PH8252 – PHYSICS FOR INFORMATION SCIENCE

UNIT – III

MAGNETIC PROPERTIES OF MATERIALS

Part – B

1. Explain dia, para and Fermi magnetic materials on the basis of spin.

Sl.No	Properties	Dia-Magnetic Material	Para-Magnetic Material	Ferro-Magnetic Material
1.	Definition	In diamagnetic material, there are equal number of electron spins which are randomly oriented and hence the net magnetic dipole moment is zero.	In paramagnetic material, there are unequal number of electron spins and hence there exists a permanent magnetic dipole moment.	In Ferro-magnetic material there will be large number of unequal electron spins and hence there exists enormous amount of permanent magnetic dipole moment.
2.	Magnetized direction	When the external magnetic field is applied, the electron will align perpendicular to the field direction and hence it reduces the magnetic induction present in the material. They are weak magnets.	When the external magnetic field is applied, the electrons will dlign parallel to the field direction and hence the material is magnetised. They are strong magnets.	When the external magnetic field is applied, the electrons will reorient itself along the field direction and will be very easily magnetised. They are very strong magnets.
3.	Behaviour	When the material is placed in the magnetic field, the magnetic	When the material is placed in the magnetic field, the magnetic	When the material is placed in the magnetic field, the magnetic

		flux lines are repelled away from the material.	flux lines passes through the material.	flux lines are highly attracted towards the centre of the material.
4.	Susceptibility	Susceptibility is negative (χ = -ve)	Susceptibility is positive. (χ = +ve)	Susceptibility is positive and large (χ = +ve)
5.	χ with temperature	Susceptibility is independent of temperature	Susceptibility varies inversely with the absolute temperature.	Susceptibility depends on temperature.
6.	Permeability Relative permeability (μ_r)	Permeability is less than 1 $\mu_r < 1$	Permeability is greater than 1 $\mu_r > 1$	Permeability is very much greater than 1 $\mu_r \gg 1$
7.	Magnetic phase transition	When the temperature is less than critical temperature the diamagnetism suddenly disappears and becomes a normal material.	When the temperature of the material is less than curie temperature, para magnetic material converted into diamagnetic material.	When the temperature is greater than curie temperature, the ferromagnetic material is converted into paramagnetic material.
8.	Examples:	Gold, silicon, Germanium, Bismuth, water, antimony, hydrogen, alcohol, etc..,	Platinum, chromium, aluminium, copper sulphate, Manganese, sulphate, etc..,	Iron, Nickel, cobalt, steel, etc..

2. (a) Explain Ferro, Anti Ferro and Ferri magnetic materials.

Ferromagnetic materials:

Ferromagnetic materials when placed in a magnetic field, become strongly magnetized in a direction of the applied field and the magnetic lines of force are highly attracted towards the center of the material. This property of the material is known as ferromagnetism.

Properties:

* The magnetic lines of force are crowded into the material.

* They have permanent dipole moment. So they act as strong magnets.

* Relative permeability is very much greater than unity. ($\mu_r \gg 1$).

* The susceptibility is positive and high and is given by $\chi = \frac{C}{T-\theta}$, for $T > \theta$, where C is the curie constant and θ is the paramagnetic curie constant and θ is the paramagnetic Curie temperature.

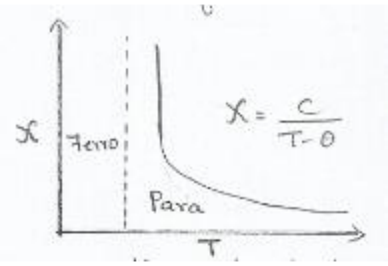
* When the temperature is greater than Curie temperature ferromagnetic material becomes paramagnetic material.

* They exhibit magnetization even in the absence of magnetic field. This property of ferromagnetic materials is called spontaneous magnetization.

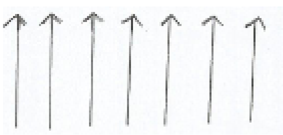
* They exhibit hysteresis curve.

* During heating, ferromagnetic materials lose the magnetization slowly.

* The variation of χ with T is given below.



* The dipole alignment is parallel as shown below



* Examples: Iron, Nickel, cobalt and some steels.

Antiferromagnetic materials:

In an antiferromagnetic material, the electron spin of neighboring atoms are aligned antiparallel to each other and they have equal magnitudes. This type of magnetic ordering is called antiferromagnetic. Here, the net magnetization is zero.

Properties:

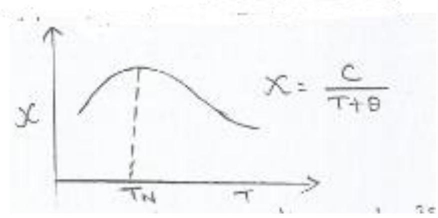
* The opposite alignment of adjacent dipoles is due to exchange interaction.

