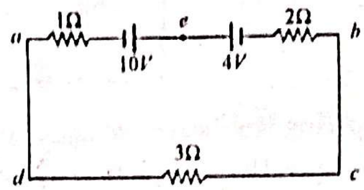
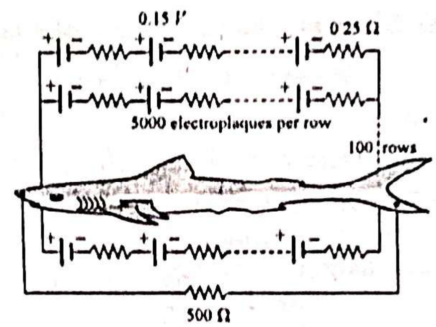
MULTIPLE CHOICE QUESTIONS

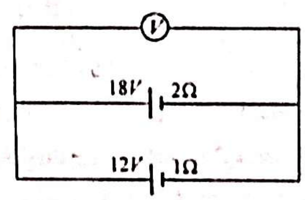
1. Every atom makes one free electron in copper. If 1.1 ampere current is flowing in the wire of copper having 1 mm diameter, then the drift velocity (approx.) will be (Density of copper = $9 \times 10^3 kgm^{-3}$ and atomic weight = (63)
   (a) $0.3mm/sec$ (b) $0.1mm/sec$ (c) $0.2mm/sec$ (d) $0.2cm/sec$
2. The resistivity of iron is $1 \times 10^{-7} ohm - m$. The resistance of a iron wire of particular length and thickness is 1 *ohm*. If the length and the diameter of wire both are doubled, then the resistivity in $ohm - m$ will be
   (a) 1×10^{-7} (b) 2×10^{-7} (c) 4×10^{-7} (d) 8×10^{-7}
3. It is easier to start a car engine on a hot day than on a cold day. This is because the internal resistance of the car battery
   (a) Decreases with rise in temperature (b) Increases with rise in temperature
   (c) Decreases with a fall in temperature (d) Does not change with a change in temperature
4. The magnitude and direction of the current in the circuit shown will be
   (a) $\frac{7}{3}A$ from a to b through e
   (b) $\frac{7}{3}A$ from b to a through e
   (c) 1 A from b to a through e
   (d) 1 A from a to b through e



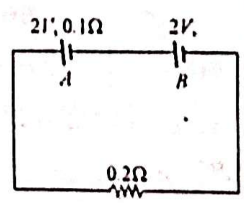
5. Two identical cells send the same current in 2 ohm resistance, whether connected in series or in parallel. The internal resistance of the cell should be
   (a) 0 (b) 0.5 *ohm* (c) 1.5 ohm (d) 2 ohm
6. Eels are able to generate current with biological cells called electro plaques. The electro plaques in an eel are arranged in 100 rows, each row stretching horizontally along the body of the fish containing 5000 electro plaques. The arrangement is suggestively shown below. Each electro plaques has an emf of 0.15 V and internal resistance of 0.25 Ω The water surrounding the eel completes a circuit between the head and its tail. If the water surrounding it has a resistance of 500 Ω, the current an eel can produce in water is about



   (a) 1.5 A (b) 3.0 A
   (c) 15 A (d) 30 A
7. Two batteries, one of emf 18 *volts* and internal resistance 2Ω and the other of emf 12 *volt* and internal resistance 1Ω, are connected as shown. The voltmeter V will record a reading of
   (a) 15 *volt* (b) 30 *volt* (c) 14 *volt* (d) 18 *volt*



8. The internal resistances of two cells shown are 0.1Ω and 0.3Ω. If $R = 0.2\Omega$, the potential difference across the cell
   (a) B will be zero
   (b) A will be zero
   (c) A and B will be $2V$
   (d) A will be > $2V$ and B will be < $2V$



9. In Wheatstone's bridge $P = 9ohm$, $Q = 11ohm$, $R = 4ohm$ and $S = 6ohm$. How much resistance must be put in parallel to the resistance S to balance the bridge
   (a) 24 *ohm* (b) $\frac{44}{9}ohm$ (c) 26.4 *ohm* (d) 18.7 *ohm*

ANSWERS

1. (b) Density of $Cu = 9 \times 10^3 kg/m^3$ (mass of 1 m^3 of Cu)

$\because$ 6.0×10^{23} atoms has a mass $= 63 \times 10^{-3}\ kg$

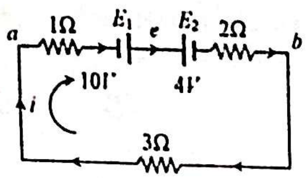
$\therefore$ Number of electrons per m^3 are $= \frac{6.0\times10^{23}}{63\times10^{-3}} \times 9 \times 10^3 = 8.5 \times 10^{28}$

Now drift velocity $= v_d = \frac{i}{neA} = \frac{1.1}{8.5\times10^{28}\times1.6\times10^{-19}\times\pi\times(0.5\times10^{-3})^2} = 0.1 \times 10^{-3} m/sec$

2. (a) Resistivity of some material is its intrinsic property and is constant at particular temperature. Resistivity does not depend upon shape.

3. (b) Because as temperature increases, the resistivity increases and hence the relaxation time decreases for conductors $\left(\tau \propto \frac{1}{\rho}\right)$.

4. (d)



Applying Kirchoff's voltage law

$-1 \times i + 10 - 4 - 2 \times i - 3i = 0 \Rightarrow i = 1A$ (a to b via e)

$\therefore$ Current $= \frac{V}{R} = \frac{10-4}{6} = 1.0 ampere$

5. (d) In series, $i_1 = \frac{2E}{2+2r}$

In parallel, $I_2 = \frac{E}{2+\frac{r}{2}} = \frac{2E}{4+r}$, Since $i_1 = i_2 \Rightarrow \frac{2E}{4+r} = \frac{2E}{2+2r} \Rightarrow r = 2\Omega$

6.(a) Given problem is the case of mixed grouping of cells

So total current produced $i = \frac{nE}{R + \frac{nr}{m}}$

Here $m = 100$, $n = 5000$, $R = 500\Omega$

$E = 0.15V$ and $r = 0.25\Omega$

$$i = \frac{5000\times0.15}{500+\frac{5000\times0.25}{100}} = \frac{750}{512.5} \approx 1.5\,A$$

7(c) Reading of voltmeter

$Eeq = \frac{E1r2+E2r1}{r1+r2}$

=(18*1+12*2)/(1+2) = 14 V

8(a) Applying Kirchhoff law, $(2 + 2) = (0.1 + 0.3 + 0.2)i \Rightarrow i = \frac{20}{3}A$

Hence potential difference across A

$= 2 - 0.1 \times \frac{20}{3} = \frac{4}{3}V$ (less than $2V$)

Potential difference across $B = 2 - 0.3 \times \frac{20}{3} = 0$

9(c) $\frac{P}{Q} = \frac{R}{S}$ (For balancing bridge)

$\Rightarrow S' = \frac{4\times11}{9} = \frac{44}{9} \Rightarrow \frac{1}{S'} = \frac{1}{r} + \frac{1}{6} \Rightarrow \frac{9}{44} - \frac{1}{6} = \frac{1}{r} \Rightarrow r = \frac{132}{5} = 26.4\Omega$

ASSERTION & REASON QUESTIONS

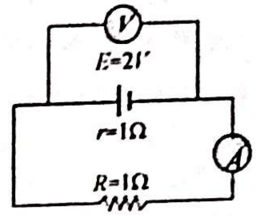
Read the assertion and reason carefully to mark the correct option out of the options given below :

(a)If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b)If both assertion and reason are true but reason is not the correct explanation of the assertion.

c) If assertion is true but reason is false.
d) If the assertion and reason both are false.

1. **Assertion:** The resistivity of a semiconductor increases with temperature.
   Reason: The atoms of a semiconductor vibrate with larger amplitude at higher temperatures thereby increasing its resistivity.
2. **Assertion:** In a simple battery circuit the point of lowest potential is positive terminal of the battery
   Reason: The current flows towards the point of the higher potential as it flows in such a circuit from the negative to the positive terminal.
3. **Assertion:** The temperature coefficient of resistance is positive for metals and negative for p-type semiconductor.
   Reason: The effective charge carriers in metals are negatively charged whereas in p-type semiconductor they are positively charged.
4. **Assertion:** In the following circuit emf is $2V$ and internal resistance of the cell is 1 Ω and $R = 1\Omega$, then reading of the voltmeter is $1V$.
   Reason: $V = E - ir$ where $E = 2V$, $i = \frac{2}{2} = 1A$ and $R = 1\ \Omega$



5. **Assertion:** There is no current in the metals in the absence of electric field.
   Reason: Motion of free electron are randomly.
6. **Assertion:** Electric appliances with metallic body have three connections, whereas an electric bulb has a two pin connection.
   Reason: Three pin connections reduce heating of connecting wires.
7. **Assertion:** The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.
   Reason: On increasing temperature, conductivity of metallic wire decreases.
8. **Assertion:** The electric bulbs glows immediately when switch is on.
   Reason: The drift velocity of electrons in a metallic wire is very high.

