Unit – 3 MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT

Short Answers Questions (Book back)

1.What is meant by magnetic induction or total magnetic filed

The magnetic induction (**total magnetic field**) inside the specimen $\vec{B}$ is equal to the sum of the magnetic field B produced in vacuum due to the magnetising field and the magnetic field $\overrightarrow{B_m}$ due to the induced magnetisation of the substance.

$$\vec{B} = \overrightarrow{B_m} + \overrightarrow{B_0}$$

2.Define magnetic flux

The number of magnetic field lines crossing per unit area is called magnetic flux Φ_B

$$\Phi_B = \vec{B}.\vec{A} = BA\ COS\Theta$$

Unit : weber (Wb)
Quantity : Scalar

3.Define dipole moment

The magnetic dipole moment is defined as the product of its pole strength and magnetic length.

Magnitude of dipole moment
$$P_m = 2\ q_m l$$
Unit : Am^2
Quantity : Vector

4.State COULOMB'S INVERSE SQUARE LAW OF MAGNETISM

The force of attraction or repulsion between two magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them.

$$\vec{F}\ \alpha\ \frac{q_{mA}q_{mB}}{r^2}\ \hat{r}$$

5.What is magnetic susceptibility ?

It is defined as the ratio of the intensity of magnetisation ($\vec{M}$) induced in the material due to the magnetising field ($\vec{H}$)

$$\varkappa_m = \frac{|\vec{M}|}{|\vec{H}|}$$

It is a **dimensionless quantity**

6.State Biot – Savart's law

Biot and Savart observed that the magnitude of magnetic field $\overrightarrow{dB}$ at a point P at a distance r from the small elemental length taken on a conductor carrying current varies
(i) directly as the strength of the current I
(ii) directly as the magnitude of the length element $\overrightarrow{dl}$
(iii) directly as the sine of the angle (say,θ) between $\overrightarrow{dl}$ and $\hat{r}$
(iv) inversely as the square of the distance between the point P and length element $\overrightarrow{dl}$.

7.What is magnetic permeability

It is measure of ability of the material to allow the passage of magnetic field lines through it

It is measure of the capacity of the substance to take magnetisation or the degree of penetration of magnetic field through the substance.

8.State Ampere's circuital law

The line integral of magnetic field over a closed loop is μ_0 times net current enclosed by the loop.

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

$I_{enclosed}$ - Net current linked by the closed loop C.

9. Compare dia , para & ferro magnetism

Dia magnetism	Para magnetism	Ferro magnetism
Magnetic susceptibility is **negative**	Magnetic susceptibility is **positive & small**	Magnetic susceptibility is **postive and large**
Relative permeability is slightly less than unity.	Relative permeability is slightly greater than unity.	Relative permeability is large .
Susceptibility is nearly temperature independent.	Susceptibility is inversely proportional to temperature	Susceptibility is inversely proportional to temperature
Ex: Bismuth, Copper and Water	**Ex:**Aluminium, Platinum & chromium	**Ex:** Iron, Nickel and Cobalt

10. What is meant by hysteresis?

The phenomenon of lagging of magnetic induction behind the magnetising field is called hysteresis

Hysteresis – **Lagging Behind**

Short answers (Book inside)

1. What is Geomagnetism

The branch of physics which deals with the Earth's magnetic field is called Geomagnetism or Terrestrial magnetism.

2. What are elements of the Earth's magnetic field.

(a) magnetic declination (D)
(b) magnetic dip or inclination (I)
(c) the horizontal component of the Earth's magnetic field (B_H)

3. Define Magnetic declination

The angle between magnetic meridian at a point and geographical meridian is called the *declination or magnetic declination (D)*.

At higher latitudes, the declination is greater whereas near the equator, the declination is smaller.

4. Define dip or magnetic inclination

The angle subtended by the Earth's total magnetic field with the horizontal direction in the magnetic meridian is called dip or magnetic inclination (I) at that point

5. Define horizontal component of Earth's magnetic field

The component of Earth's magnetic field along the horizontal direction in the magnetic meridian is called horizontal component of Earth's magnetic field, denoted by B_H.

6. Define Magnetic field

The magnetic field at a point is defined as a force experienced by the bar magnet of unit pole strength

$$\vec{B} = \frac{F}{q_m}$$

Unit : **N A^{-1} m^{-1}**

+2 PHYSICS   SAIVEERA ACADEMY - 8098850809   STUDY MATERIAL

16.Define Meissner effect.

The expulsion of magnetic flux from a superconductor during its transition to the superconducting state is known as Meissner effect.

17.Define Curie's law

Susceptibilty is inversely proportional to temperature

$$\varkappa_m \; \alpha \; \frac{1}{T}$$

18.Why there is a strong net magnetisation of the Ferro magnetic material in the direction of the applied field

i)The domains having magnetic moments parallel to the field grow in size
2) the other domains (not parallel to field) are rotated so that they are aligned with the field.

19.Define Curie-Weiss law.

At a particular temperature, ferromagnetic material becomes paramagnetic. This temperature is known as Curie temperature T_C. The susceptibility of the material above the Curie temperature is given by

$$\varkappa_m \; = \; \frac{C}{T - T_C}$$

20.Define coercivity.

The magnitude of the reverse magnetising field for which the residual magnetism of the material vanishes is called its coercivity.