* The susceptibility is very small and is positive. It is given by $\chi = \frac{C}{T+\theta}$, for T $> T_N$

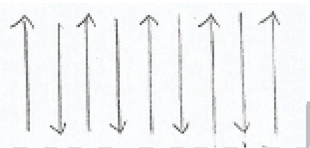
Where θ → paramagnetic Curie temperature.

* The susceptibility increases with increasing temperature and reaches a maximum at a certain temperature called Neel temperature T_N. With further increase in temperature, the material goes in to paramagnetic state.

* The variation of χ with T is



* The antiparallel dipole alignment is shown below



* Examples: Ferrous oxide, Manganese oxide, Chromium oxide, etc..,

Ferromagnetic Materials:

In a ferromagnetic material, the electron spin of neighbouring atoms are aligned antiparallel to each other with different magnitudes. Therefore, for a small value of magnetic field, it will produce a large value of magnetization.

Properties:

* Ferromagnetic materials possess net magnetic moment.

* The susceptibility is very large and is a positive quantity. It is given by

$\chi = \frac{C}{T \pm \theta}$ for T $> T_N$

Where θ → $paramagnetic\ curie\ temperature.$

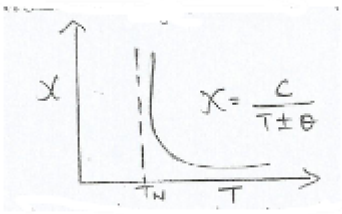
* Above Curie temperature, it becomes paramagnetic and below Curie temperature it behaves as ferromagnetic material.

* These are also called Ferrites.

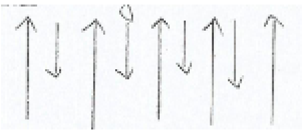
* Mechanically, it has pure iron character.

* They have high permeability, high resistivity, low eddy current losses and low hysteresis.

* The variation of χ with T is given below



* The dipole alignment is shown below.



* Examples: Ferrous ferrite, Nickel ferrite, etc...,

3. (a) Describe the Ferro magnetic domain theory in detail and how will you account Hysteresis of Ferro magnetic material based on domain theory.

(OR)

(b) Discuss Weiss theory of ferromagnetism.

(OR)

(c) Explain the reason for the formation of domain structure in a ferromagnetic material and how the hysteresis curve is explained on the basis of the domain theory.

(OR)

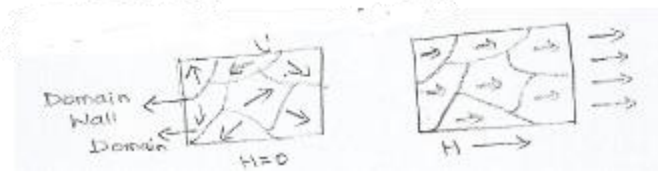
(d) Explain domain theory of ferromagnetism and the types of energy involved in the process of domain growth in detail.

Weiss proposed the concept of domains in 1907 to explain the properties of ferromagnetic materials as well as to explain the hysteresis effects observed in ferromagnetic materials.

Magnetic domains:

A group of atoms organized into tiny bounded regions in the ferromagnetic material, where all the magnetic, dipole moments are aligned in same direction is called a domain.

The direction of magnetization varies from domain to domain and hence the resultant magnetization is zero in the absence of external magnetic field.

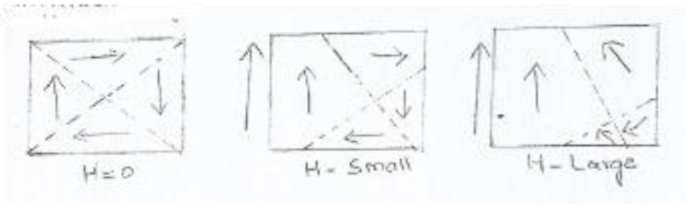


Process of domain magnetization:

When an external magnetic field is applied, there are two possible ways of alignment of a random domain.

(i) By motion of domain walls.

When the applied field is small, domains which are favorably oriented respect to the applied field, increases their volume than that of unfavorably oriented.



