UNIT III

MAGNETIC EFFECTS OF CURRENT AND MAGNETISM

Weightage 8 Marks

TOPICS TO BE COVERED

Concept of magnetic field and Oersted's experiment Biot-savart law and its application to current carrying circular loop.

Ampere's law and its applications to infinitely long straight wire, straight and toroidal solenoids.

Force on a moving charge in uniform magnetic and electric fields.

Cyclotron

Force on a current carrying conductor in a uniform magnetic field, force between two parallel current carrying conductors, definition of ampere. Torque experienced by a current loop in a uniform magnetic field.

Moving coil Galvanometer – its current sensitivity.

Moving Coil Galvanometer – Conversion to ammeter and voltmeter, Current loop as a magnetic dipole and it's magnetic dipole moment, Magnetic dipole moment of a revolving electron, Magnetic field intensity due to a magnetic dipole (bar magnet) along it's axis and perpendicular to it's axis.

Torque on a magentic dipole (bar magnet) in a uniform magnetic field; bar magnet as an equivalent solenoid, Magnetic field lines Earth's Magnetic field and magnetic elements. Para-, dia- and ferro-magnetic substances with examples.

Electromagnets and factors affecting their strengths, Permanent magnets.

KEY POINTS

Physical Quantity	Formulae	SI Unit
Biot-Savart's Law	$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{l}\times\vec{r}}{r^3}$	Tesla (T);
	$\lvert d\vec{B}\rvert = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}$	10^4 Gauss = 1T
Magnetic field due to a straight current carrying conductor	$B = \frac{\mu_0 I}{2\pi R}$	T
Magnetic field at the centre of a circular loop For *n* loops,	$B = \frac{\mu_0 I}{2a}$ $B = \frac{\mu_0 n I}{2a}$	T
Magnetic Field at a Point on the Axis of a current carrying loop	$B = \frac{\mu_0 I}{4\pi}\frac{2\pi a^2}{(a^2+x^2)^{\frac{3}{2}}}$	T
	When, x = 0, $B = \frac{\mu_0 I}{2a}$	
	For a << x, $B = \frac{\mu_0 I a^2}{2x^3}$	

	For n loops, $B=\frac{\mu_0 nIa}{2x^3}$	
Ampere's Circuital Law	$\oint \vec{B}.d\vec{l}=\mu_0 I$	T – m
Magnetic field due to a long straight solenoid	$B=\mu_0 nI$	T
	At the end of solenoid, $B=\frac{1}{2}\mu_0 nI$	
	If solenoid is filled with material having μr	
	$B = \mu_0\mu_r nI$	
Magnetic field due to a toroidal solenoid	$B = \mu_0 n I$	T
Motion of a charged partical inside electric field	$y=\frac{qE}{2m}\left(\frac{x}{v_x}\right)^2$	m
Magnetic force on a moving charge	$\vec{F}=q(\vec{v}\times\vec{B})$	N
	Or $F = B qv \sin\theta$	
Lorentz Force (Electric and magnetic)	$\vec{F}=q\vec{E}+q(\vec{v}\times\vec{B})$	N

The Cyclotron

Radius of circular path	$r = \frac{mv}{qB}$
The period of circular motion	$T = \frac{2\pi m}{Bq}$
The cyclotron frequency	$\nu = \frac{1}{T} = \frac{Bq}{2\pi m}$
Maximum energy of the positive ions	$\frac{1}{2} m{v^2}_{max} = \frac{B^2 q^2 r^2}{2m} = qV$
The radius corresponding to maximum velocity	$r = \frac{1}{B}\left(\frac{2mV}{q}\right)^{\frac{1}{2}}$
The maximum velocity	$v_{max} = \frac{Bqr}{m}$
The radius of helical path when $\vec{V}$ and $\vec{B}$ are inclined to each other by an angle θ	$r = \frac{mv \sin\theta}{qB}$
Force on a current carrying conduct placed in a magnetic field	$I \vec{l} \times \vec{B}$ N

Force per unit length between tow parallel current carrying conductors	$f = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$	Nm^{-1}
Magnetic dipole moment	$\vec{M} = I\vec{A}$	Am^2 or JT^{-1}
Torque on a rectangular current carrying loop ABCD	$\tau = BIA \cos\theta$ $\theta \rightarrow$ angle between loop and magnetic field $\vec{\tau} = \vec{M} \times \vec{B} \Rightarrow \tau = MB \sin\alpha$ If coil has n turns, $\tau = n\, B\, I\, A \sin\alpha$ $\tau = n\, BIA \sin\alpha$; $\tau = n\, BIA \sin\alpha$ $\alpha \rightarrow$ angle between notmal drawn on the plane of loop and magnetic field	
Period of oscillation of bar magnet if external magnetic field	$T = 2\pi\sqrt{\frac{I}{MB}}$	s
The potential energy associated with magnetic field	$U = \vec{M} \cdot \vec{B}$	J

