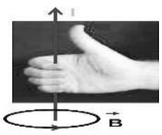
# UNIT III MAGNETIC EFFECTS OF CURRENT AND MAGNETISM

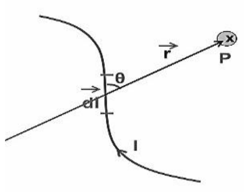
## CH 4– MOVING CHARGES AND MAGNETISM

## GIST OF LESSON

1. **Magnetic field**- A magnetic field is associated with an electric current flowing through a metallic wire. This is called the magnetic effect of current. On the other hand, a stationary electron produces an electric field only.
2. **SI Unit of Magnetic field**-
   The SI unit of magnetic field is $Wm^{-2}$ or T (tesla). The strength of magnetic field is called one tesla, if a charge of one coulomb, when moving with a velocity of 1 $ms^{-1}$ along a direction perpendicular to the direction of the magnetic field experiences a force of one newton.
3. 1 tesla (T) = 1 weber meter$^{-2}$ ($Wbm^{-2}$ ) = 1 newton ampere$^{-1}$ meter$^{-1}$ ($NA^{-1}$ $m^{-1}$)
4. CGS units of magnetic field is called gauss or oersted.
5. 1 gauss = $10^{-4}$ tesla.
6. **Right hand thumb rule-** Hold a conductor is Right Hand in such a way that thumb indicates the direction of current and curled finger encircling the conductor will give the direction of magnetic field lines.
7. **Biot- Savart law**- It states that the magnetic field strength B produced due to a current element (of current I and length dl) at a point having position vector r relative to current element is-



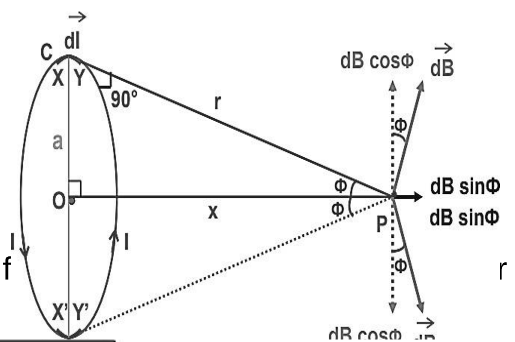
$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2} \quad \text{or} \quad dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$




   where $\mu_0$ 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.

8. **Magnetic field due to a current carrying circular loop** –
   (a) The magnetic field due to current carrying circular coil of N-turns, radius a, carrying current I at a distance x from the centre of coil is –




   (b) The magnetic f r coil is along the axis. At center, x=0

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

**($\mu_0$ , I, a, sinΦ are constants, ∫dl = 2πa and r & sinΦ are replaced with measurable and constant values.)**

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

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

9. **Ampere's circuital law-** It states that the line integral of magnetic field $\vec{B}$ along a closed boundary of an open surface is equal to $\mu_0$-times the current (I) passing through the open surface with closed boundary.

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_0$$

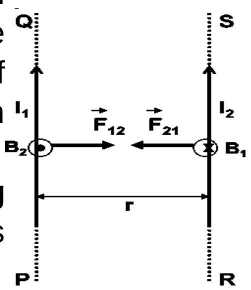
10. Magnetic field due to infinitely long straight wire using Ampere's law- According to Ampere's circuital law.

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_0$$

11. 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.
    Tip - When we look at any end of the coil carrying current, If the current is in anticlockwise direction then that end of the coil behaves like north pole, and If the current is in clockwise direction then that end of the coil behaves like the south pole.
12. **Force on a current-carrying conductor in a uniform magnetic field $\vec{B}$**
    Magnitude of force is F = IlBsinθ.
    Direction of force is normal to and $\vec{}$ given by Fleming's Left Hand Rule. If θ = 0 (i.e. is parallel to $\vec{B}$), then the magnetic force is zero.

13. **Force on a moving charge in uniform magnetic field**-The force on a charged particle moving with velocity in a uniform magnetic field $\vec{}$ is given by $\vec{F}$ = qvBsinθ.
14. . The direction of this force is perpendicular to both v and $\vec{B}$ ,
    When v is parallel to $\vec{B}$ ,ie θ=0, then $\vec{F}=0$
    When v is perpendicular to $\vec{B}$ , ie θ=90, then $\vec{F}$ is maximum, i.e., F=qvB

    Lorentz force -The total force on a charged particle moving in simultaneous electric field $\vec{}$ and magnetic field $\vec{}$ is given by $F= qvB + qE$
    This is called the Lorentz force equation.
15. The direction of this force is determined by using Fleming's left hand rule **Fleming's Left Hand Rule**- Stretch the 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 of current then thumb gives the direction of the force acting on the conductor.




16. **Force between two parallel current-carrying conductors-** Two parallel current carrying conductors

attract while antiparallel current carrying conductors repel. The magnetic force per unit length on either current carrying conductor at separation a is given by

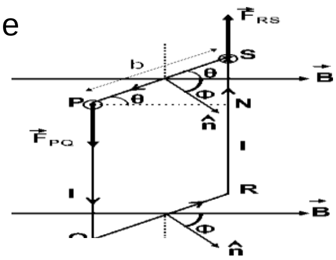
$$F / l = \frac{\mu_0 I_1 I_2}{2\pi r} \text{ N / m}$$

Its unit is newton/meter (N/m)