(ii) By rotation of domains:

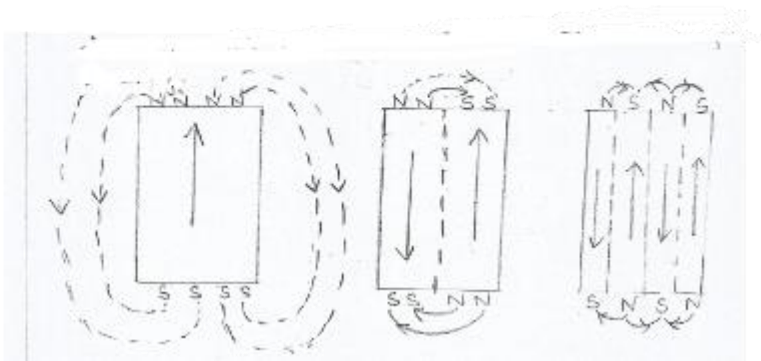
When the applied magnetic field is strong, rotation of the direction of magnetization occurs in the direction of the field.

Energies Involved in the domain growth:

In the process of domain growth, four types of energies are involved.

(i) Exchange energy:

Exchange energy arises from the interaction of electron spin. It depends upon the interatomic distance. This energy is also called magnetic field energy. It is the energy required in assembling the atomic magnets into a single domain and this work done is stored as potential energy.



(ii) Anisotropy energy:

In ferromagnetic crystals, the energy of magnetization is found to be a function of crystal orientation. That is crystals have easy and hard directions of magnetization.

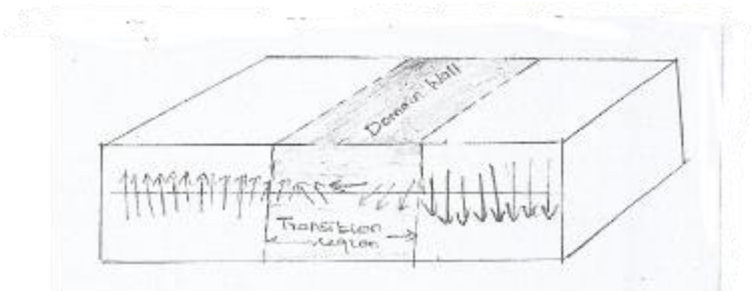
For example, in Bcc iron, the easy direction is[100], the medium direction is [110]and the hard direction is [111].

The excess energy required to magnetize a specimen in a particular direction over that required to magnetize it along the easy direction is called crystalline anisotropy energy.

(iii) Domain Wall energy (or) Bloch wall energy:

A thin region that separates adjacent domains magnetized in different directions is called domain wall or Bloch wall.

The domain wall energy is the sum of contributions from the exchange and crystalline anisotropy energies in the domain wall region. Thickness of the wall is approximately 1000A.



(iv) Magnetostriction energy:

When a material is magnetized, it undergoes change in dimension. This is known as magnetostriction.

If the material is magnetized, the domains will expand or contract. This means, that work must be done against the elastic restoring force. The work done by the magnetic field against the elastic restoring force is called magnetostriction energy.

Hysteresis curve on the basis of domain theory:

The hysteresis of ferromagnetic materials refers to the lag of magnetization or magnetic induction behind magnetic field.

(a) Reversible Wall displacement:

When a small external field is applied, on the ferromagnetic specimen, the domain wall is slightly displaced in the easy direction of magnetization. This gives rise to the initial position of the hysterels curve OA. When the field is removed, the domains return to the original position. This gives a reversible domain wall movement and the domain is called reversible domain.

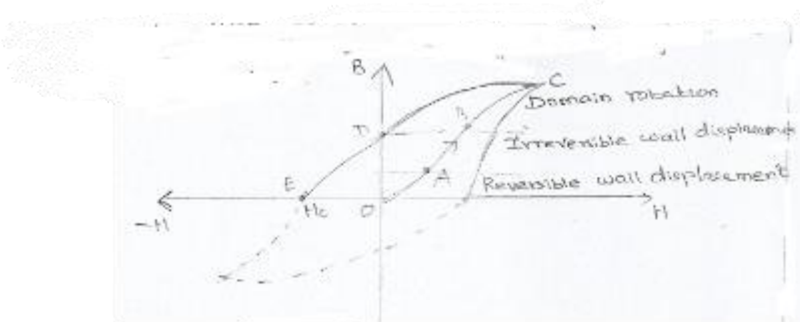
(b) Irreversible wall displacement:

When large external field is applied, the domain wall may be displaced to a more distant position and is unable to return to its initial position. This gives an irreversible domain wall movement and the domain is called irreversible domain. This process is indicated as AB in the figure.

(c) Domain rotation:

When the field is further increased, the domains start rotating along the field direction. The increase in magnetization is relatively slow, represented as BC in fig.

When the applied field is reduced, there is a little change in the domain structure so the magnetization remains high, until high reverse fields are applied.



(d) Removal of field:

On removal of the field, the specimen tries to attain its original configuration. It requires more energy to overcome the opposing forces.

The negative field that is supplied to reduce the magnetization of the specimen to zero is called coercive field.

Thus, the reversible and irreversible domain wall movements give rise to hysteresis in the ferromagnetic materials.