Current through a galvanometer $\phi \rightarrow$ angle by which the coil rotates	$I = \frac{k}{nBA}\phi = G\phi$ $G \rightarrow$ galvanometer constant	A
Sensitivity of a galvanometer or		
Current sensitivity	$\frac{\phi}{I} = \frac{nBA}{k} = \frac{1}{G}$	rad A^{-1}
Voltage sensitivity	$\frac{\theta}{V}, \frac{nBA}{KR} = \frac{1}{GR}$	rad V^{-1}
The current loop as a magnetic dipole	$B = \frac{\mu_0}{4\pi}\frac{2M}{x^3}$	T
Gyromagnetic ratio	$\frac{\mu_e}{l} = \frac{e}{2m_e} = 8.8 \times 10^{10}\frac{C}{kg}$	C Kg^{-1}
Bohr magneton	$(\mu_e)_{min} = \frac{e}{4\pi m_e}h = 9.27 \times 10^{-24}$	Am^2
Magnetic dipole moment	$\vec{M} = m \times (\vec{2l})$	JT^{-1} or Am^2
Magnetic field on axial line of a bar magnet	$B_{axial} = \frac{\mu_0}{4\pi}\left[\frac{2Mr}{(r^2 - l^2)^2}\right]$	T

	When, $l << r$, $B_{axial} = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$
Magnetic field on equatorial line of a bar magnet	$B_{eq} = \frac{\mu_0}{4\pi}\left[\frac{M}{(r^2+l^2)^{\frac{3}{2}}}\right]$ T
	When, $l << r$, $B_{eq} = \frac{\mu_0}{4\pi}\frac{M}{r^3}$
Gauss' Law in magnetism	$\oint_S \vec{B}.d\vec{S} = 0$ Tm^2 or weber
Magnetic inclination (or Dip)	$\tan\delta = \frac{B_V}{B_H}$, $\delta \rightarrow$ angle of dip
Magnetic intensity (or Magnetic field strength)	$H = \frac{B_0}{\mu_0} = nI$ Am^{-1} *n* is the no. of terms/length
Intensity of magnetization	$I_m = \frac{M}{V}$ Am^{-1}
Magnetic flux	$\phi = \vec{B}.\Delta\vec{S}$ Weber (Tm^2)
Magnetic induction (or Magnetic flux	$B = B_0 + \mu_0 I_m$ T

density or Magnetic field)	$= \mu_0 (H + I_m)$
Magnetic susceptibility	$\chi_m = \frac{I_m}{H}$
Magnetic permeability	$\mu = \frac{B}{H}$ TmA^{-1} (or NA^{-2})
Relative permeability (μ)	$\frac{\mu}{\mu_0} = \mu_r = (1 + \chi_m)$ —
Curie's Law	$\chi_m = \frac{C}{T}$ C → curie conctant

QUESTIONS

VERY SHORT ANSWERS QUESTIONS (I Mark)

1. Must every magnetic field configuration have a north pole and a south pole? What about the field due to a toroid?

2. How are the figure of merit and current sensitivity of galvanometer related with each other?

3. Show graphically the variation of magnetic field due to a straight conductor of uniform cross-section of radius 'a' and carrying steady currently as a function of distance r ($a > r$) from the axis of the conductor.

4. The force per unit length between two parallel long current carrying conductor is F. If the current in each conductor is tripled, what would be the value of the force per unit length between them?

5. How does the angle of dip vary from equator to poles?

6. What is the effect on the current measuring range of a galvanometer when it is shunted?

7. An electric current flows in a horizontal wire from East to West. What will be the direction of magnetic field due to current at a point (i) North of wire; (ii) above the wire.

8. Suggest a method to shield a certain region of space from magnetic fields.

*9. Why the core of moving coil galvanometer is made of soft iron?

10. Where on the earth's surface, is the vertical component of earth's magnetic field zero?

11. If the current is increased by 1% in a moving coil galvanometer. What will be percentage increase in deflection?

12. Write S.I. unit of (i) Pole strength and (ii) Magnetic dipole moment.

13. If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis, which way would the Lorentz force be for (a) an electron (negative charge), (b) a proton (positive charge)

Sol : When velocity $(\vec{v})$ of positively charged particle is along x-axis and the magnetic field $(\vec{B})$ is along y-axis, so $\vec{v} \times \vec{B}$ is along the z-axis (Fleming's left hand rule).

Therefore,

(a) for electron Lorentz force will be along –z axis;

(b) for a positive charge (proton) the force is along +z axis.

14. If a toroid uses Bismuth as its core, will the field in the core be lesser or greater than when it is empty?

Ans : Bismuth is diamagnetic, hence, the overall magnetic field will be slightly less.

15. An electron beam projected along + x-axis, experiences a force due to a magnetic field along the + y-axis. What is the direction of the magnetic field?