17. **Definition of ampere: -** 1 ampere is the current which when flowing in each of the two parallel wires in vacuum separated by 1 m from each other exert a force of 2x $10^{-7}$N/m on each other.
18. **Torque experienced by a current loop in uniform magnetic field-**

$$\vec{\tau} = \vec{M} \times \vec{B}$$

If the angle between the normal to the coil and the direction of the magnetic field, then Φ + θ = 90° i.e. θ = 90° - Φ




$$\vec{\tau} = I\,A\,B\cos(90° - \Phi) \quad \tau = N\,I\,A\,B\sin\Phi$$

**Hence,**

$$\tau = N\,I\,A\,B\sin\Phi$$

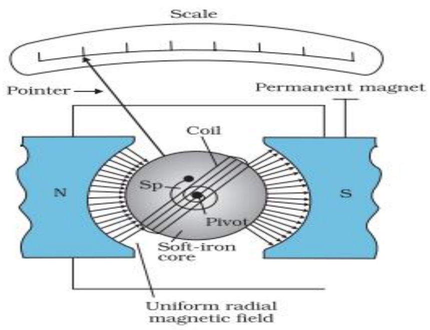
$$\vec{\tau} = (N\,I\,A\,B\sin\Phi)\,\hat{n}$$ (where $\hat{n}$ is unit vector normal to the plane of the loop)

$$\vec{\tau} = N\,I\,(\vec{A} \times \vec{B})$$ or $$\vec{\tau} = N\,(\vec{M} \times \vec{B})$$

(since $\vec{M} = I\vec{A}$ is the Magnetic Dipole Moment)

The unit of magnetic moment in SI system is $Am^2$.
The torque is maximum when the coil is parallel to the magnetic field and zero when the coil is perpendicular to the magnetic field.

19. **Potential energy of a current loop in a magnetic field**- When a current loop of magnetic moment M is placed in a magnetic field, then potential energy of magnetic dipole is $\vec{U}$=MB cos ϴ
    (i) When ϴ=0, U = - MB (minimum or stable equilibrium position)
    (ii) When ϴ=180, U = +MB (maximum or unstable equilibrium position)
    (iii) When ϴ=90, potential energy is zero
20. **Moving coil galvanometer**- A moving coil galvanometer is a device used to detect flow of current in a circuit. A moving coil galvanometer consists of a rectangular coil placed in a uniform radial magnetic field produced by cylindrical pole pieces.




**Torque on coil due to current $\tau$ = NIBA where N is the number of turns, A is the area of coil.**

If k is torsional rigidity of material of suspension wire, then for deflection θ, torque $\tau$. For equilibrium NIAB = k

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

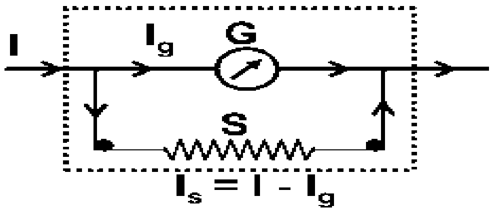
Use of radial magnetic field- The angle between the normal of the plane of loop and magnetic field θ = 90°,

$\tau \propto$ I, when radial magnetic field is used the deflection of coil is proportional to the current flowing through it. Hence a linear scale is used to determine the deflection of coil.

**Uses of galvanometer**: (i) Used to detect electric current is a circuit. (ii) Used to convert the ammeter by putting a low resistor. (iii) Used to convert voltmeter by putting a high resistor. (iv) Used as ohmmeter by making special arrangement

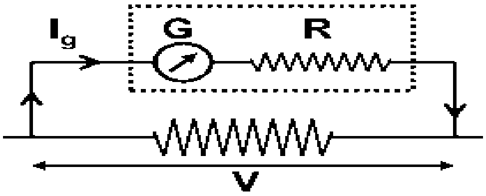
21. **Current sensitivity:** It is defined as the deflection of coil per unit current flowing in it. Current Sensitivity, $S_\theta = \frac{\theta}{I} = \frac{NAB}{K}$.
22. **Voltage sensitivity:** It is defined as the deflection of coil per unit potential difference across its ends. Voltage Sensitivity, $S_V = \frac{\theta}{V} = \frac{NAB}{GK}$ ,where *G* is the resistance of galvanometer.
23. **Conversion of Galvanometer into Ammeter**: - A galvanometer may be converted into ammeter by using very small resistance in parallel with the galvanometer coil. The small resistance connected in parallel is called a shunt. If G is resistance of galvanometer, Ig is current in galvanometer for full scale deflection, then for conversion of galvanometer into ammeter of range I ampere, the shunt is given by