4. (a) what are ferrites? Describe the different types of ferrites structure with suitable diagrams. What are the applications of ferrites?

(OR)

(b) Describe the structure formation of ferrites and the interaction of molecules in it. Mention the application of ferrites.

(OR)

(c) Give an account of structure, properties and applications of ferrites. How magnetic moment is calculated in a ferrite molecule?

Ferromagnetic materials are also called as ferrites. Ferrites are the magnetic compounds consisting of two or more different. Kinds of atoms. These materials have anti-parallel magnetic moments of different magnitudes, giving rise to large magnetic moment in the presence of external magnetic field.

Examples

Ferrous ferrite, manganese ferrite, cadmium ferrite, Zinc ferrite, etc.., are some examples.

The general formula for ferrites is X^{2+} Fe_2^{3+} O_4 where X^{2+} stands for suitable divalent metal ion such as Mg^{2+}, Zn^{2+}, Fe^{2+}, Ni^{2+} etc...

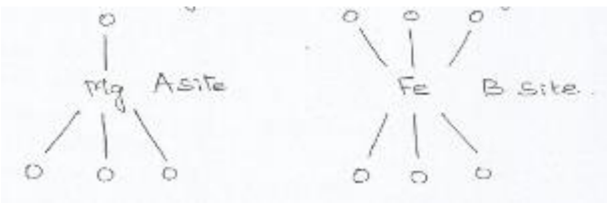
Structure of ferrites:

Ferrites crystallize in the form of a cubic structure. Each and every corner atom of a

Ferrite unit cell consists of a ferrite molecule. So, in a ferrite unit cell, there are 8 ferrite molecules. Therefore, in a ferrous ferrite unit cell, there are 8 ferrous ions. If only the oxygen ions are considered, it is found that they constitute a close – packed face centred cubic structure.

In a ferrite unit cell, there are 16 octahedral sites surrounded by 6 0^{2-} irons and 8 tetrahedral sites surrounded by 40^{2-} ions. The tetrahedral sites are represented by Asites, whereas the octahedral sites are represented as B sites.

For example, in Mg^{2+} Fe_2^{3+} O_4^{2+}, the structure of Mg^{2+} and $Fe^{3+}$are given below.



Types of structures:

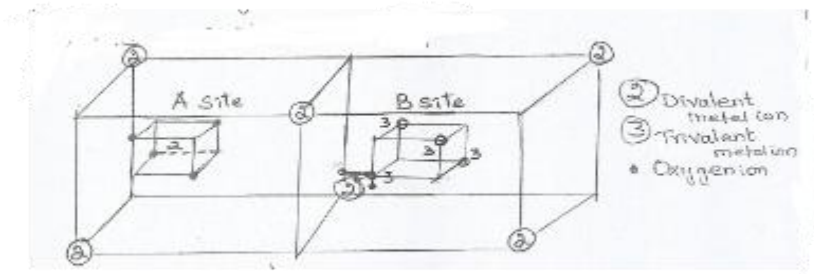
There are two types of structures in ferrite. They are regular spinel and inverse spinel.

(i) Regular Spinel:

* In a regular spinel structure, each divalent metal ion (Mg^{2+}) exists in a tetrahedral form (A site) and each trivalent metal ion Fe^{3+} exists in an octahedral form (B site).

* Trivalent metal ion occupies octahedral site (B-site) and divalent metal ion occupies tetrahedral site (A site)

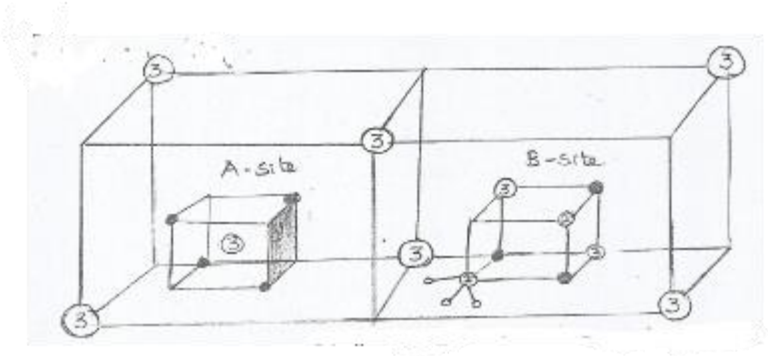
Hence the sites A and B combine together to form a regular spinel ferrit B structure as shown in figure>



(ii) Inverse spinel:

In Inverse spinel consider the arrangement of dipoles of a single ferrous ferrite molecule Fe^{3+} $[Fe^{2+}\ Fe^{3+}]$ O_4^{2-}. Fe^{3+} ions (trivalent) occupy a sites and half of the B sites also.

