Unit III: Dielectric and Magnetic Materials

Introduction:

- Dielectrics are the substances which do not contain free electrons or the number of such electrons is too low to constitute the electric current.
- So, the dielectric is insulating materials.
- But the insulating materials are used to resist the flow of current whereas dielectrics are used to store electrical energy.
- Dielectrics are nonmetallic materials of high specific resistance and have negative temperature coefficient of resistance

Definitions:

1. Electric field intensity: the force acting per unit test charge is defined as electric field strength or electric field intensity.

- From coulombs law,

$$F = \frac{1}{4\pi\varepsilon_o} \times \frac{q_1 q_2}{r^2}$$

$$\frac{F}{q_1} = \frac{1}{4\pi\varepsilon_o} \times \frac{q_2}{r^2}$$

$$\boxed{E = \frac{F}{q} = \frac{1}{4\pi\varepsilon_o} \times \frac{q}{r^2}}$$

- Units are N/C

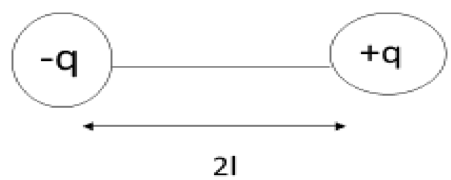
$$\boxed{generally, E = \frac{q}{\varepsilon(4\pi r^2)} = \frac{q}{\varepsilon A}}$$

2. Electric flux density: the number of flux lines crossing per unit surface area.

$$elctric\ flux\ density = \frac{\phi}{A}$$

- Units are Wb/sq. mts

3. Electric dipole: The arrangement of two equal and opposite point charges at a fixed distance is called an electric dipole.

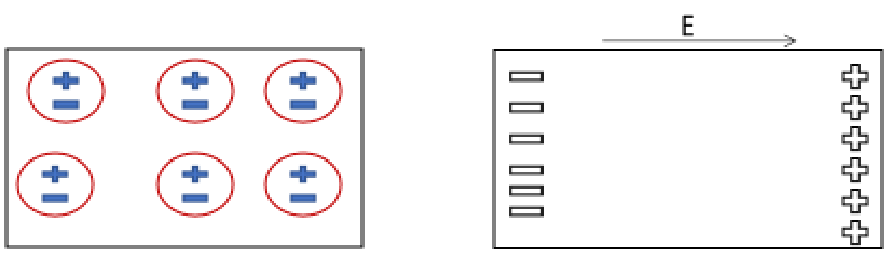


4. Electric dipole moment: (p) the product of charge and distance between the dipoles is called as electric dipole moment.

$$p = q \times 2l$$

- Units are C-m

5.Polarization: the displacement of positive and negative charges by application of external electric field is called as polarization.



6. Polarization vector: (P) the polarization vector is defined as the ratio of induced dipole moment per unit volume.

$$P = \frac{p}{v}$$

- It is also defined as the ratio of induced charge per unit area.

$$P = \frac{q'}{A}$$

- Units are C/sq. mts

7. Polarizability: as the external field increases, dipole moment also increases.

$$p \alpha E$$
$$p = \alpha E$$

- Where α is called polarizability.
- Polarizability is defined as the ratio of dipole moment per unit electric field.

$$\alpha = \frac{p}{E}$$

- Units are $\frac{C^2 - m}{N}$

8. Dielectric constant(K) or relative permittivity(ε_r)

It is defined as the ratio of permittivity of the medium to permittivity of the free space.

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_o}$$

- There is no units for relative permittivity or dielectric constant.
- It is also defined as the ratio of capacitance of a capacitor with medium to a capacitance of a capacitor without medium.

$$K = \frac{C}{C_o}$$

9. Susceptibility:(χ)

- As the applied field increases, polarisation also increases. There fore,

$$P \alpha E$$

$$P = \chi E$$

- Where χ is called susceptibility.
- Susceptibility is defined as the ratio ofpolarisation vector per unit electric field.

$$\chi = \frac{P}{E}$$

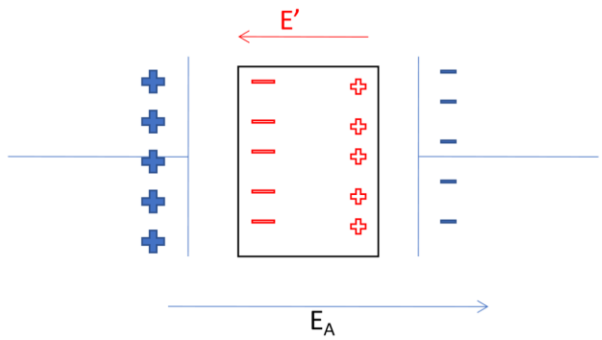
10. Displacement vector(D)

- The displacement vector is defined as the ratio of charge per unit area.

$$D = \frac{q}{A}$$

- Units are C/sq.mts

- Relation between D, P & E:
- Consider a parallel plate capacitor with a dielectric material is placed in a external electric field.