$\therefore (I - I_g) S = I_g G$ or $S = \frac{I_g G}{I - I_g}$



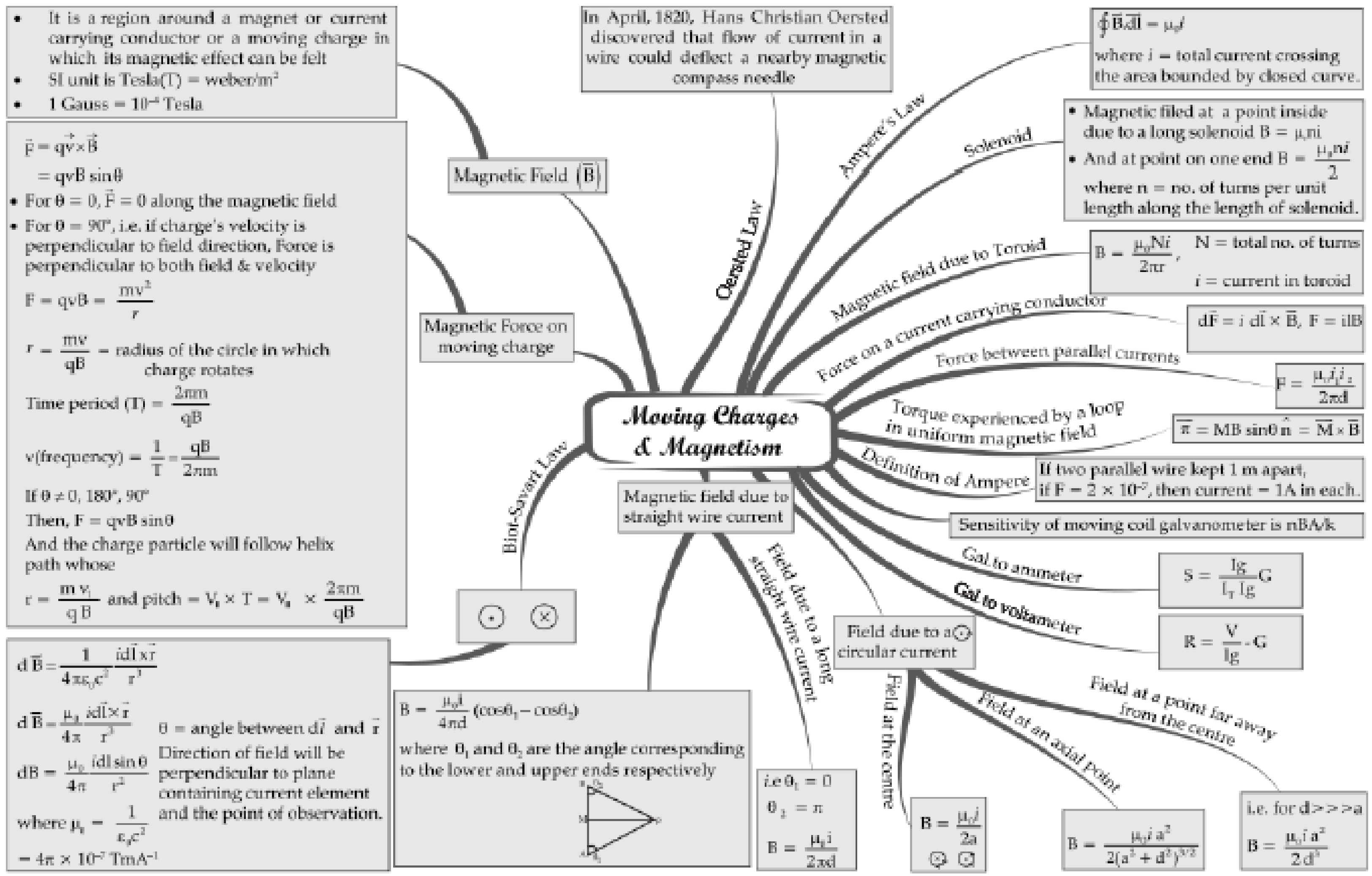

24. **Conversion of Galvanometer into Voltmeter**: - A galvanometer may be converted into voltmeter by connecting high resistance (R) in series with the coil of the galvanometer. If V volt is the range of voltmeter formed, then series resistance is given by

$\therefore V = I_g (G + R)$ or $R = \frac{V}{I_g} - G$



# MIND MAP

## MIND MAP : LEARNING MADE SIMPLE — CHAPTER - 4



## MULTIPLE CHOICE QUESTIONS

## LEVEL 1

1 In a current-carrying loop, the magnetic field is strongest:

a) At the centre of the loop
b) Along the edges of the loop
c) Inside the loop
d) Outside the loop

2 The magnetic field inside a current-carrying conductor.

(a) increases with the increase in current
(b) decreases with the increase in current
(c) remains constant with the increase in current
(d) is zero

3 The direction of the magnetic field at the centre of a current-carrying circular loop is:

(a) Along the axis of the loop
(b) Parallel to the plane of the loop
(c) Radially inward
(d) Tangential to the loop

4 Which of the following statements is correct regarding the magnetic field around a straight current-carrying conductor?

a) The magnetic field lines form concentric circles centred on the conductor.
b) The magnetic field lines form straight lines parallel to the conductor.
c) The magnetic field lines form radial lines away from the conductor.
d) The magnetic field lines form hyperbolic curves around the conductor.

5 A current carrying closed loop of an irregular shape lying in more than one plane whe placed in uniform magnetic field, the force acting on it

(a) Will be more in the plane where its larger position is covered.
(b) Is zero.
(c) Is infinite.
(d) May or may not be zero.

6 A strong magnetic field is applied on a stationary electron. Then the electron

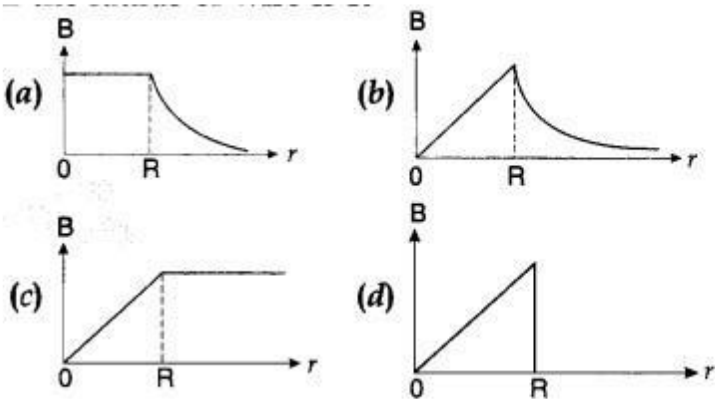
a) Moves in the direction of the field.
b) Remained stationary.
c) moves perpendicular to the direction of the field
d) moves opposite to the direction of the field

7 A charged particle is moving on circular path with velocity v in a uniform magnetic field B, if the velocity of the charged particle is doubled and strength of magnetic field is halved, then radius becomes

a) 8 times
b) 4 times
c) 2 times

d) 16 times

8 The correct plot of the magnitude of magnetic field $\vec{B}$ vs distance r from centre of the wire is, if the radius of wire is R

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**Select the most appropriate answer from the options given below:**

**(a) Both A and R are true and R is the correct explanation of A**

**(b) Both A and R are true but R is not the correct explanation of A.**

**(c) A is true but R is false.**

**(d) A is false and R is also false.**

9 **Assertion (A):** An electron projected parallel to the direction of magnetic force will experience maximum force.

**Reason (R):** Magnetic force on a charge particle is given by F = (IL x B).

10 **Assertion (A):** A proton is placed in a uniform electric field, it tends to move along the direction of electric field.