21.Define retentivity

It is defined as the ability of the materials to retain the magnetism in them even magnetising field vanishes.

22.State Right hand thumb rule

If we hold the current carrying conductor in our right hand such that the thumb points in the direction of current flow, then the fingers encircling the wire points in the direction of the magnetic field lines produced.

23. State Maxwell's right hand cork screw rule

If we rotate a right hand screw using a screw driver then the direction of current is same as direction in which screw advances and the direction of rotation of screw gives direction of magnetic field

24. Difference between Coulomb's law and Biot – Savart law

Electric field	Magnetic field
Produced by scalar source (**q**)	Produced by vector source (I $\overrightarrow{dl}$)
It is directed along the position vector joining the source & the point at which field is calculated	It is directed perpendicular to the position vector $\vec{r}$ **and the current element** I. $\overrightarrow{dl}$
Does not depend on angle	Depend an angle between position vector and current element

25. Define the magnetic dipole moment of any current loop

The magnetic dipole moment of any current loop is equal to the product of the current and area of the loop.

$$\overrightarrow{P}_m \; = \; I \; \overrightarrow{A}$$

Unit : A m²

Long Answer Question (Book Back)
1.Discuss Earth's magnetic field in detail

Gover suggested that the Earth's magnetic field is due to hot rays coming out from the Sun. These rays will heat up the air near equatorial region. Once air becomes hotter, it rises above and will move towards northern and southern hemispheres and get electrified. This may be responsible to magnetize the ferromagnetic materials near the Earth's surface

The north pole of magnetic compass needle is attracted towards the magnetic south pole of the Earth which is near the geographic north pole . Similarly, the south pole of magnetic compass needle is attracted towards the geographic north pole of the Earth which is near magnetic north-pole. **The branch of physics which deals with the Earth's magnetic field is called Geomagnetism or Terrestrial magnetism.**

The three elements of of the Earth's magnetic field are

(a) magnetic declination (D)
(b) magnetic dip or inclination (I)
(c) the horizontal component of the Earth's magnetic field (B_H)

The angle between magnetic meridian at a point and geographical meridian is called the declination or magnetic declination (D).

The angle subtended by the Earth's total magnetic field with the horizontal direction in the magnetic meridian is called dip or magnetic inclination (I) at that point

The component of Earth's magnetic field along the horizontal direction in the magnetic meridian is called horizontal component of Earth's magnetic field, denoted by B_H.
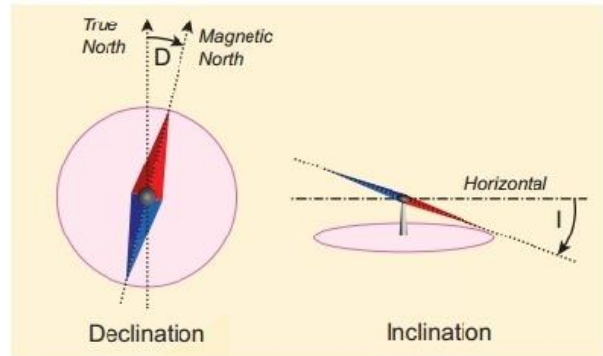
2.Deduce the relation for the magnetic induction at a point due to an infinitely long straight conductor carrying current

Consider a long straight wire NM with current I flowing from N to M.
P be the point at a distance *a* from point O.
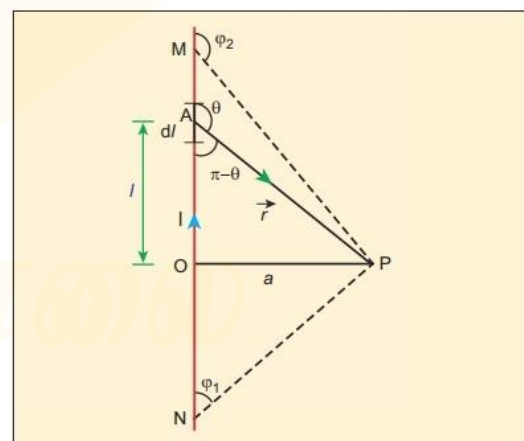Consider an element of length d*l* of the wire at a distance *l* from point O

Figure 3.39 Magnetic field due to a long straight current carrying conductor

$\vec{r}$ be the vector joining the element d*l* with the point P.
θ − angle between $\vec{r}$ & $\vec{dl}$

Horizontal components of each current element cancels out while the vertical components (dB cos θ) alone contribute to total magnetic field at the point P.

PC = PD = r = $\sqrt{R^2 + Z^2}$

Then the net magnetic field at point P is

$\vec{B} = \int \vec{dB} = \int dB \cos\theta \hat{k}$

$= \frac{\mu_0}{4\pi} I \int \frac{dB}{r^2} \cos\theta \hat{k}$ …….. (2)

