-book, full time). Then come here. For 2-mark+ questions, compare your answer to the model. For 3-4 mark questions, also consult the **Topper Templates** below — these show the exact step-by-step structure that scores full marks per CBSE marking-scheme conventions.

MODEL ANSWERS · BOARD PAPER

Section A — Very Short Answer (1 mark each)

Q1. Why does a magnetic force do no work on a moving charge? [1 mark]

Ans: Because F = qv x B is always perpendicular to the velocity v, so F.v = 0; it changes only the direction of motion, not the speed.

Q2. Write the expression for the magnetic field at the centre of a circular loop of radius R carrying current I. [1 mark]

Ans: B = mu_0 I/(2R), directed along the axis of the loop.

Q3. On what factors does the cyclotron frequency depend? [1 mark]

Ans: f = qB/(2*pi*m); it depends on charge q, magnetic field B and mass m, but NOT on the speed or radius.

Q4. Do two parallel wires carrying currents in opposite directions attract or repel? [1 mark]

Ans: They repel each other (opposite-direction currents repel; same-direction currents attract).

Q5. Write the expression for the magnetic moment of a coil of N turns, area A, carrying current I. [1 mark]

Ans: m = N I A, directed perpendicular to the plane of the coil (right-hand rule).

Section B — Short Answer (2 marks each)

Q6. A charge of 1 mC moves at 4 x 10^4 m/s perpendicular to a uniform field of 0.5 T. Find the magnetic force on it. [2 marks]

Ans: F = qvB sin(90) = (1 x 10^-3)(4 x 10^4)(0.5) = 20 N.

Q7. A long straight wire carries a current of 8 A. Find the magnetic field at a perpendicular distance of 4 cm from it. [2 marks]

Ans: B = mu_0 I/(2*pi*r) = (4*pi x 10^-7 x 8)/(2*pi x 0.04) = (16 x 10^-7)/(0.04) = 4 x 10^-5 T.

Q8. Distinguish between the magnetic field of a long solenoid and that of a toroid. [2 marks]

Ans: Solenoid: B = mu_0 n I is uniform deep inside and (ideally) zero outside, with field lines emerging at the open ends like a bar magnet. Toroid: B = mu_0 N I/(2*pi*r) is confined entirely within the closed core and is zero both inside the hole and outside; it has no free ends.

Section C — Short-Long Answer (3 marks each)

Q9. Using the Biot-Savart law, derive the expression for the magnetic field on the axis of a circular current loop of radius R at an axial distance x. Hence write the field at the centre. [3 marks]

Ans: dB = (mu_0/4*pi) I dL/r^2 with r = sqrt(R^2+x^2), sin(theta)=1. Perpendicular components cancel by symmetry; axial components add with cos(alpha)=R/sqrt(R^2+x^2). Integrating over 2*pi*R: B = mu_0 I R^2/[2(R^2+x^2)^(3/2)]. At centre x=0: B = mu_0 I/(2R).

Q10. **Derive an expression for the force per unit length between two long parallel straight conductors carrying currents I1 and I2 separated by a distance d. Hence define the ampere.** **[3 marks]**

> **Ans:** Wire 1 produces B1 = mu_0 I1/(2*pi*d) at wire 2. Force per unit length on wire 2: F/L = I2 B1 = mu_0 I1 I2/(2*pi*d); same-direction currents attract, opposite repel. One ampere is the steady current which, flowing in each of two infinitely long parallel wires 1 m apart in vacuum, produces a force of 2 x 10^-7 N per metre.

Q11. **Derive the expression for the torque on a rectangular current loop placed in a uniform magnetic field, and define the magnetic moment of the loop.** **[3 marks]**

> **Ans:** Forces on opposite sides form a couple. For a loop of N turns, area A, current I in field B, tau = NIAB sin(theta) = m x B, where theta is the angle between the area-vector (normal) and B. The magnetic moment is m = NIA, directed along the normal by the right-hand rule. Torque is maximum when the plane of the loop is parallel to B (theta = 90 deg).

