3. Dielectric, magnetic & Energy Materials

Dielectrics:-

1) **Electric dipole** :- A system which consists two equal and opposite charges (+q, -q) respectively separated by a distance 2a is called electric dipole.

2) **Dipole moment** :- The product of charge and distance between two charges is called Dipole moment. It is represented by μ.

$$\boxed{\mu = 2aq}$$

3) **Permitivity (ε)** :- It is a quantity which represents the dielectric property of the medium and it describes the conductivity capacity in the given medium. It is represented by ε.

4) **Dielectric constant (or) relative permitivity** :-

It is defined as the ratio between permitivity of the medium to the permitivity of free space. It is represented by 'ε_r'

$$\boxed{\varepsilon_r = \varepsilon / \varepsilon_0} \quad \text{(or)} \quad \boxed{\varepsilon_r = \varepsilon / \varepsilon_0}$$

where ($\varepsilon_0 = 8.85 \times 10^{-12}$ f/m)

Dielectric Polarization :- When a dielectric is placed in an ~~field~~ electric field, electric charges slightly shift from their average equilibrium process, this is known as dielectric polarization.

It is represented by [P].

$$P = \frac{\sum du}{V}$$

P = total dipole moment

Polarizibality :- It is found dipole moment of system is directly proportional to electric field

$$u \propto E$$

$$u = \alpha E$$

$$\boxed{\alpha = \frac{u}{E}}$$

where α is polarizability.

Electric Succeptability :- When a dielectric material is placed in an electri field E then polarization takes place. The polarization is proportional to electric field.

$$P \propto E$$

$$P = \chi E$$

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

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Types of polarization :- 1) electronic polarization

2) Ionic polarization 3) orientation polarization

4) space charge polarization

1) Electronic polarization :- The displacement of the positively charged nucleus and the negatively charged electrons in the presence of an electric field this process is known as electronic polarization

$$\mu \propto E$$

$$\Rightarrow \mu = \alpha_e E$$

$$\Rightarrow \boxed{\alpha_e = \mu / E}$$

where 'α_e' is electronic polarization.

→ It is independent on temperature

2) Ionic polarization :- Ionic polarization is due to the displacement of cation and anion in opposite directions.

→ Ionic polarization occurs in an ionic solids

It is represented by 'α_i'

$$\boxed{\alpha_i = \frac{\mu}{E} = \frac{e^2}{\omega_0^2}\left(\frac{1}{m}+\frac{1}{M}\right)}$$

$\frac{c^2}{\omega_0^2}$ → natural frequency of material

M → mass of -ve ion

m → mass of +ve ion

No field / field

3) **Orientation polarization** :- In some materials which have molecules with permanent dipole moment, In the presence of electric field all the dipoles are orienting along the field direction. polarization due to this orientation is known as orientation polarization.

• orientation polarization is ~~defined~~ as represented by

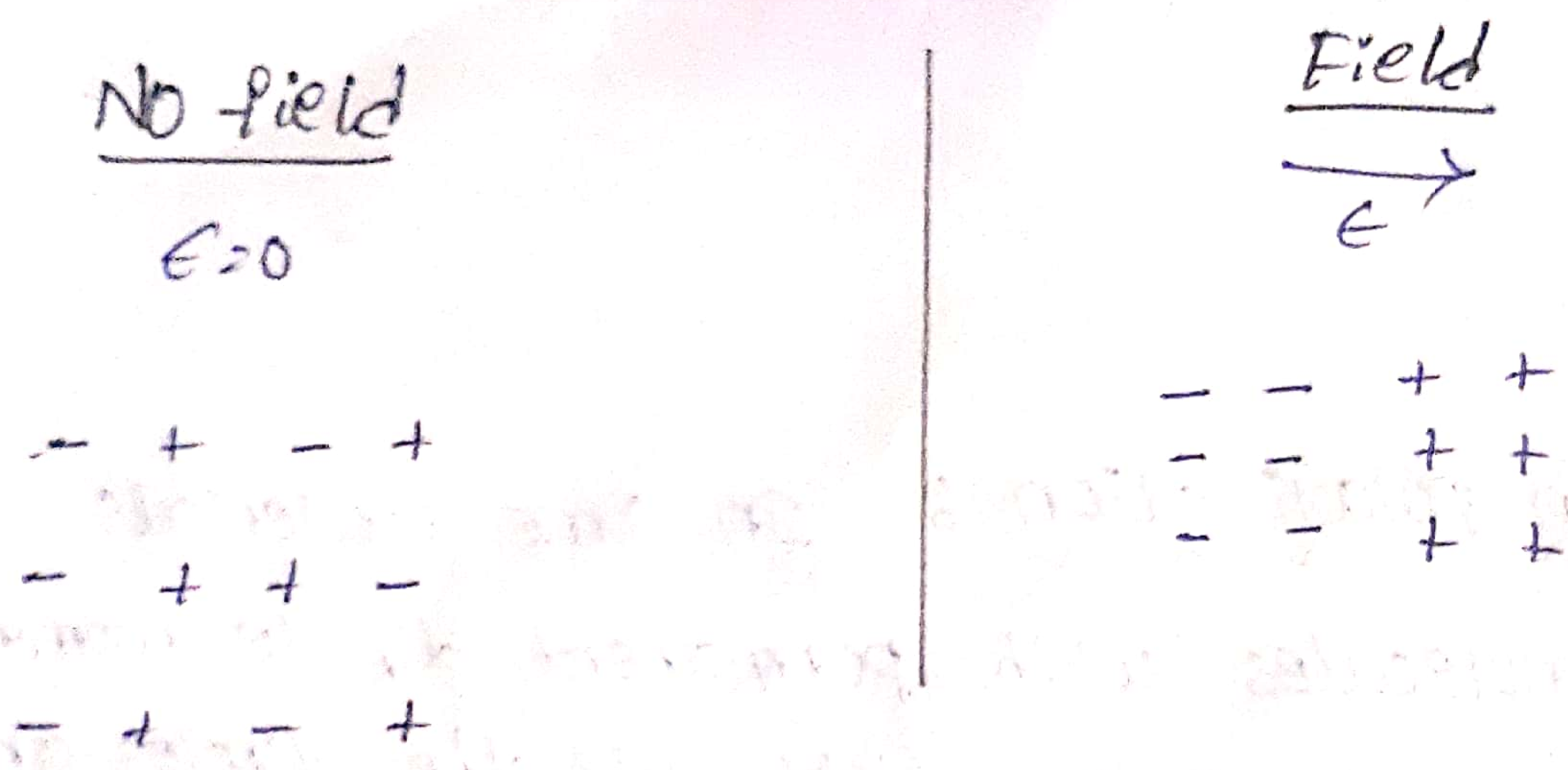
$$\boxed{\alpha_o = \frac{P_o}{NE} = \frac{\mu^2}{8kT}}$$