By triangle POD

cos θ = $\frac{R}{\sqrt{R^2+Z^2}}$

sub cos θ value in (2) ,
integrating line element from 0 to 2πR, we get

$$\vec{B} = \frac{\mu_0}{2\pi} I \frac{R^2}{(R^2+z^2)^{\frac{3}{2}}} \hat{k}$$

4. Compute the torque experienced by a magnetic needle in a uniform magnetic field
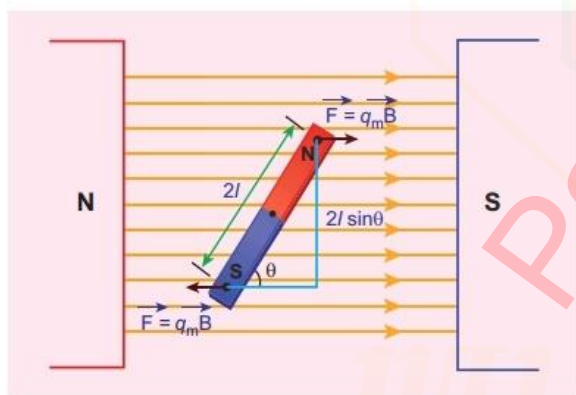
Figure 3.19 Magnetic dipole kept in a uniform magnetic field

Consider a magnet of length 2l of pole strength q_m kept in a uniform magnetic field

Each pole experiences a force of magnitude q_mB but acts in opposite direction. Therefore, the net force exerted on the magnet is zero, so that there is no

translatory motion. These two forces constitute a couple (about midpoint of bar magnet) which will rotate and try to align in the direction of the magnetic field

The force experienced by north pole

$\vec{F_N}$ = q$_m$ B ………..(1)

The force experienced by South pole

$\vec{F_S}$ = -q$_m$ B ………..(2)

Adding (1) & (2)
Net force on the dipole as

$\vec{F} = \vec{F_N} + \vec{F_S} = 0$

The moment of force or torque experienced by north and south pole about point O is

$\vec{\tau} = \vec{ON} \times \vec{F_N} + \vec{OS} \times \vec{F_S}$

$= \vec{ON} \times q_m B + \vec{OS} \times (-q_m B)$

By using right hand cork screw rule, we conclude that the total torque is pointing into the paper.

Since the magnitudes
$|\vec{ON}| = |\vec{OS}| = l$
$|Bq_m| = |-Bq_m|$

magnitude of total torque about point O

$\tau = l \times q_m B \sin\theta + l \times q_m B \sin\theta$

$= 2l \times q_m B \sin\theta$

Since P$_m$ = q$_m$ × 2l

$= P_m B \sin\theta$

In vector notation

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

5. Calculate the magnetic induction at a point on the axial line of bar magnet

Consider a bar magnet NS.
Let N be the North Pole and S be the south pole of the bar magnet, each of pole strength q$_m$ and separated by a distance of 2l.
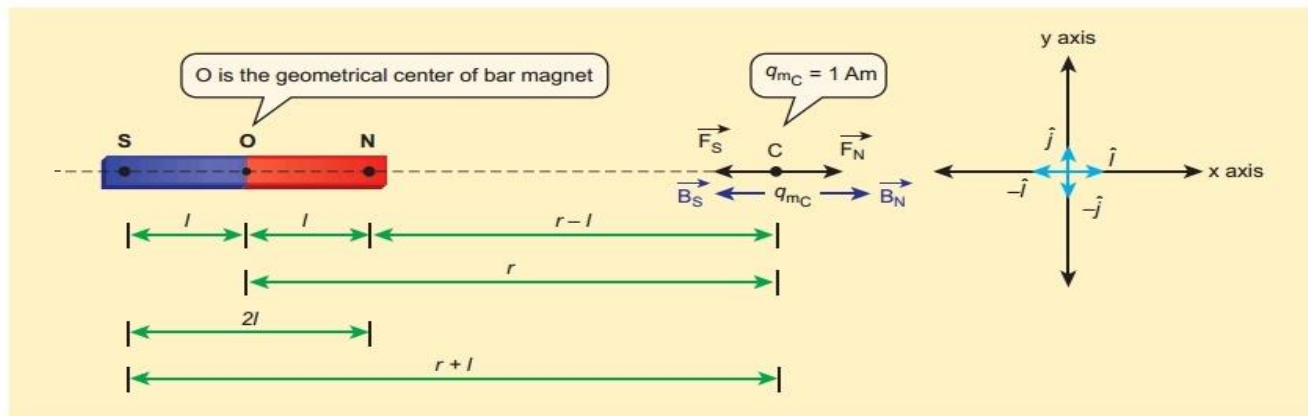
Figure 3.16 Magnetic field at a point along the axial line due to magnetic dipole

The magnetic field at a point C (lies along the axis of the magnet) at a distance from the geometrical center O of the bar magnet can be computed by keeping unit north pole (q_{mc} = 1 A m) at C. The force experienced by the unit north pole at C due to pole strength can be computed using Coulomb's law of magnetism

The force of repulsion between north pole of the bar magnet and unit north pole at point C (in free space) is

$$\vec{F_N} = \frac{\mu_0}{4\pi} \frac{q_m}{(r-l)^2} \hat{\imath} \quad ....(1)$$

The force of attraction between South Pole of the bar magnet and unit North Pole at point C (in free space) is

$$\vec{F_S} = -\frac{\mu_0}{4\pi} \frac{q_m}{(r+l)^2} \hat{\imath} \quad ....(2)$$

$$\vec{F} = \vec{F_N} + \vec{F_S}$$
$$\vec{F} = \vec{B}$$
$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q_m}{(r-l)^2} \hat{\imath} - \frac{\mu_0}{4\pi} \frac{q_m}{(r+l)^2} \hat{\imath}$$
$$= \frac{\mu_0}{4\pi} q_m \left(\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2} \right) \hat{\imath}$$
$$= \frac{\mu_0}{4\pi} 2r \left(\frac{q_m\, 2l}{(r^2-l^2)^2} \right) \hat{\imath}$$
$$\mathbf{P_m = q_m \times 2l}$$
$$= \frac{\mu_0}{4\pi} \frac{2r\, P_m}{(r^2-l^2)^2} \hat{\imath}$$
$$\mathbf{r^2 \gg l^2 \quad l^2 \ can\ ne\ neglected}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{2 P_m}{r^3} \hat{\imath}$$
$$= \frac{\mu_0}{4\pi} \frac{2}{r^3} \vec{P_m}$$

