MODEL QUESTION PAPER

HIGHER SECONDARY EXAMINATION

PHYSICS (Class XII) – Chapter 4

Moving Charges and Magnetism

Time Allowed: 120 min
Cool-off Time: 15 min
Maximum Marks: 60

General Instructions:
Read each question carefully before answering. Use $\mu_0 = 4\pi \times 10^{-7}$ T m/A wherever required. Answer only the required number of questions from each Part.

Part I Very Short Answer

*Answer any **5** questions from the following **7**. Each question carries **1** mark.* *(5 × 1 = 5)*

1. Define the SI unit of magnetic field, the tesla, in terms of the force on a moving charge.
2. State the rule used to find the direction of the force on a positive charge moving in a magnetic field.
3. Fill in the blank: To convert a moving-coil galvanometer into an ammeter, a resistance of __________ value is connected in __________ with the coil.
4. What is the nature of the path of a charged particle moving at an angle of 30° to a uniform magnetic field?
5. Write the SI unit of magnetic moment.
6. State whether True or False: "Two magnetic field lines can intersect each other."
7. Name the device that uses crossed electric and magnetic fields to select charged particles of a specific velocity.

Part II Short Answer – I

*Answer any **5** questions from the following **7**. Each question carries **2** marks.* *(5 × 2 = 10)*

1. Write down the expression for the Lorentz force on a charge q moving with velocity $\vec{v}$ in the presence of both an electric field $\vec{E}$ and a magnetic field $\vec{B}$. Explain why the magnetic part of this force does no work on the charge.
2. State Ampere's circuital law and write its mathematical form.
3. A proton and an alpha particle enter a uniform magnetic field with the same speed, moving perpendicular to $\vec{B}$. Given that the mass and charge of the alpha particle are 4 and 2 times that of the proton respectively, compare the radii of their circular paths.
4. Distinguish between the current sensitivity and the voltage sensitivity of a moving-coil galvanometer.
5. State the rule used to determine the direction of the magnetic field due to (a) a long straight current-carrying conductor, and (b) a circular current loop.
6. Two long, straight, parallel conductors carry currents in the same direction. Using the expression for the force per unit length between them, explain why they attract each other.

7. Define the ampere, the SI unit of electric current, using the force between two current-carrying conductors.

Part III Short Answer – II

*Answer any **6** questions from the following **7**. Each question carries 3 marks.* *(6 × 3 = 18)*

1. A charged particle q moving with velocity $\vec{v}$ experiences a force in the presence of both an electric field $\vec{E}$ and a magnetic field $\vec{B}$. [Previous Year Question – Say 2011, adapted]

   (a) Write down the expression for this force. *(1)*

   (b) A configuration of mutually perpendicular electric and magnetic fields, used to select charged particles of a particular speed, is called a ________________. *(1)*

   (c) Name the cyclic accelerator that uses a magnetic field to accelerate charged particles to high energies. *(1)*

2. Derive an expression for the radius of the circular path described by a charged particle moving with speed v, perpendicular to a uniform magnetic field B. Hence obtain an expression for its cyclotron frequency, and state one important property of this frequency.

3. State the Biot–Savart law in vector form. Mention **two** points of similarity and **two** points of difference between the Biot–Savart law for a magnetic field and Coulomb's law for an electric field.

4. Derive an expression for the magnetic field at the centre of a circular coil of N turns and radius R, carrying a steady current I.

5. With the help of a labelled circuit diagram, explain how a moving-coil galvanometer of resistance G and full-scale current I_g can be converted into a voltmeter of range 0 to V volts. Obtain the expression for the resistance to be used.

6. A straight wire carrying a current I is bent into a semicircular arc of radius R.

   (a) What is the magnetic field at the centre of the arc due to the straight parts? *(1)*

   (b) Derive the expression for the magnetic field at the centre due to the semicircular part. *(2)*

7. A rectangular current loop is placed in a uniform magnetic field $\vec{B}$. Show that the loop experiences a torque but no net force. Write the expression for this torque in terms of the magnetic moment $\vec{m}$ of the loop.

Part IV Long Answer – I (Numerical Application)

*Answer any **3** questions from the following **4**. Each question carries **4** marks.* *(3 × 4 = 12)*

1. A charged particle of mass 1×10^{-26} kg and charge 1.6×10^{-19} C, travelling with velocity 1.28×10^{6} m/s along the $+x$ direction, enters a region where a uniform electric field ($E_z = -1.024 \times 10^{5}$ V/m, $E_x = E_y = 0$) and a uniform magnetic field ($B_y = 8 \times 10^{-2}$ T, $B_x = B_z = 0$) exist together. [Previous Year Question – March 2009, adapted]

   (a) Write the expression for the force on the particle due to the electric field alone. *(1)*

   (b) Calculate the magnitude and direction of this electric force. *(2)*

   (c) Write the expression for the force experienced by the particle due to the magnetic field alone. *(1)*

2. A circular coil of wire consisting of 100 turns, each of radius 8.0 cm, carries a current of 0.40 A.

   (a) Write the formula for the magnetic field at the centre of a coil of N turns. *(1)*

   (b) Calculate the magnitude of the magnetic field B at the centre of the coil. *(3)*

3. A closely wound solenoid, 80 cm long, has 5 layers of windings of 400 turns each. The diameter of the solenoid is 1.8 cm and it carries a current of 8.0 A.