Ans : +Z axis.

16. What is the principle of a moving coil galvanometer?

Ans : When a current carrying coil is placed in uniform magnetic field, it experiences a torque.

17. What is the direction of magnetic dipole moment?

Ans : S to N

18. What is the angle of dip at a place where vertical and horizontal component of earth's field are equal?

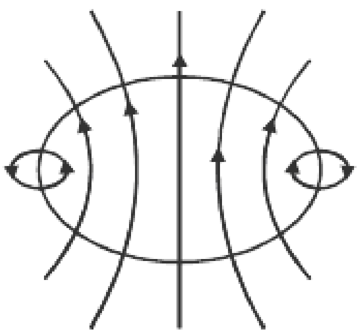
Ans : 45°

19. Is any work done on a moving charge by a magnetic field?

Ans : No, as magnetic field is in perpeudicular direction.

20. Sketch the magnetic field lines for a current carrying circular loop.

Ans :

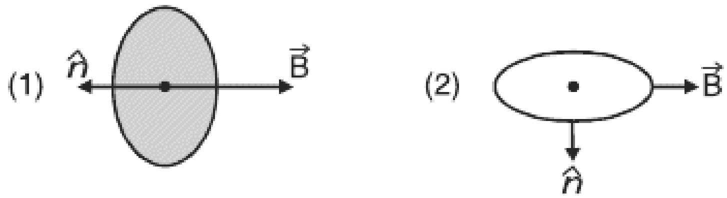


SHORT ANSWERS QUESTIONS (2 MARKS)

1. Write the four measures that can be taken to increase the sensitivity of a galvanometer.

2. A galvanometer of resistance 120Ω gives full scale deflection for a current of 5mA. How can it be converted into an ammeter of range 0 to 5A? Also determine the net resistance of the ammeter.

3. A current loop is placed in a uniform magnetic field in the f ollowing orientations (1) and (2). Calculate the magnetic moment in each case.



4. A current of 10A flows through a semicircular wire of radius 2cm as shown in figure (a). What is direction and magnitude of the magnetic field at the centre of semicircle? Would your answer change if the wire were bent as shown in figure (b)?

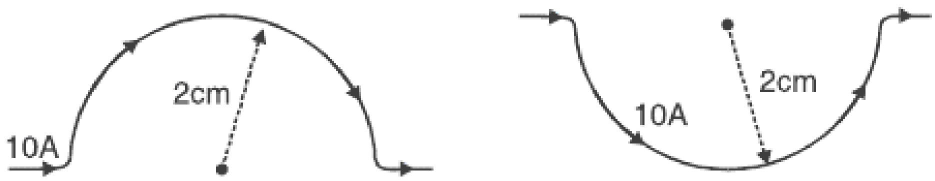


Fig. (a) Fig. (b)

5. A proton and an alpha particle of the same enter, in turn, a region of uniform magnetic field acting perpendicular to their direction of motion. Deduce the ratio of the radii of the circular paths described by the proton and alpha particle.

6. Which one of the two an ammeter or milliammeter, has a higher resistance and why?

7. Mention two properties of soft iron due to which it is preferred for making electromagnet.

8. A magnetic dipole of magnetic moment M is kept in a magnetic field B. What is the minimum and maximum potential energy? Also give the most stable position and most unstable position of magnetic dipole.

9. What will be (i) Pole strength (ii) Magnetic moment of each of new piece of bar magnet if the magnet is cut into two equal pieces :

   (a) normal to its length?

   (b) along its length?

10. A steady current I flows along an infinitely long straight wire with circular cross-section of radius R. What will be the magnetic field outside and inside the wire at a point *r* distance far from the axis of wire?

11. A circular coil of *n* turns and radius R carries a current I. It is unwound and rewound to make another square coil of side 'a' keeping number of turns and current same. Calculate the ratio of magnetic moment of the new coil and the original coil.

12. A coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current remaining the same. Calculate the ratio of the magnetic moment of the new coil and original coil.

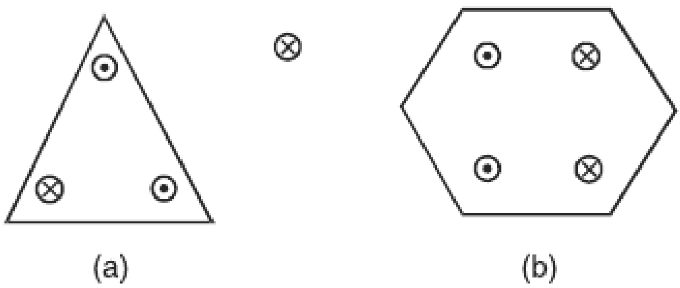
13. At a place horizontal component of the earths magnetic field is B and angle of dip at the place is 60°. What is the value of horizontal component of the earths magnetic field.