6.Obtain the magnetic induction at a point on the equatorial line of bar magnet

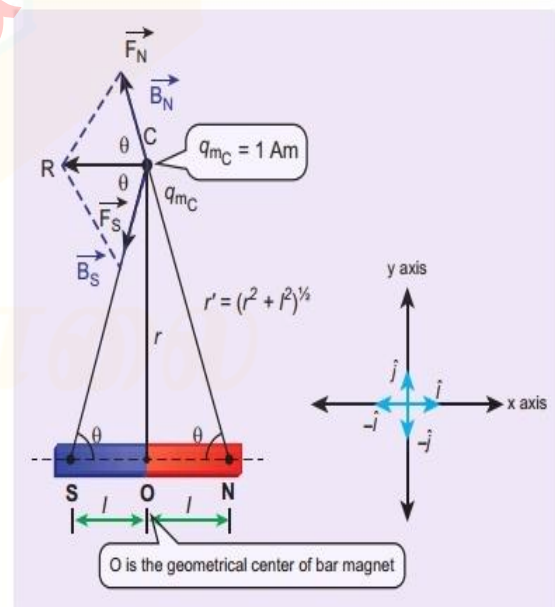Figure 3.17 Magnetic field at a point along the equatorial line due to a magnetic dipole

$\vec{dl}$ is the line element along the amperian loop (tangent to the circular loop).
Hence, the angle between magnetic field vector and line element is zero

$$\oint_C \vec{B}\,\vec{dl} = \mu_0\,I$$

Magnitude of the magnetic field is uniform over the Ampèrian loop

$$\vec{B}\oint_C \vec{dl} = \mu_0\,I$$

$$B\int_0^{2\pi r} dl = \mu_0\,I$$

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

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

In vector form

$$\vec{B} = \frac{\mu_0}{2\pi r}I\,\hat{n}$$

$\hat{n}$ − the unit vector along the tangent to the Ampèrian loop
This perfectly agrees with the result obtained from Biot-Savart's law

8.Discuss the working of cyclotron in detail

Cyclotron is a device used to accelerate the charged particles to gain large kinetic energy.

Principle

When a charged particle moves normal to the magnetic field, it experiences magnetic Lorentz force.

Working

Ion ejected from source S is positively charged.
As soon as ion is ejected, it is accelerated towards a Dee (say, Dee – 1) which has negative potential at that time.
Since the magnetic field is normal to the plane of the Dees, the ion undergoes circular path. After one semi-circular path in Dee-1, the ion reaches the gap between Dees.

At this time, the polarities of the Dees are reversed so that the ion is now accelerated towards Dee-2 with a greater velocity.
For this circular motion, the centripetal force of the charged particle q is provided by Lorentz force.

Lorentz force = Bqv

Centripetal force $= \dfrac{mv^2}{r}$

$$\frac{mv^2}{r} = Bqv$$

$$r = \frac{mv}{qB} \quad .... (1)$$

$r \; \alpha \; v$
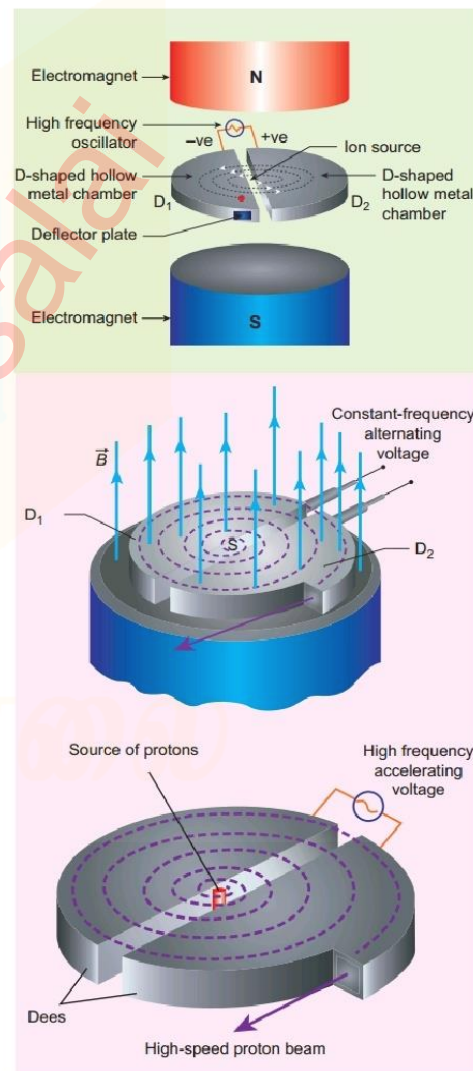
Figure 3.55 construction and working of cyclotron

+2 PHYSICS   SAIVEERA ACADEMY - 8098850809   STUDY MATERIAL

In a fine suspension strip W, a small plane mirror is attached in order to measure the deflection of the coil with the help of lamp and scale arrangement.

