Moving Charges and Magnetism

<table>
<tr><th>Q.No</th><th>Question</th><th>Marks</th></tr>
<tr><td colspan="3">Multiple Choice Question</td></tr>
<tr><td>Q.61</td><td>Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.

Assertion (A): The work done by the magnetic field on a proton moving in a circular path in a uniform magnetic field is zero.

Reason (R): The force on a charged particle moving in a uniform magnetic field is perpendicular to the direction of motion.

A. Both assertion and reason are true and reason is the correct explanation for assertion.
B. Both assertion and reason are true and reason is not the correct explanation for assertion.
C. Assertion is true but the reason is false.
D. Both assertion and reason are false.</td><td>1</td></tr>
<tr><td>Q.62</td><td>Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.

Assertion (A): The kinetic energy of a charged particle describing a circular path in a uniform magnetic field does NOT remain constant with time.

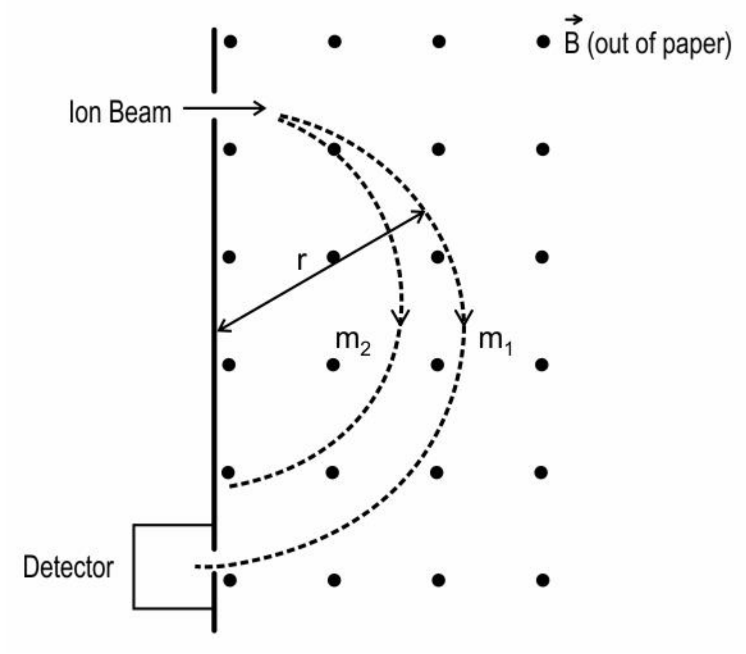
Reason (R): The velocity of a charged particle moving in a circular path in a uniform magnetic field changes with time.

A. Both assertion and reason are true and reason is the correct explanation for assertion.
B. Both assertion and reason are true and reason is not the correct explanation for assertion.
C. Assertion is true but the reason is false.
D. Assertion is false but the reason is true.</td><td>1</td></tr>
<tr><td>Q.63</td><td>Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.

Assertion (A): All atoms have a net magnetic moment.

Reason (R): Every electron in an atom possesses an intrinsic magnetic moment.</td><td>1</td></tr>
</table>

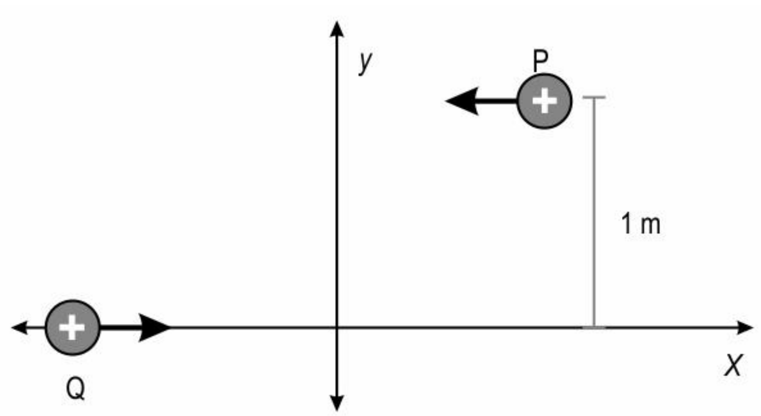
	A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true and reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but reason is true.	
Q.64	A wire of length L is bent to make a triangular coil. All the sides of the triangle are of the same length. If the triangular coil carries a current I, what is its magnetic dipole moment? A. Zero B. IL^2 C. $(\sqrt{3} \times IL^2)/4$ D. $(\sqrt{3} \times IL^2)/36$	1
Q.65	Assertion: In a velocity selector arrangement, with $E \perp B$, all charged particles that move perpendicular to both E and B fields, with speeds $v = E/B$, go undeflected. The magnetic force on the particles moving at speeds greater than v, is stronger than the electric force, and those moving at speeds less than v will experience a magnetic force that is less than the electric force. Reason: Electric force on the charged particles is independent of velocities, and the magnetic force is directly proportional to the speed of the charged particle. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Free Response Questions/Subjective Questions		
Q.66	A straight wire of length 4 m carrying a current of 0.5 A can be turned into either a square or a circular loop of 2 turns, before placing it in a magnetic field of intensity 0.1 T. Which loop do you think will require less counter torque in order to hold it in a position such that the axis of the loop is perpendicular to the magnetic field? Find the value of this counter-torque.	2
Q.67	A stream of singly charged particles of mass $m_1 = 0.8 \times 10^{-26}$ kg accelerated through a potential difference V are projected into a uniform magnetic field $B_1 = 0.2$ T. The stream deflects along a curved path under the effect of the magnetic field and strikes the detector.	3