    (i) at Equator; (ii) at a place where dip angle is 30°

14. A galvanometer coil has a resistance G. 1% of the total current goes through the coil and rest through the shunt. What is the resistance of the shunt?

15. Prove that the magnetic moment of a hydrogen atom in its ground state is $eh/4\pi m$. Symbols have their usual meaning.

16. Each of eight conductors in figure carries 2A of current into or out of page. Two path are indicated for the line integral $\oint \vec{B} \cdot d\vec{l}$ What is the value of the integral for the path (a) and (b).



17. What is the radius of the path of an electron (mass 9×10^{-31} kg and charge 1.6×10^{-19} C) moving at a speed of 3×10^{7} m/s in a magnetic field of 6×10^{-4} T perpendicular to it? What is its frequency? Calculate its energy in keV. (1 eV = 1.6×10^{-19} J).

Sol : Radius, r = mv/ (qB)

$= 9.1 \times 10^{-31}\text{kg} \times 3 \times 10^{7}\ \text{ms}–1/ (1.6 \times 10^{-19}\ \text{C} \times 10^{-4}\ \text{T}) = 26\ \text{cm}$

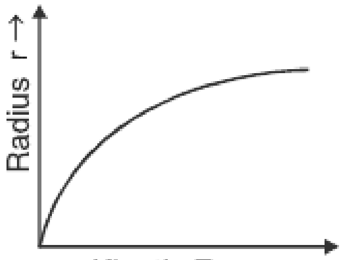
$\nu = v/(2\pi r) = 2 \times 10^{8}\ \text{s}^{-1} = 2 \times 10^{8}\ \text{Hz} = 200\ \text{MHz}.$

$E = (½)mv^2 = (½)\ 9 \times 10^{-31}\ \text{kg} \times 9 \times 10^{14}\ \text{m}^2/\text{s}^2$

$= 40.5 \times 10^{-17}\ \text{J} = 4 \times 10^{-16}\ \text{J} = 2.5\ \text{keV}.$

18. A particle of mass m and charge q moves at right angles to a uniform magnetic field. Plot a graph showing the variation of the radius of the circular path described by it with the increase in its kinetic energy, where, other factors remain constant.

Ans : $r \propto \sqrt{K.E}$



19. Magnetic field arises due to charges in motion. Can a system have magnetic moments even though its net charges is zero? Justify.

Ans : Yes; for example the atoms of a paramagnetic substance possess a net magnetic moment though its net charge is zero.

20. Define the term magnetic dipole moment of a current loop. Write the expression for the magnetic moment when an electron revolves at a speed '*v*', around an orbit of radius '*r*' in hydrogen atom.

Ans : The product of the current in the loop to the area of the loop is the magnetic dipole moment of a current loop.
The magnetic moment of electron

$$\bar{\mu} = -\frac{e}{2}(\vec{r} \times \vec{v}) = -\frac{e}{2m_e}(\vec{r} \times \vec{p}) = -\frac{e}{2m_e}\vec{\ell}$$

SHORT ANSWERS QUESTIONS (3 MARKS)

1. Derive the expression for force between two infinitely long parallel straight wires carrying current in the same direction. Hence define 'ampere' on the basis of above derivation.

2. Define (i) Hysteresis (ii) Retentivity (iii) Coercivity

3. Distinguish bet ween diamagnetic, paramagnetic and ferromagneti c substances in terms of susceptibility and relative permeability.

*4. Name all the three elements of earth magnetic field and define them with the help of relevant diagram.

5. Describe the path of a charged particle moving in a uniform magnetic field with initial velocity

   (i) parallel to (or along) the field.

   (ii) perpendicular to the field.

   (iii) at an arbitrary angle θ ($0° < \theta < 90°$).

6. Obtain an expression for the magnetic moment of an electron moving with a speed 'v' in a circular orbit of radius 'r'. How does this magnetic moment change when :

   (i) the frequency of revolution is doubled?

   (ii) the orbital radius is halved?

7. State Ampere, circuital law. Use this law to obtain an expression for the magnetic field due to a toroid.

*8. Obtain an expression for magnetic field due to a long solenoid at a point inside the solenoid and on the axis of solenoid.

9. Derive an expression for the torque on a magnetic dipole placed in a magnetic field and hence define magnetic moment.

10. Derive an e xpression fo r mag netic field in tensity due to a b ar ma gnet (magnetic dipole) at any point (i) Along its axis (ii) Perpendicular to the axis.

*11. Derive an expression for the torque acting on a loop of N turns of area A of each turn carrying current I, when held in a uniform magnetic field B.

*12. How can a moving coil galvanometer be converted into a voltmeter of a given range. Write the necessary mathematical steps to obtain the value of resistance required for this purpose.

13. A long wire is first bent into a circular coil of one turn and then into a circular coil of smaller radius having n turns. If the same current passes in both the cases, find the ratio of the magnetic fields produced at the centres in the two cases.