'α_o' is dependent on temperature.

No field / field

4) Space charge polarization :- Space charge polarization is takes place in heterogenous dielectric material. In the presence of electric field charges are migrated.

⇒ It is represented by 'α_s'.



→ Total polarization of the material is the some of the contribution fro

* Ferroelectrics :-

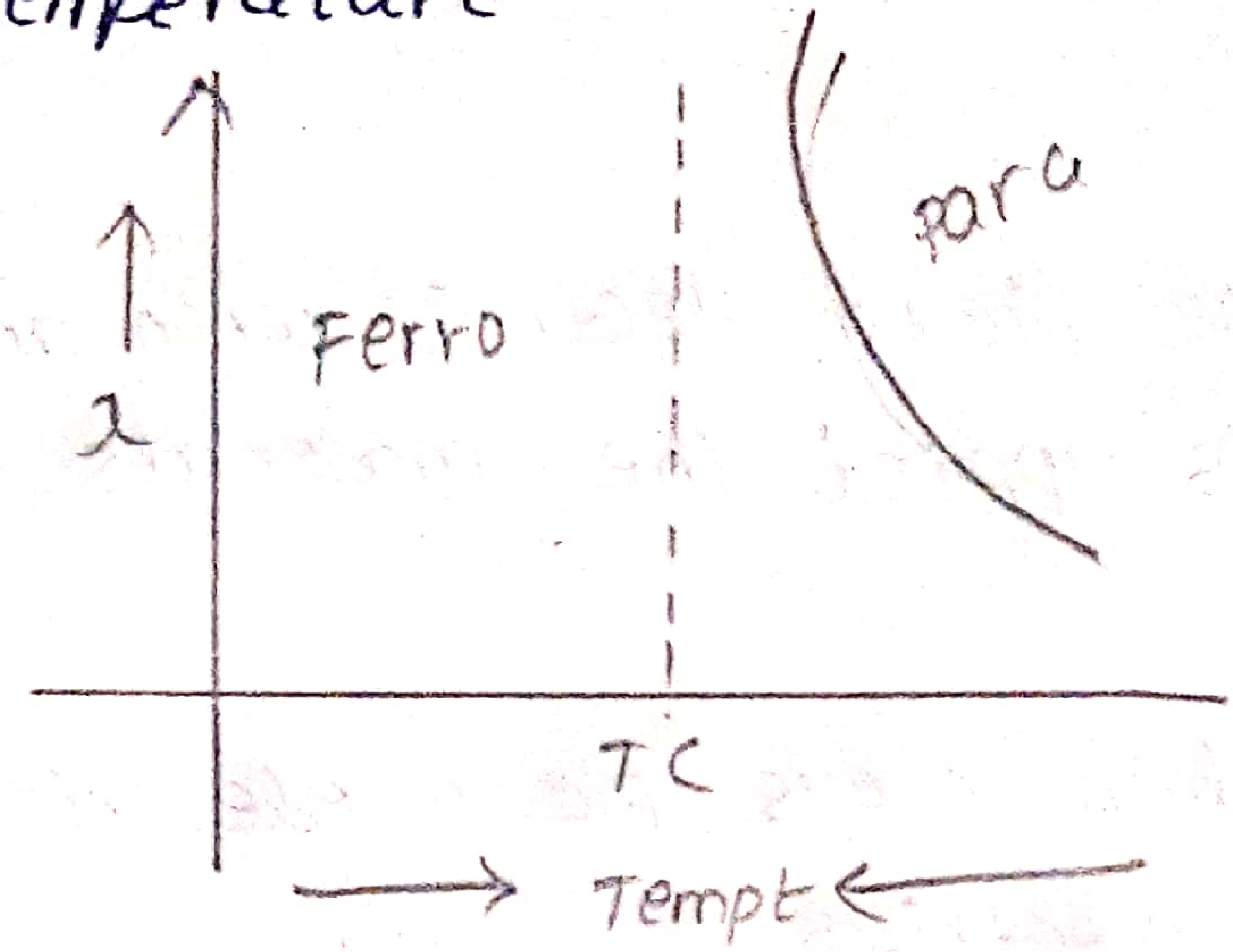
The dielectric materials which are having spontaneous polarization in the absence of electric field is known as ferroelectricity.

→ Meterials which exibhit ferroelectricity are called ferro electric materials.