ANSWERS

1. (d) Resistivity of a semiconductor decreases with the temperature. The atoms of a semiconductor vibrate with larger amplitudes at higher temperatures thereby increasing it's conductivity not resistivity.
2. (d) It is quite clear that in a battery circuit, the point of lowest potential is the negative terminal of the battery and the current flows from higher potential to lower potential.
3. (b) The temperature co-efficient of resistance for metal is positive and that for semiconductor is negative. In metals free electrons (negative charge) are charge carriers while in P-type semiconductors, holes (positive charge) are majority charge carriers.
4. (a) Here, $E = 2V, 1 = \frac{2}{2} = 1A$ and $r = 1\Omega$

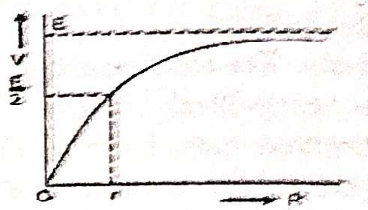
   Therefore, $V = E - ir = 2 - 1 \times 1 = 1V$
5. (a) It is clear that electrons move in all directions haphazardly in metals. When an electric field is applied, each free electron acquire a drift velocity. There is a net flow of charge, which constitute current. In the absence of electric field this is impossible and hence, there is no current.
6. (c) The metallic body of the electrical appliances is connected to the third pin which is connected to the earth. This is a safety precaution and avoids eventual electric shock. By doing this the extra charge flowing through the metallic body is passed to earth and avoid shocks. There is nothing such as reducing of the heating of connecting wires by three pin connections.
7. (b) On increasing temperature of wire the kinetic energy of free electrons increase and so they collide more rapidly with each other and hence their drift velocity decreases. Also when temperature increases, resistivity increase and resistivity is inversely proportional to conductivity of material.

8. (c) In a conductor there are large number of free electrons. When we close the circuit, the electric field is established instantly with the speed of electromagnetic wave which cause electron drift at every portion of the circuit. Due to which the current is set up in the entire circuit instantly. The current which is set up does not wait for the electrons flow from one end of the conductor to the another end. It is due to this reason, the electric bulb glows immediately when switch is on.

VERY SHORT ANSWER TYPE QUESTIONS

1. A cell of emf (E) and internal resistance (r) is connected across a variable external resistance (R). Plot graphs to show variation of (i) E with R, (ii) Terminal p.d. of the cell (V) with R.

Sol. (i) The emf E of a cell is independent of external resistance (R).



(ii) The terminal p.d. $V = IR = \frac{E}{r+R}R = \frac{E}{1+\frac{r}{R}}$

On increasing R, V increases.

When R = 0, V→ 0. When R = r, $V = \frac{E}{2}$

When R → ∞, V = E.

2. A p.d. of V volts is applied to a conductor of length L and diameter D. How will the drift velocity of e's and the resistance of the conductor change when (i) V is doubled (ii) L is halved and (iii) D is halved, where is each case , the other two factors remain same . Give reason in each case.

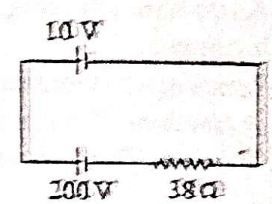
Sol. $V_d = \frac{eE}{m}\tau = \frac{eV}{ml}\tau$ and $R = \rho\frac{l}{A} = \rho\frac{l}{\pi D^2}$

(i) When V is doubled, V_d becomes double and R remains unchanged.

(ii) When l is halved, V_d becomes double and R becomes halved

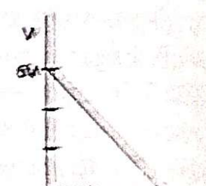
(iii) When D is halved, V_d remains unchanged and R becomes 4R.

3. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω. Find the value of the current in circuit.



Sol. $I = \frac{E}{r+R} = \frac{200-10}{0+38} = 5A$

4. The plot of the variation of potential difference across a combination of three identical cells in series, versus current is as shown below. What is the emf of each cell?



Sol. Let E be emf of each cell and r be the total internal resistance of circuit. The equation of terminal potential difference $V = 3E - Ir$..............(1)

At V = 6V, I = 0. Therefore from eq (1), $6 = 3E - 0 \Rightarrow E = 2V$

5. Write any two factors on which internal resistance of a cell depends.

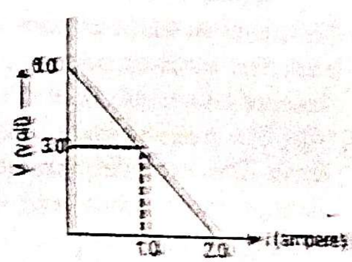
Sol. The internal resistance of a cell depends on

(i) distance (l) between electrodes.

(ii) area (A) of immersed part of electrode, and

(iii) nature and concentration of electrolyte.

6. The following graph shows the variation of terminal potential difference V, across a combination of three cells in series to a resistor, versus the current, I.



(i) Calculate the emf of each cell and internal resistance

(ii) For what current I will the power dissipation of the circuit be maximum?

Sol. (i) Let E be emf of each cell and r be the total internal resistance of circuit. The equation of terminal potential difference $V = 3E - Ir$...........(1)

At $V = 6V, I = 0$. Therefore from eq (1), $6 = 3E - 0 \Rightarrow E = 2V$

(ii) At $V = 0V, I = 2A$. Therefore from eq (1), $0 = 6 - 2r \Rightarrow r = 3\Omega$

(iii) For maximum power dissipation, external resistance (R) = Internal resistance (r)

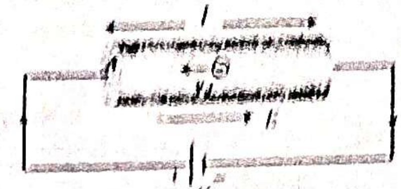
Current, $I = \frac{3E}{r+R} = \frac{6}{3+3} = 1A$

SHORT ANSWER TYPE QUESTIONS

1. Define the term drift velocity and relaxation time. On the basis of electron drift derive an expression for drift velocity of free electrons in term of relaxation time.

Sol. Drift velocity - Drift velocity is the average uniform velocity acquired by free electrons inside a metal by the application of an electric field which is responsible for current through it.

Relaxation time (τ) : The time interval between two successive collisions of electrons with the positive ions in the metallic lattice is defined as relaxation time.



In a metallic conductor, the free electrons are in continuous random motion due to thermal energy. The net flow of electrons in any direction is zero. Therefore the average velocity of electrons is zero. $\vec{u} = 0$

In the presence of external electric field $\vec{E}$ the free electron experiences a force opposite to the direction of applied field.

The electric force on electron $\vec{F} = -e\vec{E}$

The acceleration produced in electron $\vec{a} = \frac{\vec{F}}{m} = -\frac{e\vec{E}}{m}$

Since electrons are colliding frequently with each other and atoms of metal, therefore they are accelerated only for a short time interval between two successive collisions (relaxation time τ).

The average velocity of electrons after relaxation time τ,

$$\vec{v} = \vec{u} + \vec{a}\tau \Rightarrow \vec{v} = 0 - \frac{e\vec{E}}{m}\tau \Rightarrow \vec{v} = -\frac{e\vec{E}}{m}\tau$$

This velocity is called drift velocity. $\therefore \vec{v}_d = -\frac{e\vec{E}}{m}\tau$

2. Define the term 'mobility' of charge carriers in a current carrying conductor. Obtain the relation for mobility in term of relaxation time.

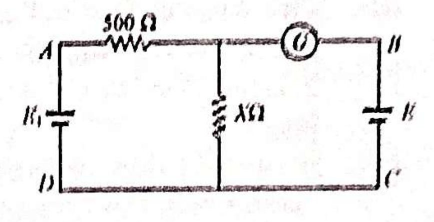
Sol. Mobility : Drift velocity per unit electric field is called mobility of electron *i.e.* $\mu = \frac{v_d}{E}$.

It's unit is $\frac{m^2}{volt-sec}$

$$V_d = \frac{-eE}{m}\tau$$

$$\mu = \frac{V_d}{E} = \frac{-e}{m}\tau, \quad \text{i.e.} \quad |\mu| = \frac{e}{m}\tau$$

3. In the adjoining circuit, the battery E_1 has an $e.m.f.$ of $12volt$ and zero internal resistance while the battery E has an $e.m.f.$ of $2volt$. If the galvanometer G reads zero, then the value of the resistance X in ohm is



Sol. For no current through galvanometer, we have

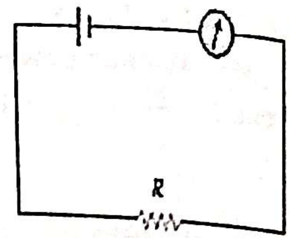
$$\left(\frac{E_1}{500+X}\right)X = E \Rightarrow \left(\frac{12}{500+X}\right)X = 2 \Rightarrow X = 100\ \Omega$$

CASE STUDY BASED QUESTIONS

Read the following paragraphs and answer the questions that follow.