Ans : When there is only one turn, the magnetic field at the centre,

$$B = \frac{\mu_0 I}{2a}$$

$2\pi a^1 xn = 2\pi a \Rightarrow a^1 = a/n$

The magnetic field at its centre, $B_1 = \frac{\mu_0 nI}{2a/n} = \frac{\mu_0 n^2 I}{2a} = n^2 B$

The ratio is, $B_1/B = n^2$

LONG ANSWER QUESTIONS (5 Marks)

1. How will a diamagnetic, paramagnetic and a ferromagnetic material behave when kept in a non-uniform external magnetic field? Give two examples of each of these materials. Name two main characteristics of a ferromagnetic material which help us to decide suitability for making
(i) Permanent magnet (ii) Electromagnet.

2. State Biot-Savart law. Use it to obtain the magnetic field at an axial point, distance d from the centre of a circular coil of radius 'a' and carrying current I. Also compare the magnitudes of the magnetic field of this coil at its centre and at an axial point for which the value of d is $\sqrt{3}a$.

3. Write an expression for the force experienced by a charged particle moving in a uniform magnetic field B. With the help of diagram, explain the principle and working of a cyclotron. Show that cyclotron frequency does not depend on the speed of the particle.

*4. Write the principle, working of moving coil galvanometer with the help of neat labelled diagram. What is the importance of radial field and phosphor bronze used in the construction of moving coil galvanometer?

NUMERICALS

1. An electron travels on a circular path of radius 10m in a magnetic field of 2×10^{-3} T. Calculate the speed of electron. What is the potential difference through which it must be accelerated to acquire this speed? [**Ans. :** Speed = 3.56×10^9 m/s; V = 3.56×10^7 volts]

2. A ship is to reach a place 15° south of west. In what direction should it be steered if declination at the place is 18° west? [**Ans. :** 87° west of North]

3. Calculate the magnetic field due to a circular coil of 500 turns and of mean diameter 0.1m, carrying a current of 14A (i) at a point on the axis distance 0.12m from the centre of the coil (ii) at the centre of the coil. [**Ans. :** (i) 5.0×10^{-3} Tesla; (ii) 8.8×10^{-2} tesla]

4. An electron of kinetic energy 10 keV moves perpendicular to the direction of a uniform magnetic field of 0.8 milli testa. Calculate the time period of rotation of the electron in the magnetic field.
[**Ans. :** 4.467×10^{-8} s.]

5. If the current sensitivity of a moving coil galvanometer is increased by 20% and its resistance also increased by 50% then how will the voltage sensitivity of the galvanometer be affected?
[**Ans. :** 25% decrease]

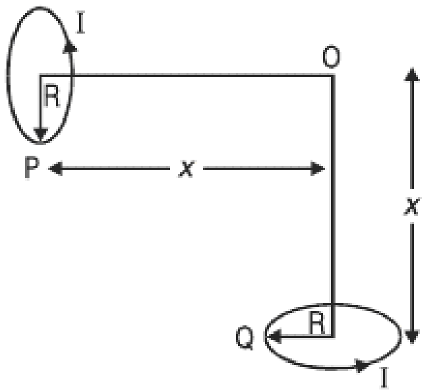
6. A uniform wire is bent into one turn circular loop and same wire is again bent in two turn circular loop. For the same current passed in both the cases compare the magnetic field induction at their centres.
[**Ans. :** Increased 4 times]

7. A horizontal electrical power line carries a current of 90A from east to west direction. What is the magnitude and direction of magnetic field produced by the power line at a point 1.5m below it?
[**Ans. :** 1.2×10^{-5} T south ward]

*8. A galvanometer with a coil of resistance 90Ω shows full scale deflection for a potential difference 225 mV. What should be the value of resistance to convert the galvanometer into a voltmeter of range 0V to 5V. How should it be connected? [**Ans. :** 1910Ω in series]

9. Two identical circular loops P and Q carrying equal currents are placed such that their geometrical axis are perpendicular to each other as shown in figure. And the direction of current appear's anticlockwise as seen from

point O which is equidistant from loop P and Q. Find the magnitude and direction of the net magnetic field produced at the point O.



$$\left[\textbf{Ans. :}\ \frac{\mu_0 I R^2 \sqrt{2}}{2\left(R^2 + x^2\right)^{3/2}}\right]$$

10. A cyclotron's oscillator frequency is 10 MHz. What should be the operating magnetic field for accelerating protons, if the radius of its dees is 60cm? What is the kinetic energy of the proton beam produced by the accelerator? Given $e = 1.6 \times 10^{-19}$ C, m = 1.67×10^{-27} kg. Express your answer in units of MeV [1MeV = 1.6×10^{-13} J]. [**Ans. :** B = 0.656T, E_{max} = 7.421 MeV]

11. The coil of a galvanometer is 0.02×0.08 m^2. It consists of 200 turns of fine wire and is in a magnetic field of 0.2 tesla. The restoring forque constant of the suspension fibre is 10^{-6} Nm per degree. Assuming the magnetic field to be radial.