- Total field,

$$E = E_A + (-E')$$

Relation between D,P,E

- Relation between D & E:

$$D = \frac{q}{A}$$

$$D = \frac{q}{A} \times \frac{\varepsilon}{\varepsilon}$$

$$D = \frac{q}{\varepsilon A} \times \varepsilon$$

$$\boxed{D = E \times \varepsilon}$$

From relative permittivity,

$$\varepsilon = \varepsilon_0 \, \varepsilon_r$$

Therefore

$$\boxed{D = E \times \varepsilon_0 \, \varepsilon_r}$$

Relation between P & E:

- From the above relations,

$$\boxed{D = E \times \varepsilon_0 \, \varepsilon_r}$$

- Combining the above $\boxed{D = \varepsilon_o E + P}$

$$\varepsilon_0 \varepsilon_r E = \varepsilon_0 E + P$$

$$\varepsilon_0 \varepsilon_r E - \varepsilon_0 E = P$$

$$\boxed{P = (\varepsilon_r - 1)\varepsilon_0 E}$$

Relation between χ & ε_r

- From above relation

$$\boxed{P = (\varepsilon_r - 1)\varepsilon_0 E}$$

- Susceptibility,

$$P = \chi E$$

- Comparing above two equations,

$$\boxed{\chi = (\varepsilon_r - 1)\varepsilon_0}$$

Types of polarization:

There are three mechanisms by which polarization can occur in dielectric materials when they are subjected to an external electric field.

They are

- Electronic polarization
- Ionic polarization
- Orientation polarization.

<u>Electronic polarization</u>:

❖On the application of electric field, the displacement of positively charged nucleus and negatively charged electrons of an atom of radius R in opposite directions, results in electronic polarization.

❖Since the nucleus and centre of electron cloud are separated, the dipole moment is created in each atom.

❖Therefore induced dipole moment is directly proportional to applied electric field

$$p_e \alpha E$$

$$p_e = \alpha_e E$$

❖Where $\alpha_e = 4\pi\varepsilon_0 R^3$ Is called electronic polarizability

Ionic polarization:

- This type of polarization occurs only in ionic bonded dielectric materials such asNaCl.
- When such materials are subjected to external electric field, the adjacent ions of opposite sign undergo displacement.
- Hence ionic polarization is due to displacement of cations of mass m and anions of mass M in opposite direction.
- Therefore induced dipole moment is directly proportional to applied electric field

$$p_i \alpha E$$

$$p_i = \alpha_i E$$

- Where $\alpha_i = \frac{e^2}{\omega_0^2}\left[\frac{1}{m} + \frac{1}{M}\right]$ is called ionic polarizability.

Orientation polarization

- Polar dielectrics exhibit orientation polarization
- When an external field is applied to polar dielectrics, they tend to align themselves in the direction of external electric field.
- The polarization due to such alignment is called orientation polarization.
- Therefore induced dipole moment is directly proportional to applied electric field

$$p_o \alpha E$$

$$p_o = \alpha_o E$$

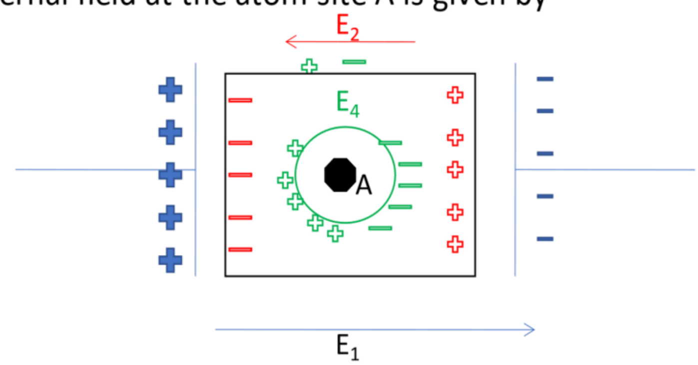
- Where $\alpha_o = \frac{\mu^2}{3KT}$ is called orientation polarizability
- Orientation polarization depends on temperature.

Internal field of a dielectric solid

The electric field at any given atom is the sum of applied electric field plus the electric field due to surrounding dipoles. This resultant local field is called as internal field.

DERIVATION:

- Consider a solid dielectric be placed between the plates of a parallel plate capacitor.
- let there be an imaginary spherical cavity around the atom a inside the dielectric.
- It is also assumed that the radius of the cavity is large compared to the radius of the atom.
- The internal field at the atom site A is given by



E_1 field:

- E_1 is the field intensity at A due to the charge density on the plates.

since,

Therefore,

$$E_1 = \frac{D}{\varepsilon_o}$$

$$D = P + \varepsilon_o E$$

$$E_1 = \frac{P + \varepsilon_o E}{\varepsilon_o}$$

$$E_1 = \frac{P}{\varepsilon_o} + E$$

E_2 field:

- E_2 is the field intensity at a due to the charge density induced on the two sides of the dielectric.