The other end of the mirror is connected to a torsion head T. In order to pass electric current through the galvanometer, the suspension strip W and the spring S are connected to terminals.
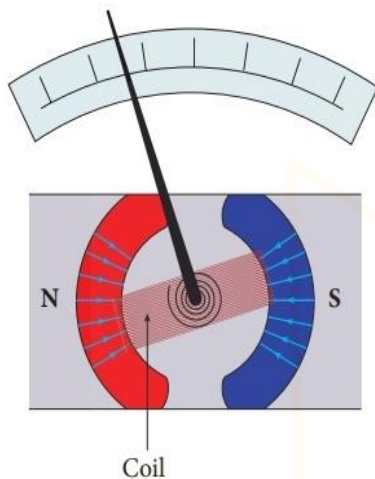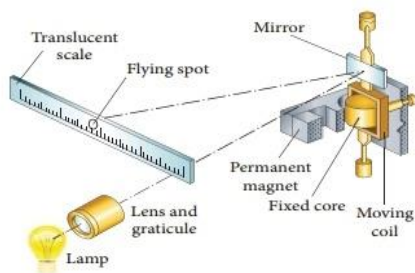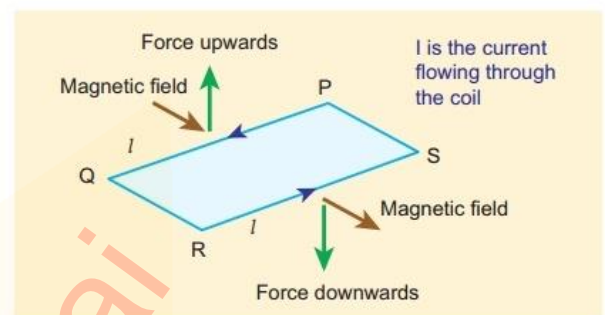

Figure 3.66 Moving coil galvanometer – its parts
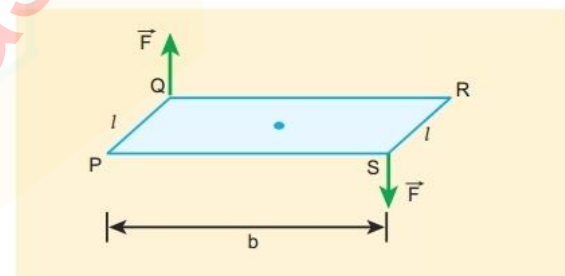

Figure 3.67 Force acting on current carrying coil

Figure 3.68 Deflection couple

Construction

A moving coil galvanometer consists of a rectangular coil PQRS of insulated thin copper wire.

The coil contains a large number of turns wound over a light metallic frame.

A cylindrical soft-iron core is placed symmetrically inside the coil .

The rectangular coil is suspended freely between two pole pieces of a horse-shoe magnet.

The upper end of the rectangular coil is attached to one end of fine strip of phosphor bronze and the lower end of the coil is connected to a hair spring which is also made up of phosphor bronze.

Working

Coil PQRS whose length be l and breadth b. PQ = RS = l and QR = SP = b.

Let I be the electric current flowing through the rectangular coil PQRS The horse-shoe magnet has hemi - spherical magnetic poles which produces a radial magnetic field.

Due to this radial field, the sides QR and SP are always parallel to to the B-field (magnetic field) and experience no force.

+2 PHYSICS   SAIVEERA ACADEMY - 8098850809   STUDY MATERIAL
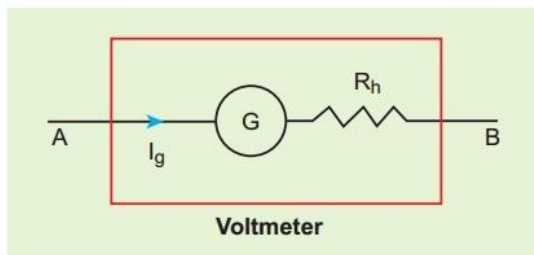
Galvanometer to a voltmeter

Figure 3.70 Shunt resistance connected in series

Voltmeter must have high resistance and when it is connected in parallel, it will not draw appreciable current so that it will indicate the true potential difference

A galvanometer is converted into a voltmeter by connecting high resistance R_h in series with galvanometer as shown in Figure 3.74. The scale is now calibrated in volt and the range of voltmeter depends on the values of the resistance connected in series i.e. the value of resistance is so adjusted that only current Ig produces full scale deflection in the galvanometer.
Let R_g be the resistance of galvanometer and I_g be the current with which the galvanometer produces full scale deflection. Since the galvanometer is connected in series with high resistance, the current in the electrical circuit is same as the current passing through the galvanometer.
$I = I_g$

$I_g = \dfrac{potential\ difference}{total\ resistance}$

Since the galvanometer and high resistance are connected in series, the total resistance or effective resistance gives the resistance of voltmeter. The voltmeter resistance is

$R_V = R_S + R_h$

$I_g = \dfrac{V}{R_s + R_h}$

$R_h = \dfrac{V}{I_g} - R_s$

$I_g \; \alpha \; V$

But current I_g is proportional to the potential difference. Hence the deflection in the galvanometer is proportional to potential difference. Since the resistance of voltmeter is very large, a voltmeter connected in an electrical circuit will draw least current in the circuit. An ideal voltmeter is one which has infinite resistance.