Whenever an electric current is passed through a conductor, it becomes hot after some time. The

. Phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit the energy expended by the source entirely appears as heat. But if the circuit has an active element like a motor, then a part of the energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating form the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc



I. Alloys used for making standard resistance coils as alloys
   (a) have more conductivity
   (b) less conductivity
   (c) less temperature coefficient of resistivity
   (d) more temperature coefficient of resistivity

II. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Wire which gets heated up more is
   (a) Nichrome (b) copper
   (c) both gets heated up to same values (d) can't say

III. A 25 W and 100 W are joined in series and connected to the mains. The bulb which will glow brighter is
   (a) 25W as it has high resistance (b) 100 W as it has high resistance
   (c) 25W as it has low resistance (d) 100 W as it has low resistanc

IV. The heat emitted by an iron of 100 W in 1 minute is
   (a) 600J (b) 6000J (c) 60J (d)60000J

2. When electric field is applied across a conductor then the electrons move in the direction opposite to the electric field due to electric force on them. The average velocity with which free electrons get drifted in the direction opposite to the applied electric field inside a conductor is called drift velocity. This motion of the electrons in the direction opposite to the electric field is superimposed on their random motion. Drift velocity depends on electric field applied, the nature of material and temperature. On increasing the temperature, relaxation time decreases. Hence decrease in relaxation time, due to increase in temperature, will reduce the drift speed.

I. When a potential difference V be applied across a cylindrical conductor of length L and radius R, is doubled then the drift velocity of electrons gets:
   (a) doubled (b) four times (c) remain same (d) halved

II. Two wires made of same material but of different diameters are connected in series in a circuit. The current flows in the combination of wires. When the current flows from the wire with larger diameter to the one with smaller diameter then drift velocity of electrons:
   (a) will decrease (b) will increase
   (c) remains same (d) first will increase and after some time decrease

III. Two wires each of radius of cross section r but of different materials are connected together end to end (in series). If the densities of charge carriers in the two wires are in the ratio 1:4, the drift velocity of electrons in the two wires will be in the ratio:
   (a) 1 : 2 (b) 2 : 1 (c) 4 :1 (d) 1 : 4

IV. A current I flows through a uniform wire of diameter d when the electron drift velocity is v.The same current will flow through a wire of diameter d/2 made of the same material if the drift velocity of the electrons is
   (a)v/4 (b) v/2 (c) 2v (d) 4v

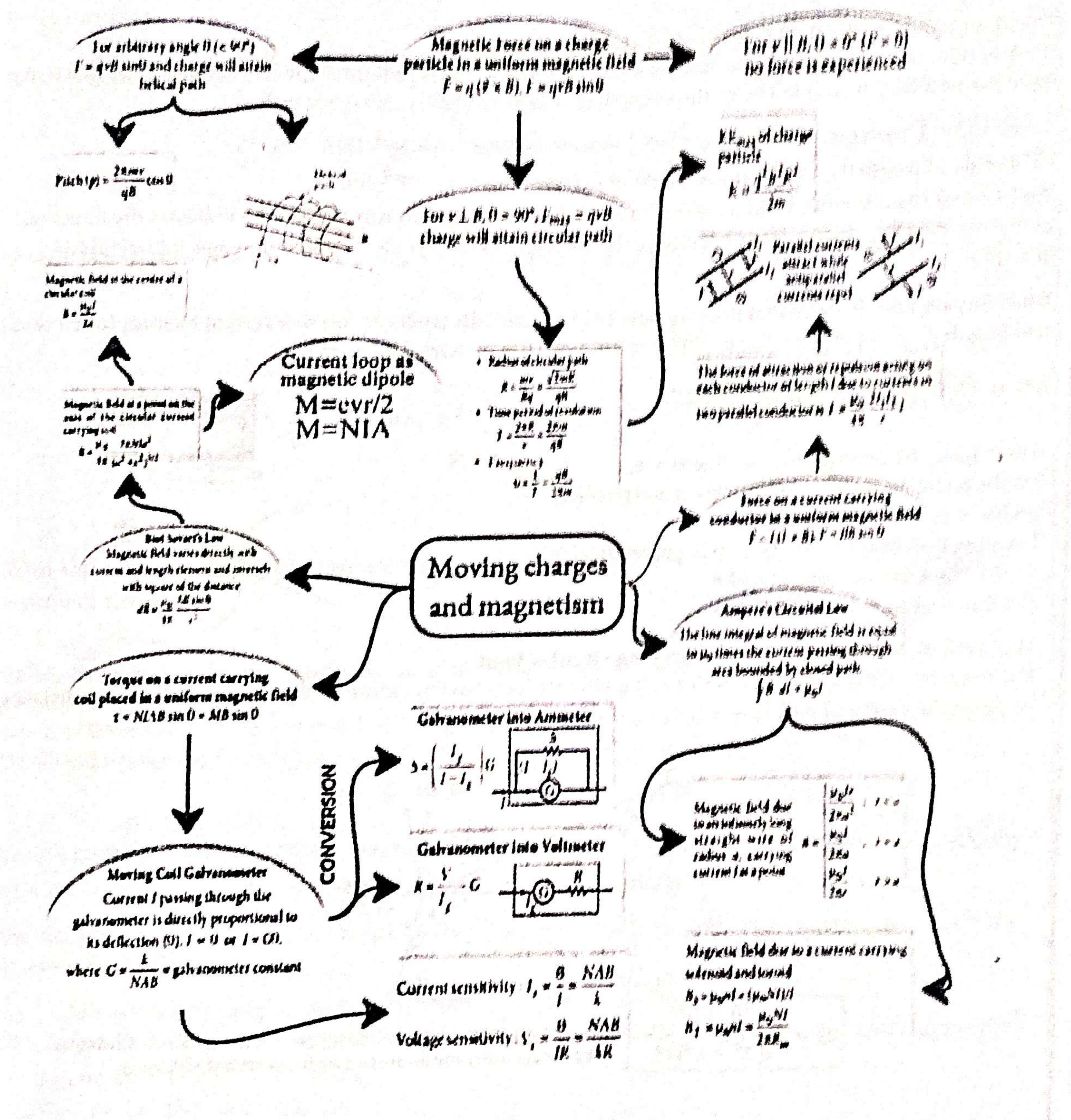
ANSWERS-

1	(i) c	(ii) a	(iii) a (iv) b
2	(i) a	(ii) b	(iii) c (iv) d

CHAPTER 4: Magnetic Effects of Current and Magnetism

Syllabus- Chapter–4: Moving Charges and Magnetism Concept of magnetic field, 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 solenoid (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields. 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 uniform magnetic field; Current loop as a magnetic dipole and its magnetic dipole moment, moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

MIND MAP



GIST OF THE CHAPTER

Magnetic field- It is a region of space around a magnet or a current carrying conductor in which it can exert force on other magnetic materials, moving charges, magnets and current carrying conductor.
A moving charge produces both electric and magnetic field while a stationary electron produces an electric field only.

SI Unit of Magnetic field-

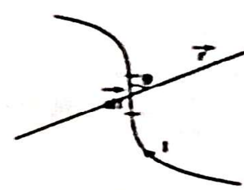
The SI unit of magnetic field is Wm^{-2} or T (tesla).
If 1A current is flowing through a straight conductor and it is kept at right angle to a magnetic field such that force per unit length on it is $1Nm^{-1}$ the strength of magnetic field is called one tesla.

1 tesla (T) = 1 weber meter^{-2} (Wbm^{-2}) = 1 newton ampere^{-1} meter^{-1} ($NA^{-1}m^{-1}$)
CGS units of magnetic field is called gauss or oersted. 1 gauss = 10^{-4} tesla.
Right hand thumb rule- Hold a conductor is Right Hand in such a way that thumb indicates the direction of current then the curled finger encircling the conductor will give the direction of magnetic field lines around it.

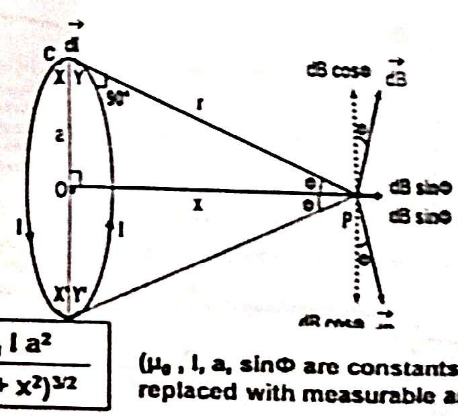
Biot- Savart law- It states that the magnetic field strength dB produced due to a current element (of current I and length dl) at a point having position vector r relative to current element is-

$$dB = \frac{\mu_0}{4\pi}\frac{(I\vec{dl}\times\vec{r})}{r^3} \quad or \quad dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

where μ_0 is the permeability of free space,
θ is the angle between current element and position vector r as shown in the figure.
The direction of magnetic field B is perpendicular
To the plane containing Idl and r
The value of $\mu_0 = 4\pi \times 10^{-7}$ Wb/A-m.



Magnetic field due to a current carrying circular loop –
The magnetic field due to current carrying circular loop having radius 'a',carrying current 'I' at a distance 'x' from the centre of coil is –



$$B = \frac{\mu_0 I a^2}{2(a^2 + x^2)^{3/2}}$$

(μ_0, I, a, sinΦ are constants, $\int dl = 2\pi a$ and r & sinΦ are replaced with measurable and constant values.)