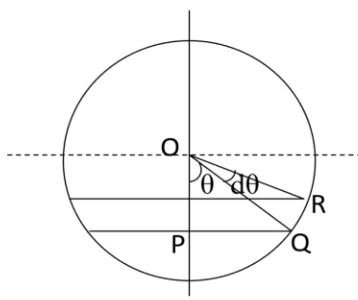
$$E_2 = -\frac{P}{\varepsilon_o}$$

E_3 field:

- It is the field due to other atoms contained in the cavity. Since it is a cubic structure, due to symmetry $E_3=0$.

E_4 field:

- It is the field due to polarization charges on the surface of the cavity and was calculated by Lorentz.



- If dA is the surface area of the sphere of radius r lying between θ and θ+dθ. then,

$$dA=2\Pi(PQ)(QR)$$

- Since, PQ=r sin θ, from right angle triangle OPQ

QR=r dθ, from triangle OQR

- Therefore, $\mathbf{dA=2\Pi r^2 \sin\theta\, d\theta}$

- The charge on the surfacedA is

$$dq = P\cos\theta\, dA$$
$$= P2\Pi r^2 \sin\theta \cos\theta\, d\theta$$
$$= P\Pi r^2 \sin 2\theta\, d\theta$$

Since, P=q/A, then q=PA. as the field is moving horizontally, the horizontal component of charge is q=(Pcosθ) A

- Therefore,

$$dE_4 = \frac{dq \times 1 \times \cos\theta}{4\pi\varepsilon_o r^2}$$
$$= \frac{P}{4\varepsilon_o}\cos\theta \sin 2\theta\ d\theta$$

- So,

$$E_4 = \int d\,E_4$$
$$= \frac{P}{4\varepsilon_o}\int \cos\theta \sin 2\theta\ d\theta$$

Sin 2θ = 2 cosθ sinθ

$$= \frac{P}{2\varepsilon_o}\int \cos^2\theta \sin\theta\ d\theta$$

Since, d(cosθ) = -sinθ dθ. Then sinθ dθ = d(-cosθ)

$$= \frac{P}{2\varepsilon_o}\int \cos^2\theta\ d(-\cos\theta)$$

limits extending from 0 toπ

$$= -\frac{P}{2\varepsilon_o}\frac{\cos^3\theta}{3}$$
$$= -\frac{P}{6\varepsilon_o}[-1-1]$$
$$= \frac{P}{3\varepsilon_o}$$

- Therefore internal field,

$$E_i = E_1 + E_2 + E_3 + E_4$$

$$E_i = E + \frac{P}{\varepsilon_o} - \frac{P}{\varepsilon_o} + 0 + \frac{P}{3\varepsilon_o}$$

$$\boxed{E_i = E + \frac{P}{3\varepsilon_o}}$$

Classius- mosotti relation :

- Consider a dielectric having cubic structure with N atoms.

$$P = \alpha_e N E_i = \alpha_e N \left[E + \frac{P}{3\varepsilon_o}\right]$$

$$P\left[1 - \frac{\alpha_e N}{3\varepsilon_o}\right] = [\alpha_e N E]$$

- We know that

$$P = \frac{[\alpha_e N E]}{\left[1 - \frac{\alpha_e N}{3\varepsilon_o}\right]}$$

$$\varepsilon_o E(\varepsilon_r - 1) = P$$

$$\varepsilon_o E(\varepsilon_r - 1) = \frac{[\alpha_e N E]}{\left[1 - \frac{\alpha_e N}{3\varepsilon_o}\right]}$$

$$1-\frac{\alpha_e N}{3\varepsilon_o}=\frac{[\alpha_e N]}{[\varepsilon_o(\varepsilon_r-1)]}$$

$$1=\frac{\alpha_e N}{3\varepsilon_o}+\frac{[\alpha_e N]}{[\varepsilon_o(\varepsilon_r-1)]}$$

$$1=\frac{\alpha_e N}{3\varepsilon_o}\left[1+\frac{3}{[(\varepsilon_r-1)]}\right]$$

$$\frac{\alpha_e N}{3\varepsilon_o}=\frac{1}{1+\frac{3}{[(\varepsilon_r-1)]}}$$

$$\frac{\alpha_e N}{3\varepsilon_o}=\frac{\varepsilon_r-1}{\varepsilon_r+2}$$

- This is called classius-mosotti relation.

Piezo electricity:

- Piezo electric phenomenon was discovered by curie brothers in 1880.
- Some of the materials when compressed or stretched in a certain direction become polarized and polarization charges appear on its surface.
- Polarization of a dielectric as a result of mechanical deformation is called as Piezo electric effect.
- The crystals that exhibit this effect are called Piezo electrics.
- These materials exhibit inverse Piezo electric effect.
- When electric stress is applied to materials they become strained. Strain is proportional to applied field.
- This piezoelectric effect is utilized in conversion of mechanical energy in to electrical energy and vice versa.