**Reason(R):** A proton is placed in a uniform electric field it experiences a force in the direction opposite to electric field.

11 **Assertion (A):** The magnetic field at the ends of a very long current carrying solenoid is half of that at the centre.

**Reason (R):** If the solenoid is sufficiently long, the field within it is uniform.

12 **Assertion (A):** Magnetic field due to an infinite straight conductor varies inversely as the distance from it.

**Reason (R):** The magnetic field due to a straight conductor is in the form of concentric circles.

13 **Assertion(A):** Torque on the coil is maximum when the coil is suspended in a radial magnetic field

**Reason(R) :** If the coil is set with its plane parallel to the direction of the magnetic field, then torque on it is maximum

14 **Assertion (A):** Two parallel conducting wires carrying currents in same direction come close to each other.

**Reason (R):** Parallel currents attract and antiparallel currents repel.

15 **Assertion(A):** Galvanometer cannot as such be used as an ammeter to measure the value of current in a given circuit

**Reason (R):** It gives full scale deflection for a current of the order of micro ampere**.**

16 **Assertion (A):** A galvanometer can be converted to voltmeter by connecting a very small resistance in series to it**.**

**Reason (R) :** Voltmeter is to be connected in series with the circuit

17 Name the rule which gives the direction of force, on an electron moving perpendicular to the uniform magnetic field.

(a) Fleming's right hand Rule (b) Fleming's left hand Rule (c) Right hand Thumb Rule (d) Swimming Rule

18 Which law/rule gives the direction of a magnetic field due to a conductor carrying current?

(a) Faraday's law (b) Fleming's right hand rule

(c) Right hand thumb rule (d) Fleming's left hand rule

19 According to the Right hand thumb rule, direction of which physical quantity is indicated by the thumb?

(a) Electric current (b) Magnetic field (c) Magnetic force (d) Motion of conductor

20 What is the shape of magnetic field lines passing through the centre of current carrying circular ring?

(a) Circular (b) Straight line (c) Ellipse (d) no definite shape

## MCQ-LEVEL 2

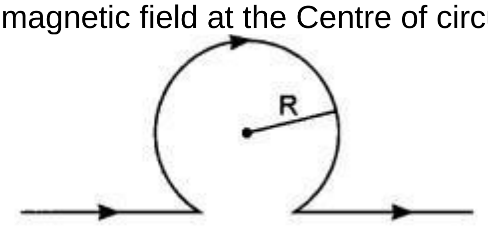
1 A circular coil of radius 4 cm and of 20 turns carries a current of 3 amperes. It is placed in a magnetic field of intensity of 0.5 weber/m². The magnetic dipole moment of the coil is

a) 0.15 ampere-m² b) 0.3 ampere-m² c) 0.45 ampere-m² d) 0.6 amp-m²

2 A flat circular coil of 100 turns and radius 10 cm carries a current of 1 A. Then the magnetic dipole moment of the coil is A.

a) π A·m² b) π/2 A·m² c) 2π A·m² d) π/4 A·m²

3 The strength of magnetic field at the Centre of circular coil is




(a) $\frac{\mu_0 I}{R}\left(1-\frac{1}{\pi}\right)$ (b) $\frac{\mu_0 I}{\pi R}$

(c) $\frac{\mu_0 I}{2R}\left(1-\frac{1}{\pi}\right)$ (d) $\frac{\mu_0 I}{2R}\left(1+\frac{1}{\pi}\right)$

4 If the beams of electrons and protons move parallel to each other in the same direction, then they

a) Attract each other. b) Repel each other. c) No relation. d) Neither attracts nor repel.

**Select the most appropriate answer from the options given below:**
**(a) Both A and R are true and R is the correct explanation of A**
**(b) Both A and R are true but R is not the correct explanation of A.**
**(c )A is true but R is false.**
**(d) A is false and R is also false.**

5 **Assertion (A):** If a proton and an α-particle enter a uniform magnetic field perpendicularly with the same speed, the time period of revolution of α-particle is double than that of proton.
**Reason (R):** In a magnetic field, the period of revolution of a charged particle is directly proportional to the mass of the particle and inversely proportional to the charge of the particle.

6 **Assertion (A):** The magnetic field produced by a current carrying long solenoid is independent of its length and cross- sectional area.
**Reason(R):** The magnetic field inside the solenoid is uniform.

7 **Assertion (A):** The voltage sensitivity may not necessarily increase on increasing the current sensitivity
**Reason (R)**: Current sensitivity decreases on increasing the number of turns of the coil

8 **Assertion (A):** When radius of circular loop carrying current is doubled, its magnetic moment becomes four times
**Reason (R):** Magnetic moment depends on area of the loop

9 **Assertion (A):** An electron projected parallel to the direction of magnetic force will experience maximum force.
**Reason (R):** Magnetic force on a charge particle is given by F = (IL x B).

10 Along which axis the magnetic field due to a current element is minimum?
(a) along its axis (b) perpendicular to its axis (c) at any angle to its axis (d) at an angle of 450 with the axis.

## LEVEL 3

1 If a charged particle moves through a magnetic field perpendicular to it
a) Both momentum and energy of particle change.
b) Momentum as well as energy is constant.
c) Energy is constant but momentum changes.
d) momentum is constant but energy changes

2 The maximum current that can be measured by a galvanometer of resistance 40 Ω is 10 mA. It is converted into voltmeter that can read up to 50 V. The resistance to be connected in the series with the galvanometer is
a) 2010 Ω b) 4050 Ω c) 5040 Ω d) 4960 Ω

3 Two α-particles have the ratio of their velocities as 3: 2 on entering the field. If they move in different circular paths, then the ratio of the radii of their paths is

a) 2 : 3 b) 3 : 2 c) 9 : 4 d) 4 : 9

4 The time period of a charged particle undergoing a circular motion in a uniform magnetic field is independent of:

(a) speed of the particle (b) mass of the particle

(c) charge of the particle (d) magnetic field of the particle

5 If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter a:

(a) low resistance in parallel (b) high resistance in parallel

(c) high resistance in series (d) low resistance in series

6 A particle of charge q and mass m moves in a circular orbit of radius r with angular speed ω. The ratio of the magnitude of its magnetic moment to that of its angular momentum depends on

(a) ω and q (b)ω, q and m (c) q and m (d) ω and m

**Select the most appropriate answer from the options given below:**

**(a) Both A and R are true and R is the correct explanation of A**

**(b) Both A and R are true but R is not the correct explanation of A.**

**(c ) A is true but R is false.**

**(d) A is false and R is also false.**

7 **Assertion (A):** If an electron and proton enter a magnetic field with equal momentum, then the paths of both of them will be equally curved.