Thus, the left-out B sites will be occupied by the divalent (Fe^{2+}). The inverse spinel is shown in fig.



Types of interaction present in the ferrites:

* The spin arrangement between the A site B site is in an antiparallel manner and it was explained by Neel.

* According to him, in ferrites the spin arrangement is antiparallel and there exist some interaction between A and B sites which is represented as AB interaction.

* A part from this, there are two more interactions (i.e.) AA and BB interaction which is negative and considerable weaker than AB interaction.

* The tendency of AB interaction is to align all A spins parallel to each other and antiparallel to all B spins, but the tendency of AA and BB interaction is to spoil the parallel arrangement of AB spins respectively.

* Since AB is very strong as compared with AA and BB, the effect of AB interaction dominates and gives rise to antiparallel spin arrangement.

Magnetic Moment of a Ferrite molecule:

The antiparallel alignment of a ferrous ferrite molecule in inverse spinel structure is explained by the calculation of its magnetic moment. In a ferrous ferrite molecule, there are one ferrous ion and 2 ferric ions.

Each unpaired 3d electron has a magnetic moment of 1 μB, the Fe^{2+} ion has a moment of 4μB and Fe^{3+} ion has a moment of 5μB.

If parallel alignments of ferrous and ferric ions are considered,

The total dipole moment = 4 + (2 x 5)

= 14μB

The observed value doesn't coincide with the experimental value.

Consider the antiparallel alignment of dipoles. If one ferrous ion and one ferric ion are in one direction and another ferric ion is in the opposite direction.

Then the total dipole moment = $[4 + 5 - 5]\,\beta$

= 4β

The observed value is in agreement with the experimental value of 4.08 β and hence, this confirms the antiparallel alignment of dipoles in ferrites.

Application of ferrites:

1. Ferrites are used in radio receivers to increase the sensitivity and selectivity of the Receiver.
2. Ferrites are used as cores in audio and T.V transformers.
3. Ferrites are used in digital computers and data processing circuits.
4. Ferrites are used to produce low frequency ultrasonic waves by magnetostriction principle.
5. Since the ferrites have low hysteresis loss and eddy current loss, they are used in two port devices such as gyrator, circulator and isolator.
6. Ferrites are used in power limiting and harmonic generation devices.
7. Hard ferrites are used to make permanent magnets, which are used in instruments like galvanometers, ammeters, voltmeters, speedometers, compasses, wattmeter, flux meters and recorders.

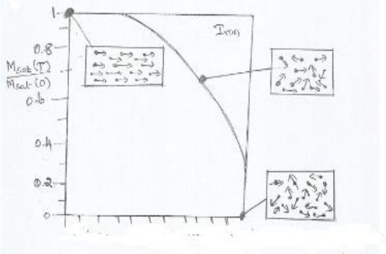
5. (a) Explain saturation magnetization and Curie temperature.

(OR)

(b) Write briefly about saturation magnetization and Curie temperature.

Saturation Magnetization:

The maximum magnetization in a Ferro magnet when all the atomic magnetic moments have been aligned as much as possible is called the saturation Magnetization. (M_{sat}).



The spins cannot align perfectly with each other as the temperature increases due to lattice vibration.

When an energetic lattice vibration passes through a spin site, the energy in the vibration may be sufficient to disorientate the spin of the atom. The ferromagnetic behaviour disappears at a critical temperature called the Curie temperature denoted by T_c.

When the thermal energy of lattice vibrations in the crystal overcome the potential energy of the exchange interaction, the spin alignments are destroyed.

Above the Curie temperature, the crystal behaves as paramagnetic. The saturation magnetization M_{sat}, decreases from its maximum value $M_{sat(0)}$ at absolute zero of temperature to zero at the Curie temperature.

Curie temperature

In Ferro magnets the electronic exchange forces are very large, thermal energy eventually overcomes the exchange and produce a randomizing effect. This occurs at a particular temperature called the Curie temperature (T_c). Below the Curie temperature, the Ferro magnet is ordered and above it, disordered. The saturation magnetization goes to zero, at the Curie temperature. The Curie temperature is also an intrinsic property and is a diagnostic parameter that can be used for mineral identification.

6. (a) Explain how magnetization varies with applied magnetic field.

(OR)

(b) Draw the M-H curve for a ferromagnetic material and explain the hysteresis.

When a ferromagnetic material is made to undergo through a cycle of magnetization, the variation of magnetisation (M) with respect to the applied field (H) can be represented by a closed curve known as hysteresis curve. The intensity of magnetization (M) log behind the applied field (H).

Explanation:

Consider an unmegnetized ferromagnetic material is subjected to an external magnetic field.