Examples :- Rachelle Salt
Lithium Niobate
Barium titanate

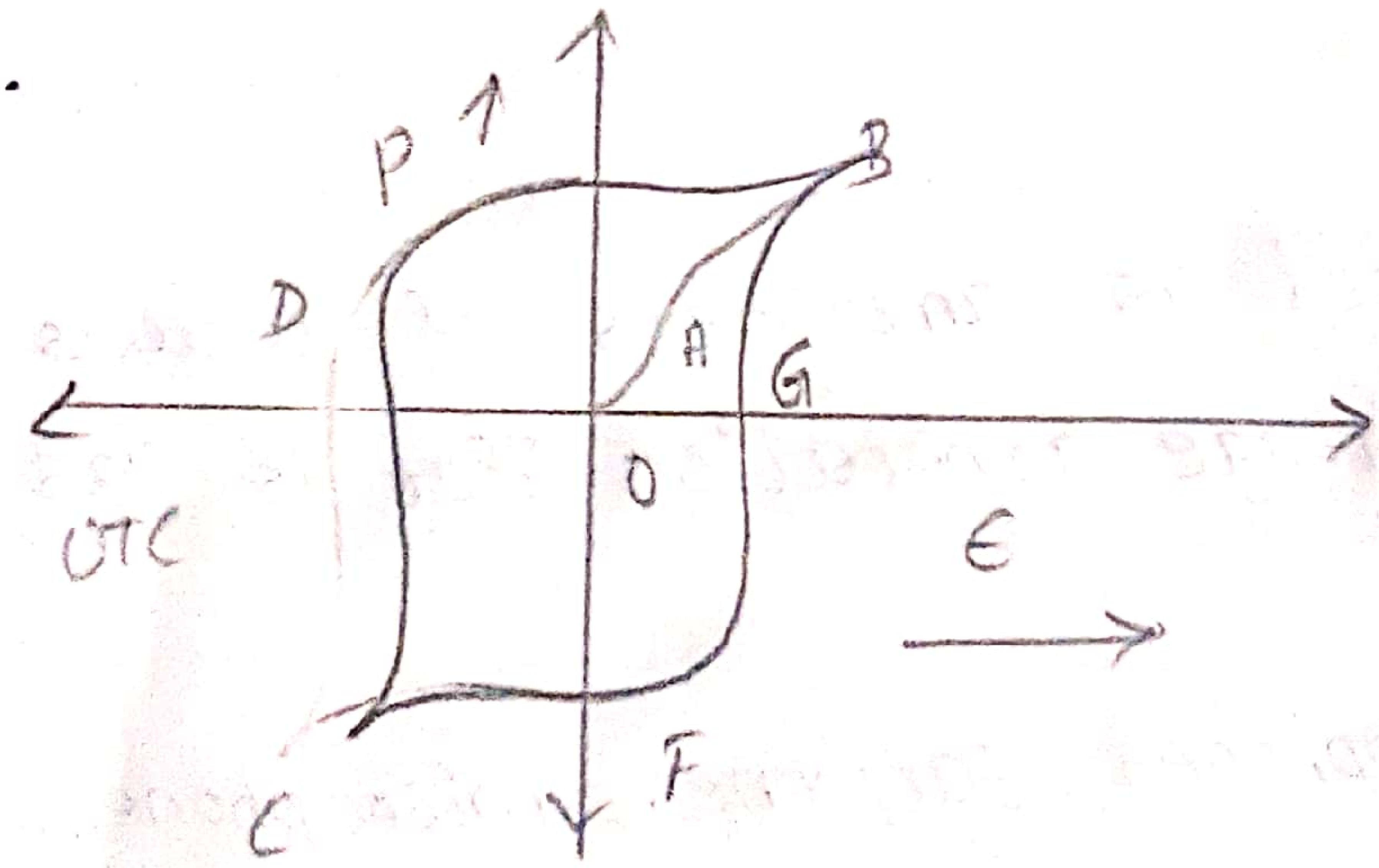
Properties :- 1) All ferroelectric materials posess spontaneous polarization below a certain temperature

ii) The temperature at which a ferroelectric material gets converted into a paraelectric material called curie temperature



iii) All ferroelectric materials exibhit piezoelectricity and pyroelectricity.

iv) Ferroelectric material exibhits electric Hysterisis property.



Applications:-

→ Ferroelectric materials used as storage device in capacitors.

→ Used to make infrared detectors and used in transducers (to convert electrical energy into non-electrical energy).

→ Used in microphones

Piezo electrics :- The materials have the property of becoming electrically polarized when mechanical stress is applied these property is known as piezo electric effect. It has an inverse.

→ According inverse piezo electric, when an electric stress or voltage is applied the materials become strained.

→ The materials which obeys piezo electric effect are called piezo electrics.

Example :- Quartz
Barium Titanate
Zinc oxide.

Applications :-

→ They are used as amplifiers of walls

→ used high voltage generation. That is gas ligtes, transducers.

→ used in gramphones, earphones, microphones, hearing aid

→ used in filters.

Pyro electrics :-

Pyro electric effect is the change in spontaneous Polarization when the temperature of speciman is change the materials which obeys the pyro electricity are known as pyro electric materials.

→ Pyro electric coefficient λ is defined as the change is polarization per unit temperature change of speciman

$$\lambda = \frac{dP}{dT}$$

Examples :- Barium Titanate
Lithium Niobate
$NaNO_2$

Applications :-

→ They are used to make good infrared detectors.
→ They are used in the construction of pyo electric image tubes.

Classification of Magnetic Materials :-

The solids can be divided into two broad groups, on the basis of magnetic dipole moments. The atoms of one group do not possess permanent magnetic dipole moment whereas atoms of the other group possess permanent magnetic dipole moment,

- The materials consisting of atoms or ~~molecules~~ with zero magnetic dipole moment are called as Diamagnetic materials.

- Materials composed of atoms or molecules having permanent magnetic moment are classified into four categories depending on the interaction between the atomic magnetic dipoles.

* If the interaction between the atomic magnetic dipoles is negligible, the material is paramagnetic.

* If the magnetic dipoles interact in such a way that they tend to orient in the same direction, the material is ferromagnetic.

* If neighbouring dipoles orient in opposite directions and if the dipoles are of equal magnitude, the material is antiferromagnetic.

* If the neighbouring dipoles are of different magnitude and orient antiparallel, the material is ferrimagnetic.

