CLASS XII – PHYSICS (042)
STEP-BY-STEP SOLUTIONS AND MARKING SCHEME

Chapter 4: Moving Charges and Magnetism – Practice Paper (35 Marks)

Answer key – Section A

Q.	1	2	3	4	5	6	7	8	9
Ans.	(a)	(b)	(d)	(b)	(c)	(a)	(d)	(a)	(d)

Marks are shown in square brackets. Equivalent correct methods are acceptable. Take $\mu_0/4\pi = 10^{-7}$ T m A^{-1}.

SECTION A

Q.1 (a)

Take v along +x and B into the page. For a positive charge $F = qv \times B = q(\hat{x} \times (-\hat{z})) = +\hat{y}$, i.e. upward. Particle 1 bends upward, so it is positive; particle 3 bends the opposite way, so it is negative; particle 2 is undeviated, so it is neutral. **[1]**

Q.2 (b)

By the right-hand rule, for a current into the page the field lines are clockwise circles. At a point to the right of the wire the clockwise tangent points downward (in the plane of the paper). **[1]**

Q.3 (d)

$f = \mu_0 I_1 I_2/(2\pi d) = (2 \times 10^{-7})(6)(3)/0.1 = 3.6 \times 10^{-5}$ N m^{-1}. Parallel currents attract. **[1]**

Q.4 (b)

The straight leads pass through O, so $dl \times r = 0$ and they give no field. A full circle gives $\mu_0 I/2R$; the semicircle gives half of it, $\mu_0 I/4R$. The current goes clockwise over the arc, so the field at O is into the plane of the paper. **[1]**

Q.5 (c)

$r = mv/qB \propto mv/q$. Relative values: A = 1×4/1 = 4; B = 4×3/2 = 6; C = 2×5/1 = 10; D = 1×6/2 = 3. Particle C has the largest radius. **[1]**

Q.6 (a)

$n = 500/0.25 = 2000$ turns m^{-1}. $B = \mu_0 nI = 4\pi \times 10^{-7} \times 2000 \times 5 = 4\pi \times 10^{-3}$ T. **[1]**

Q.7 (d)

$v_{\parallel} = v \cos 30°$, $v_{\perp} = v \sin 30°$. Pitch $p = 2\pi m\, v \cos 30°/qB$ and radius $r = m\, v \sin 30°/qB$. So $p/r = 2\pi \cot 30° = 2\pi\sqrt{3}$. **[1]**

Q.8 (a)

Both true. Since $F \perp v$, the magnetic force does no work ($F \cdot v = 0$), so the speed and kinetic energy remain constant; R explains A. **[1]**

Q.9 (d)

A is false: antiparallel currents repel. R is true. **[1]**

SECTION B

Q.10

$r = mv/eB = (9.1 \times 10^{-31})(1.76 \times 10^{7})/[(1.6 \times 10^{-19})(10^{-3})] = 0.10$ m = 10 cm. **[1]**

$T = 2\pi m/eB = 2 \times 3.14 \times 9.1 \times 10^{-31}/(1.6 \times 10^{-19} \times 10^{-3}) \approx 3.6 \times 10^{-8}$ s (independent of speed). **[1]**

Q.11

$F = I\, l\, B \sin\theta = 4 \times 0.5 \times 0.3 \times \sin 30° = 0.3$ N. **[1]**

Direction of $\mathbf{l} \times \mathbf{B}$ (l along +x, B in the xy-plane above it): perpendicular to the plane containing the wire and the field, i.e. out of the plane of the paper. **[1]**

Q.12 (A)

$B = \mu_0 NI/2R = (4\pi \times 10^{-7})(50)(4)/(2 \times 0.05) = 8\pi \times 10^{-4}$ T $\approx 2.5 \times 10^{-3}$ T. **[1]**

$m = NIA = NI\pi R^2 = 50 \times 4 \times 3.14 \times (0.05)^2 \approx 1.57$ A m^2. **[1]**