Another stream of singly charged particles of mass $m_2 = 0.2 \times 10^{-26}$ kg, projected through the same accelerating potential and into the same magnetic field B_1, fail to reach the detector.

To what value should the magnetic field be changed so that this stream of particles strikes the detector?

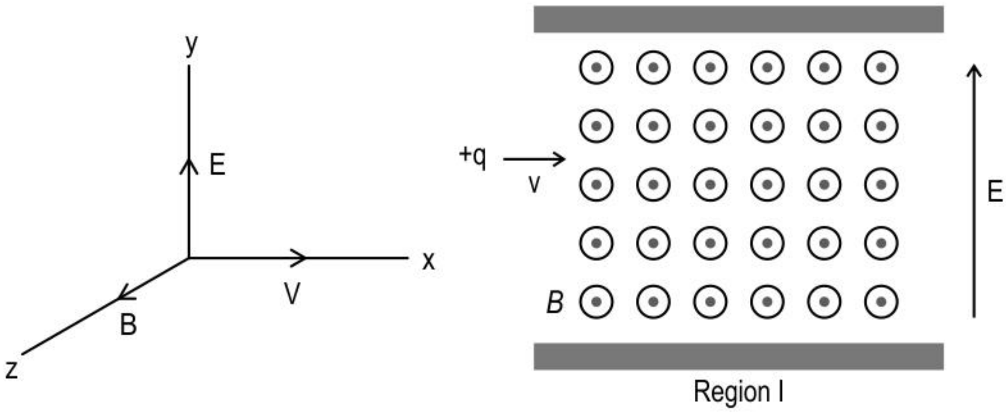
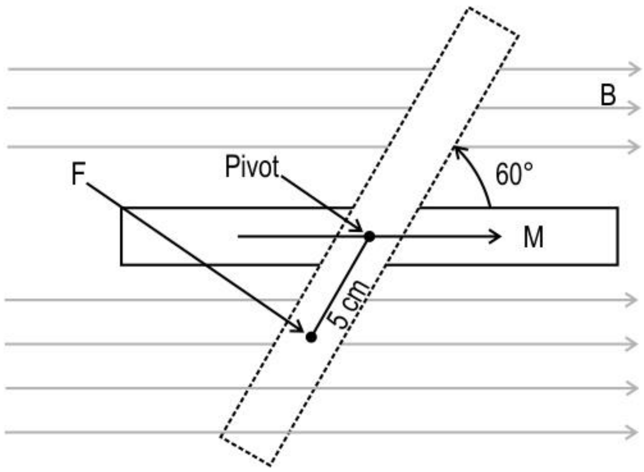
Q.68 P and Q are two identical charged particles of mass 4×10^{-26} kg and charge 4.8×10^{-19} C, each moving with the same speed of 2.4×10^{5} m/s as shown in the figure. The two particles are equidistant from the vertical y-axis. At some instant, a magnetic field B is switched on so that the two particles undergo head-on collision. **2**



Find (a) the direction of the magnetic field and (b) the magnitude of the magnetic field applied in the region.

Q.69 A magnetic dipole of dipole moment m is aligned parallel to an external magnetic field B. Work of 0.25 J has to be done in order to turn it through angle of 60°. **2**

Find the external counter torque that is required in order to maintain the dipole at this angle.