12.Calculate the magnetic field inside and outside of the long solenoid using Ampere's circuital law
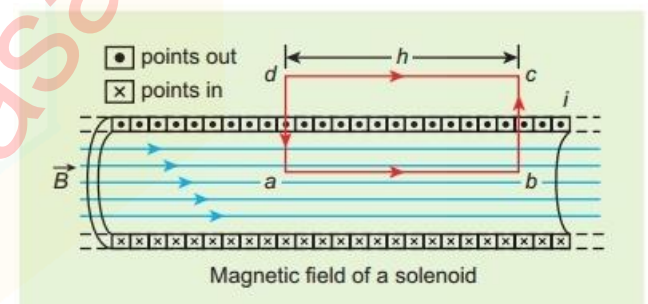

Figure 3.46 Amperian loop for solenoid

Consider a solenoid of length L having N turns. The diameter of the solenoid is assumed to be much smaller when compared to its length and the coil is wound very closely.
    We use Ampere's circuital law by considering a rectangular loop abcd
From Ampere's circuital law
$\oint_C \vec{B}\ \vec{dl} = \mu_0 I_{enclosed}$ ………………(1)

$$\oint \overrightarrow{B}\,\overrightarrow{dl} = \int_a^b \overrightarrow{B}\,\overrightarrow{dl} + \int_b^c \overrightarrow{B}\,\overrightarrow{dl} + \int_c^d \overrightarrow{B}\,\overrightarrow{dl} + \int_d^a \overrightarrow{B}\,\overrightarrow{dl}$$

For elemental length along bc & da magnetic field perpendicular to them

$$\int_b^c \overrightarrow{B}\,\overrightarrow{dl} = \int_b^c |\vec{B}|\,|\overrightarrow{dl}| \cos 90^0 = 0$$

Similarly $\int_d^a \overrightarrow{B}\,\overrightarrow{dl} = 0$

Magnetic field outside the solenoid is zero
$$\int_c^d \overrightarrow{B}\,\overrightarrow{dl} = 0$$

For the path along ab , integral is
$$\int_a^b \overrightarrow{B}\,\overrightarrow{dl} = B \int_a^b dl \cos 0^0 = B \int_a^b dl$$

NI – current passing through the solenoid of N turns
$$\mu_0\,I_{enclosed} = \mu_0\,N\,I = \mu_0 \frac{NI}{L} = \mu_0\,nI \;\;.....(3)$$
Equating (2) & (3)
$$B = \mu_0 nI$$
n is a constant for a given solenoid and μ_0 is also constant. For a fixed current I, the magnetic field inside the solenoid is also a constant.

Long answers (Book inside)
1. Write about Properties of magnet

 1.A freely suspended bar magnet will always point along the north-south direction.

 2. A magnet attracts another magnet or magnetic substances towards itself. The attractive force is maximum near the end of the bar magnet

 3.When a magnet is broken into pieces, each piece behaves like a magnet with poles at its ends.

 4. Two poles of a magnet have pole strength equal to one another.

 5. The length of the bar magnet is called geometrical length and the length between two magnetic poles in a bar magnet is called magnetic length. Magnetic length is always slightly smaller than geometrical length. The ratio of magnetic length and geometrical length is 5 / 6

2.Write about properties of Magnetic field lines

 1. Magnetic field lines are continuous closed curves.

 2.The direction of magnetic field lines is from North pole to South pole outside the magnet and South pole to North pole inside the magnet.

 3. The direction of magnetic field at any point on the curve is known by drawing tangent to the magnetic line of force at that point.

 4. Magnetic field lines never intersect each other.

 5. The degree of closeness of the field lines determines the relative strength of the magnetic field. The magnetic field is strong where magnetic field lines crowd

Working

When no current is passed through the coil, the small magnetic needle lies along horizontal component of Earth's magnetic field.

When the circuit is switched ON, the electric current will pass through the circular coil and produce magnetic field.

Now there are two fields which are acting mutually perpendicular to each other. They are:

(1) the magnetic field (B) due to the electric current in the coil acting normal to the plane of the coil.

(2) the horizontal component of Earth's magnetic field (B_H).

Because of these crossed fields, the pivoted magnetic needle deflects through an angle θ. From tangent law $B = B_H \tan θ$ ………(1)

When an electric current is passed through a circular coil of radius R having N turns, the magnitude of magnetic field at the center is

$$B = \mu_0 \frac{NI}{2R} ………..(2)$$

Comparing (1) & (2)

$$\mu_0 \frac{NI}{2R} = B_H \tan θ$$

$$B_H = \mu_0 \frac{NI}{2R} \frac{1}{\tan θ} \text{ in tesla}$$

$$I = K θ$$

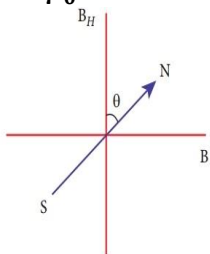$$K = \frac{2RB_H}{N\mu_0} ……… \text{ Reduction factor}$$

Figure 3.24 (a) circuit connection (b) resultant position of pivoted needle

The tangent Galvanometer is most sensitive at a deflection of 45º. Generally the deflection is taken between 30º and 60º.