Q.12 (B)

Inside ($r = 1$ mm $< a = 2$ mm): $B = \mu_0 Ir/(2\pi a^2) = (2 \times 10^{-7})(10)(10^{-3})/(2 \times 10^{-3})^2 = 5 \times 10^{-4}$ T. **[1]**

Outside ($r = 4$ mm $> a$): $B = \mu_0 I/2\pi r = (2 \times 10^{-7})(10)/(4 \times 10^{-3}) = 5 \times 10^{-4}$ T. **[1]**

Q.13

$m = NIA = 20 \times 2 \times (0.10 \times 0.05) = 0.2$ A m^2. **[1]**

The plane is parallel to B, so m is perpendicular to B ($\theta = 90°$): $\tau = mB \sin 90° = 0.2 \times 0.4 = 0.08$ N m. **[1]**

SECTION C

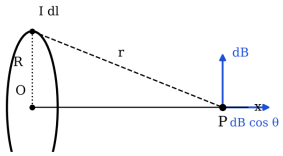
Q.14

(a) Distance of P from each wire = 5 cm. $B_1 = B_2 = \mu_0 I/2\pi r = (2 \times 10^{-7})(5)/0.05 = 2 \times 10^{-5}$ T each. **[1]**

Wire 1 (out of page) gives a field upward at P (to its right); wire 2 (into page) also gives a field upward at P (to its left). They add: $B = 4 \times 10^{-5}$ T, directed upward (perpendicular to the line joining the wires, in the plane of the paper). **[1]**

(b) $f = \mu_0 I_1 I_2/2\pi d = (2 \times 10^{-7})(5)(5)/0.1 = 5 \times 10^{-5}$ N m^{-1}. The currents are antiparallel, so the force is repulsive. **[1]**

Q.15 (A)

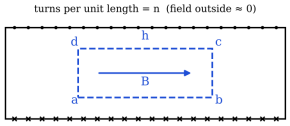


Take a current element I d**l** of the loop. By the Biot–Savart law $dB = (\mu_0/4\pi)\, I\, |d\mathbf{l} \times \mathbf{r}|/r^3$. Every element is perpendicular to its **r**, so $|d\mathbf{l} \times \mathbf{r}| = r\, dl$ and $dB = (\mu_0/4\pi)\, I\, dl/(x^2 + R^2)$. **[1]**

dB has a component dB cos θ along the axis and dB sin θ perpendicular to it. The perpendicular components of diametrically opposite elements cancel; only the axial components add, with $\cos\theta = R/(x^2 + R^2)^{1/2}$. **[1]**

$B = \int dB \cos\theta = (\mu_0 I/4\pi) \cdot R/(x^2 + R^2)^{3/2} \cdot \int dl$, and $\int dl = 2\pi R$. So $B = \mu_0 IR^2/[2(x^2 + R^2)^{3/2}]$ along the axis. At the centre $x = 0$: $B = \mu_0 I/2R$. **[1]**

Q.15 (B)



Ampere's circuital law: the line integral of **B**·d**l** around any closed loop equals μ_0 times the total current passing through the surface bounded by the loop: $\oint \mathbf{B}\cdot d\mathbf{l} = \mu_0 I$. **[1]**

Take a rectangular Amperian loop abcd of length h, with ab inside the solenoid. Along cd (outside) $B \approx 0$; along bc and da, B is perpendicular to the path (or zero), so these contribute nothing. Hence $\oint B\cdot dl = Bh$. **[1]**

The current enclosed is $I_e = (nh)I$, where n is the number of turns per unit length. $Bh = \mu_0 nhI$, so $B = \mu_0 nI$ (uniform, along the axis). **[1]**

Q.16

(a) The field is maximum at the surface of the wire, where the graph peaks: radius a = 2 mm. **[½]**