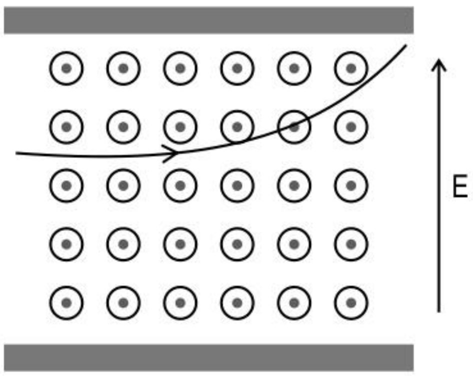
Q.70	Two identical metal loops A and B lie close to each other on the same plane without touching each other. If a current begins to flow through loop A, whose magnitude increases with time, state if the two loops attract or repel each other. Give a reason for your answer.	2
Q.71	A charged particle '+q' moving with a velocity 'v' enters region I of crossed electric and magnetic field as shown below.  Represent the various paths that can be described by the particle in the region I. Also, specify the condition under which it describes each path. (*Neglect the effect of gravity acting on the particle*)	3
Q.72	A bar magnet pivoted at its centre rests in a uniform magnetic field. 4 J of work is done in rotating the bar magnet through an angle of 60° from its stable equilibrium position as shown below.  Calculate the force F that should be applied at right angles to the axis of the magnet at a distance of 5 cm from the pivot to hold the magnet at 60°.	2
Q.73	A current-carrying solenoid of 50 turns/cm carries a current of 2 A. a. Find the magnetic intensity H at the center of the solenoid.	3

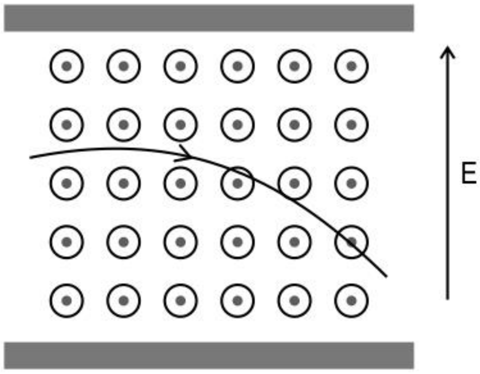
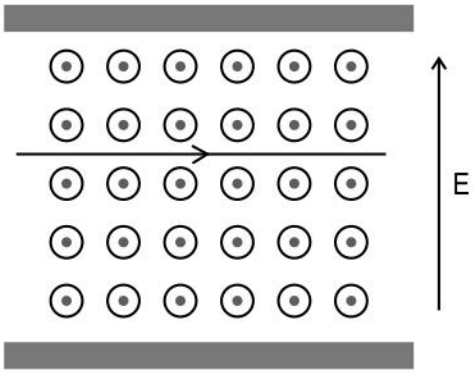
	b. A material P of magnetic susceptibility $\chi_p = 5 \times 10^{-3}$ is introduced as the core of the solenoid. Is the material P diamagnetic, paramagnetic or ferromagnetic? Find the magnetization M developed in the core. c. The material P is now replaced by the material Q of magnetic susceptibility $\chi_q = 5 \times 10^3$. Is the material Q diamagnetic, paramagnetic or ferromagnetic? d. Mention the type of magnetic material that has (i) M >> H (ii) M << H	

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.61	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.62	D. Assertion is false but the reason is true.	1
Q.63	D. Assertion is false but reason is true.	1
Q.64	D. $(\sqrt{3} \times IL^2)/36$	1
Q.65	A. Both A and R are true and R is the correct explanation of A	1
Q.66	Length of wire = 4 m The perimeter of the coil with 2 turns = 2 m For a given perimeter, a circular loop will have more area than the square loop. Torque on the loop is directly proportional to the area of the loop. Therefore, the counter-torque required to hold the coil in a position such that the axis of the loop is perpendicular to the magnetic field will be less for square loop than for the circular loop. [1 mark for the correct conclusion of lesser counter-torque with correct argument] The counter torque required is $\tau = MB \sin 90 = n\, I\, A\, B = 2 \times 0.5 \times (\text{side} \times \text{side}) \times 0.1$ Side of square = perimeter /4 = 2/4 = 0.5 m $\tau = 2 \times 0.5 \times (0.5 \times 0.5) \times 0.1$ = 0.0250 Nm. [1 mark for the correct calculation of the counter torque]	2
Q.67	Equating the kinetic energy of charged particles to the energy gained due to accelerating potential V,	3

