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 ($\vec{H}$)
   \[
   \chi_m = \frac{\vec{M}}{\vec{H}}
   \]
   It is a dimensionless quantity

6. State Biot – Savart’s law
   Biot and Savart observed that the magnitude of magnetic field $d\vec{B}$ 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 $dl$
   (iii) directly as the sine of the angle (say, θ) between $dl$ and $\hat{r}$
   (iv) inversely as the square of the distance between the point P and length element $dl$

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 $\mu_0$ times net current enclosed by the loop.
   \[
   \oint \vec{B} \cdot dl = \mu_0 I_{\text{enclosed}}
   \]
   $I_{\text{enclosed}}$ - Net current linked by the closed loop C.
9. Compare dia, para, & ferro magnetism

<table>
<thead>
<tr>
<th>Dia magnetism</th>
<th>Para magnetism</th>
<th>Ferro magnetism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic susceptibility is negative</td>
<td>Magnetic susceptibility is positive &amp; small</td>
<td>Magnetic susceptibility is positive and large</td>
</tr>
<tr>
<td>Relative permeability is slightly less than unity.</td>
<td>Relative permeability is slightly greater than unity.</td>
<td>Relative permeability is large.</td>
</tr>
<tr>
<td>Susceptibility is nearly temperature independent.</td>
<td>Susceptibility is inversely proportional to temperature.</td>
<td>Susceptibility is inversely proportional to temperature.</td>
</tr>
<tr>
<td>Ex: Bismuth, Copper and Water</td>
<td>Ex: Aluminiunm, Platinum &amp; chromium</td>
<td>Ex: Iron, Nickel and Cobalt</td>
</tr>
</tbody>
</table>

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
   \[ \vec{B} = \frac{\vec{F}}{q_m} \]
   Unit: N A⁻¹ m⁻¹

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.
   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
   Susceptibility is inversely proportional to temperature
   \[ \chi_m \alpha \frac{1}{T} \]

18. Why there is a strong net magnetisation of the Ferromagnetic 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
   \[ \chi_m = \frac{C}{T - T_C} \]

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

   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

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
<table>
<thead>
<tr>
<th>Electric field</th>
<th>Magnetic field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produced by scalar source ( q )</td>
<td>Produced by vector source ( I , dl )</td>
</tr>
<tr>
<td>It is directed along the position vector joining the source &amp; the point at which field is calculated</td>
<td>It is directed perpendicular to the position vector ( \vec{r} ) and the current element ( I , dl )</td>
</tr>
<tr>
<td>Does not depend on angle</td>
<td>Depend an angle between position vector and current element</td>
</tr>
</tbody>
</table>

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.
   \[ \vec{P}_m = I \vec{A} \]
   Unit : A m^2
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 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 dl of the wire at a distance l from point O.

\[ \mathbf{B} = \mathbf{B}_H \sin \theta \]

\[ \mathbf{B}_H = \frac{\mu_0 I}{2\pi l} \]

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

\( \vec{r} \) be the vector joining the element dl with the point P.

\[ \theta = \text{angle between } \vec{r} \text{ & } \overrightarrow{dl} \]
Horizontal components of each current element cancels out while the vertical components \((dB \cos \theta)\) alone contribute to total magnetic field at the point P.

\[
\mathbf{PC} = \mathbf{PD} = r = \sqrt{R^2 + Z^2}
\]

Then the net magnetic field at point P is

\[
\mathbf{B} = \int d\mathbf{B} = \int d\mathbf{B} \cos \theta \hat{k} = \frac{\mu_0}{4\pi} I \int \frac{dB}{r^2} \cos \theta \hat{k}
\]

By triangle POD

\[
\cos \theta = \frac{R}{\sqrt{R^2 + Z^2}}
\]

sub \(\cos \theta\) value in (2),

integrating line element from 0 to \(2\pi R\), we get

\[
\mathbf{B} = \frac{\mu_0}{2\pi} I \frac{R^2}{(R^2 + x^2)^{3/2}} \hat{k}
\]

4. Compute the torque experienced by a magnetic needle 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 \(q_m B\) but acts in opposite direction. Therefore, the net force exerted on the magnet is zero, so that there is no transitory 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

\[
\mathbf{F_N} = q_m \mathbf{B} \quad \text{(1)}
\]

The force experienced by South pole

\[
\mathbf{F_S} = -q_m \mathbf{B} \quad \text{(2)}
\]

Adding (1) & (2)

Net force on the dipole as

\[
\mathbf{F} = \mathbf{F_N} + \mathbf{F_S} = 0
\]

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

\[
\mathbf{\tau} = \mathbf{ON} \times \mathbf{F_N} + \mathbf{OS} \times \mathbf{F_S}
\]

\[
= \mathbf{ON} \times q_m \mathbf{B} + \mathbf{OS} \times (-q_m \mathbf{B})
\]

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

Since the magnitudes

\[
|\mathbf{ON}| = |\mathbf{OS}| = l
\]

\[
|Bq_m| = |-Bq_m|
\]

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 \(P_m = q_m \times 2l\)

\[
P_m B \sin \theta
\]

In vector notation

\[
\mathbf{\tau} = \mathbf{P_m} \times \mathbf{B}
\]

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 \(2l\).
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 \( (q_{mc} = 1 \text{ A m}) \) 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

\[
\vec{F}_N = \frac{\mu_0 q_m}{4\pi (r-l)^2} \hat{i} \quad \text{.........(1)}
\]