   (a) Write the formula for the magnetic field inside a long solenoid. *(1)*

   (b) Estimate the magnitude of B inside the solenoid, near its centre. *(3)*

4. A moving-coil galvanometer has a coil resistance of 12 Ω and gives full-scale deflection for a current of 3 mA.

   (a) How should it be converted into an ammeter of range 0–3 A? Find the value of the shunt resistance required. *(2)*

   (b) How should it be converted into a voltmeter of range 0–15 V? Find the value of the series resistance required. *(2)*

Part V Long Answer – II (Derivations)

*Answer any **3** questions from the following 4. Each question carries **5** marks.* *(3 × 5 = 15)*

1. Using the Biot–Savart law, derive an expression for the magnetic field at a point on the axis of a circular current loop of radius R carrying current I, at a distance x from its centre. Hence obtain the magnetic field at the centre of the loop.

2. State Ampere's circuital law. Using it, derive an expression for the magnetic field (a) inside, and (b) outside a long, straight, current-carrying solenoid having n turns per unit length and carrying current I.

3. Derive an expression for the force per unit length between two long, straight, parallel current-carrying conductors placed a distance d apart. Hence define the SI unit of current, the ampere.

4. A rectangular loop of area A, carrying a steady current I, is placed in a uniform magnetic field $\vec{B}$ such that the normal to the loop makes an angle θ with $\vec{B}$.
   (a) Derive an expression for the torque experienced by the loop. *(3)*
   (b) Briefly describe how this principle is used in the construction and working of a moving-coil galvanometer. *(2)*

– End of Question Paper –

Answer Key & Marking Notes

Compact reference for self-checking. Full derivations should be reproduced from your textbook/notes for exam practice.

Part I 1. $B = F/(qv)$, 1 T when $F = 1$ N for $q = 1$ C, $v = 1$ m/s $\perp B$ 2. Right-hand (screw) rule 3. low; parallel 4. Helical 5. A m^2 6. False 7. Velocity selector

Part II 1. $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$; magnetic force $\perp \vec{v}$, so no work done. 2. $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$ 3. $r = mv/qB \Rightarrow r_\alpha/r_p = (4/2) = 2$ 4. Current sensitivity $= \phi/I = NAB/k$; Voltage sensitivity $= \phi/V = NAB/kR$; doubling N doubles the former but leaves the latter unchanged. 5. Right-hand rule (both cases; thumb/curl conventions differ) 6. $f = \mu_0 I_a I_b / 2\pi d$, attractive force pulls wires together for parallel currents 7. $I_a = I_b = 1$A, $d = 1$m $\Rightarrow f = 2 \times 10^{-7}$ N/m defines 1 A

Part III 1. (a) $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$ (b) velocity selector (c) cyclotron 2. $r = mv/qB$; $\nu = qB/2\pi m$ (independent of speed) 3. $d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{l} \times \hat{r}}{r^2}$; similarities: both $\propto 1/r^2$, obey superposition; differences: vector vs scalar source, angle dependence present only in Biot–Savart 4. $B = \mu_0 NI/2R$ 5. $R = V/I_g - G$, connected in series 6. (a) zero (b) $B = \mu_0 I/4R$ 7. $F_{net} = 0$; $\tau = \vec{m} \times \vec{B}$, $m = NIA$

Part IV 1. (a) $\vec{F} = q\vec{E}$ (b) $F = qE_z \approx 1.64 \times 10^{-14}$ N along $-z$ (c) $\vec{F} = q(\vec{v} \times \vec{B})$ 2. $B = \mu_0 NI/2R \approx 3.14 \times 10^{-4}$ T 3. $n = (5 \times 400)/0.8 = 2500$ turns/m; $B = \mu_0 nI \approx 8 \times 10^{-3}$ T 4. (a) $S = I_g G/(I - I_g) \approx 0.048\ \Omega$ (b) $R = V/I_g - G \approx 4988\ \Omega$

Part V 1. $B = \dfrac{\mu_0 I R^2}{2(x^2 + R^2)^{3/2}}$; at centre ($x = 0$): $B = \mu_0 I/2R$ 2. Inside: $B = \mu_0 nI$; Outside: $B \approx 0$ 3. $f = \mu_0 I_a I_b / 2\pi d$; ampere defined via $I_a = I_b = 1$A, $d = 1$m $\Rightarrow f = 2 \times 10^{-7}$ N/m 4. $\tau = IAB \sin\theta = \vec{m} \times \vec{B}$; MCG: coil in radial field, $NIAB = k\phi \Rightarrow \phi \propto I$