**Reason (R):** The magnitude of charge on an electron is same as that on a proton.

8 **Assertion (A):** The torque acting on square and circular current carrying coils having equal areas, placed in uniform magnetic field, will be same.

**Reason (R):** Torque acting on a current carrying coil placed in uniform magnetic field does not depend on the shape of the coil, if the areas of the coils are same.

9 **Assertion (A):** Electron enters into a magnetic field at an angle of 60 degree. Its path will be Parabola.

**Reason (R):** Force on electron moving perpendicular to magnetic field is zero.

10 **Assertion (A):** Higher the range, lower is the resistance of ammeter**.**
**Reason (R):** To increase the range of an ammeter, additional shunt is added in series to it

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# 2 MARK QUESTIONS
## LEVEL 1

1 I) Write the expression, in a vector form, for the Lorentz magnetic force $\vec{F}$ due to a charge moving with velocity $\vec{V}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force?
II) Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.

2 A charge 'q' moving B along the X-axis with a velocity v is subjected to a uniform magnetic field B acting along the Z-axis as it crosses the origin O.
(i) Trace its trajectory.
(ii) Does the charge gain kinetic energy as it enters the magnetic field? Justify your answer.

3 A steady current (I1) flows through a long straight wire. Another wire carrying steady current (I2) in the same direction is kept close and parallel to the first wire. Show with the help of a diagram how the magnetic field due to the current I1 exerts a magnetic force on the second wire. Write the expression for this force.

4 A circular coil of closely wound N turns and radius r carries a current I. Write the expressions for the following :
(i) the magnetic field at its centre
(ii) the magnetic moment of this coil

5 Draw the magnetic field lines due to a current passing through a long solenoid. Write the expression for the magnetic field due to the current I in a long solenoid having n number of turns per unit length.

6 (i) State Biot – Savart law in vector form expressing the magnetic field **B** due to an element **dl** carrying current I at a distance **r** from the element.
(ii) Write the expression for the magnitude of the magnetic field at the centre of a circular loop of radius r carrying a steady current I. Draw the field lines due to the current loop.

7 State Ampere's circuital law. How is it similar to the Gauss Law?

8 How do convert a galvanometer into an ammeter? Why is an ammeter always connected in series?

## LEVEL 2

1 A solenoid of length 50 cm having 100 turns carrying a current of 4.5 A find the magnetic field
(i) in the interior of the solenoid
(ii) outside the solenoid

2 An ammeter of resistance 0.6 Ω can measure current up to 1.0 A. Calculate (i) The shunt resistance required to enable the ammeter to measure current up to 5.0 A (ii) The combined resistance of the ammeter and the shunt.

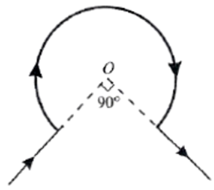
3 A proton and a deuteron, each moving with velocity **v** enter simultaneously in the region of magnetic field **B** acting normal to the direction of velocity. Trace their trajectories establishing the relationship between the two.

4 A galvanometer of coil resistance 50 Ω shows full scale deflection for a current of 5 mA. How can it be converted into a voltmeter of range 0 to 15 V?

5 Why is the magnetic field radial in a moving coil galvanometer? Explain how it is achieved.

## LEVEL 3

1 The wire shown below carries a current *I*. Determine magnetic field at the centre. Radius of circular section is *R*.




2 To increase the current sensitivity of a moving coil galvanometer by 50%, its resistance is increased so that the new resistance becomes twice its initial resistance. By what factor does its voltage sensitivity change?

3 A helium nucleus makes a full rotation in a circle of radius 0.8 m in 2 seconds. Find the value of the magnetic field at the centre of the circle.

## 3 MARKS QUESTIONS
## LEVEL-1

1 State the underlying principle of working of a moving coil galvanometer. Write two reasons why a galvanometer cannot be used as such to measure current in a given circuit. Name any two factors on which the current sensitivity of a galvanometer depends.

2 Using Biot-Savart law derive the expression for the magnetic field due to a current carrying loop of radius *R* at a point which is at a distance of *x* from its centre along the axis of the loop.

3 Derive an expression for a force acting per unit length between two long straight parallel conductors carrying current in the same direction and kept near each other. Hence also define one Ampere.

4 State Ampere's circuital law. Derive an expression for magnetic field intensity at a point due to a current carrying straight wire of infinite length.

5 Derive an expression for the torque on a rectangular coil of area A carrying current I and paced in a magnetic field B which is at an angle ϴ with the normal to the plane of the coil.

## LEVEL 2

1 A wire carrying a steady current is first bent in form of a circular coil of one turn and then in form of a circular coil of two turns. Find the ratio of magnetic fields at the centres of the two coils.

2 A galvanometer of resistance ‘G’ can be converted into a voltmeter of range (0-V) volts by connecting a resistance ‘R’ in series with it. How much resistance will be required to change its range from 0 to V/2 ?