Example: quartz crystal, ceramic.

Applications:

- Quartz is used for filter, resonator.
- Rochelle salt used as transducer in gramophones, ear phones.
- Ceramics are used as high voltage generators, accelerometers.
- Semiconductors used as amplifier of ultrasonic waves.

Ferro electricity:

- There are some classes of dielectrics which possess a
  - Nonlinear relation between P & E.
  - Dielectric constant that changes with temperature.
  - Electrical hysteresis.

    i.e., variation of polarization with applied field.
- Therefore, Ferro electric materials are that class of dielectric materials which possess electrical properties which are analogues to the magnetic properties of a Ferro magnetic materials.

Example: $BaTiO_3$, KH_2PO_4, $NaKC_4H_4O_6.4H_20$, Rochelle salt.

Applications:

- Used to manufacture small sized capacitors of large capacitance
- Used as memory devices in computers
- Used to detect infrared solutions
- Used in electromechanical filters.

Pyroelectric Materials:

- Pyroelectricity is the property of a material to produce electrical energy when they are subjected to thermal energy change.
- Pyroelectric crystals are those poses the Pyroelectric effect, that is the ability of crystals to generate electricity when they are heated.
- When Pyroelectric materials are heated or cooled, it polarises in proportional to the change in temperature. As a result, the crystal generates an opposite polarity that creates a short period of electrical potential difference or a temporary voltage.
- The points that generate a particular polarity can also generate a reverse polarity at the same locations when it has applied with a negative temperature. That is, the charge polarity developed on a location during the heating will be reversed during cooling.

Pyroelectric materials applications:

- Passive infrared (PIR) sensors are a common type of motion detector sensors, which can detect the movement of human beings, animals, objects, etc., or anything which radiates thermal infrared radiation.
- The infrared thermometers or pyrometers are used for non-contact temperature measurements. They are used for temperature measurement in the areas where physical contact is not possible.
- Pyroelectric sensors are most commonly used sensor type, for measuring the Power and Energy of Lasers.

Introduction to LCDs

Liquid crystal displays (LCDs) are a type of flat-panel display that is commonly used in electronic devices, including televisions, computer monitors, and mobile phones. LCDs are made up of a layer of liquid crystals that are sandwiched between two sheets of polarizing material. The liquid crystals are able to change their alignment when an electric field is applied, allowing them to block or transmit light.

LCDs were first developed in the 1960s, and they have since become one of the most widely used display technologies in the world. They are popular because they are thin, lightweight, and energy-efficient. LCDs also have a high resolution and are able to display bright, vivid images.

Applications of LCDs

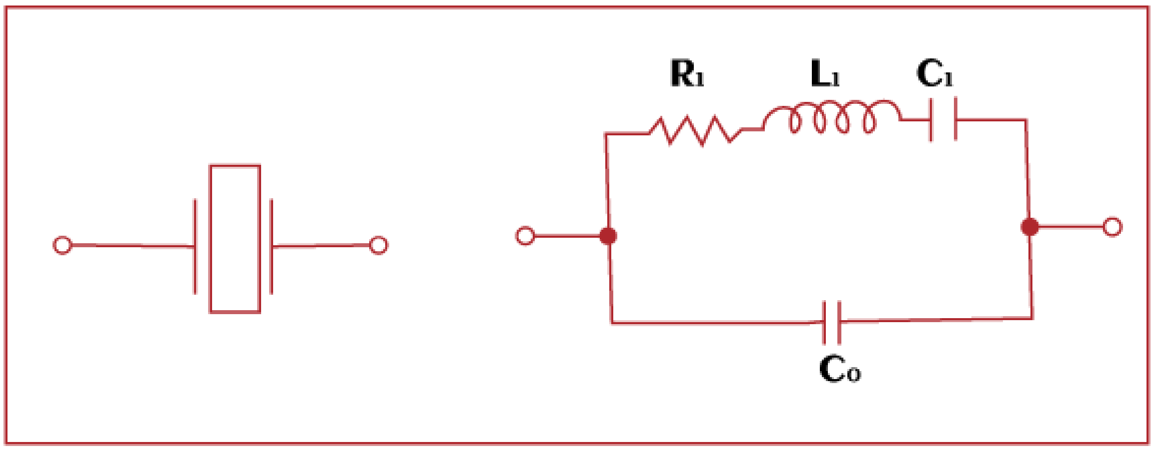
LCDs are used in a wide range of electronic devices, including televisions, computer monitors, digital cameras, and mobile phones. They are also used in industrial applications, such as in aircraft displays and medical equipment. LCDs have become increasingly popular in recent years because they are thin, lightweight, and energy-efficient.