    (i) what is the maximum current that can be measured by the galvanometer, if the scale can accommodate 30° deflection?

    (ii) what is the smallest, current that can be detected if the minimum observable deflection is 0.1°?

    [**Ans. :** (i) 4.69×10^{-4} A; (ii) 1.56×10^{-6} A]

12. A voltmeter reads 8V at full scale deflection and is graded according to its resistance per volt at full scale deflection as 5000 ΩV^{-1}. How will you convert it into a voltmeter that reads 20V at full scale deflection? Will it still be graded as 5000 ΩV^{-1}? Will you prefer this voltmeter to one that is graded as 2000 ΩV^{-1}? [**Ans. :** 7.5×10^4 Ω]

13. A short bar magnet placed with its axis at 30° with an external field 1000G experiences a torque of 0.02 Nm. (i) What is the magnetic moment of the

magnet. (ii) What is the w ork done in turning it from its most stable equilibrium to most unstable equilibrium position?

[**Ans. :** (i) 0.4 Am^2; (ii) 0.08 J]

14. What is the magnitude of the equatorial and axial fields due to a bar magnet of length 4cm at a distance of 40 cm from its mid point? The magnetic moment of the bar magnet is 0.5 Am^2.

[**Ans. :** $B_E = 7.8125 \times 10^{-7}$ T; $B_A = 15.625 \times 10^{-7}$ T]

15. What is the magnitude of magnetic force per unit length on a wire carrying a current of 8A and making an angle of 30° with the direction of a uniform magnetic field of 0.15T?

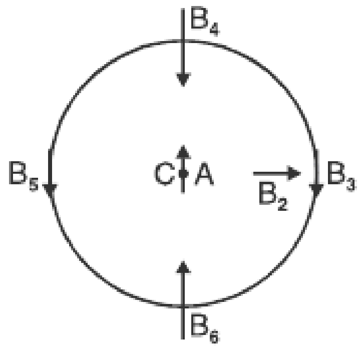
16. Two moving coil galvanometers, M_1 and M_2 have the following specifications.

$$R_1 = 10\Omega,\ N_1 = 30,\ A_1 = 3.6 \times 10^{-3} m^2,\ B_1 = 0.25T$$

$$R_2 = 14\Omega,\ N_2 = 42,\ A_2 = 1.8 \times 10^{-3} m^2,\ B_2 = 0.50T$$

Given that the spring constants are the same for the two galvano meters, determine the ratio of (a) current sensitivity (b) voltage sensitivity of M_1 & M_2.

17. In the given diagram, a small magnetised needle is placed at a point O. The arrow shows the direction of its magnetic moment. The other arrows shown different positions and orientations of the magnetic moment of another identical magnetic needs B



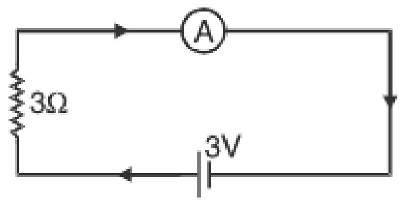
(a) In which configuration is the systems not in equilibrium?

(b) In which configuration is the system.

(i) stable and (ii) unstable equilibrium?

(c) Which configuration corresponds to the lowest potential energy among all the configurations shown?

18. In the circuit, the current is to be measured. What is the v alue of the current if the ammeter shown :

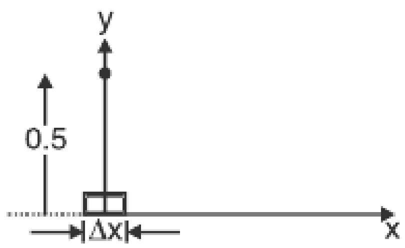


(a) is a galvanometer with a resistance R_G = 60Ω,

(b) is a galvanometer described in (i) but converted to an ammeter by a shunt resistance r_s = 0.02Ω

(c) is an ideal ammeter with zero resistance?

19. An element $\Delta l = \Delta x \cdot \hat{i}$ is placed at the origin and carries a large current I = 10A. What is the magnetic field on the y-axis at a distance of 0.5m. Δx = 1 cm.



20. A straight wire of mass 200g and length 1.5 m carries a current of 2A. It s suspended in mid-air by a uniform horizontal magnetic field B. What is the magnitude of the magnetic field?