3 A voltmeter V of resistance 400 Ω is used to measure the potential difference connected (in parallel) across a100 Ω resistance which is connected in series with a 200Ω resistor to which a 84 V battery source is connected,
(i) What will be the reading on the voltmeter? (ii) Calculate the potential difference across 100 Ω resistance before the voltmeter is connected

## LEVEL 3

1 Two long parallel wires separated by 0.1 m carry currents of 1A and 2A respectively in opposite directions. A third current-carrying wire parallel to both of them is placed in the same plane such that it feels no net magnetic force. Find the distance of the third wire.

2 A hollow cylindrical conductor of radii *a* and *b* carries a current *I* uniformly spread over its cross section. Find the magnetic field *B* for points inside the body of the conductor at a distance *r* from the axis.

3 A long straight conductor PQ, carrying a current of 60 A, is fixed horizontally. Another long conductor XY is kept parallel to PQ at a distance of 4 mm, in air. Conductor XY is free to move and carries a current ‘I’. Calculate the magnitude and direction of current ‘I’ for which the magnetic repulsion just balances the weight of the conductor XY.

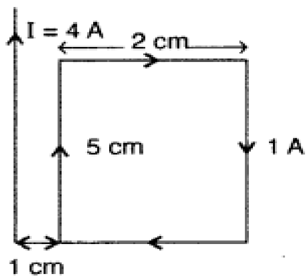
# 5 MARKS QUESTIONS

## LEVEL 1

1 (a) State the principle of the working of a moving coil galvanometer, giving its labelled diagram. (b) “Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity.” Justify this statement (c) Outline the necessary steps to convert a galvanometer of resistance G into a voltmeter of a given range.

## LEVEL 2

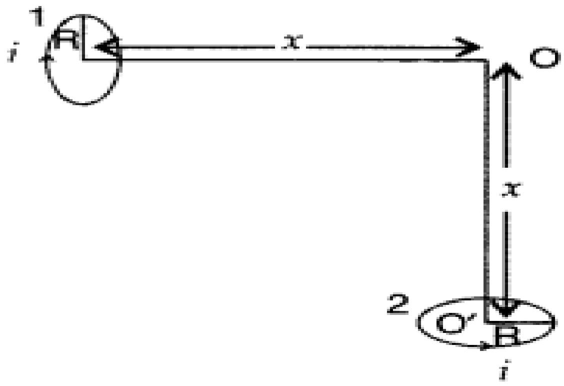
1 (a) Derive an expression for the torque on a rectangular coil of area A carrying current I and paced in a magnetic field B which is at an angle θ with the normal to the plane of the coil.
(b) A rectangular loop of wire of size 2 cm × 5 cm carries a steady current of 1 A. A straight long wire carrying 4 A current is kept near the loop as shown in the figure. If the loop and the wire are coplanar, find (i) the torque acting on the loop and (ii) the magnitude and direction of the force on the loop due to the current carrying wire.



## LEVEL 3

1 (a) A uniform magnetic field **B** is set up along the positive x-axis. A particle of charge 'q' and mass 'm' moving with a velocity v enters the field at the origin in X-Y plane such that it has velocity components both along and perpendicular to the magnetic field **B**. Trace, giving reason, the trajectory followed by the particle. Find out the expression for the distance moved by the particle along the magnetic field in one rotation.

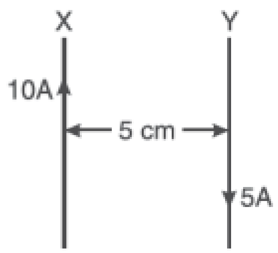
(b) Two small identical circular coils marked 1, 2 carry equal currents and are placed with their geometric axes perpendicular to each other as shown in the figure. Derive an expression for the resultant magnetic field at O.




## NUMERICALS

## LEVEL 1

| | | |
|---|---|---|
| 1 | A circular coil of wire consisting of 100 turns, each of radius 8 cm carries a current of 0.4 A. What is the magnitude of magnetic field at its centre? | 2 |
| 2 | A long straight wire carries a current of 35 A. What is the magnitude of magnetic field at a point 20 cm from the wire? | 2 |
| 3 | An electron of kinetic energy 25KeV moves perpendicular to the direction of a uniform magnetic field of 0.2 milli Tesla. Calculate the time period of rotation of the electron in the magnetic field? | 2 |
| 4 | Two parallel straight wires X and Y separated by a distance 5 cm in air carry current of 10 A and 5 A respectively in opposite direction as shown in diagram. Calculate the magnitude and direction of the force on a 20 cm length of the wire Y. | 2 |




## LEVEL 2

| | | |
|---|---|---|
| 1 | A galvanometer gives deflection of 10 division per mA. The resistance of galvanometer is 60 Ω. If a shunt of 2.5 Ω is connected to the galvanometer and there are 50 divisions on the galvanometer scale, what maximum current can this galvanometer read? | 3 |

2 A straight wire of mass 200 g and length 1.5 m carries a current of 2 A. It is suspended in mid-air by a uniform horizontal magnetic field. What is the magnitude of the field? 3

3 A long straight wire in the horizontal plane carries a current of 50 A in north to south direction. Give the magnitude and direction of B at a point 2.5 m east of the wire. 3

## LEVEL 3

1 A beam of proton passes undeflected through a region of mutually perpendicular electric and magnetic fields of magnitudes 50 $kVm^{-1}$ and 100 mT respectively. Calculate the velocity of the beam. If this beam of current *I* strikes a screen with *n* protons per second, Find the force on the screen. 3

2 A circular coil of 200 turns and radius 10 cm is placed in a uniform magnetic field of 0.5 T, normal to the plane of the coil. If the current in in the coil is 3.0 A, calculate the 5

(a) total torque on the coil

(b) total force on the coil

(c) Average force on each electron in the coil, due to the magnetic field.