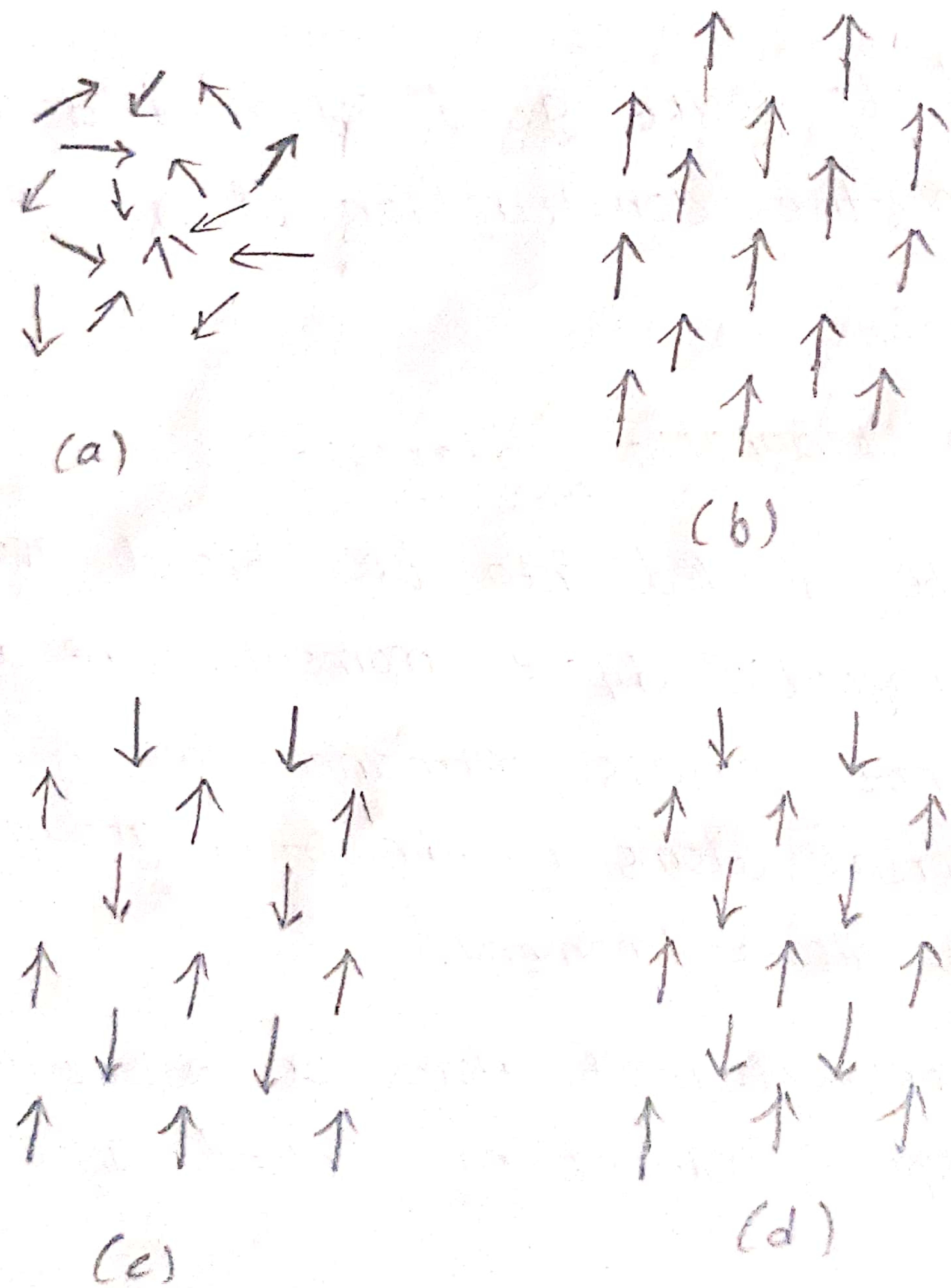


Fig. 3.23: Schematic illustration of the orientation of spins in (a) paramagnetic, (b) ferromagnetic, (c) antiferromagnetic and (d) ferrimagnetic materials.

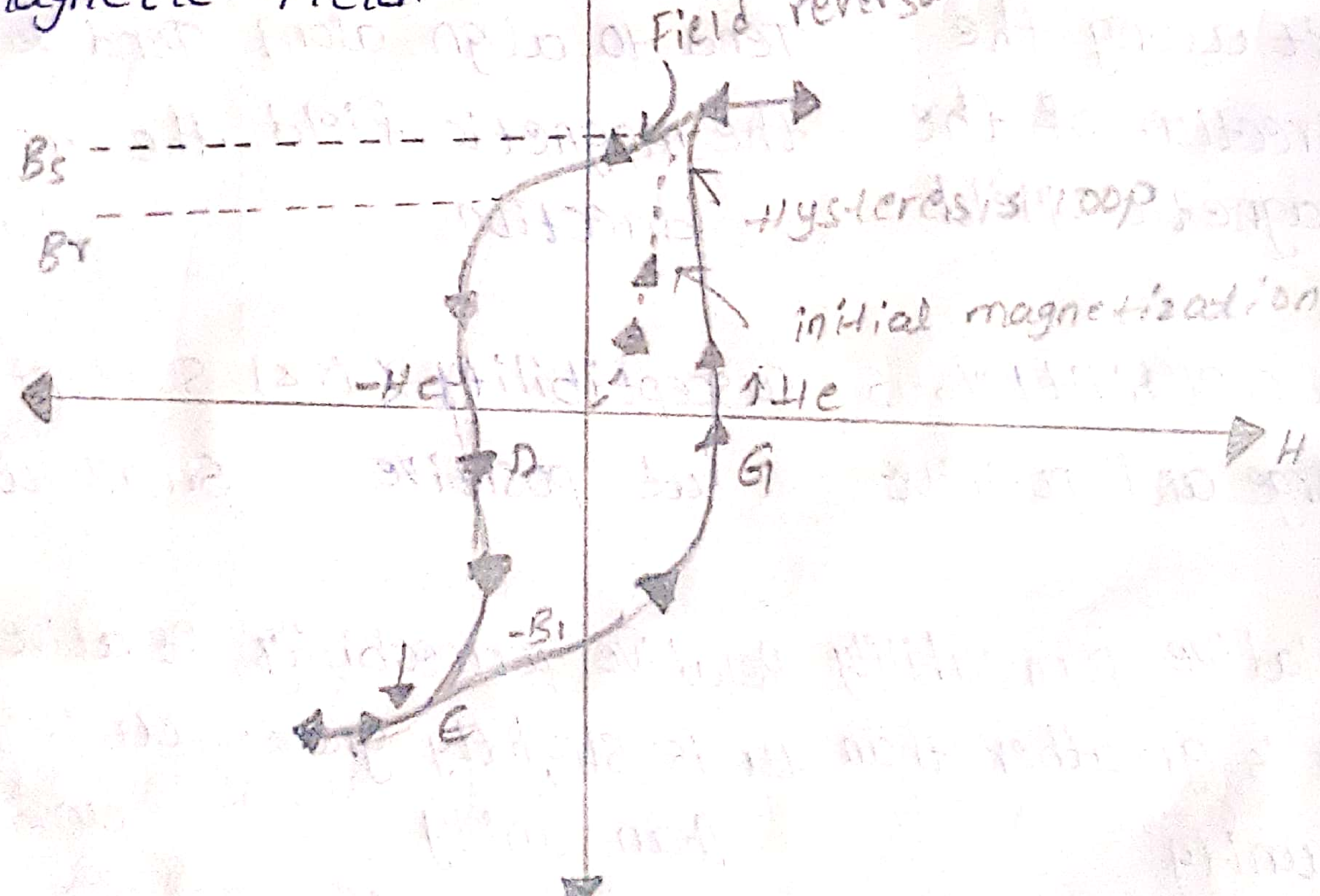
comparison of the Three Magnetic Materials