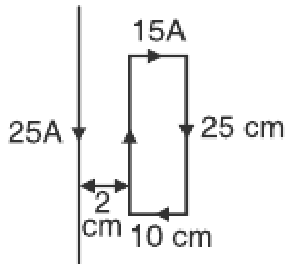
21. A rectangular loop of sides 25 cm and 10 cm carrying current of 15A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying a current of 25A. What is the new force on the loop?
Ans : 7.82 x 10^{-4} N towards the conductor

Hint :

$$F_1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r_1} \times \ell = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.02} = 9.38 \times 10^{-4}\text{N} \text{ attractive}$$

$$F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r_2} \times \ell = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.12} = 1.56 \times 10^{-4} \text{N repalsive}$$

Net F = $F_1 - F_2$ = 7.82 x 10^{-4} N



22. In a chamber of a uniform magnetic field 6.5G is maintained. An electron is shot into the field with a speed of 4.8 x 10^6 ms^{-1} normal to the field. Explain why the path of electron is a circle.

    (a) Determine the radius of the circular orbit (e = 1.6 x 10^{-19} C, m_e = 9.1 x 10^{-31} kg)

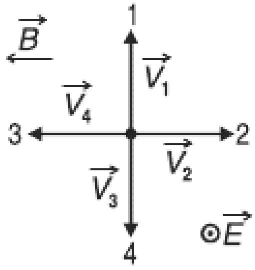
    (b) Obtain the frequency of resolution of the electron in its circular orbit.

Hint : (a) $r = \frac{m_e v}{eB} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2\,\text{cm}$

(b) frequency $\nu = \frac{1}{T} = \frac{eB}{2\pi m_e} \frac{1.6 \times 10^{-19} \times 6.510^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 1.8\ MH_2$

SHORT ANSWER QUESTIONS (2 Marks)

1. The figure shows four directions of motion of a positively charged particle moving through a uniform electric field $\vec{E}$ (directed out of the page and represented with an encircled dot) and a uniform magnetic field $\vec{B}$. (a) Rank, directions 1, 2 and 3 according to the magnitude of the net force on the particle, maximum first. (b) Of all four directions, which might result in a net force of zero?



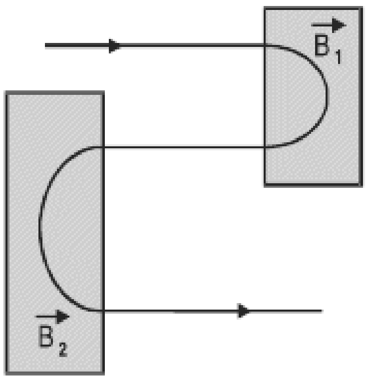
$$|\vec{V_1}| = |\vec{V_2}| = |\vec{V_3}| = |\vec{V_4}|$$

NUMERICALS

2. The true value of dip at a place is 30°. The vertical plane carrying the needle is turned through 45° from the magnetic meridian. Calculate the apparent value of dip. **[Ans. :** $\delta' = 39°14'$]

3. Figure shows the path of an electron that passes through two regions containing uniform magnetic fields of magnitude B_1 and B_2. Its path in each region is a half circle. (a) Which field is stronger? (b) What are the directions of two fields? (c) Is the time spend by the electron in the $\vec{B_1}$, region greater than, less than, or the same as the time spent in $\vec{B_2}$ region?

[**Ans. :** (a) $B_1 > B_2$; (b) B_1 inward; B_2 outward. (c) Time spent in B_1 < Time spent in B_2]



ANSWERS / HINTS

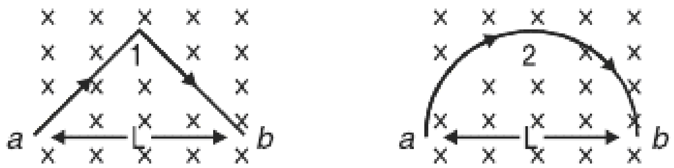
I MARK QUESTIONS

1. No, pole exists only when the source has some net magnetic moment. In toroid, there is no pole.

VERY SHORT ANSWER QUESTIONS (I Mark)

1. The figure shows two wires 1 and 2 both carrying the same current I from point a to point b through the same uniform magnetic field B. Determine the force acting on each wire.

Ans. : Same for both = ILB



2. Reciprocal.
3. Fig. NCERT.
4. Nine Times.
5. 0° to 90°
6. Increased.
7. (i) Going into the plane of the paper; (ii) Emerging out of the plane of the paper.
8. By putting in a ferromagnetic case
10. At equator.
11. 1%.
12. (i) Am; (ii) Am^2.

2 MARKS QUESTIONS

2. $$S = \frac{I_g}{(I - I_g)} G = \frac{5 \times 10^{-3}}{5 - 5 \times 10^{-3}} \times 120 = 0.12\ \Omega.$$

3. (i) – mB (ii) zero

4. (i) $B = \dfrac{10^{-7} \times \pi \times 10}{2 \times 10^{-2}} = 5\pi \times 10^{-5} T \text{ (outwards)}.$

(ii) $B = 5p \times 10^{-5}$ T (inwards).