3 A proton and an alpha particle having the same kinetic energy are, in turn, passed through a region of uniform magnetic field, acting normal to the plane of the paper and travel in circular paths. Deduce the ratio of the radii of the circular paths described by them. 5

## CASE BASED QUESTIONS

1 **FORCE ON A MOVING CHARGE** 4

Stationary charge creates an electric field but a moving charge creates a magnetic field also that can affect other moving charges. It was observed by Oersted. He saw that if a magnetic needle is placed near current carrying wire it shows slight deflection. The direction of the magnetic field can be determined by using the Right hand thumb rule. Magnetic field is the space around a magnet, a current carrying conductor up to which it can attract or repel magnetic material. Force on a moving charge in magnetic field is given by the formula

$\boldsymbol{F} = q (\boldsymbol{v} \times \vec{B})$

Where q = charge on particle

v = velocity of charge particle

B = magnetic field and

F = magnetic force

When a current carrying conductor is placed in an external magnetic field, it experiences a mechanical force. A conductor of length 1 carrying current I held in a magnetic field B at an angle θ with it, experiences a force given by F = IlB sin θ.

1. Moving charge can create

(a) Electric field (b) magnetic field

(c) Both electric and magnetic field (d) none of them

2. If a current is flowing from south to north in a straight wire what will be the direction of magnetic field to its left side

(a) Outward (b) inward (c) Towards right (d) towards left

3. Which of the following cannot be the source of magnetic field?

(a) Current carrying wire (b) moving electron

(c) Moving proton (d) stationary charge

4. Force acting on a conductor of length 10 m carrying a current of 6A kept perpendicular to the magnetic field of 2T is

(a) 60N (b) 120N (c) 90N (d) 100N

## COMPETENCY BASED QUESTION

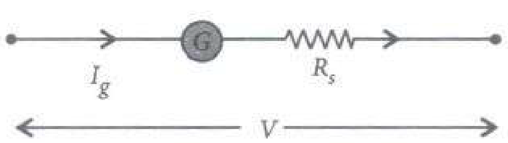
1 **CONVERSION OF GALVANOMETER TO VOLTMETER** 4

A galvanometer can be converted into voltmeter of given range by connecting a suitable resistance Rs in series with the galvanometer, whose value is given by

$R_S = \frac{V}{Ig} - G$

where V is the voltage to be measured, Ig is the current for full scale deflection of galvanometer and G is the resistance of galvanometer Series resistor ($R_S$) increases range of voltmeter and the effective resistance of galvanometer. It also protects the galvanometer from damage due to large currents.

Voltmeter is a high resistance instrument and it is always connected in parallel with the circuit element across which potential difference is to be measured. In order to increase the range of voltmeter n times the value of resistance to be connected in series with galvanometer is $R_S = (n-1)G$




i) 10 mA current can pass through a galvanometer of resistance 25Ω. What resistance in series should be connected through it, so that it is converted into a voltmeter of 100V?

a) 0.975Ω b) 99.75Ω c) 975 Ω d) 9975Ω

ii) There are 3 voltmeter A, B, C having the same range but their resistance are 15000 Ω, 10000 Ω and 5000 Ω respectively. The best voltmeter amongst them is the one whose resistance is

a) 5000 Ω b) 10000 Ω c) 15000 Ω d) all are equally good

iii) A milliammeter of range 0 to 25 mA and resistance of 10 Ω is to be converted into a voltmeter with a range of 0 to 25 V. The resistance that should be connected in series will be

a) 930 Ω b) 960 Ω c) 990 Ω d) 1010 Ω

iv) To convert a moving coil galvanometer (MCG) into a voltmeter

a) a high resistance R is connected in parallel with MCG
b) a low resistance R is connected in parallel with MCG
c) a low resistance R is connected in series with MCG
d) a high resistance R is connected in series with MCG

**OR**

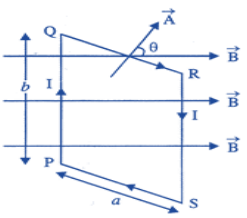
v) The resistance of an ideal voltmeter is

a) zero b) low c) high d) infinity

## CREATIVE & CRITICAL THINKING

1 **TORQUE ON A RECTANGULAR LOOP PLACED IN UNIFORM MAGNETIC FIELD** 4

When a rectangular loop PQRS of sides 'a' and 'b' carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with direction of magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, there by perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, they give rise to torque on the loop.




Force on side PQ or RS of loop is F = Ib sin90°=Ib B and perpendicular distance between two non-collinear forces is a sinθ

So, torque on the loop, τ=I AB sinθ

In vector form torque, $\vec{\tau} = \vec{M} \times \vec{B}$

where M= NIA is called magnetic dipole moment of current loop and is directed in direction of area vector A i-e., normal to the plane of loop.

1. A circular loop of area $1 cm^2$, carrying a current of 10 A is placed in a magnetic field of 0.1 T perpendicular to the plane of the loop. The torque on the loop due to the magnetic field is

A) zero B) $10^{-4}$ Nm C) $10^{-2}$ Nm D) 1 N m

2. Relation between magnetic moment and angular velocity is

A) $M \propto \omega$ B) $M \propto \omega^2$ C) $M \propto \sqrt{\omega}$ D) none of these

3. A current loop in a magnetic field

A) can be in equilibrium in two orientations, both the equilibrium states are unstable

B) can be in equilibrium in two orientations, one stable while the other is unstable

C) experiences a torque whether the field is uniform or non-uniform in all orientations

D) can be in equilibrium in one orientation.