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

\[
\vec{F}_S = -\frac{\mu_0 q_m}{4\pi (r+l)^2} \hat{i} \quad \text{.........(2)}
\]

\[
\vec{F} = \vec{F}_N + \vec{F}_S
\]

\[
\vec{B} = \frac{\mu_0 q_m}{4\pi (r-l)^2} \hat{i} - \frac{\mu_0 q_m}{4\pi (r+l)^2} \hat{i}
\]

\[
= \frac{\mu_0}{4\pi} q_m \left( \frac{1}{(r-l)^2} - \frac{1}{(r+l)^2} \right) \hat{i}
\]

\[
= \frac{\mu_0}{4\pi} 2r \left( \frac{q_m 2l}{(r^2 - l^2)^2} \right) \hat{i}
\]

\[
\vec{B} = \frac{\mu_0}{4\pi} \frac{2P_m}{r^3} \hat{i}
\]

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

\[
\vec{B} = \frac{\mu_0}{4\pi} \frac{2P_m}{r^3} \hat{i}
\]

\[
= \frac{\mu_0}{4\pi} \frac{2}{r^3} P_m
\]

\[
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\]

\[
\text{PEELAMEDU 8098850809}
\]
\( d\ell \) 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

\[ \phi \mathbf{B} \cdot \mathbf{d\ell} = \mu_0 I \]

Magnitude of the magnetic field is uniform over the Ampèrian loop

\[ \mathbf{B} \cdot \oint_{0}^{2\pi r} \mathbf{dl} = \mu_0 I \]

\( B \int_{0}^{2\pi r} \mathbf{dl} = \mu_0 I \)

\( B = \frac{\mu_0 I}{2\pi r} \)

In vector form

\[ \mathbf{B} = \frac{\mu_0 I}{2\pi r} \mathbf{\hat{n}} \]

\( \mathbf{\hat{n}} \) - 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 = \( \frac{mv^2}{r} \)

\[ \frac{mv^2}{r} = Bqv \]

\[ r = \frac{mv}{qB} \]  \hspace{1cm} (1)

\( r \propto v \)

**Figure 3.55** construction and working of cyclotron

---

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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.

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.

\[ \text{Figure 3.66 Moving coil galvanometer – its parts} \]

\[ \text{Figure 3.67 Force acting on current carrying coil} \]

\[ \text{Figure 3.68 Deflection couple} \]
Galvanometer to a voltmeter

![Diagram of a voltmeter](image)

**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 \( I_g \) 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.

\[
I = I_g \quad I_g = \frac{\text{potential difference}}{\text{total resistance}}
\]

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

\[
R_v = R_s + R_h
\]

\[
I_g = \frac{V}{R_s + R_h}
\]

\[
R_h = \frac{V}{I_g} - R_s
\]

\[
I_g \propto V
\]

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

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

\[
\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enclosed}} \quad \text{(1)}
\]
\[\Phi = \int B \, dl = \int_a^b B \, dl + \int_b^c B \, dl + \int_c^d B \, dl + \int_d^a B \, dl\]

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

\[\int_b^c B \, dl = \int_b^c |B| \, |dl| \cos 90^\circ = 0\]

Similarly \[\int_d^a B \, dl = 0\]

Magnetic field outside the solenoid is zero

\[\int_c^d B \, dl = 0\]

For the path along ab, integral is

\[\int_a^b B \, dl = B \int_a^b dl \cos 0^\circ = B \int_a^b dl\]

\[N I \text{ – current passing through the solenoid of } N \text{ turns}\]

\[\mu_0 I_{\text{enclosed}} = \mu_0 NI = \mu_0 \frac{NI}{L} = \mu_0 n I \ldots \ldots (3)\]

Equating (2) & (3)

\[B = \mu_0 n I\]

\(n\) is a constant for a given solenoid and \(\mu_0\) 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 \(\frac{5}{6}\).

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.
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

<table>
<thead>
<tr>
<th>Soft ferro magnetic materials</th>
<th>Hard ferro magnetic materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of loop is small</td>
<td>Area of loop is large</td>
</tr>
<tr>
<td>Retentivity is low</td>
<td>Retentivity is large</td>
</tr>
<tr>
<td>Coercivity is low</td>
<td>Coercivity is large</td>
</tr>
<tr>
<td>Hysteresis loss is less</td>
<td>Hysteresis loss is More</td>
</tr>
<tr>
<td>Uses ;</td>
<td>Uses ;</td>
</tr>
<tr>
<td>Permanent magnets</td>
<td></td>
</tr>
</tbody>
</table>
7. State Biot – Savart’s law

Biot and Savart observed that the magnitude of magnetic field $dB$ 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 $dl$
- (iii) directly as the sine of the angle (say, $\theta$) between $dl$ and $\hat{r}$
- (iv) inversely as the square of the distance between the point $P$ and length element $dl$.

$dB \propto \frac{Idl}{r^2} \sin \Theta$

$dB = k \frac{Idl}{r^2} \sin \Theta$

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

In vector notation

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

8. Derive Magnetic dipole moment of revolving electron

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

$\vec{\mu}_L = I \vec{A}$ \hspace{1cm} (1)

In magnitude $\mu_L = IA$ \hspace{1cm} (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 $F = mv^2 / r$ ..............(2)

Equating (1) & (2)

$Bqv = mv^2 / r$

$r = \frac{mv}{qB}$ ............(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 $\omega$,

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

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.

Consider a small segment of wire of length $dl$, 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

$I = nAe v_d$ ..............(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 $n = \frac{N}{V}$ .......(3)

$N$ - is the number of free electrons

$V = A \cdot dl$

$N = nA dl$

$q = Ne = enAdl$ ..............(4)

$\frac{dF}{dl} = -e nA dl (\vec{v}_d \times \vec{B})$

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

$\frac{dF}{dl} = I\vec{v}_d \times \vec{B}$

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

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

In magnitude $F = BI\sin\theta$

(a) If the conductor is placed along the direction of the magnetic field, the angle between them is $\theta = 0^\circ$. 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](image)

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

Refer topic number (3.11.1)