One of the main advantages of LCDs is their ability to produce high-quality images. They are able to display bright, vivid colors and have a high resolution. They are also able to display a wide range of content, including text, images, and video.

Crystal Oscillator:

The crystal oscillator is a quartz crystal used as a frequency selective element. The quartz crystal is also known as piezoelectric crystal. Hence the oscillator circuit containing piezoelectric crystal is called a **crystal oscillator.** It has two electrodes that supply signals to the crystal. Crystal oscillators have high-frequency stability and a **high-Quality factor** compared to RC and LC tuned circuit oscillators. It is considered one of the highly stable oscillators suitable for high-frequency applications.

The circuit of a crystal oscillator is shown below



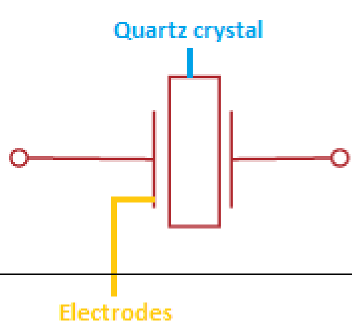
The quartz crystal is attached in parallel with the resonant circuit of the oscillator. The resonant circuit includes a resistor, capacitor, and an inductor connected in series. Co is the static capacitance associated with the quartz crystal.

Working

The input signal is applied to crystal oscillator circuit. It consists of a **crystal** and the **resonance circuit,** as shown above. The signal first passes through the electrodes of the quartz crystal. It changes its shape due to the applied voltage. When the voltage is removed, the crystal returns to its original shape. The crystal generates a small voltage before returning to its original position.

The piezoelectric crystal uses the electrical signal to produce vibrations. It means that the crystal converts electrical energy into mechanical energy. The vibrations get converted into oscillations of constant frequency. The other terminal converts the mechanical energy back to electrical energy.

The produced oscillations of constant frequency act like an RLC circuit. Once a crystal is adjusted to a specific frequency and other environmental factors, it starts maintaining a high frequency or high-Quality factor.



The crystal oscillators cover frequencies below 1000 Hz and above 200M Hz.

MAGNETIC PROPERTIES

1. MAGNETIC FIELD INTENSITY: (H)

- The magnetic field intensity (H) at any point in the magnetic field is the force experienced by an unit north pole placed at that point.
- Units are A/m

2. MAGNETIC FIELD INDUCTION: (B)

- The magnetic field induction (B) or magnetic flux density in any material is the no. of lines of magnetic force passing through unit area perpendicularly.
- Units are Wb/m^2 or Tesla

3. Magnetic dipole:

- The arrangement of any two opposite poles separated by certain distance is called as magnetic dipole.

4. magnetic dipole moment: (M)

- The product of magnetic pole strength with length of the magnet is called magnetic dipole moment.

$$M = m \times 2l$$

- Units are A-sq.mts

5. Magnetisation: (I)

- The magnetic moment per unit volume of the substance is called as intensity of magnetization or magnetisation.
- Units are A/m

6.MAGNETIC SUSCEPTIBILITY: (χ)

- It is defined as the ratio of intensity of magnetization I to magnetic intensity H.
- It has no units.

7. PERMEABILITY:

- The magnetic induction B and intensity H are related by

$$B=\mu_0 H$$

- Where μ_0 is permeability of free space$=4\pi\times10^{-7}$ H/m

- For a medium

$$B=\mu H$$

- Where μ=B/H is called as permeability.
- Permeability is defined as the ratio of magnetic induction in the sample to the applied magnetic field intensity.

Units are H/m

8. Relative permeability:

- It is defined as the ratio of permeability of medium to permeability of free space.
- There is no units for relative pemeability.

MAGNETIC MATERIALS:

- Magnetic materials are those substances which get magnetized when placed in a magnetic field.
- So, the substance develop magnetization which may be parallel or antiparallel to the applied field.
- Depending upon the magnitude and sign of response to the applied field, and also on the basis of temperature on the magnetic properties, all materials are classified as follows.

- **Diamagnetic materials:** Materials which are lack of permanent dipoles are called **diamagnetic.**

- **Paramagnetic materials:** If the atoms of the material carry permanent magnetic dipoles and they do not interact among themselves then the materials are called **Paramagnetic**