S.No	Ferromagnetics	paramagnetics	Diamagnetics
1.	Solids and possess crystalline structure	Solid, liquid or gas	Solid, liquid or gas
2.	Strongly attracted towards magnetic field	Feeble attraction towards magnetic field	Feeble repulsion from the magnetic field
3.	Field lines are connected in the material.	More no. of field lines pass through the material than outside	Less no. of field lines pass through the material than outside.
4.	Set along the direction of the magnetic field	Tend to align along the magnetic field direction	Tend to align ⊥er to the magnetic field direction
5.	susceptibility χ, is large and positive	susceptibility χ is <1 but positive	susceptibility, χ is small but negative
6.	Relative permeability μ_r is greather than unity	Relative permeability, μ_r is slightly greater than unity	Relative permeability, μ_r is less than unity
7.	susceptibility χ decreases with temp in a complex manner.	obeys curie law, i.e., $\chi = 1/T$	χ is independ of temperature.
8.	Have definite curie point above which they become paramagnetic	No curie point	No curie point
9.	B and M vary with H but not linearly and ultimately attain saturation	B and M vary with H linearly at low temp and at high field tend towards saturation	B and M vary with H linearly but no saturation is reached

10.	Exhibit phenomenon of Hysteresis	Hysteresis is not exhibited	Hytersis is not exhibited
11.	Posses retentivity	No retentivity	No retentivity

* <u>Hysteresis</u>

The magnetization of ferromagnetic material depends not only on the strength of the magnetizing field at the given instant but also on the magnetization history of the material. Hysteresis is the lag in the changes of magnetization behind variations of the magnetic field.



Def :- Hysteresis is a loop pattern of the magnetic field induction B and increasing or decreasing magnetic field H applied to an initially unmagnetized ferromagnetic specimen

The curve starts at the origin O. As H is increased the field B begins to increase slowly, then more rapidly It finally reaches a saturation value and becomes independent of H. The maximum value of B is known as the Saturation flux density Bs and the corresponding magnetization is the saturation magnetization Ms.

If H is now decreased, B also decreases but following a path AC instead of the original path AO. Thus, B lags behind H. When H becomes zero, B does not become zero but has a value equal to OC (B_r)

It indicates that the material remains magnetized even in the absence of an external applied field H. The power of retaining the magnetism is called retentivity or remanence of the material.

Def:- The retentivity of a material is a measure of the magnetic flux density remaining in the material when the magnetizing field is removed.

When the magnetic field H is applied in the reverse direction a field of magnitude $-H_c$ must be applied to reduce the flux density to zero H_c is called the coercivity or the coercive force.

