

Moving Charges and Magnetism — Assignment 2

Class 12 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Lorentz Force and Motion in a Magnetic Field

1. Derive the expression for the radius of the circular path of a charged particle moving perpendicular to a uniform magnetic field.
2. A proton moves at $3 \times 10^6 \text{ m/s}$ perpendicular to a field of 0.5 T . Find the magnetic force on it.
3. Show that the magnetic force does no work on a moving charged particle.

Biot-Savart Law

1. State the Biot-Savart law and write its vector form.
2. A long straight wire carries 10 A . Find the field at 0.2 m from it.
3. Derive the magnetic field on the axis of a circular current loop using the Biot-Savart law.

Ampere's Circuital Law

1. State Ampere's circuital law and use it to find the field due to a long straight conductor.
2. Use Ampere's law to find the field inside a long solenoid.
3. State the electrostatic law analogous to Ampere's circuital law.

Force Between Two Parallel Currents

1. Derive the force per unit length between two long parallel current-carrying wires.
2. Two wires 0.1 m apart carry 5 A and 10 A in the same direction. Find the force per unit length.
3. State how the ampere is defined from this force.

Moving Coil Galvanometer

1. Derive the expression for the current sensitivity of a moving coil galvanometer.
2. Explain how a galvanometer is converted into an ammeter.
3. Explain how a galvanometer is converted into a voltmeter.

Cyclotron

1. State the principle of a cyclotron and derive the cyclotron frequency.
2. Calculate the cyclotron frequency of a proton in a 1 T field.
3. State why a cyclotron cannot accelerate electrons to high speeds.

Part B — Integrated problems (multi-topic)

1. A charged particle of mass 6.7×10^{-27} kg and charge 3.2×10^{-19} C enters a magnetic field of 0.5 T perpendicular to it with a speed of 2×10^5 m/s. Find the radius of its circular path and its time period.
2. A straight wire of length 0.5 m carrying a current of 4 A is placed perpendicular to a magnetic field of 0.2 T. Find the force on the wire, and then the force if the wire is parallel to the field.
3. Two long parallel wires are 5 cm apart. One carries 10 A and the other 20 A in the same direction. Find the force per unit length and locate the point between them where the net magnetic field is zero.
4. A moving coil galvanometer of resistance 20Ω gives a full-scale deflection for a current of 10 mA. Find the shunt resistance needed to convert it into an ammeter reading up to 5 A.
5. A solenoid of length 0.5 m has 500 turns and carries a current of 2 A. Find the magnetic field inside it, and the field if a soft-iron core of relative permeability 1000 fills it.

Answer Key

Lorentz Force and Motion in a Magnetic Field

$F = qvB \sin \theta$; for $\theta = 90^\circ$, $F = qvB = 1.6 \times 10^{-19} \times 3 \times 10^6 \times 0.5 = 2.4 \times 10^{-13}$ N. $r = mv/qB$.

Biot-Savart Law

$dB = (\mu_0/4\pi)(I \, dl \times \hat{r})/r^2$. Long wire: $B = \mu_0 I/2\pi r = 1 \times 10^{-5}$ T. Axis of loop: $B = \mu_0 N I R^2/2(R^2+x^2)^{3/2}$.

Ampere's Circuital Law

$B \cdot dl = \mu_0 I$. Long wire: $B = \mu_0 I/2\pi r$. Solenoid interior: $B = \mu_0 n I$. Analogous to Gauss's law.

Force Between Two Parallel Currents

$F/L = \mu_0 I_1 I_2/2\pi d = 1 \times 10^{-4}$ N/m, attractive. The ampere is the current that produces a force of 2×10^{-7} N/m between two parallel wires 1 m apart.

Moving Coil Galvanometer

Current sensitivity = NBA/k . Ammeter: shunt $S = I_g G/(I - I_g)$ in parallel. Voltmeter: $R = V/I_g - G$ in series.

Cyclotron

$v = qB/2\pi m$. For a proton in 1 T: $v \approx 1.5 \times 10^7$ Hz. Electrons (small m) reach relativistic speeds quickly, so the resonance condition fails.

Integrated problems

1: $r = mv/qB \approx 8.4 \times 10^{-3}$ m; $T = 2\pi m/qB \approx 2.6 \times 10^{-7}$ s. 2: $F = BIL = 0.4$ N; parallel $\vec{B} = 0$. 3: $F/L = \mu_0 I_1 I_2/2\pi d = 8 \times 10^{-4}$ N/m; zero-field point at $d_1 = 5/3$ cm from the 10 A wire. 4: $S = I_g G/(I - I_g) \approx 0.04 \Omega$. 5: $B = \mu_0 n I \approx 2.5 \times 10^{-3}$ T; with core $B = \mu_r \mu_0 n I \approx 2.5$ T.