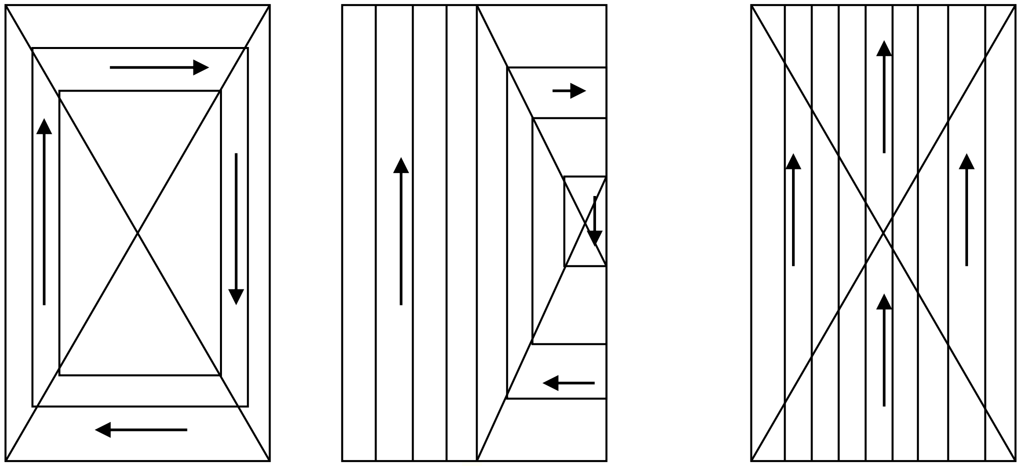
- **Ferromagnetic materials:** If the atoms of the material carry permanent magnetic dipoles and they interact and line up themselves in parallel, then the materials are called **Ferromagnetic**

- **Antiferromagnetic materials:** If the atoms of the material carry permanent magnetic dipoles and they interact and line up themselves in anti-parallel with equal magnitude, then the materials are called **Anti-Ferromagnetic.**
- **Ferrimagnetic materials:** If the atoms of the material carry permanent magnetic dipoles and they interact and line up themselves in anti-parallel with unequal magnitude, then the materials are called **Ferrimagnetic.**

S.No.	Diamagnetic material	Paramagnetic material	Ferromagnetic material	Antiferromagnetic material	Ferrimagnetic material
1.	Net magnetic moment exists in the presence of magnetic field in opposite direction.	Net magnetic moment exists in the direction of applied magnetic field.	Large net magnetic moment exists in the direction of applied magnetic field.	Net magnetic moment exists in the direction of applied magnetic field.	Net large magnetic moment exists in the direction of applied magnetic field.
2.	There is an induced magnetism opposite to applied field.	There is an induced magnetism in the direction of the field.	There is strong induced magnetism in the direction of the field.	There is an induced magnetism in the direction of the field.	There is a large induced magnetism in the directio of the field.
3.	It repels the magnetic lines of forces due to the external magnetic field.	It allows the magnetic lines of forces to pass through it.	It allows a large number of magnetic lines of forces to pass through it.	It allows magnetic lines of forces to pass through it.	It allows large number of lines of forces to pass through it.
4.	Relative permeability $\mu_r < 1$	$\mu_r > 1$	$\mu_r >> 1$	$\mu_r > 1$	$\mu_r >> 1$
5.	Since the induced magnetic moment is opposite to the direction of the applied field, the intensity of magnetization 'M' is negative.	Since the induced magnetic moment is in the direction of applied field, intensity of magnetization 'M' is positive and moderate.	Intensity of magnetization 'M' is +ve and high, since large magnetic moment is induced in the direction of the field.	Intensity of magnetization 'M' is positive and moderate.	Intensity of magnetizati 'M' is positive and high
6.	Susceptibility 'χ' is negative.	'χ' is low and positive.	'χ' is high and positive.	'χ' is low and positive.	'χ' is high and positive.
7.	Susceptibility χ is independent of temperature.	$\chi = \frac{C}{T}$ which is Curie law where C = Curie const.	$\chi = \frac{C}{T \pm T_C}$ which is Curie–Weiss law where T_C = Curie temperature.	$\chi = \frac{C}{T + T_C}$	$\chi = \frac{C}{T \pm T_C}$
8.	Examples: organic materials.	Examples: Alkali metals and transition metals.	Examples: Transition and rate earth metals	Examples: Salts of transition elements.	Examples: Ferrites.

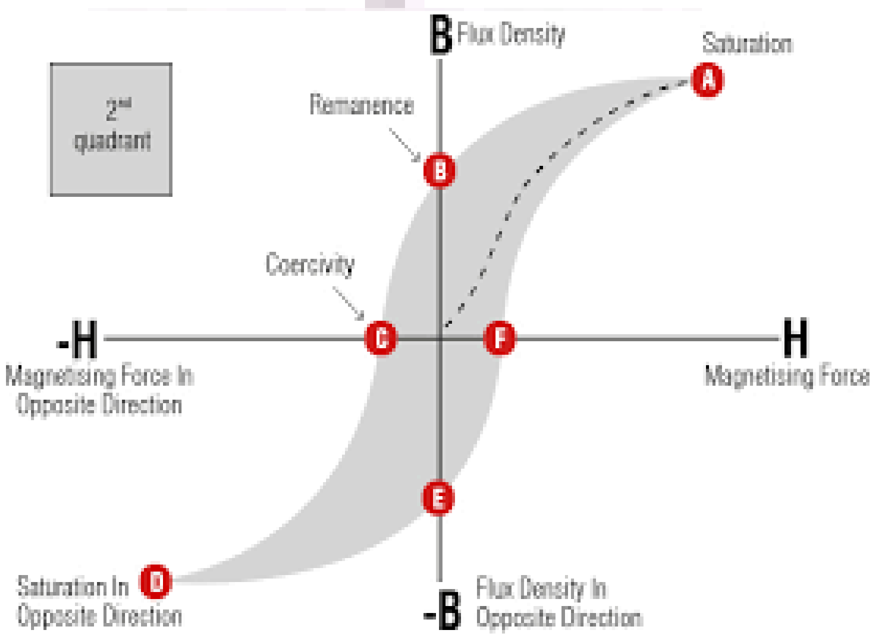
DOMAIN THEORY OF FERROMAGNETISM ON THE BASIS OF HYSTERESIS CURVE:

- In Ferro magnetic substances, the atoms due to certain mutual interaction, form innumerable small effective regions called **domains**.
- When a ferromagnetic substance is placed in an external magnetic field, the magnetic moment increase in two different ways:
- ***By the displacement of the boundaries of the domains:***
  - When the substance is placed in magnetic field, the domains which are oriented favourable with respect to the external field increases in size while those oriented opposite to the external field are reduced.
- ***By the rotation of domains:***
  - The domains rotate until their magnetic moment aligned more or less in the direction of external magnetic field.
  - When external field is weak, the substance is magnetized mostly by the boundary displacement. On the other hand, in strong magnetic fields, the magnetization takes place mostly by the rotation of domains.
  - On the removal of external field, the boundaries do not move completely back to their original position and hence the substance is not completely demagnetized. At high temperatures, the domains break up and ferromagnetic substance becomes paramagnetic.



HYSTERESIS CURVE:

- Consider an unmagnified ferromagnetic substance in a magnetizing field. The substance shows a relation between magnetic flux density and strength of magnetic field. This property is called hysteresis.
- When a substances is slowly magnetized, the flux density B increases with field H. As part OA.
- At point A, the flux density B becomes constant. That is the state of magnetic saturation.
- Now, consider that magnetizing field H is decreased, B also decreases but it doesn′t follows the path AO. It follows the path AB. At point B, flux density has some value even H=0. The value of B for which H=0 is called retentivity or residual magnetism.



SOFT AND HARD MAGNETIC MATERIALS:

Hard magnetic materials	Soft magnetic materials
Hard magnetic materials are those which are difficult to magnetize and demagnetize.	Soft magnetic materials are those which are easy to magnetize and demagnetize.
These materials have large hysteresis loss due to large hysteresis loop area.	These materials have less hysteresis loss due small hysteresis loop area.
In these materials domain wall movement is difficult.	In these domain walls movement is relatively easier.
Coercivity and retentivity are large	Coercivity and retentivity are small.
Susceptibility and permeability values are low.	Susceptibility and permeability values are high.
Eg: tungsten steels	Eg: iron silicon alloys
Applications: Toys, compass needles, microphonesspeed motors,	Applications: Transformer cores, motors, relays, sensors, storage components.

APPLICATIONS MAGNETIC MATERIALS:

- Soft magnetic materials are used in transformer cores, motors, relays and sensors.
- Iron-silicon alloy magnets are used in electrical equipments.
- Silicon steel magnets are used in alternators and high frequency rotating materials.
- Soft magnetic materials are used in storage components and microwave isolators.
- Hard magnetic materials are used in production of permanent magnetism
- Carbon steel magnets are used in toys, compass needles, meters etc.
- tungsten steel magnets are used in dc meters and measuring devices.
- Neodymium magnets are used in microphones.
- Cast AlNiCo magnets are used in speed meters, and sensors in automobiles, motors etc.,
- Microwave devices like isolators and circulator phase shifters are prepared employing ferrites.
- Hard ferrites are used to make loud speakers and wiper motors.
- Ferrite rods are used to make small antennas

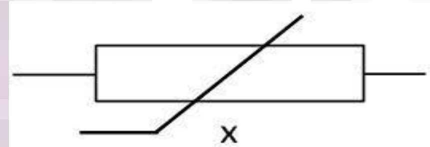
Magnetostriction:

- In ferromagnetic materials, the magnetic moments of individual atoms tend to align themselves in a specific direction when exposed to a magnetic field. This alignment causes a change in the material's dimensions, which is termed as magnetostriction.
- The effect is reversible, meaning that when the magnetic field is removed, the material returns to its original dimensions.
- **Significance and Applications**
- Magnetostriction has various practical applications, including:

1. **Actuators:** The reversible nature of magnetostriction allows it to be used in actuators, which convert electrical energy into mechanical energy for precise motion control.
2. **Sensors**: Magnetostrictive materials can be used as sensors to detect changes in magnetic fields or mechanical stress.
3. **Energy harvesting**: Magnetostrictive materials can also be employed for energy harvesting, converting mechanical energy into electrical energy.