<table>
<tr><td></td><td>$\frac{1}{2}mv^2 = qV$
$v = \sqrt{\frac{2qV}{m}}$
[1 mark for the correct expression of speed]
Equating the magnetic force on the charged particles to the centripetal force acting on them,
$qvB = \frac{mv^2}{r}$
$B = \frac{1}{r}\sqrt{\frac{2mv}{q}}$
[1 mark for the correct expression of magnetic field]
For same accelerating potential V, radius r and charge q,
$\frac{B_2}{B_1} = \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{0.2}{0.8}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$
$B_2 = B_1/2 = 0.2/2 = 0.1$ T
[1 mark for correct calculation of value of B_2]</td><td></td></tr>
<tr><td>Q.68</td><td>(a) Perpendicular and into the page.
[0.5 mark]
(b) For a head-on collision to take place, the radius of the path of each ion should be equal to 0.5 m.
$\mathbf{r = \frac{mv}{qB} = 0.5\ m}$
$\mathbf{B = \frac{mv}{qr} = \frac{4 \times 10^{-26} \times 2.4 \times 10^{5}}{4.8 \times 10^{-19} \times 0.5}}$
Solving for B = 0.04 T
[0.5 mark for determining the value of r]
[1 mark for correct calculations & result]</td><td>2</td></tr>
<tr><td>Q.69</td><td>Work done to rotate from parallel to 60º ,
$W = \mid mB(\cos\theta_2 - \cos\theta_1) \mid$
$= \mid mB(\cos 60 - \cos 0) \mid$
$= \mid mB(1/2 - 1) \mid$</td><td>2</td></tr>
</table>

	$= mB/2$ [1 mark for correct formula and final expression of W] Counter torque required to hold the dipole at angle 60°, $\tau = mB\sin\theta = mB \sin 60 = \sqrt{3}mB/2$ $\tau = \sqrt{3} \times W = \sqrt{3} \times 0.25 = \sqrt{3}/4$ N-m [1 mark for correct calculation and final result]	
Q.70	Due to increasing current through loop A, magnetic field lines through loop B also increase. This induces an emf in loop B so that current through loop B is in the direction opposite to that in loop A. [1 mark for the reason] This is as per Lenz's law. Since the currents are in opposite direction, loop B is repelled by loop A. [1 mark for the conclusion]	2
Q.71	The particle experiences a force due to an electric field along the + y direction and magnetic force along the - y direction. $F_E = qE$ $F_B = qvB$ The various paths described by the particle depend on the relation between F_E and F_B **Case 1**: $F_E > F_B$  **Case 2:** $F_E < F_B$	3

	 **Case 3:** $F_E = F_B$  (*1 mark each for representing each case correctly along with the condition*)	
Q.72	A magnet is in stable equilibrium in a uniform magnetic field when its magnetic moment is aligned with the direction of the magnetic field ie when $\theta = 0°$ Let M be the dipole moment of the magnet and B be the magnetic field. Work done in rotating the bar magnet through 60° = $U_f - U_i$ = - MBcos60° + MB cos0° = MB/2 4 = MB/2 MB = 8 units (1 mark) The force applied at 5cm from the pivot should provide the necessary torque required to hold the magnet at 60°. Torque acting on dipole at 60° = MBsin 60° = 8 × √3/2 = 4√3 N m 4√3 = F × 5/100 F = 400√3/5 =80√3 N (1 mark)	2
Q.73	a. Magnetic intensity, H = n I = 50 x 100 x 2 = 10^4 A/m [0.5 mark for correct value of H]	3

	b. Since $\chi_p = 5 \times 10^{-3}$ is small and positive, the material P is paramagnetic. [0.5 mark for correct identification of the material P] Magnetization M developed in P, $M = \chi_p H = 5 \times 10^{-3} \times 10^4 = 50$ A/m [0.5 mark for correct value of M] c. Since $\chi_q = 5 \times 10^3$ is large and positive, the material Q is ferromagnetic. [0.5 mark for correct identification of the material Q] d. (i) Ferromagnetic material has magnetization $M >> H$ (ii) Paramagnetic material has magnetization $M << H$. [0.5 mark for the correct statements]	