In case of coil having N turn, B(coil) = N x B(loop)

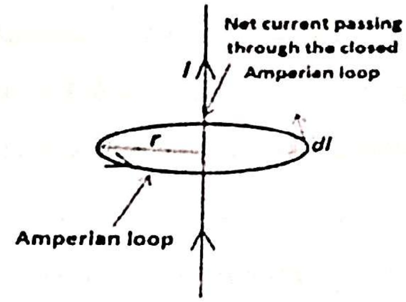
$$\therefore \quad B = \frac{\mu_0 I}{2a}$$

The magnetic field due to current carrying circular coil is along the axis. At the center, x=0

The direction of the magnetic field at the center is perpendicular to the plane of the coil.

Ampere's Circuital law - It states that line integral of magnetic field around any closed loop (called Amperean loop) is equal to μ_0-times the current (I) threading through that loop.

$$\oint \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$$



Magnetic field due to infinitely long straight wire using Ampere's law- Accordingto Ampere's circuital law.

$$\oint \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$$

$$B\,(2\pi r) = \mu_0 I$$

$$B = \frac{\mu_0 I}{2\pi r}$$

Straight solenoid- At the axis of a long solenoid, carrying current I, $B=\mu_0 nI$, where n = N/L = number of turns per unit length.

Force on a current-carrying conductor in a uniform magnetic field $\vec{B}$
Magnitude of force is $F = I\,L\,B\sin\theta$.
Direction of force is normal to and B & I ,given by Fleming's Left Hand Rule. If $\theta=0$ (i.e. I or L is parallel to $\vec{B}$), then the magnetic force is zero.

Force on a moving charge in uniform magnetic field-The force on a charged particle moving with velocity 'v' in a uniform magnetic field is given by $\vec{F} = q(\vec{v} \times \vec{B})$ or $F = qvb \sin\theta$

θ is the angle between velocity(**v**) and magnetic field(**B**). Force (**F**) is perpendicular to both **v** and **B**. (i) If **v** and **B** are parallel F=0

(ii) When v is perpendicular to B, i.e. $\theta = 90^0 \cdot F = qvB$ i.e F is maximum

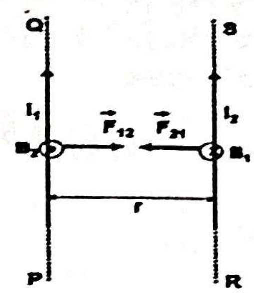
Lorentz force -The total force on a charged particle moving in co-existing electric field → and magnetic field → is given by $\vec{F} = q\,[\vec{E} + (\vec{v} \times \vec{B})]$
This is called the Lorentz force equation.

The direction of this force is determined by using Fleming's left hand rule

Fleming's Left Hand Rule- Stretch out the fingers in left hand such that the fore-finger, the central finger and thumb are mutually perpendicular to each other. When the fore-finger points in the direction of the magnetic field and the central finger points in the direction ofcurrent then thumb gives the direction of the force acting on the conductor.

Force between two long straight parallel current carrying conductors-

Two parallel current carrying conductors attract while they repel if current in them is anti-parallel. The magnetic forceper unit length on either current carrying conductor at separation a is given by

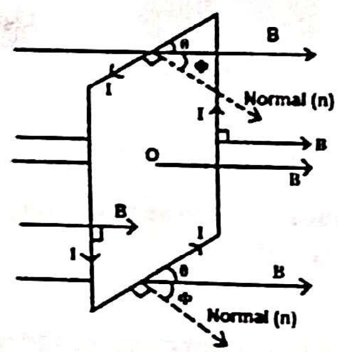


$$\frac{F}{l} = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}\ N/m$$

Definition of ampere: - *1 ampere is the current which when flowing in each ofthe two parallel wires in vacuum separated by 1 m from each other exert a forceof $2 X 10^{-7}$N/m on each other.*

Torque experienced by a current loop in uniform magnetic field-

A coil of N turns and area A is carrying current I is kept in a magnetic field as shown in figure as shown in figure. Force on it will be zero and torque on it will be



τ = NIBA cosθ

θ = angle between coil and magnetic field

If Φ = angle between Normal ($\hat{n}$) to coil and magnetic field (B)

, $\Phi + \theta = 90°$ so i.e. $\theta = 90° - \Phi$

So $\tau = NIAB\cos(90° - \Phi) = NIAB\sin\Phi$

$\tau = NIAB\sin\Phi$

As $\tau = MB\sin\Phi$ so $M = NIA$

In vector form $\vec{\tau} = NI(\vec{A} \times \vec{B})$

The unit of magnetic moment in SI system is Am^2.

The torque is *maximum* when the plane of the coil is *parallel to the magnetic field* and *zero*when the plane of the coil is *perpendicular to the magnetic field.*

Potential energy of a current loop in a magnetic field- When a current loopof magnetic moment M is placed in a magnetic field (B), then potential energy of magnetic dipole is

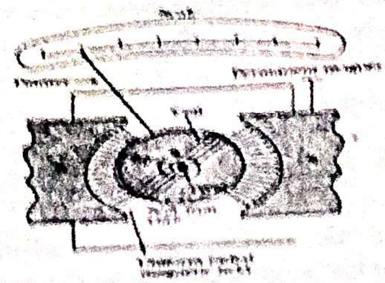
$$U = -MB\cos\theta = -\vec{M}.\vec{B}$$

When θ=0, U=-MB (minimum or stable equilibrium position)

When $\theta = 180°$, U=+MB (maximum or unstable equilibrium position)

When $\theta = 90°$, potential energy is zero

Moving coil galvanometer- A moving coil galvanometer is a device used to detect flowof current in a circuit. A moving coil galvanometer consists of a rectangular coil placed in an uniform radial magnetic field produced by cylindrical poles pieces.Torque on coil due to current



$$\tau = NIBA \sin\Phi$$

for a radial magnetic field $\sin\Phi = 1$ so $\tau = NIBA$

where N is the number of turns, A is the area of coil. If C is torsional rigidity of material of suspension wire. For deflection Φ, restoring torque $\tau = C\,\theta$. For equilibrium

$$NIAB = C\,\Phi \quad \text{or} \quad I = C\,\Phi/(NBA)$$

Clearly, deflection in galvanometer is directly proportional to current, so the scale of galvanometer is linear.

Use of radial magnetic field- when radial magnetic field is used the angle between the normal to the plane of loop (A) and magnetic field (B) $\Phi = 90^0$ for any orientation of loop, in a radial magnetic field the angular deflection of coil is proportional to the current flowing through it. Hence a linear scale can be used to determine the deflection of coil i.e. measurement of current.

Uses of galvanometer: (i) Used to detect electric current and direction of its flow in given branch of circuit. (ii) Usedto convert the ammeter by putting a low resistor in parellel. (iii) Used to convert voltmeterby putting a high resistor in series. (iv) Used as ohmmeter by making special arrangement

Current sensitivity: It is defined as the deflection of coil per unit current flowing in it.

$$\Phi/I = NBA/C$$

Voltage sensitivity: It is defined as the deflection of coil per unit potential

$$\Phi/V = NBA/RC$$

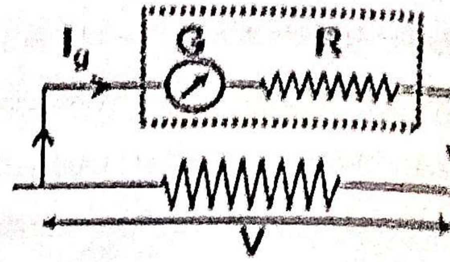
Conversion of Galvanometer into Ammeter: - A galvanometer can be converted into an ammeter by using a suitably small resistance in parallel with the galvanometer coil. The small resistance connected in parallel is called a shunt.If G is resistance of galvanometer, I_g is current in galvanometer for full scale deflection, then for conversion of galvanometer into ammeter of range I ampere,the shunt required can be found as

$I_g G = (I - I_g)S$ (As 'S' and 'G' are parallel combination)

So $S = \dfrac{I_g G}{(I - I_g)}$

Ammeter

Conversion of Galvanometer into Voltmeter: - A galvanometer may be converted into voltmeter by connecting high resistance (R) in series with the coil of the galvanometer. If V volt is the range of voltmeter formed, then series resistance is given by



$$V = I_g(R + G) \qquad \text{So } R = \frac{V}{I_g} - G$$

Magnetic moment due to a revolving charge or electron-

A current loop or a revolving charge can be considered as a magnet. The magnetic moment of such a loop is M= qvr/2.