Section D — Long Answer (5 marks; internal choice)

Q12. **(a) With a labelled diagram, explain the working of a cyclotron and show that the cyclotron frequency is f = qB/(2*pi*m). (b) A proton (q = 1.6 x 10^-19 C, m = 1.67 x 10^-27 kg) moves in a cyclotron with B = 0.5 T. Calculate the cyclotron frequency. State one limitation of the cyclotron.** **[5 marks]**

> **Ans:** (a) A positive ion is accelerated across the gap between two dees by an alternating voltage; a perpendicular field B bends it into a semicircle in each dee. Force balance qvB = mv^2/r gives r = mv/qB; the time for a semicircle pi*m/qB is independent of v, so T = 2*pi*m/qB and f = qB/(2*pi*m). (b) f = (1.6e-19 x 0.5)/(2*pi x 1.67e-27) = (8.0e-20)/(1.049e-26) = 7.6 x 10^6 Hz. Limitation: at high speeds the relativistic increase in mass lowers f, breaking resonance with the fixed-frequency oscillator.

Q13. **OR (a) Explain how a moving-coil galvanometer works and why its field is made radial. (b) A galvanometer of resistance 50 Ohm shows full-scale deflection at 1 mA. Convert it into (i) an ammeter of range 1 A and (ii) a voltmeter of range 5 V.** **[5 marks]**

> **Ans:** (a) A current-carrying coil in a radial magnetic field experiences torque tau = NIAB (sin(theta) = 1 because the field is radial), balanced by a spring torque k*phi, so NIAB = k*phi and deflection phi is proportional to current — giving a uniform (linear) scale. The radial field, produced by a concave magnet and soft-iron core, keeps the coil plane always parallel to B. (b)(i) Ammeter: S = I_g G/(I - I_g) = (1e-3 x 50)/(1 - 1e-3) = 0.05/0.999 = 0.05 Ohm (low shunt in parallel). (ii) Voltmeter: R = V/I_g - G = 5/(1e-3) - 50 = 5000 - 50 = 4950 Ohm (high resistance in series).

★ TOPPER ANSWER TEMPLATES

5 TEMPLATES · MEMORISE THE FORMAT

★ TOPPER TEMPLATE — Derive B on the axis of a circular current loop using Biot-Savart (3 marks)

Appeared 5+ times in 2018-2024

Step 1 [1 mark]	**State Biot-Savart + element field**	For a current element I dL, dB = (mu_0/4*pi) I dL sin(theta)/r^2, directed by dL x r. For a loop of radius R, a point at axial distance x has r = sqrt(R^2 + x^2) and dL is perpendicular to r so sin(theta) = 1.
Step 2 [1 mark]	**Resolve and use symmetry**	Each dB has an axial component dB cos(alpha) and a perpendicular component. By symmetry, perpendicular components from diametrically opposite elements cancel. Only axial components add, where cos(alpha) = R/sqrt(R^2 + x^2).
Step 3 [1 mark]	**Integrate around the loop**	B = integral dB cos(alpha) = (mu_0 I)/(4*pi) * (1/(R^2+x^2)) * (R/sqrt(R^2+x^2)) * (2*pi*R) = mu_0 I R^2 / [2 (R^2 + x^2)^(3/2)]. At centre x = 0: B = mu_0 I/(2R).

COMMON LOSS OF MARKS:

- Not stating sin(theta) = 1 because dL is perpendicular to r (loses 0.5)
- Forgetting the symmetry argument that perpendicular components cancel
- Dropping the factor 2*pi*R when integrating over the full loop

★ TOPPER TEMPLATE — Cyclotron — working, radius and frequency (3 marks)

Appeared 4+ times in 2018-2024

Step 1 [1 mark]	**Principle + working**	A positive ion is accelerated across the gap between two D-shaped electrodes (dees) by an alternating voltage. A uniform magnetic field perpendicular to the plane bends it into a semicircle inside each dee. Each crossing of the gap adds energy.
Step 2 [1 mark]	**Radius from force balance**	Magnetic force provides the centripetal force: qvB = mv^2/r, so r = mv/qB. The radius grows as the ion speeds up.
Step 3 [1 mark]	**Frequency independent of v**	Time for one semicircle = pi*m/qB; full period T = 2*pi*m/qB is independent of v and r. Cyclotron frequency f = qB/(2*pi*m). The oscillator is tuned to this f (resonance). Limitation: relativistic mass increase at high speed breaks resonance.