(b) At the surface $B = \mu_0 I/2\pi a = 500\ \mu T = 5 \times 10^{-4}$ T. So $I = 2\pi aB/\mu_0 = (2 \times 10^{-3})(5 \times 10^{-4})/(2 \times 10^{-7}) = 5$ A. **[1½]**

(c) For r > a, B ∝ 1/r. At r = 4 mm (twice the radius), B = 500/2 = 250 μT (check: $(2 \times 10^{-7})(5)/(4 \times 10^{-3}) = 2.5 \times 10^{-4}$ T). **[1]**

SECTION D

Q.17 (Case study)

(i) **(b)** The soft-iron core strengthens the magnetic field and makes it radial, so the torque on the coil is the same (sin θ = 1) at every deflection. **[1]**

(ii) **(b)** Current sensitivity φ/I = NAB/k ∝ N doubles. The resistance of the coil also doubles (longer wire), so the voltage sensitivity (φ/V = (NAB/k)(1/R)) is unchanged. **[1]**

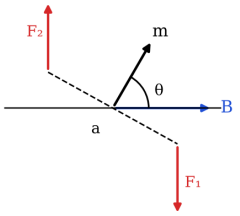
(iii) **(c)** $S = I_g G/(I - I_g) = (0.002 \times 50)/(1 - 0.002) \approx 0.1\ \Omega$ (in parallel). **[1]**

(iv) **(d)** $R = V/I_g - G = 10/0.002 - 50 = 5000 - 50 = 4950\ \Omega$ (in series). **[1]**

OR (iv) (d) The galvanometer (50 Ω) and shunt (0.1 Ω) are in parallel: $R_A = GS/(G + S) \approx 0.1\ \Omega$. A very small resistance makes an ammeter perturb the circuit negligibly. **[1]**

SECTION E

Q.18 (A)



top view: the two forces form a couple

Let a rectangular loop of sides a (AB, CD) and b (BC, DA) carry current I in a uniform field B, with the normal making angle θ with B. The forces on arms BC and DA are equal, opposite and collinear (along the axis); they cancel and give no torque. **[1]**

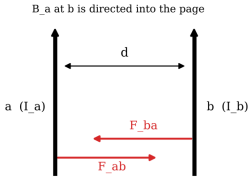
The forces on AB and CD are F = IbB each, equal and opposite but not collinear: they form a couple. Net force = 0. The arm of the couple is a sin θ. **[1]**

$\tau = F \cdot a \sin\theta = I(ab)B \sin\theta = IAB \sin\theta = mB \sin\theta$, i.e. $\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B}$, where the magnetic moment m = IA (NIA for N turns). **[1]**

Numerical: $m = NIA = 100 \times 0.5 \times 2 \times 10^{-2} = 1.0\ \text{A m}^2$. **[1]**

$\tau = mB \sin\theta = 1.0 \times 0.2 \times \sin 30° = 0.1\ \text{N m}$. **[1]**

Q.18 (B)



Wire a carries I_a and produces at wire b a field $B_a = \mu_0 I_a/2\pi d$, perpendicular to the plane of the wires (into the page in the figure). **[1]**

The force on a length L of wire b is $F_{ba} = I_b L B_a$, so the force per unit length $f = \mu_0 I_a I_b/2\pi d$. By the right-hand rule, $\mathbf{l} \times \mathbf{B}$ for b points towards a: parallel currents attract (antiparallel repel); $F_{ab} = -F_{ba}$. **[1]**

Ampere: that steady current which, flowing in each of two very long straight parallel conductors of negligible cross-section, 1 m apart in vacuum, produces a force of 2×10^{-7} N per metre of length on each. **[1]**

Numerical: $f = (2 \times 10^{-7})(10)(20)/0.05 = 8 \times 10^{-4}\ \text{N m}^{-1}$. **[1]**

Force on 2 m: $F = 8 \times 10^{-4} \times 2 = 1.6 \times 10^{-3}$ N. The currents are parallel, so the force is attractive. **[1]**

— End of Solutions —