The face from which current flow appears **anticlockwise** is the **north pole** of equivalent magnet with magnetic moment M. I.e magnetic moment is outward

If we have a coil having N turns carrying current I having A as area of cross-section the magnetic moment is given by *M= NIA*

For an electron moving in Hydrogen atom
M=evr/2
As per Bohr's theory of Hydrogen atom L= mvr = nh/2π n= 0,1,2,3,4.......... Where n is principal quantum number
M= -eL/2m

MULTIPLE CHOICE QUESTIONS

1 A proton and an alpha particle with same kinetic energy enters normally into a uniform magnetic field (B), the ratio of their radii of curvature of their path respectively will be

(a) More than 1 (b) 1 (c)Lesser than 1 (d) Dependent on the |B|

2 If a galvanometer of resistance R_g is connected with a shunt of resistance 'S' such that R_g=n.S the ratio of power consumed by R_g and S respectively will be

(a) n^2 (b) n (c) 1/n (d) $1/n^2$

3 A galvanometer of can measure current up to 200μA. if a resistor of 10Ω is connected across it the range of it enhances to 1mA.If a resistor of 20Ω is connected in place of 10Ω the range will be

(a) 2mA (b) 0.4mA (c) 0.5mA (d) 0.6mA

4 A charge enters into a uniform magnetic field with a K.E. 'E' and leaves it after some time. The K.E. of the charge while leaving the field will be

(a) Lesser than E (b) More than E (c) Equal to E (d) Lesser than or equal

5 An electric field is applied along positive Y-axis and a magnetic field along negative Z-axis. An electron moving through this region along positive X-axis will

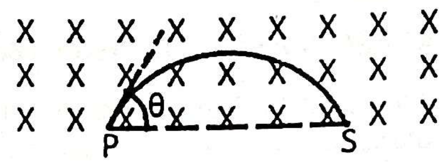
(a) Move undeflected (b) Deflect towards B (c) Deflect along E (d) Deflect against E

6 A positive charge moves parallel to flow of current in a long straight wire the charge will be

(a) Repelled by the wire (b) Attracted by the wire

(c) Unaffected by the wire (d) Oscillating

7 A particle of mass 'm' and charge 'q' enters at 'P' Into a uniform magnetic field 'B' and leaves it at 'S' as shown time spent by the charge inside the field will be



(a) $2m\theta/qB$
(b) $2m/qB$
(c) $2m/\theta qB$
(d) $m\theta/qB$

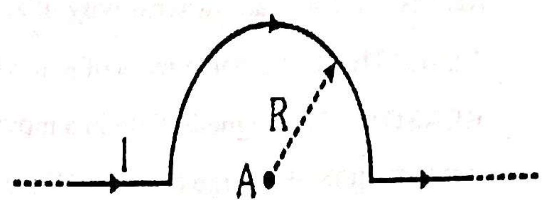
8 In a moving coil galvanometer the current sensitivity is given by

(a) NBA/C (b) C/NBA (c) NBA/CR (d) NBR/C

9 The magnetic field at a point due to a long straight wire carrying current I is B. A circular loop carries same current. For same magnetic field at its center the radius of the circular loop shall be

(a) 2a (b) a (c) a/2 (d) much more than 'a'

10 In the shown figure magnetic field at point A will be



(a) $\frac{\mu_0 I}{4\pi}$ (b) $\frac{\mu_0 I}{4R}$ (c) $\frac{\mu_0 I}{4\pi R}$ (d) Zero

SOLUTIONS-

1-b $(\sqrt{m})/q$ is same for both and $r = (\sqrt{2mE})/qB$
2-c $P \alpha R^{-1}$ as 'V' is constant
3-d $S_1 = I_g R_g/(I_1 - I_g)$ so $S_1/S_2 = (I_2 - I_g)/(I_1 - I_g)$
4-c F perpendicular to v so no work is done and work done = change in KE =0 and
5-d $F = q(\mathbf{v} \times \mathbf{B})$ and flemming's left hand rule
6-b Right hand palm rule and flemming's left hand rule
7-a $T = 2\pi m/qB$ arc makes an angle 2θ at center so replace 2π by 2θ
8-a equilibrium of deflection needle in galvanometer requires

$C\theta = NIBA$ so $\theta/I = NBA/C$

9-b compare result for B due to circular loop and long straight wire
10-b $B = B_0/2$ and $B_0 = \mu_0 I/2r$ for full circle

ASSERTION –REASON QUESTIONS

1 ASSERTION- The magnetic field at a point due to long straight current carrying wire is inversely proportional to the of distance

REASON- Magnetic field at a point due to a current element is inversely proportional to the distance

2 ASSERTION- When a charge moves in a uniform magnetic field its kinetic energy doesn't change.

REASON-Lorentz force on the charge is normal to velocity at every point.

3 ASSERTION-A current carrying coil in a uniform magnetic field feels maximum torque when it is kept in the field parallel to its plane

REASON-Torque on a current carrying coil in magnetic field does not depend on the shape of the coil.

4 ASSERTION-The current sensitivity(Is) of a moving coil galvanometer is proportional to its voltage sensitivity(Vs).

REASON- Both are inversely proportional to resistance of the coil

5 ASSERTION- The magnetic field falls as inverse square with distance as me move from the axis to the surface of a long Current carrying bar.

REASON-The current density causing the magnetic field is falling as we move from axis to surface

6 ASSERTION- The magnetic moment of electron in outer orbit of Hydrogen atom is higher

REASON- The kinetic energy of electrons in outer orbit Hydrogen atom is lower

7 ASSERTION- The resistance of a milli-ammeter is higher than the resistance of an ammeter

REASON- The current sensitivity of an ideal ammeter shall be zero

8 ASSERTION-The pole pieces of a moving coil galvanometer are cylindrical.

REASON- The magnetic field in a moving coil galvanometer shall be radial in nature

9 ASSERTION-A charge fired at oblique incidence in magnetic field moves along a helical path such that axis of helix and magnetic field are at right angle.

REASON-The radius and pitch of helix is independent of angle of projection with respect to the magnetic field

10 ASSERTION- A current carrying wire in magnetic field experiences a force

REASON- A charge moving in magnetic field experience a Loretz force

SOLUTIONS

1-b 2-a 3-b 4-d 5-c 6-b 7-c 8-a 9-d 10-a

SHORT ANSWER (2 MARKS)

1 An insulated circular loop carrying current is placed on a table and a light straight long wire carrying current is kept on it parallel to the diameter. Can the wire be pushed up by loop? Explain

2 Can a magnetic monopole exist in nature? Give reason

3 Write the Expression for magnetic field in a long solenoid. Draw the magnetic field for a solenoid having finite length. What is the ratio of magnetic field near the end and well inside it.

4 An arc of a circle of radius 10cm subtends angle 60^0 at its center. Find the magnetic field at the center if current in arc is 30A

5 A positive charge 'q' moves along X- axis with a speed 'v'. if largest Lorentz's force 'F' on it due to uniform magnetic field 'B' is along –Z axis. Find the magnitude and direction of magnetic field.

6 The velocity of a charge fired into a magnetic field normally is doubled. How would this effect the frequency of motion and curvature of path followed by the charge in magnetic field? Explain

7 A charge is moving in magnetic field in a circular orbit. Give the expression for its KE in terms of applied external magnetic field.How would the Kinetic energy be affected if it is made to move in a magnetic field of double the strength ? Explain.

8 A long solenoid has a magnetic field of 0.25T inside it. If a bar of magnetic susceptibility 5 is inserted into it what will be the magnetic flux density inside it?

9 The torsional constant of the hair spring in MCG is increased what will be the affect on voltage. sensitivity of it due to this? Give reason.

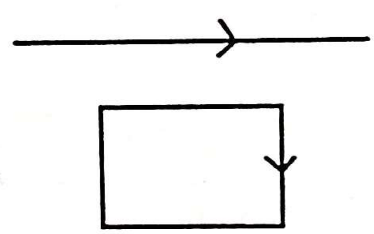
10 A proton, neutron electron and alpha particle enters normally into a magnetic field of uniform nature with same momentum directed into the plane of paper. Draw suitable diagram to indicate their paths.

SOLUTION

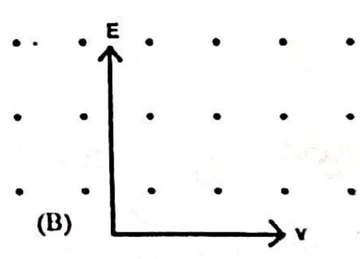
1-No Lorentz force is parallel to wire for all cases
2- No , A loop having clockwise current from one side will appear anticlockwise from other face of it
3- B = μonI and near ends it is halved , usual figure from NCERT
4- B= μoIθ/4πr where θ in radians only, 3.14 x10^{-5} T
5- -y axis and B= F/qB (use Lorentz force in vector form)
6- No change 'f' doesn't depend on speed
7- KE = $(qBr)^2/2m$, No change because change of B affects r in inverse ratio
8- μ_r =1 +X_m = 6 so B= 0.25 x 6 = 1.5T
9- V.S. = θ/V = NBA/CR C rises V.S. decreases
Conceptually stiff hair spring will not allow the needle to move if voltage is low i.e Voltage sensitivity has decreased.
10- r = p/qB , neutron goes

SHORT ANSWER (3 MARKS)

1- A square loop of side 'a' is kept near a long charged wire in a plane such that a side of it is parallel to the wire (kept in same plane) at a distance 'a' from it. Find the force on the wire due to the loop. If Current in wire is I_1 and in loop is I_2 in clockwise direction



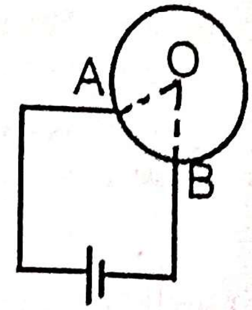
2- In a region of crossed electric (E) and magnetic(B) fields many particles of same mass but charge (positive, negative or neutral) are fired into a direction normal to both **E** and **B** with their velocity in the range 5m/s to 500m/s as shown in the figure . if E is 80v/m and B is 0.4T which of these can pass through the region without any deflection?