* When the magnetic field strength (H) is gradually increased from zero, the magnetization (M) increases rapidly as shown by the curve OA.

* As H is further increased, magnetization reaches a saturation value M_s

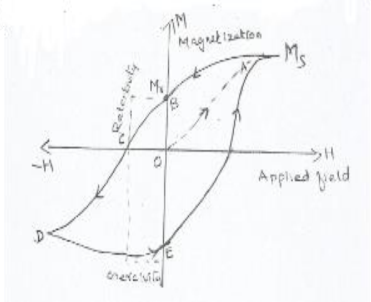
* When H is reversed to zero, magnetisation decreases along AB. It does not become zero.

The amount of magnetization retained by the material is called retentively.

Retentively is the amount of magnetization retained in the material after removing the magnetic field.

* In order to make the magnetization to zero, a certain amount of magnetic field strength (H) is applied in opposite direction called coercively.

Coercively or coercive force is the amount of magnetic field intensity applied in the reverse direction to remove the residual magnetism completely from the material.



* If the field strength is further increased in the opposite direction, M increases rapidly along the curve CD until a negative saturation is reached.

* On reducing H to zero, M reaches E and then increasing H in the positive direction, M reaches A, thus completing one full cycle.

* The path traced by this M-H plot is called hysteresis loop.

* When a ferromagnetic material is taken through a cycle of magnetization, then there is a loss of energy in the form of heat. This loss of energy is known as hysteresis loss.

7. (a) Explain the magnetic principle in computer data storage.

(OR)

(b) Give an account on magnetic principle in computer data storage.

* Computer system need to store data in the digital format. Magnetic storage refers to any type of data storage using a magnetized medium.

* Magnetic recording heads are the hearts of disk drives and other magnetic storage devices.

* Digital data consists of binary information, which is data in the form of O's and 1's.

* The read-write head moves very close to the magnetic surfaces whose distance is often no more than tens of nanometres.

*The head is able to detect and modify the magnetization of the material.

* The magnetic surface is divided into very small regions, each of has mostly uniform magnetization.

* As the head moves relative to the surface, the changes in magnetization from region to region are detected and recorded as zeros and ones.

Magnetic parameters for recording head function:

(1) When current is passed through a coil, a magnetic field is induced. This principle is called as electromagnetic induction. Which is the basic parameter in the storage devices.

(2) Soft magnetic materials can be easily magnetized and demagnetized. Such magnetic materials are used in temporary storage devices.

(3) Hard magnetic materials cannot be easily magnetized and demagnetized. Such magnetic materials are used in permanent storage devices.

(4) In some soft magnetic materials, the electrical resistance varies with respect to the magnetization and this effect is called Magneto- Resistance (MR effect) or Giant Magneto Resistance (GMR effect). It is used in specific thin film system.

These four phenomena are used in the design and manufacture of magnetic recording heads which read and write data for storage and retrieval in computer disk drive memories, tape drives and other magnetic storage devices.

8. (a) Discuss the concepts of magnetic recording and reading on a storage medium with suitable diagrams.

(OR)

(b) Explain different magnetic storage media.

(OR)

(C) Explain the principle of magnetic data storage in HOPPY disc and computer hard disc.

(a) <u>Magnetic Tape:</u>

* Magnetic tape is one of the most popular storage mediums for data.

* The tape is a plastic (mylar) ribbon with metal oxide material coated on one side which can be magnetized.

* In this, information can be written and also can be read by write/read heads.

* Information Recorded in the tape is in the form of tiny magnetized and non-magnetized spots on the metal oxide coating.

* The magnetized spot represents '1' and unmagnified spot represent 'o' in binary code.

* The information can be accessed, processed, erased and can be again stored in the same area.

<u>Advantages:</u>

1. Magnetic tape is easy to handle and is portable.
2. Its storage capacity is large.
3. Its cost is less than other storage devices.
4. It can be erased and reused.

<u>Disadvantages:</u>

It consumes lot of time.

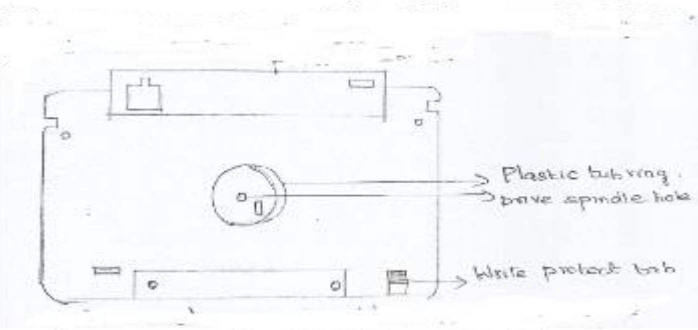
<u>Applications:</u>

1. Generally they are used only for long term storage and backup.

2. They are used for transporting large amount of data.

(b) Floppy disk (Diskettes)

* In computer, magnetic floppy disk are the most popular direct access storage medium. They are made of very thin and flexible plastic (mylar) material and are coated with magnetic material such as iron oxide.