5. $r_p = \dfrac{mv}{qB}$ and $r_\alpha = \dfrac{4mv}{(2q)B} = 2r_\alpha \quad \Rightarrow \quad \dfrac{r_p}{r_a} = \dfrac{1}{2}.$

6. $R_{mA} > R_A.$

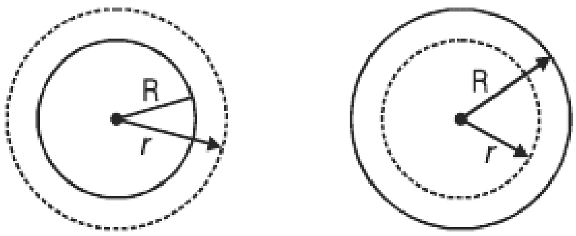
7. Low Retentivity and high permeability.

8. Minimum potential = $-MB$ when $\theta = 0$ (most stable position)

Maximum potential = MB when $\theta = 180°$ (most unstable position).

9. (a) Pole strength same; magnetic moment half.

(b) pole strength half; magnetic moment half.



10. $$B(2\pi r) = \mu_0 \left[\frac{I}{\pi R^2}(\pi r^2)\right]$$

$$Br = \left(\frac{\mu_0 I}{2\pi R^2}\right) \qquad (R \geq r)$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

$\therefore$ $$Br = \frac{\mu_0 I}{2\pi r} \qquad (\ \geq R).$$

11. $M_1 = MI\pi R^2;\ M_2 = MIa^2$

$$2\pi rN = 4aN \Rightarrow a = \frac{\pi R}{2}$$

$$\frac{M_2}{M_1} = \pi/4$$

12. $$\frac{m_{new}}{m_{original}} = \frac{2I \times \pi\left(\frac{r}{2}\right)^2}{I \times \pi R^2} = \frac{1}{2}.$$

13. 0° and 90°.

14. (a) $\oint \vec{B}.d\vec{l} = \mu_o I = 2\mu_o$ T.m

(b) zero

ANSWER FOR NUMERICALS

15. Force experienced by current carrying conductor in magnetic field.

$F = I\vec{L} \times \vec{B} = ILB\sin\theta$

Hence, force permit length, $f = \frac{F}{L} IB\sin 30°$

$= 8 \times 0.15 \times ½ = 0.6\ Nm^{-1}$

16. (a) Current sensitivity, $\frac{\phi}{I} = \frac{NBA}{K}$

Ratio of current Sensitivity $= \left(\frac{N_1 B_1 A_1}{K}\right) \Big/ \left(\frac{N_2 B_2 A_2}{K}\right)$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3}}{42 \times 0.50 \times 1.8 \times 10^{-3}} = 5/7$$

(b) Voltage sensitivity, $\frac{\phi}{V} = \frac{NBA}{kR}$

Ratio of voltage sensitivity $= \left(\frac{N_1 B_1 A_1}{kR_1}\right) \Big/ \left(\frac{N_2 B_2 A_2}{kR_2}\right)$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3} \times 14}{42 \times 0.50 \times 1.8 \times 10^{-3} \times 10} = 1$$

17. (a) For equilibrium the dipole moment should be parallel or auto paralle to B. Hence, AB_1 and AB_2 are not in equilibrium.

(b) (i) for stable equilibrium, the dipole moments should be parallel, examples : AB_5 and AB_6 (ii) for unstable equilibrium, the dipole moment should be anti parallel examples : AB_3 and AB_4

(c) Potential energy is minimum when angle between M and B is 0°, *i.e*, U = –MB Example : AB_6

18. (a) Total resistance, $R_G + 3 = 63\Omega$.

Hence, $I = \frac{3V}{63\Omega} = 0.048A$

(b) Resistance of the galvanometer as ammeter is

$$\frac{R_G r_S}{R_G r_S} = \frac{60\Omega \times 0.02\Omega}{(60+0.02)} = 0.02\Omega.$$

Total resistance R = 0.02Ω + 3Ω = 3.02Ω

Hence, $I = \frac{3}{302} = 0.99A$

(c) For the ideal ammeter, resistance is zero, the current, I = 3/3 = 1.00A

19. From Biot-Sayart's Law, $\left|\vec{d\beta}\right| = Id\ell \sin\theta \ \ r^2$

$dl = \Delta x = 1$ cm $= 10^{-2}$m, I = 10A, r = y = 0.5m

$\mu o/4\pi = 10^{-7}$ Tm/A, $\theta = 90°$ so $\sin\theta = 1$

$$\left|\vec{dB}\right| = \frac{10^{-7} \times 10 \times 10^{-2}}{25 \times 10^{-2}} = 4 \times 10T^{8} \text{ alongz+ axis}$$

20. Force experienced by wire $F_m = BIl$ (due to map field)
The force due to gravity, Fg = mg

$$mg = BIl \Rightarrow B = mg/Il = \frac{0.2 \times 9.8}{2 \times 1.5} = 0.657T$$

[Earth's magigield 4 x 10^{-5} T is negligible]