COMMON LOSS OF MARKS:

- Claiming f depends on speed (loses 1 mark)
- Not stating that magnetic force does no work — only the gap voltage adds energy
- Omitting the relativistic limitation when asked

★ TOPPER TEMPLATE — Force between two parallel wires; define the ampere (3 marks)

Appeared 4+ times in 2019-2024

Step 1 [1 mark]	**Field of wire 1 at wire 2**	An infinite straight wire carrying I1 produces, at perpendicular distance d, a field B1 = mu_0 I1/(2*pi*d), directed by the right-hand rule.
Step 2 [1 mark]	**Force per unit length**	Wire 2 (current I2) in this field feels force per unit length F/L = I2 B1 = mu_0 I1 I2/(2*pi*d). Same-direction currents attract; opposite-direction repel.
Step 3 [1 mark]	**Definition of ampere**	One ampere is that steady current which, flowing in each of two infinitely long parallel wires 1 m apart in vacuum, produces a force of 2 x 10^-7 N per metre of length between them.

COMMON LOSS OF MARKS:

- Reversing the attract/repel rule (loses 1 mark)
- Forgetting the numerical value 2 x 10^-7 N/m in the ampere definition
- Not specifying '1 m apart in vacuum'

★ TOPPER TEMPLATE — Torque on a current loop and the moving-coil galvanometer (3 marks)

Appeared 4+ times in 2018-2023

Step 1 [1 mark]	**Torque expression**	A rectangular loop of N turns, area A, carrying current I in a uniform field B experiences torque tau = NIAB sin(theta) = m x B, where the magnetic moment m = NIA, and theta is the angle between m and B.
Step 2 [1 mark]	**Radial field in galvanometer**	In a moving-coil galvanometer a concave magnet plus soft-iron core make the field RADIAL, so the plane of the coil is always parallel to B and sin(theta) = 1. Hence tau = NIAB at all deflections.
Step 3 [1 mark]	**Balance and linear scale**	The spring provides restoring torque k*phi. At equilibrium NIAB = k*phi, so I = (k/NAB) phi, i.e., deflection phi is directly proportional to current — giving a linear scale. Current sensitivity = phi/I = NAB/k.

COMMON LOSS OF MARKS:

- Not explaining WHY the field is made radial (sin(theta)=1)
- Confusing current sensitivity with voltage sensitivity
- Writing tau = NIAB without the sin(theta) for a general field

★ TOPPER TEMPLATE — Convert galvanometer to ammeter / voltmeter; numerical (3 marks)

Appeared 4+ times in 2019-2024

Step 1 [1 mark]	**Ammeter — shunt**	To read up to I, connect a low shunt S in PARALLEL with the galvanometer (resistance G, full-scale current I_g). Equal potential: I_g G = (I - I_g) S, so S = I_g G/(I - I_g). Result: a low-resistance ammeter.
Step 2 [1 mark]	**Voltmeter — series R**	To read up to V, connect a high resistance R in SERIES. Then V = I_g (R + G), so R = V/I_g - G. Result: a high-resistance voltmeter.
Step 3 [1 mark]	**Substitute numbers**	Example: G = 50 Ohm, I_g = 1 mA. Ammeter to 1 A: S = (1e-3 x 50)/(1 - 1e-3) ~ 0.05 Ohm. Voltmeter to 10 V: R = 10/1e-3 - 50 = 10000 - 50 = 9950 Ohm.

COMMON LOSS OF MARKS:

- Swapping shunt (parallel) and series resistance roles (loses 1 mark)
- Unit slips between mA and A
- Not stating ammeter is low-R and voltmeter is high-R

MARKING SCHEME — GENERAL NOTES

- Section A: Award full mark for any correct one-line answer that mentions the key term. Half-marks not allowed in this section.
- Section B: For numericals — 1 mark for the correct formula/setup, 1 mark for the correct numerical answer with unit. Deduct 0.5 for a missing unit.
- Section C: For derivations — 1 mark for the law/diagram/setup, 1 mark for the symmetry/intermediate algebraic step, 1 mark for the final stated result. Diagrams without labels lose 0.5.
- Section D: 5 marks split typically 3 (theory/derivation) + 2 (numerical) OR 2 + 1 + 2 across sub-parts as indicated.
- Common deductions: missing units (-0.5), reversing the attract/repel rule for parallel wires (-1), claiming the magnetic force does work or that f depends on speed (-1), swapping shunt (parallel) and series resistance roles in meter conversion (-1).
- If a student uses an alternate but equivalent valid method (e.g., F = IL x B cross-check), award full marks provided the working is correct.