5. What are Applications of hysteresis loop

i) Permanent magnets:

The materials with high retentivity, high coercivity and high permeability are suitable for making permanent magnets.
Examples: Steel and Alnico

ii) Electromagnets:

The materials with high initial permeability, low retentivity, low coercivity and thin hysteresis loop with smaller area are preferred to make electromagnets.

Core of the transformer:

The materials with high initial permeability, large magnetic induction and thin hysteresis loop with smaller area are needed to design transformer cores.
Examples: Soft iron

6. Difference between soft and hard ferro magnet

Soft ferro magnetic materials	Hard ferro magnetic materials
Area of loop is small	Area of loop is large
Retentivity is low	Retentivity is large
Coercivity is low	Coercivity is large
Hysteresis loss is less	Hysteresis loss is More
Uses ;	**Uses ;** Permanent magnets

+2 PHYSICS   SAIVEERA ACADEMY - 8098850809   STUDY MATERIAL

Solenoid core, transformer core and electromagnets	
Susceptibility and magnetic permeability **is high**	Susceptibility and magnetic permeability **is low**
When external field is removed Magnetisation disappears	When external field is removed Magnetisation persists
Examples ; Soft iron, Mumetal, Stalloy	**Example :** Steel,Alnico, Lodestone etc

(ii) directly as the magnitude of the length element $\vec{dl}$

(iii) directly as the sine of the angle (say,θ) between $\vec{dl}$ and $\hat{r}$

(iv) inversely as the square of the distance between the point P and length element $\vec{dl}$.

dB $\alpha \dfrac{Idl}{r^2}$ **sinΘ**

dB $= k \dfrac{Idl}{r^2}$ **sinΘ**

k $= \dfrac{\mu_0}{4\pi}$ **in S.I unit**

In vector notation

$$\vec{dB} = \dfrac{\mu_0}{4\pi}\ \dfrac{\vec{Idl}\times\hat{r}}{r^2}$$

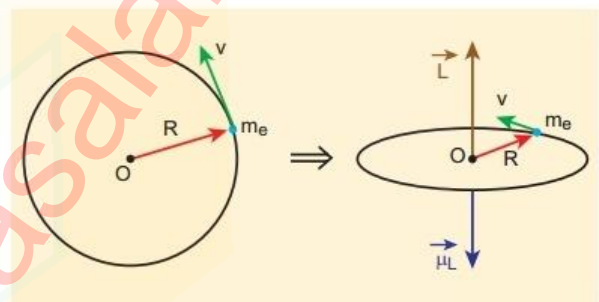**8.Derive Magnetic dipole moment of revolving electron**

Figure 3.41 (a) Electron revolving in a circular orbit (b) Direction of magnetic dipole moment vector and orbital angular momentum vector are opposite
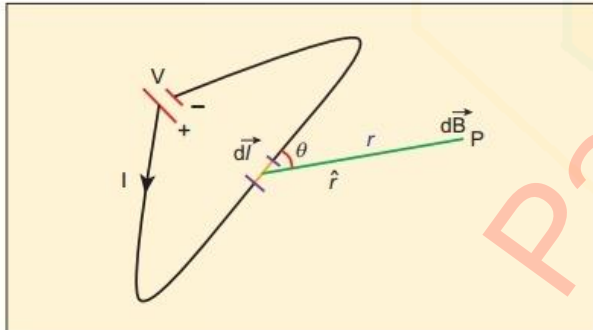
7. State Biot – Savart's law

Figure 3.37 Magnetic field at a point P due to current carrying conductor

Biot and Savart observed that the magnitude of magnetic field $\vec{dB}$ at a point P at a distance r from the small elemental length taken on a conductor carrying current varies

(i) directly as the strength of the current I

 Suppose an electron undergoes circular motion around the nucleus ,The circulating electron in a loop is like current in a circular loop (since flow of charge is current). The magnetic dipole moment due to current carrying circular loop is

$\vec{\mu}_L$ **= I** $\vec{A}$ **…….. (1)**

In magnitude μ_L **= IA ………(2)**

If T is the time period of an electron, the current due to circular motion of the electron is

Consider a charged particle of charge q having mass m enters into a region of uniform magnetic field $\vec{B}$ with velocity $\vec{v}$ such that velocity is perpendicular to the magnetic field. As soon as the particle enters into the field, Lorentz force acts on it in a direction perpendicular to both magnetic field and velocity.

As a result, the charged particle moves in a circular orbit

Since Lorentz force acts as centripetal force for the particle to execute circular motion.

Lorentz force F = Bqv ……….. (1)

Centripetal force F = mv² / r ………..(2)

Equating (1) & (2)

Bqv = mv² / r

$r = \frac{mv}{qB}$ …………(3)

T be the time taken by the particle to finish one complete circular motion, then

$T = \frac{2\pi r}{v}$ ………..(4)

Sub (3) in (4)

$T = \frac{2\pi m}{qB}$ ………..(5)