4. The magnetic moment of a current I carrying circular coil of radius r and number of turns N varies as

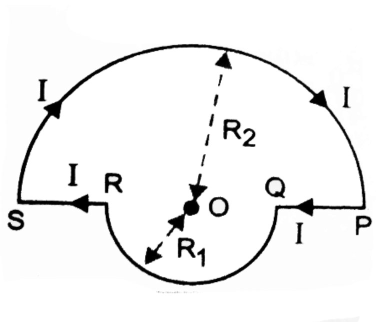
A) $\frac{1}{r2}$ B) $\frac{1}{r}$ C) r D) $r^2$

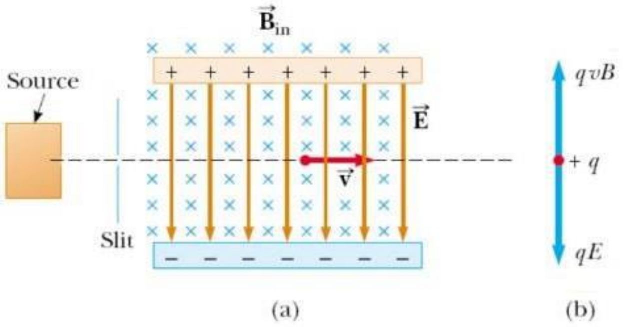
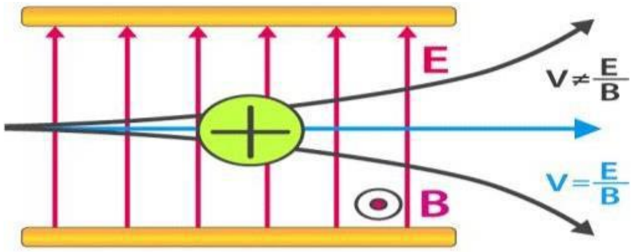
# SELF ASSESSMENT TEST

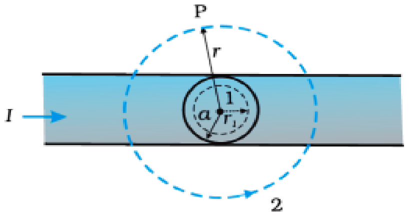
## CHAPTER 4

**MM-25** **TIME-40 MIN**

**INSTRUCTIONS- Q1-6 CARRY 1 MARK EACH**
**Q7 AND Q8- CARRY 2 MARKS EACH**
**Q9, AND Q10- CARRY 3 MARKS EACH**
**Q11-CASE BASED QS CARRIES 4 MARKS**
**Q12- CARRIES 5 MARKS**

| | | |
|---|---|---|
| 1 | Which physical quantity has unit Wb/m$^2$?<br>(a) Magnetic Flux (b) Magnetic Field<br>(c) Magnetic dipole moment (d) Torque | 1 |
| 2 | What is the magnitude of force per unit length on a current carrying wire if 8 A flows at an angle of 300 with the direction of uniform magnetic field of 1 T.<br>(a) 2 N/m (b)4 N/m (c) 0.5 N/m (d) 4√2 N/m | 1 |
| 3 | A magnetized needle of magnetic moment 0.5 J/T is placed at 300 with the direction of magnetic field of 1 T. What is the torque acting on it?<br>(a) 0.5 Nm (b) 0.25 Nm (c) 0.625 Nm (d) 2.5 Nm | 1 |
| 4 | What is the SI unit of current sensitivity?<br>(a) Ampere/radian (b) Radian/Ampere (c) Ampere (d) Radian | 1 |
| 5 | Assertion (A): The magnetic field at the ends of a very long current carrying solenoid is half of that at the centre.<br>Reason (R): If the solenoid is sufficiently long, the field within it is uniform. | 1 |
| 6 | Assertion (A): Magnetic field due to an infinite straight conductor varies inversely as the distance from it.<br>Reason (R): The magnetic field due to a straight conductor is in the form of concentric circles. | 1 |
| 7 | If only 10% of the total current can pass through a galvanometer of resistance 45Ω, what value of shunt is required? | 2 |
| 8 | Using Ampere's circuital law, derive the equation for magnetic field strength at a point near a long straight conductor. | 2 |
| 9 | A wire loop is formed by joining two semi-circular wires of radii r1, and r2, as shown in diagram. If the loop carries a current I, find the magnetic field at the centre O.<br> | 3 |
| 10 | (a) What is the principle of a moving coil galvanometer?<br>(b) Give two reasons to explain why a galvanometer cannot as such be used to measure the value of the current in a given circuit. | 3 |

| | | |
|---|---|---|
| | (c)Define the terms: (i) voltage sensitivity and (ii) current sensitivity of a galvanometer. | |
| 11 | Lorentz forces-<br><br><br><br><br>A charge q moving with a velocity v in presence of both electric and magnetic fields experience a force F = q [ E + v x B ]. If electric and magnetic fields are perpendicular to each other and also perpendicular to the velocity of the particle, the electric and magnetic forces are in opposite directions. If we adjust the value of electric and magnetic field such that magnitude of the two forces are equal. The total force on the charge is zero and the charge will move in the fields undeflected.<br><br>1. What will be the value of velocity of the charge particle, when it moves undeflected in a region where the electric field is perpendicular to the magnetic field and the charge particle enters at right angles to the fields.<br>(a) v = E/B<br>(b) v = B/E<br>(c) v = EB<br>(d) v = EB/q<br><br>2. Proton, neutron, alpha particle and electron enter a region of uniform magnetic field with same velocities. The magnetic field is perpendicular to the velocity. Which particle will experience maximum force?<br>(a) proton<br>(b) electron<br>(c) alpha particle<br>(d) neutron<br><br>3. A charge particle moving with a constant velocity passing through a space without any change in the velocity. Which can be true about the region?<br>(a) E = 0, B = 0<br>(b) E ≠ 0, B ≠ 0<br>(c) E = 0, B ≠ 0 | 4 |

| | | |
|---|---|---|
| | (d) All of these<br><br>4. Proton, electron and deuteron enter a region of uniform magnetic field with same electric potential-difference at right angles to the field. Which one has a more curved trajectory?<br>(a) electron<br>(b) proton<br>(c) deuteron<br>(d) all will have same radius of circular path | |
| | | |
| 12 | (i) State and explain Ampere’s circuital law?<br>(ii) Figure shows a long straight wire of a circular cross-section (radius a) carrying steady current I. The current I is uniformly distributed across this cross-section. Calculate the magnetic field in the region r < a and r > a<br> | 5 |

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