Draw figure to show path of positive and negative charged particles moving with 40m/s and 400m/s respectively

3 Two electrons are moving along parallel lines separated by 'r' with (i) same speed (v) . In which case force on an electron due to other will be more (a)in its own frame of reference (b) with respect to the ground. Give reason

4 Show that the magnetic field at the center is zero irrespective of the resistance of circular loop and irrespective of the angle made by arc AB at 'O'

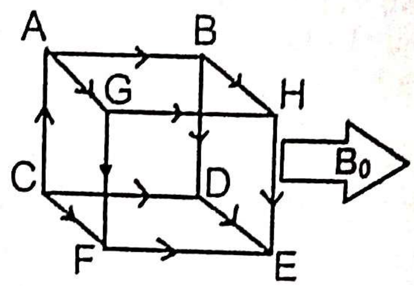


5 Use ampere's circuital law to find magnetic field due to along straight wire. Can we use it if wire is finite? Give reason

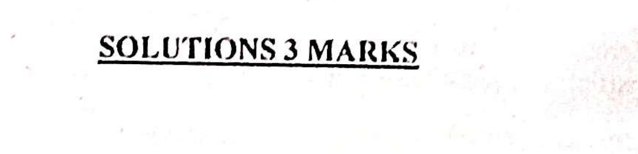
6 What is a radial magnetic field? Why do we need it in moving coil galvanometer?

Changing current sensitivity of a moving coil galvanometer may or may not affect its voltage sensitivity. Explain

7 A cube ABCDEFGH is kept in a uniform magnetic field B_0 shown. Determine the direction of force on each side. Which side(s) will experience minimum force?



8 The resistance of galvanometer is Rg and its full scale deflection current is Ig. For safety purpose a fuse of resistance 'R' is joined with it.To convert it to an ammeter of suitable range which is the correct way (a) or (b)? If he/she connects 'S' the wrong way what will be the new range of the device.



(a) connect 'S' between P and Q
(b) Connect 'S' between P and M

SOLUTIONS 3 MARKS

1. $\frac{F}{a} = \frac{\mu_0 2 I_1 I_2}{4\pi}\left[\frac{1}{a} - \frac{1}{2a}\right]$

Or $\frac{F}{a} = \frac{\mu_0 2 I_1 I_2}{4\pi}\left[\frac{a}{2a}\right]$

Or $F = \frac{\mu_0 I_1 I_2 a}{4\pi}$ attractive

2. for no deflection qE = qvB

v = E/B = 200 m/s these will go undeflected

For v< 200m/s qE > qvB

positive particle deflects along E field and negative particles deflect against electric field.

For v> 200m/s qE < qvB positive particle deflects against E field and negative particles deflect along E field.

3. In Earth Frame of reference electron experiences electric and magnetic force both. These forces will be in opposite direction and for electron's frame of reference (F O R) there is only one force electric force .

Hence in earth F.O.R. lesser force.

4. Let current splits and I_1 goes in smaller arc and $I - I_1$ in bigger arc such that

$V_{\text{small arc}} = V_{\text{big arc}}$

$I_1 R_1 = I_2 R_2$

$$\frac{I_1 \rho l_1}{A} = \frac{I_2 \rho l_2}{A}$$

$$I_1 l_1 = I_2 l_2$$

Now $B_1 = \frac{\mu_0}{4\pi} \frac{I_1}{r} \theta$

$$B_2 = \frac{\mu_0}{4\pi} \frac{I_2}{r} (2\pi - \theta)$$

Here $\theta = \frac{l_1}{r}$ and $2\pi - \theta = \frac{l_2}{r}$

Using in B_1 and B_2, we get

$$I_1 l_1 = I_2 l_2$$

Therefore $B_1 = B_2$

i.e. $B_1 - B_2 = 0$

5. $\oint B.dl = \mu_0 I$

$B\, 2\pi r = \mu_0 I$

$$B = \frac{\mu_0 I}{2\pi r}$$

No, as the symmetry condition is violated for any general point near the wire of finite length violated.

6. B parallel to plane of the coil is called radial magnetic field.

So that torque α current

Vs = NBA/CR

Is = NBA/C

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$$B = \frac{\mu_0 I}{2\pi r}$$

No, as the symmetry condition is violated for any general point near the wire of finite length violated.

6. B parallel to plane of the coil is called radial magnetic field.

So that torque α current

$V_s = NBA/CR$

$I_s = NBA/C$

Or $F = \frac{\mu_0 I_1 I_2 a}{4\pi}$ attractive

2. for no deflection $qE = qvB$

$v = E/B = 200$ m/s these will go undeflected

For v< 200m/s $qE > qvB$

positive particle deflects along E field and negative particles deflect against electric field.

For v> 200m/s $qE < qvB$ positive particle deflects against E field and negative particles deflect along E field.

3. In Earth Frame of reference electron experiences electric and magnetic force both. These forces will be in opposite direction and for electron's frame of reference (F O R) there is only one force electric force.

Hence in earth F.O.R. lesser force.

4. Let current splits and I_1 goes in smaller arc and $I-I_1$ in bigger arc such that

$V_{small\ arc} = V_{big\ arc}$

$I_1R_1 = I_2R_2$

$\frac{I_1\rho l_1}{A} = \frac{I_2\rho l_2}{A}$

$I_1l_1 = I_2l_2$

Now $B_1 = \frac{\mu_0}{4\pi}\frac{I_1}{r}\theta$

$B_2 = \frac{\mu_0}{4\pi}\frac{I_2}{r}(2\pi - \theta)$

Here $\theta = \frac{l_1}{r}$ and $2\pi - \theta = \frac{l_2}{r}$

Using in B_1 and B_2, we get

$I_1l_1 = I_2l_2$

Therefore $B_1 = B_2$

i.e. $B_1 - B_2 = 0$

5. $\oint B.dl = \mu_0 I$

$B\, 2\pi r = \mu_0 I$

$B = \frac{\mu_0 I}{2\pi r}$

No, as the symmetry condition is violated for any general point near the wire of finite length violated.

6. B parallel to plane of the coil is called radial magnetic field.

So that torque α current

$V_s = NBA/CR$

$I_s = NBA/C$

(i) If N rises both rises.
(ii) IF R rises V.S. falls but C.S. does not change.
So it depends on how change is brought about.

7. $F_{AB} = F_{GH} = F_{FE} = F_{CD} = 0 \quad (\theta = 0^{\circ})$

$F_{AC} = F_{GH} = F_{HE} = F_{BD} = +k$

$F_{AB} = F_{AB} = F_{AB} = F_{AB} = +j$

8. correct way is to join 'S' between PQ

$S = \frac{I_g R_g}{I - I_g}$ or $I = I_g\left(\frac{R_G}{S} + 1\right)$

Range becomes I when joined 'S' across 'PQ'

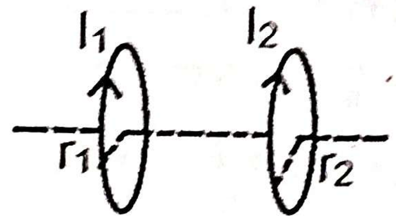
When S is connected the wrong way i.e. between PM

If $S = \frac{I_g(R_g + R)}{I - I_g}$

$I' = I_g\left[\frac{1 + R + R_g}{S}\right]$

LONG ANSWER (5 MARKS)

State Biot-Savart's law. Express it in vector form. Find the magnetic field at the mid-point if gap between the coils is 2a having N turns each.(see figure) Draw graph to show variation of B with distance between the coils.



2 Draw the diagram of a moving coil galvanometer. Give its principle.

A student needs to perform an experiment on OHM's law but he was given two galvanometers and variable resistors of all possible values along with a multimeter.

How would he be able to perform his task? Give the formula he should use to find the value of variable resistors to be used and draw relevant circuits to show the modifications to be undertaken by him

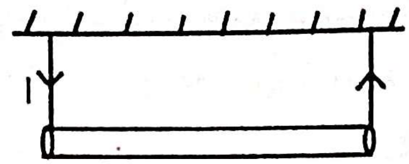
Two ammeters X and Y has resistance of 50 ohm and 80ohm if same current is sent in them which of two will show a greater deflection? Explain

3 Show that a current carrying coil in magnetic field experiences a torque. Hence find the expression for magnetic moment of the coil? Does the torque on the coil depend on the shape of the coil?

4 Derive the formula for Force per unit length between two long straight parallel wires. Define one ampere using your result.

A rectangular coil of size 40cm x 50 cm having 500 turns is carrying current of 5A. it is kept in a uniform magnetic of 0.2T field making an angle of 60^{0} from the plane of coil. Find the force and torque on the coil.

5 Figure shows a metal bar of length 'L' and mass 'm' in equilibrium in the plane of paper when a uniform magnetic field 'B' acting outward from the plane of paper. Find the magnitude of tension in each wire.