* To read or write, the floppy disk is inserted in to the floppy drive and starts to rotate the disk at 300 rpm.

* The read/write window on the disk allows the head to touch the disk surface for read/write operation.

* It contains a write protect notch to protect the stored information. A black or silver metallic tab is fixed on the notch to protect the disk from any more writing or erasing the information already stored on the disk.

* The data's are organized into a number of concentric circles or tracks each of which has a designated location number.

* There are typically 200 to 800 bracks on the disc surface. The information is recorded on tracks. Each track is divided into a number of sectors.

Working:

Read/write head is a small electromagnet with minute gaps between the poles. In writing operation, the disk moves over the gaps while the electric pulses from the central processing unit flow through the write coil of the head. It causes the iron oxide coating of the disk to be magnetized in the proper pattern.

When the disk is being read, the magnetized pattern induces pulses of current in the read coil to feed the data into the CPU. Data can be stored on both sides of the floppy disk.

Advantages:

* Floppy disk is a non-volatile storage medium.

* They are inexpensive.

* They have low-capacity storage.

* They can be easily handled.

* Storage capacity ranges from 360 kB to about 1.44MB.

Disadvantages:

* It can be affected by heat or magnetic field.

* Storage capacity is less.

* It requires careful handling and storing.

(c) Magnetic Hard disk:

* Hard disk is known as Winchester disk. The hard disk is permanently sealed and is protected from dust particles.

* It consists of a number of magnetic disk (2 to 5) or aluminum platters. The platter surface is carefully machined until it is flat or plane.

* The platter surface is coated with magnetic oxides. All these platters are mounted on a vertical shaft forming a disk pack as shown in fig.

* The disk pack is placed in a drive mechanism called hard disk drive. The drive mechanism drives the disk pack with the spindle.

* The central shaft rotates at the spead of 3600 or more revolutions per minute. All the disks move simultaneously in the same direction.

* A number of access arms and read/write heads are used to access two surfaces of the disk.

* Each disk has two sides in which information is stored on both sides of the disk. The disk consists of a number of tracks. Each track is further divided into sectors.

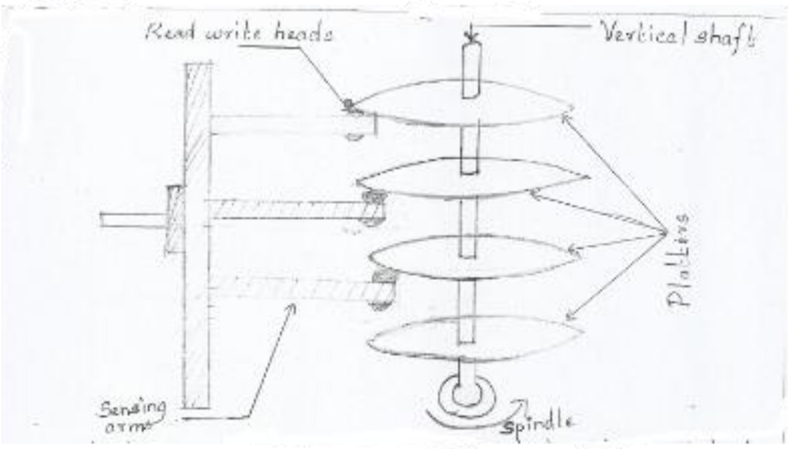
* The storage capacity of a hard disk depends on the number of disk surfaces, tracks per inch of surfaces and the bits per inch of track.

Advantages:

1. It has very large storage capacity.
2. Thousands of files can be permanently stored.
3. Very high speed in reading and writing the information.
4. Hard disk is prevented from dust particle, since they are sealed in special chamber.
5. Data can be accessed very large number of times without degradation.

Disadvantages:

1. Hard disks are not easily portable.
2. If data gets corrupted, there is a heavy loss of data.
3. It is very costly.



9. (a) what are GMR sensors? Explain their application in digital storage media with necessary diagrams.

(OR)

(b) Describe the working of magnetic hard disc based on GMR sensor. Mention its advantages and disadvantages

In some soft materials, the change in electrical resistance with respect to the applied field is called Magnetic Resistance. (MR)

Giant Magneto resistance (GMR)

It is a quantum mechanical magneto resistance effect observed in multilayers composed of alternating ferromagnetic and non-magnetic conductive layers.

Definition:

The effect is observed as a significant change in the electrical resistance depending on whether the magnetization of adjacent ferromagnetic layers is in a parallel or an anti-parallel alignment.