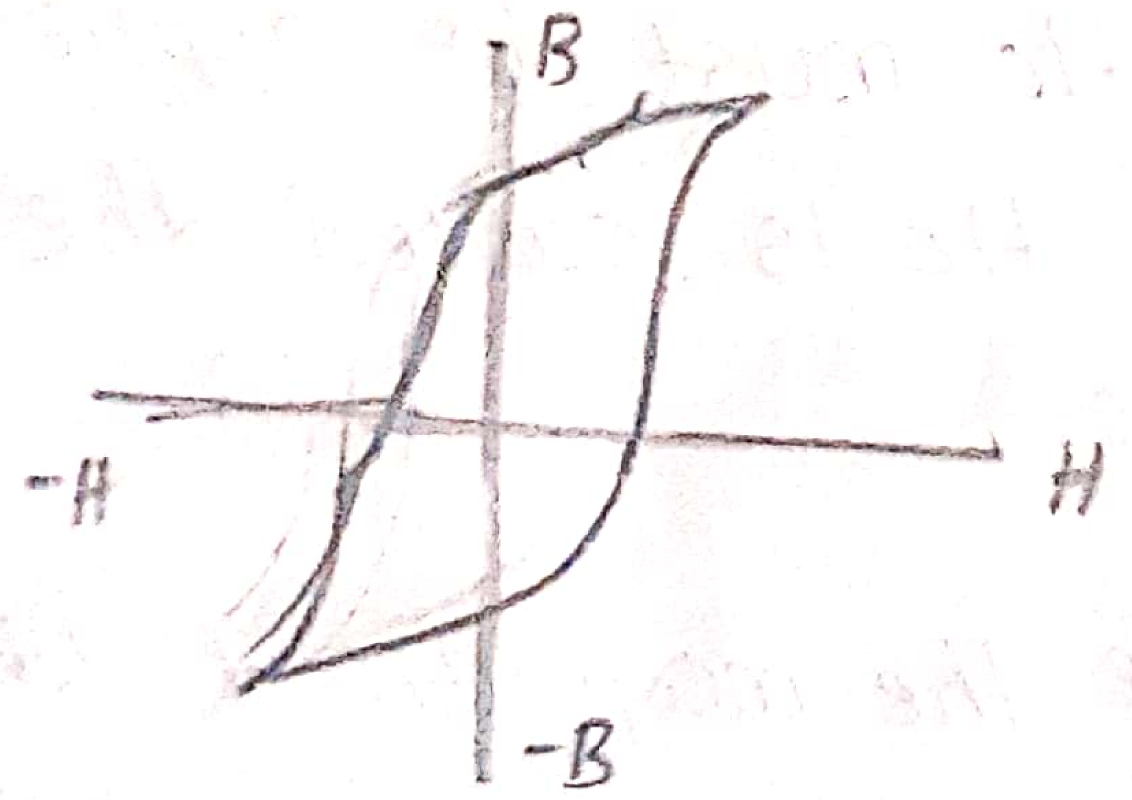
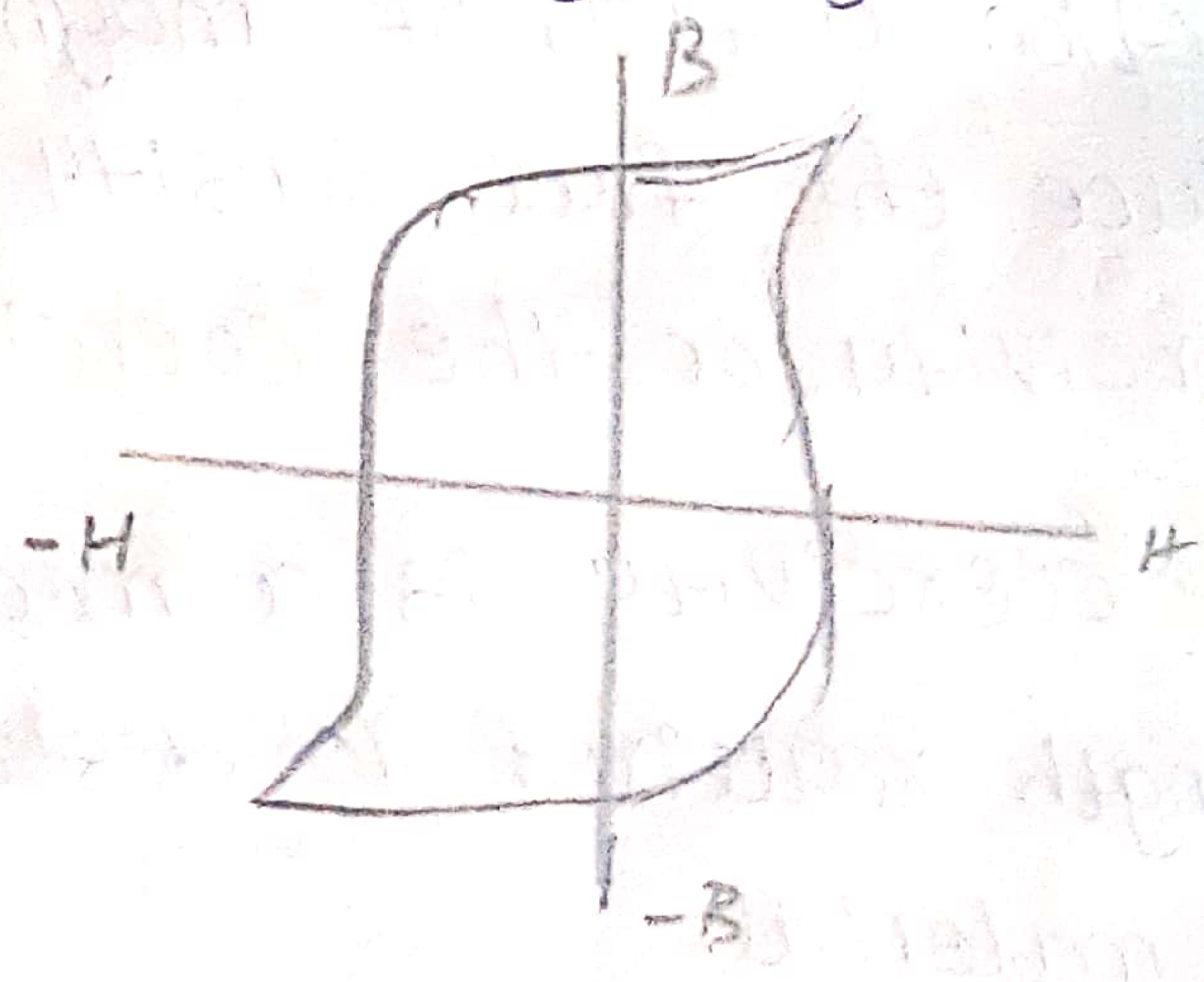
Def:- coercivity is a measure of the magnetic field strength required to destroy the residual magnetism in the material.

As the applied field H is increased further in the -ve direction. Saturation is ultimately reached in the reverse direction. (point E).

The closed curve ACDEFGA represents a cycle of magnetization of the speciman and is known as the Hysteresis loop of the speciman.