(a) What will be the tension in each wire if magnetic field is turned inward?
(b) The uniform magnetic field is made to rotate about an axis in the plane of paper perpendicular to the bar with a constant angular velocity ω. Draw a graph to show the rate of change of tension

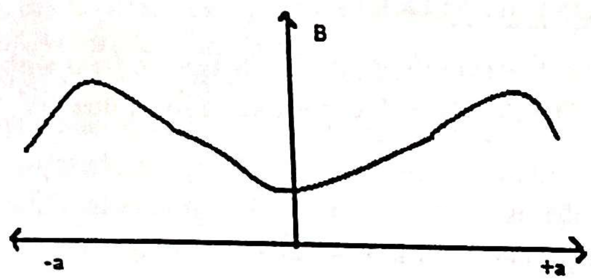
ANSWERS TO LONG ANSWER TYPES QUESTIONS:

1. $B = B_1 + B_2$

$$B_1 = \frac{\mu_0}{4\pi}\frac{2\pi N I_1 r_1^2}{(r_1^2 + a^2)^{\frac{3}{2}}}$$

where similarly B_2 can be written

so total $B = B_1 - B_2$ as they act opposite to each other

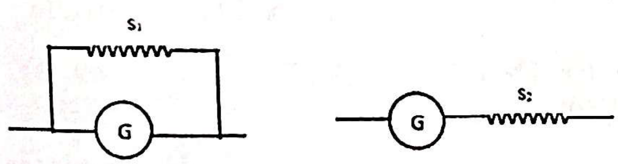


2. He will calculate Shunt / resistor Required

$$S = \frac{I_g R_g}{I - I_g}$$

Low 'S' in parallel to make ammeter

High 'S' in series to make voltmeter $S = (V/I_g) - R$



$S_1 << S_2$

50Ω will show higher deflection as it is closer to ideal behavior of an ammeter.

$I = \frac{E}{R_c + R_g}$; Where Rc = Circuit Resistance

3. $\tau = NIAB\sin\theta$ or $mB\sin\theta = NIBA\sin\theta$

Or m = NIA, No

4. $\frac{F}{L} = \frac{\mu_0}{4\pi}\frac{2I_1 I_2}{r}$

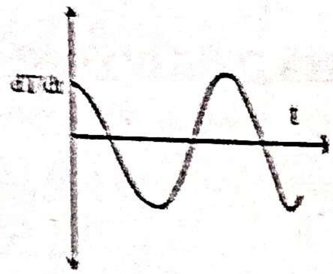
Definition of 1A: If $I_1 = I_2 = 1$ A, r = 1m then F/L = $\frac{\mu_0}{2\pi} = 2 \times 10^{-7} N/m$

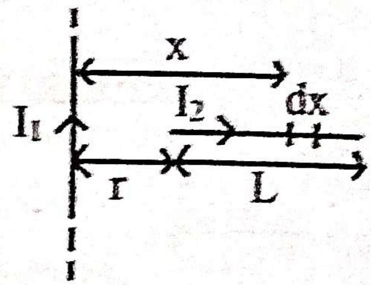
$\tau = NIAB \sin\theta = 50\ Nm$

5. $2T = mg + IBL \sin\theta$ (when B is outwards) ———— eq (i)

(a) if B is acting inwards $2T = mg - IBL \sin\theta$

(b) by eq (i) $\frac{dT}{dt} = 0 + IBL\cos\theta \frac{d\theta}{dt} = IBL\omega \cos\omega t$





SOURCE BASED QUESTIONS (4 - MARKS)

Q1 Two particles of same mass having charges q_1 and q_2 ($q_1 > q_2$) are fired into in a magnetic field with velocity v_1 and v_2 at angle θ and α respectively ($90^0 > \alpha > \theta$). The charges will experience a force due to magnetic field and that decides the path charge will follow.

(i) The locus of charges in magnetic field will be a path that is

(a)Helical (b) linear (c) circular (d) parabolic

(ii) In a case where path is helical the pitch will be same for both provided

(a) $v_1 = v_2$
(b) $v_1 \sin\alpha = v_2 \sin\alpha$
(c) $v_1 \cos\theta = v_2 \sin\alpha$
(d) $v_1 \cos\theta = v_2 \cos\alpha$

(iii) The radius of curvature of the path followed by the charges will be same if

(a) $v_1 / v_2 = \cos\alpha / \cos\theta$
(b) $v_1 / v_2 = \sin\alpha / \sin\theta$
(c) $v_1 / v_2 = \cos\theta / \cos\alpha$
(d) $v_1 / v_2 = \sin\theta / \sin\alpha$

(iv) If the magnetic field is varying with time which of the following is correct

(a)The K.E of both the particles will not change with time

(b) The K.E of both the particles may vary with time

(c) The angular frequency of both the particles will have a ratio $\sin\theta/\sin\alpha$

(d) The magnetic Lorentz force will be normal to velocity all the time

OR

The locus of path will be will have an axis of symmetry

(a) If and only if $\theta + \alpha = 180^0$

(b) If and only if $\theta + \alpha = 90^0$

(c) Along the direction of magnetic field

(d) Normal to the direction of magnetic field

Q2 A moving coil galvanometer (MCG) is a parent device that can work as an ammeter or voltmeter after suitable external modification. In practical cases a galvanometer can measure current only upto few hundred μA and voltage upto few mV so they are not much useful for measurements. R_1 and R_2 ($R_1 < R_2$) are two resistors that are available for modifying a galvanometer into an ammeter or voltmeter.

(i) When a galvanometer is converted to a voltmeter its voltage sensitivity is

(a) Decreased

(b) Doesn't change

(c) Increased

(d) May increase or decrease as per the value of R_2

OR

To convert MCG to a voltmeter of suitable range we must use

(a) R_1 in series (b) R_2 in series (c) R_1 in parallel (d) R_2 in parallel

(ii) A voltmeter with higher resistance but same range will show

(a) Greater deflection and lower voltage sensitivity (b) Lesser deflection and higher voltage sensitivity

(c) Greater deflection and higher voltage sensitivity (d) Lesser deflection and lesser voltage sensitivity

(iii) A student argues even if we modify an MCG into an ammeter of range 0 to I it never knows about the modification done. The current I (I >Ig) isn't passing through the galvanometer. Galvanometer is still permitting Ig current and the extra current (I-Ig) is not passing through the galvanometer in reality so the deflection is not a true measurement of current sent into the system. The best logic that can resolve the issue is - Student's argument is

(a) incorrect as current sensitivity is constant
(b) incorrect as network has a lower resistance than before
(c) correct and the device is merely calibrated after modification
(d) Correct as voltage sensitivity of it increases proportionally.

(iv) A galvanometer is converted to an ammeter of range I_1 using S_1 and I_2 using S_2. If $S_1 = xR_g$ and $S_2 = yR_g$ the ratio of I_1 and $_2$ will be

(a) x/y (b) y/x (c) y(1+x))/[x(1+y)] (d) y(1-x)/[(x(1-y)]