Magneto resistance:

- The resistance of some of the metal and the semiconductor material varies in the presence of the magnetic field, this effect is called the magneto resistance.
- The element which has these effects is known as the magnetoresistor.
- In other words, the magnetoresistor is a type of resistor whose resistance varies with the magnetic field.
- The magneto resistor is used for determining the presence of a magnetic field their strength and the direction of the force. It is made of the indium antimonide or indium arsenide semiconductor material.



Magnetoresistors

- The resistance of the magneto resistor is directly proportional to the magnetic field, i.e., their resistance raises with the increase of the magnetic field. The variation in resistance occurs because of the magneto effect.
- The magneto resistor operates without physical contacts which is their major advantage.

Applications of magneto resistors

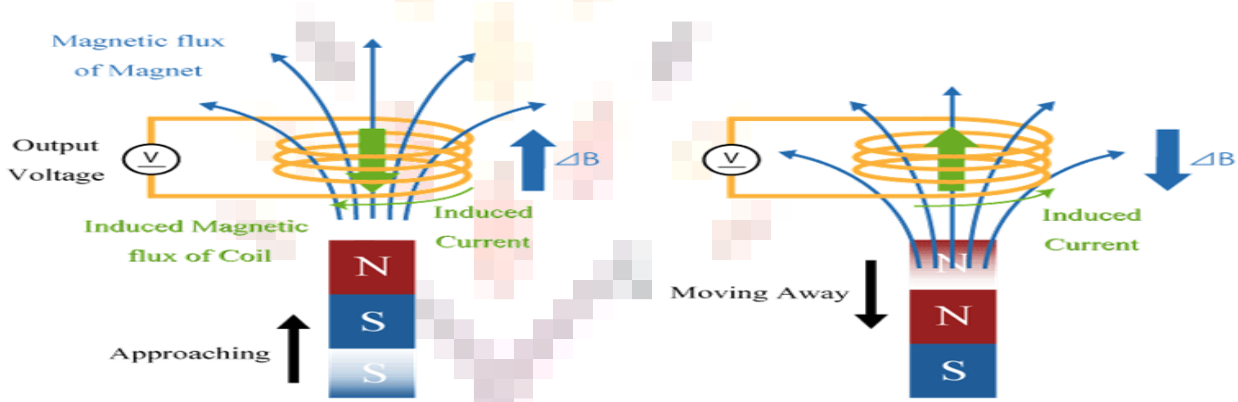
The various applications of magneto resistors include:

- Bio-sensors
- Hard disk drives
- Magnetic field sensors

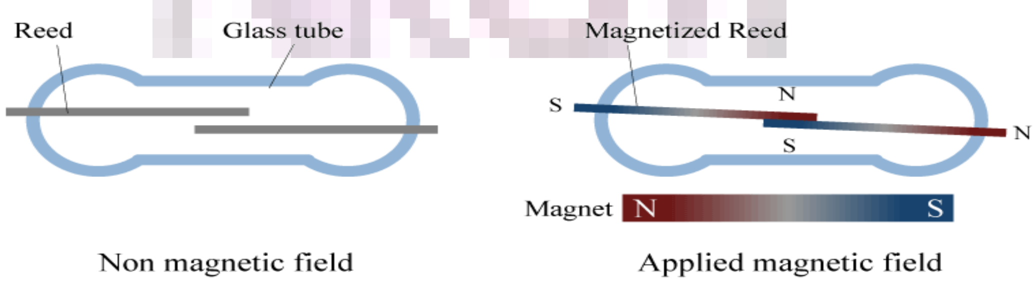
- Magneto resistors are used in electronic compass for measuring earth's magnetic field.
- Magneto resistors are used for measuring electric current.

Magnetic field sensors:

- A magnetic sensor is a sensor that detects the magnitude of magnetism and geomagnetism generated by a magnet or current. There are many different types of magnetic sensors.
- **Coil:** Coils are the simple magnetic sensors that can detect changes of the magnetic flux density. As shown in Figure 1, when a magnet is brought close to the coil, the magnetic flux density in the coil increases by ΔB.
- Conversely, moving the magnet away from the coil reduces the magnetic flux density in the coil, so induced electromotive force and induced current will be generated in the coil to increase the magnetic flux density.



Reed Switch: A reed switch is a sensor in which metal pieces (reed) extending from both the left and right sides are enclosed in a glass tube with a gap at the overlapping position of the reeds. When a magnetic field is applied externally, these reeds are magnetized. When the reeds are magnetized, the overlapping parts attract each other and come into contact, then the switch turns on.



- **Hall Element:** When a current is applied to a thin film semiconductor, a voltage corresponding to the magnetic flux density and its direction is output by the Hall effect. The Hall effect is used to detect a magnetic field.
- **Magneto resistive element:** An element that detects a magnetic field using a material, that resistance changes when magnetic force is applied, is called a magnetoresistive, (MR), element.