SOFT AND HARD MAGNETIC MATERIALS:-

Ferromagnetic materials are classified into two types based on the characteristic parameters such as hysteresis and magnetism. They are 1) Hard magnetic materials 2) soft magnetic materials

S.NO	SOFT MAGNETIC MATERIAL	HARD MAGNETIC MATERIAL
1.	Materials which can be easily magnetized and demagnetized are called soft magnetic materials.	Materials which can't be easily magnetized and demagnetized are called hard magnetic material.
2.	The nature of hysteresis loop is very steep. 	The nature of hysteresis loop is very large 
3.	They are prepared by annealing process.	They are prepared by quenching process
4.	Due to small hysteresis loop area they are small hysteresis loss	Due to large hysterisis loop area, they have large hysterisis loss.
5.	They have large value of permeability and susceptibility	They have low value of permeability and susceptibility
6.	The coercivity and retentivity are small	The coercivity and retentivity are large
7.	They are free from irregularities	They have large amount of impurities and lattic defects

8.	They are ... • To produce temporary magnets. • In the preparation of magnetic core materials used in transformers, electric motors, magnetic amplifiers, magnetic switching circuits etc.	They ... • To produce permanent magn... • In loud speakers, toys, in measuring meters, microphone, magnetic detectors, magnetic separators, etc.,
9.	ex: Iron and silicon alloys, Nickel - Iron alloy, Iron-cobalt alloy.	High carbon steel, cobalt steel, Barium ferrite.

Magnetostriction

A ferro magnetic material is magnetized, a small change occurs in its dimensions. It may either expand or contract in the direction of magnetization. The material returns back to the original dimensions on removal of the magnetic field. This is known as magnetostriction.

→ Magnetically induced reversible Elastic strain $\frac{\Delta l}{l}$ is called magnetostriction.

→ Magnetostriction is caused by the rotation of domines of a ferro magnetic material under the action of a magnetic field.

→ The first magnetostriction measurement was discovered by James Joule.

Types of magnetostriction.

1) Longitudinal :- when change in the dimensions is in the direction of applied field.

2) Transferce :- when change in the dimension is $\perp$er to applied field

3) Volume :- when change in the dimension is $\perp$ler as well as parallel to applied field.

Applications of magnetostriction

i) Magnetostrictive materials are used to create sensors to measure a magnetic field.

ii) Used in medical devices, industrial vibrators, ultrasonic cleaning devices, under water solar, noise control systems.

iii) Used in transdusers, sound detectors

*Magneto resistance

→ Magnetoresistance is the change of a materials resistivity of a substance with the application of a magnetic field.

→ These effect occurs in materials such as semi-conductors, non magnetic materials and magnetic metals.

→ Magnetoresistive effect was discovered in 1856 by william thomson

Priciple :- The magnetic force applied on the moving charges will tend to increase the no. of collisions between charges. Due to this collisions increasing the resistance of the crystal. This dependence of resistance on magnetic field is called magneto resistance.

→ magnetoresistance increases with ~~increase~~ strength of the magnetic field.

→ Types of magnetoresistive effects :-

1) Giant magneto resistance (GMR) :

2) extraodinary magneto resistance (EMR) :

3) Tunnel magneto resistance (TMR)

Applications :-

→ GMR effect is absorbed in the ferromagnetic materials.

→ GMR is used in the data storage industry, solid state compass, non-voladile magnetic memories, biomedical applications.

EMR :-

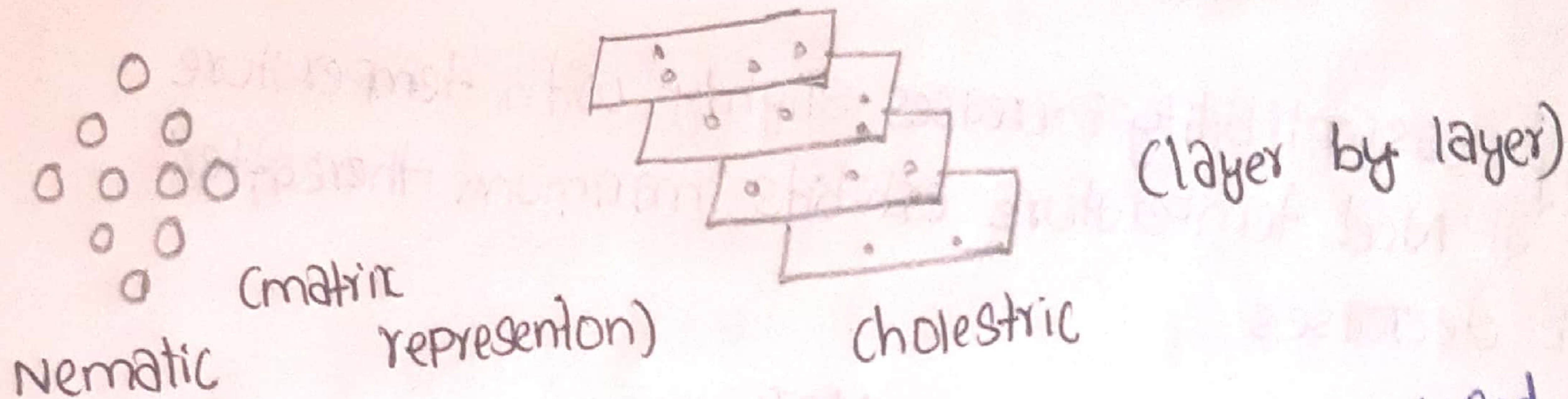
→ EMR sensor is used reading a very narrow and short magnetic field.

→ magnetoresistors used in bio sensors, hard disk drives, magnetic field sensors, contact less switches.

Liquid crystal display (LCD)

A liquid crystal display or LCD draws its defination from its name itself. It is a combination of two states of matter. one is solid 2 another one is liquid. A LCD uses liquid crystal to produce a visible image These LCD are super technology screen. used in laptop, computer screen, TV's, cell phones etc.

In general two types of liquid crystal materials are used in display technology. They are nematic 2 cholestric whose schematic arrangement of molecular.



Basically nematic liquid crystal is most populary used in liquid crystal displays. As all molecules are aligned almost parallel to a uique axis direction.

Advantages:

It consumes uss amount of power.
LCD are low cost
Provides excellent contrast.

Disadvantages:

Low relaibility
Speed is very low
Range of temp is limited.