The overall resistance is relatively low for parallel alignment. The magnetization direction can be controlled, by applying an external magnetic field>

The effect is based on the dependence of electron scattering on the spin orientation.

The main application of GMR is magnetic field sensors, which are used to read data in a hard disk drives, biosensors, micro electromechanical system (MEMS) and other devices. GMR multilayer structure are also used in magneto resistive random-access memory (MRAM) as cells that store one bit of information.

Explanation:

* The GMR is seen in structures which have normal metal and ferromagnetic layers alternatively.

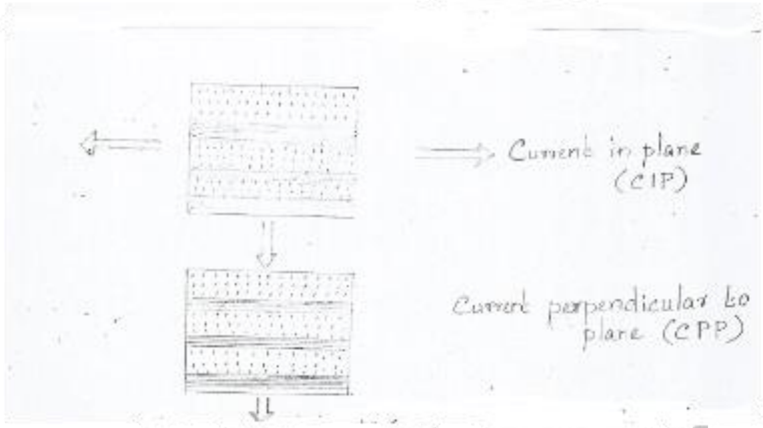
* The electrical conductivity depends on the relative orientation of magnetization in the successive ferromagnetic layers in the stack>

* When the relative magnetizations of the layers are switched from parallel to antiparallel states, high and low resistivities are obtained in the structure. This corresponds to o and 1 state in data storage format.

* Two geometries are commonly used in GMR studies are shown below.

(a) Current in plan (CIP) of layers.

(b) Current perpendicular to plan (CPP) of layers.



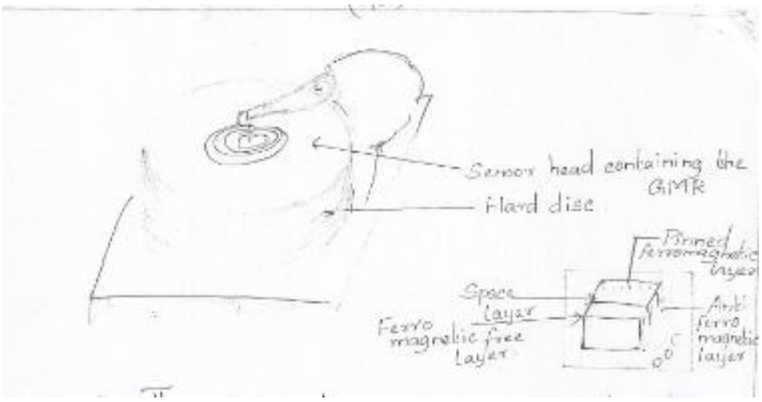
* Since the layers are only a few nanometers thick, the CIP mode offers high resistance to the small cross-sectional area encountered by the electrons.

* To alter the resistivity by controlling the spin-dependent scattering, the lateral dimensions of the structure must be small when compared with the electron mean free path.

Giant Magneto Resistance (GMR)

Sensor – spin value:

A device that works on the principle of the GMR is a spin value. This device is used in magnetic hard discs for high density data storage. There are four layers altogether in a spin value.



Two Ferro magnetic layers are separated by a thin spacer layer (cu or Ru). One ferromagnetic layer is pinned (its direction of magnetization is fixed) and is not distributed by changes in field. This layer is pinned by adding a fourth layer a strong anti-Ferro magnet.

The other layer called the free layer, is sensitive to the field produced by the data bit permalloy (an alloy of Ni and Fe) is usually chosen for both ferromagnetic layers. This structure is called the spin value.

When a weak magnetic field, such as that from bit on a hard disk, passes beneath such a structure, the magnetic orientation of the unpinned magnetic layer rotates relative to that of the pinned layer. This generates a significant change in electrical resistance due to the GMR effect.

* As the bit travels under the head, the resistance goes down, the electrons do not scatter very much and the current flow increases.

* As the bit moves on, the resistance increases, the electrons are scattered ore and the current decreases.

* As the bit travels further from the head the resistance peaks and the current decreases to its lowest point.

* As the resistance change is quite large, even small data bit can generate quite large, resistance changes, thus increasing the capacity to store data bits in the hard disc.