Above equation is time period of cyclotron

The reciprocal of time period is the frequency *f*,

$f = \frac{qB}{2\pi m}$

In terms of angular frequency ω,

$\omega = 2\pi f = \frac{qB}{m}$

12.Derive Force on a current carrying conductor placed in a magnetic field

When a current carrying conductor is placed in a magnetic field, the force experienced by the wire is equal to the sum of Lorentz forces on the individual charge carriers in the wire.
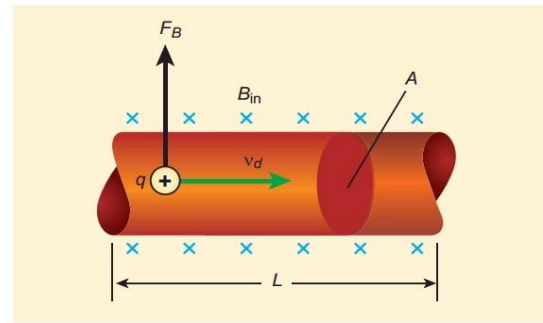

Figure 3.56 Current carrying conductor in a magnetic field

Consider a small segment of wire of length d*l*, with cross- sectional area A and current I

The free electrons drift opposite to the direction of current. So the relation between current I and magnitude of drift velocity v_d is

I = nAev_d ………… (1)

If the wire is kept in a magnetic field $\vec{B}$, then average force experienced by the charge (here, electron) in the wire is

$\vec{F} = -e\,(\vec{v}_d \times \vec{B})$ ………(2)

Let n be the number of free electrons per unit volume, therefore n = N/V ……. (3)

N - is the number of free electrons

V = A.dl

N = nAdl

q = Ne = enAdl ………….(4)

$\overrightarrow{dF} = -e\,nAdl\,(\vec{v}_d \times \vec{B})$

I. $\overrightarrow{dl}$ = -enA$\vec{v}_d$dl

$\overrightarrow{dF} = I\overrightarrow{dl} \times \vec{B}$

The force in a straight current carrying conducting wire of length *l* placed in a uniform magnetic field is

$\vec{F} = I\vec{l} \times \vec{B}$

In magnitude F = BIl sinΘ

(a) If the conductor is placed along the direction of the magnetic field, the angle between them is θ = 0₀. Hence, the force experienced by the conductor is zero.

13.Explain about Hysteresis loop

A ferromagnetic material (example, Iron) is magnetised slowly by a magnetising field . The magnetic induction of the material increases from point A with the magnitude of the magnetising field and then attains a saturated level. This response of the material is depicted by the path AC.Saturation magnetization is defined as the maximum point up to which the material can be magnetised by applying the magnetising field.

If the magnetising field is now reduced, the magnetic induction also decreases but does not retrace the original path CA. It takes different path CD. When the magnetising field is zero, the magnetic induction is not zero and it has positive value. This implies that some magnetism is left in the specimen even when H = 0. The **residual magnetism AD present in the specimen is called remanence or retentivity. It is defined as the ability of the materials to retain the magnetism in them even magnetising field vanishes.**

In order to demagnetise the material, the magnetising field is gradually increased in the reverse direction. Now the magnetic induction decreases along DE and becomes zero at E. The magnetising field AE in the reverse direction is required to bring residual magnetism to zero. **The magnitude the residual magnetism of the material vanishes is called its coercivity.** Further increase of in the reverse direction, the magnetic induction increases along EF until it reaches saturation at F in the reverse direction. If magnetising field is decreased and then

increased with direction reversed, the magnetic induction traces the path FGKC. This closed curve ACDEFGKC is called hysteresis loop and it represents a cycle of magnetisation.

In the entire cycle, the magnetic induction B lags behind the magnetising field H. This **phenomenon of lagging of magnetic induction behind the magnetising field is called hysteresis.** Hysteresis means 'lagging behind'.
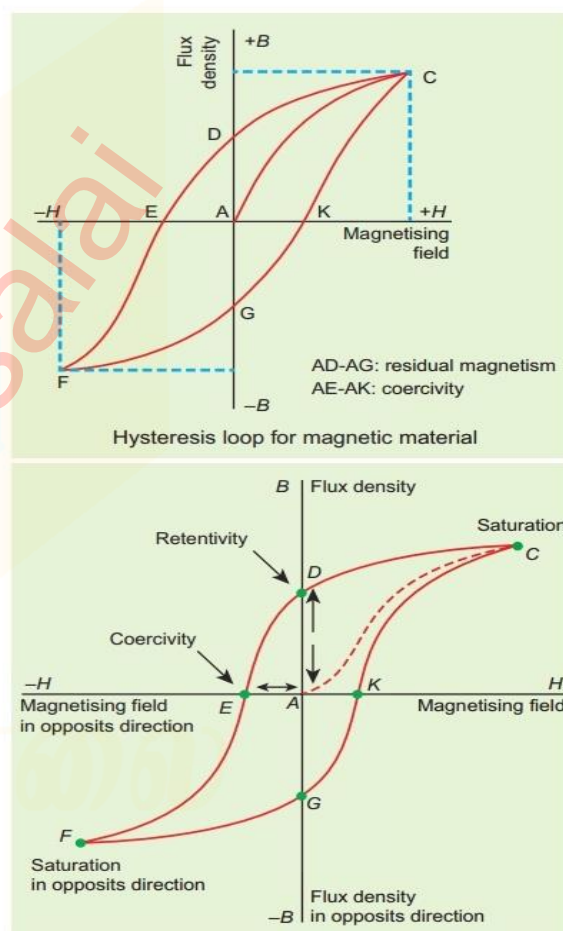

Hysteresis loop for magnetic material

Figure 3.30 Hysteresis – plot for B vs H

14.Derive Expression for torque on a current loop placed in a magnetic field

Refer topic number (3.11.1)