Applications:

Thermometer
TV, monitor, mobile
calculator, medical applications.

crystal oscillator:

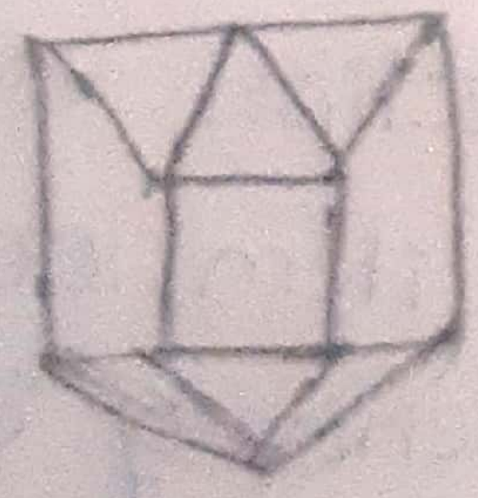
crystal oscillator is a type of sinsodual oscillator and they are used to produce sine waves at the o/p. crystal oscillators are uses piezoelectric crystal as a resonant oscillator.

It is a basically tune circuit oscillator. crystal oscillator uses the quartz crystal for the constrution of the oscillator. They are used to provide accurate signals at the o/p. crystal oscillators basically used to provide the frequency range is up to 10MHz.

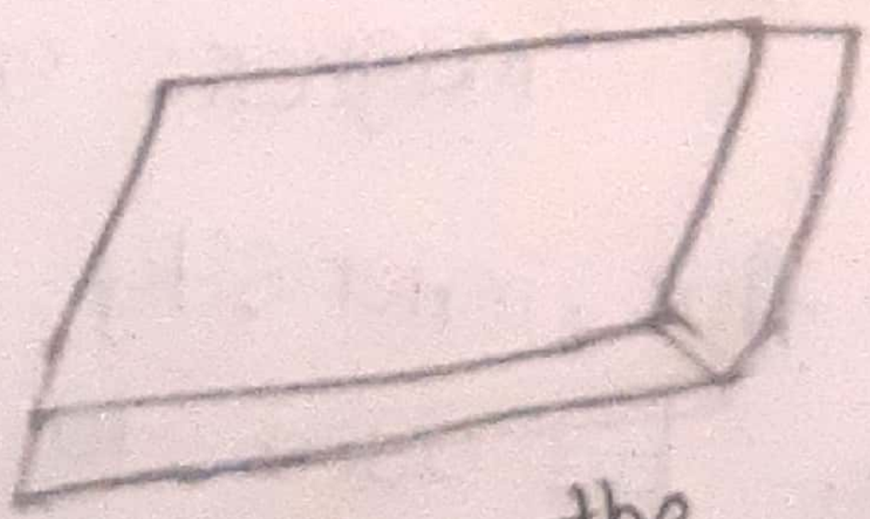
construction:

quartz crystal is used for the construction of crystal oscillator. quartz crystal having the property of piezoelectric effect. AC signal is applied to the quartz crystal. then its starts vibrating. These frequency of vibrations are equal to the Applied A.C signal. similarly if we applied mechanical vibrations to the crystal it produces the voltage at the o/p. The o/p voltage frequency is equal to the applied vibration frequency. In this process crystal oscillator produces vibrations as well as AC voltage at the o/p this effect is called piezoelectric effect.

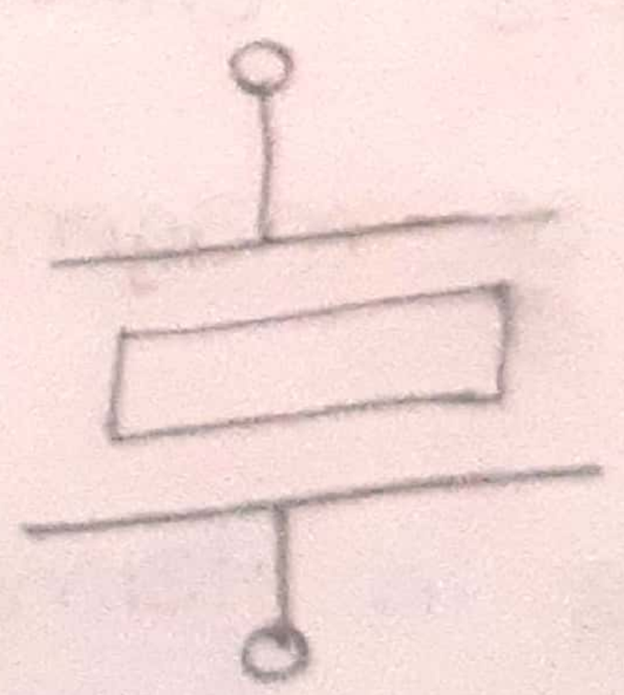
Natural shape of the quartz crystal:



Hexagonal



After cutting the rectangular slab



Here we need to list the rectangular slab to get the crystal rectangular slab is connected b/w the two plates. voltage is applied to the crystal oscillator it appears in the toin of mechanical ubrations at the o/p. The o/p frequency of vibrations is

Similar to the applied i/p voltage. The frequency at waves may, vibrations are produced by the crystal oscillators are called resonant frequency.

The frequency range is 15KHz to 10MHz.

MAGNETIC FIELD SENSORS:

A magnetic sensor is a transducer that converts a magnetic field into an electrical signal. They convert invisible magnetic fields into electrical signals and we can have visible effects. Magnetic sensors as transducers (solid-state devices) are used in detecting and sensing the distance, speed, rotation, angle and position by converting magnetic information into electrical signals. The converted signals are processed by electrical circuits.

Principle:

Magnetic field sensors either utilize an internal magnet or directly detect a permanent or electromagnetic field. The internal magnet sensors detect ferrous steel and produce either an analog or digital output.

Types of magentic sensors:

Magnetic sensors measure magnetic fields in terms of flux, intensity and direction. Magnetic sensor readings may be used to monitor item locations, directions, revolutions, and angles, the existence of an electric current, and so on. The magnetic sensors are divided into various types based on the technology or elements used. The different types of magnetic sensors.