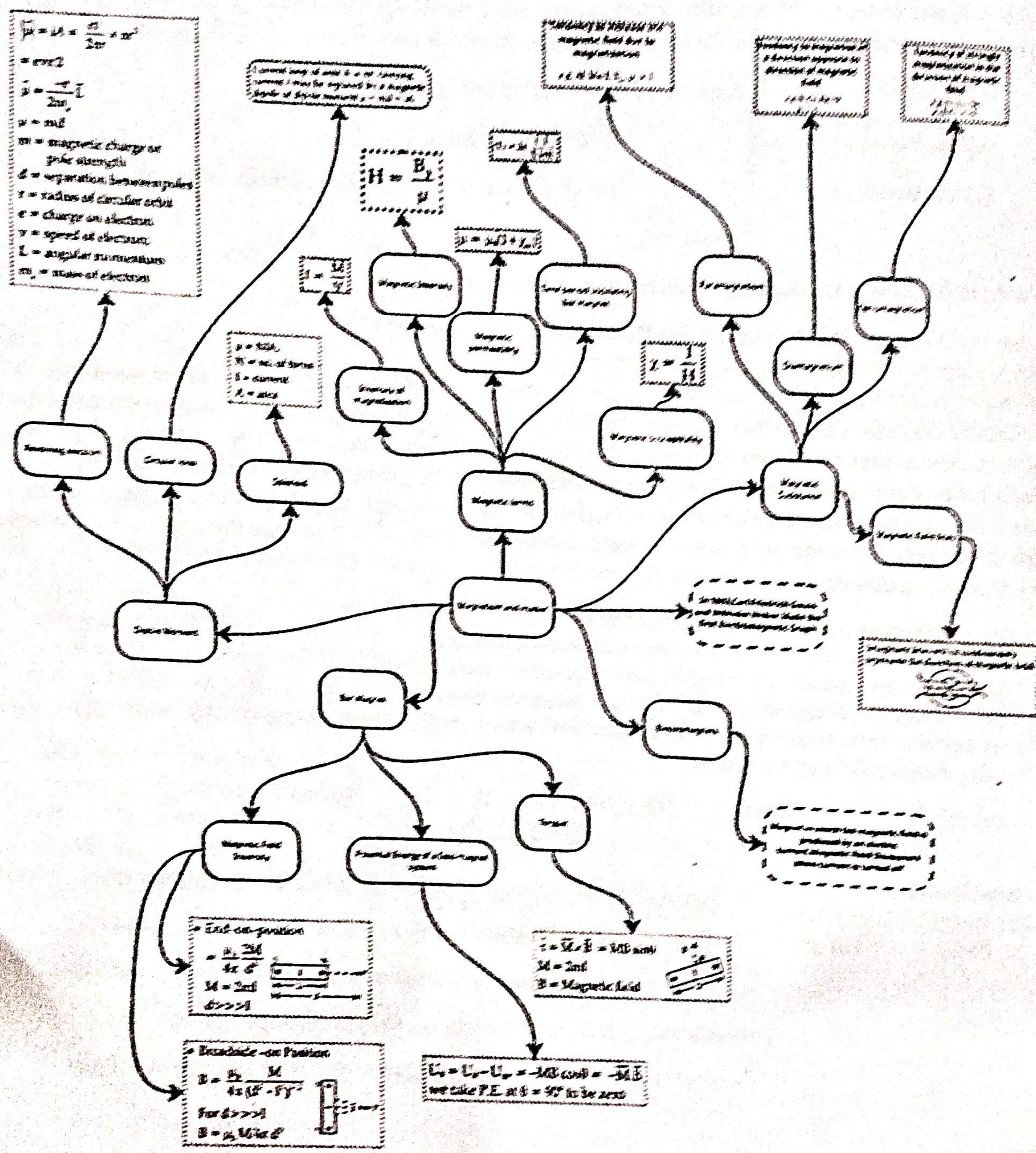
SOLUTIONS-

Case Study:

1. (i) (a) (ii) (c) (iii) (d) (iv) (b) or (c)
2. (i) (c) (ii) (c) (iii) (b) or (c) (iv) (a)

CHAPTER 5: MAGNETISM AND MATTER

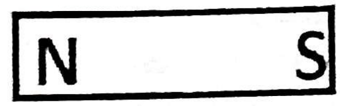
Magnetism- Magnetism is the study of with the properties magnets and magnetic materials along with their behavior and properties. The Earth itself acts like a giant magnet. With the development of atomic sciences we have come to know that magnetic effects are due to moving charges or electrons. It was discovered that some materials in nature has a natural ability to attract iron towards it. These materials are called natural magnets. These were used mainly for navigation in earlier times.



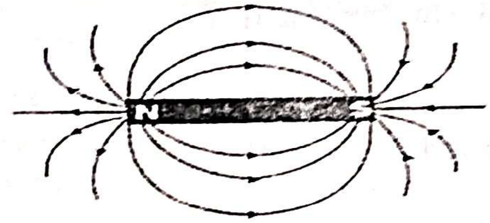
GIST OF THE CHAPTER

Magnetism- Magnetism is the study of the properties of magnets and magnetic materials along with their behavior and properties. The Earth itself acts like a giant magnet. With the development of atomic sciences we have come to know that magnetic effects are due to moving charges or electrons. It was discovered that some materials in nature has a natural ability to attract iron towards it. These materials are called natural magnets. These were used mainly for navigation in earlier times.

Bar magnet- Natural magnets can be mould into various shapes like bars, cylinder, horse-shoe etc.for different purposes. Bar is just one such shape. Such magnets are called bar magnets. So we can say that a bar magnet is a rectangular piece of an object, made of ferromagnetic substances, that shows permanent magnetic properties. It has two poles - North and South. These poles are always in pairs even if we keep splitting the magnet into smaller and smaller parts



Magnetic field- The region of space around a magnet in which it can influence other magnets is called its magnetic field. Magnetic field is represented by closed continuous curves called magnetic field lines.



A tangent at any point on magnetic field line gives the direction of magnetic field at that point. These curves are called magnetic field lines.

Magnetic field lines of a bar magnet appear to emanate from North pole and enter into its south pole but forms complete loop (considering them inside the magnet too).Inside the magnet their direction is from S pole to N- pole while outside its N-pole to S-pole

<u>The properties of magnetic lines of force are as follows</u>:

Magnetic field lines emerge from the north pole and merge at the south pole.

As the distance between the poles increases, the density of magnetic lines decreases.

The direction of field lines inside the magnet is from the South Pole to the NorthPole. Magnetic lines do not intersect with each other. The strength of the magnetic lines is the same throughout and is proportionalto how close are the lines.

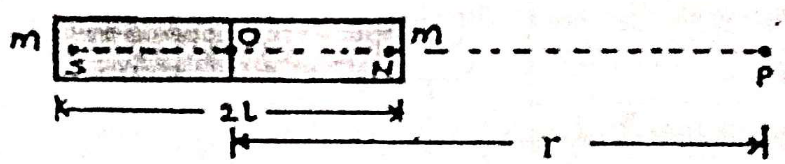
Magnetic dipole- A magnetic system like a bar magnet is essentially a magnetic dipole as its poles are not separable.

Magnetic dipole moment- It is a vector quantity having magnitude m x l where m is pole strength of each pole of magnet and l is effective length of the magnet. It is directed from South pole towards North pole of magnet

$|M| = m \times l$, SI unit of M and m are Am^{-2} and Am^{-1} respectively

Key Points:

- B it is magnetic induction or magnetic flux density
- H = magnetizing force or intensity of magnetizing field
- $B = \mu H$ for a material medium for vacuum $B_0 = \mu_0 H$
- $B/B_0 = \mu/\mu_0 = \mu_r$ is called relative magnetic permeability
- 'I' is called intensity of magnetization it is equal to magnetic moment developed per unit volume in the sample. $I = M/V$ SI unit of I is A/m
- Magnetic susceptibility (χ_m) – Ratio of intensity of magnetization (I) and intensity of magnetizing field (H) is called magnetic susceptibility. It has no units
- $\mu = \mu_0 (1+\chi_m)$
- Magnetic field lines emerge from the North pole and enter the South pole. But they completes their loop inside the magnet.
- Magnetic dipole moment (M): $M = m \times 2l$ (direction is from S pole to N pole)
- Magnetic field on axial line:



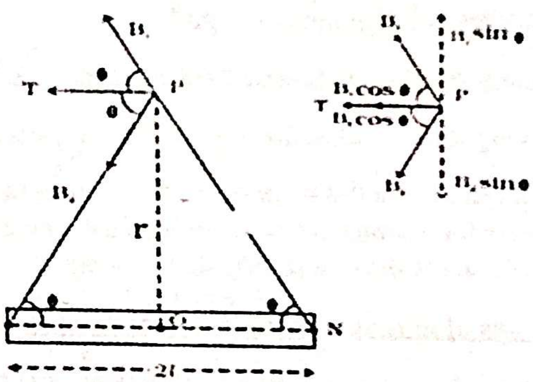
$B = (\mu_0 / 4\pi) \times (2M / r^3)$

B and M are parallel

- Magnetic field on equatorial line:

$B = (\mu_0 / 4\pi) \times (M / r^3)$

B and M are anti-parallel



Torque on a Magnetic Dipole: $\tau = M \times B$ such that $\tau = MB \sin\theta$

- Potential Energy: $U = -M . B$ or $U = -MB\cos\theta$
- Work done to rotate a magnet in magnetic field

$W = -MB (\cos\theta_2 - \cos\theta_1)$
- Gauss Law of Magnetism essentially states that the magnetic flux through a closed surface/loopis zero. i.e. $\oint \vec{B}.\vec{ds} = 0$ It means magnetic monopoles do not exist in nature
- A bar magnet of magnetic moment M is equivalent to a coil of magnetic moment NIA
- Magnetic moment of charge moving in a circle is M= qvr/2

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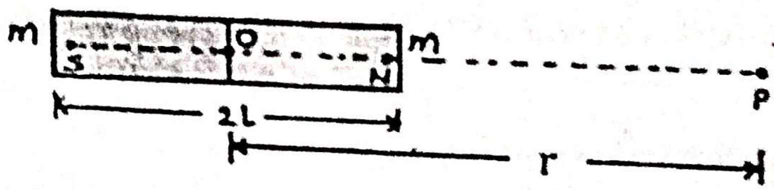

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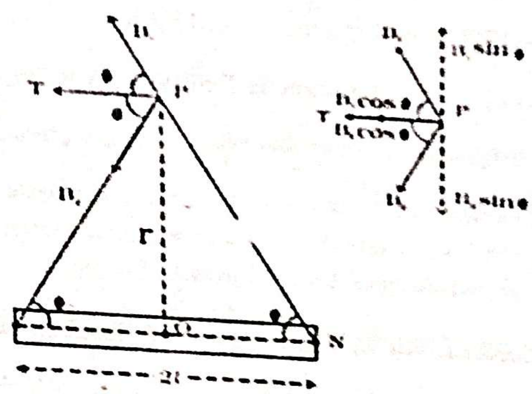
B and M are parallel



- Magnetic field on equatorial line:
  $B = (\mu_0 / 4\pi) \times (M / r^3)$
  B and M are anti-parallel

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