* UNIT-IV : Magnetism & Superconductivity

- Magnetic materials play a prominent role in modern tech.
  They are used in information storage devices.
- In 1845, Michael Faraday discovered that magnetic materials can be classified into Diamagnetic, Paramagnetic & Ferromagnetic materials.

But how he discovered this & how magnetism originated ?

* Origin of Magnetization :-

- Faraday in his laws given relation betn electrostatic & magnetostatic i.e. ~~electr~~ changing electric field will give rise to magnetic field.
- Inside an atom, the electrons are revolving around the nucleus in different orbits.
  As electrons are charged particle, moving electrons will constitute a current. because of which there is will magnetic field associated with it.
  We can say electron acts like a magnetic dipole.
  These magnetic dipoles will have magnetic dipole moment.
  These magnetic dipole moments are responsible for magnetic properties of materials.
- Magnetic dipole moments of atom arises from three sources:

① Orbital motion of electrons:

- ~~tt~~ Electrons revolving in different orbits in an atom, behaves as tiny magnets having magnetic dipole moments.
  ~~This.~~ ~~Eeac~~ Each electron will have orbital magnetic moment
  So the total orbital moment of an atom will be result of orbital magnetic moments of all electrons in it.

② The Electron Spin :-

Each electron spins (rotate about) about an axis through itself & ~~eo~~ spin constitute a magnetic dipole moment.

③ Nuclear Spin :-

In additional to electron spin, nuclear spin will also contribute to ~~dipol~~ orbital magnetic moment of atom.
Magnetic moment of nucleus is about 1/2000 of magnetic moment of electron
Hence generally, while studing magnetic properties of solids magnetic moment due to nuclear spin is neglacted.

∴ Resulting magnetic moment of an atom is sum of orbital & spin magnetic moments of electrons.
Major contribution to atomic magnetic moment comes from the spin of up unpaired valance electrons.

* Basic terms & definations :

* When a material is kept in external magnetic field, it gets magnetized.

(i) Magnetic field ($\bar{H}$) :
Magnetic field in which a material is kept is called 'magnetizng field' strength of that field is denoted by $\bar{H}$.
Unit of $\bar{H} \rightarrow$ Ampere / meter (A/m)
Permanent magnetic field is generated by permanent magnets like horse shoe magnet & temporarily by electromagnets / superconductor magnets.

(ii) Magnetization $\bar{m}$:
• magnetic moment per unit volume developed inside a solid is magnetization ($\bar{m}$)
Unit of $\bar{m} \rightarrow$ A/m. &
magnetization is produced by magnetic field.

∴ $\bar{m} \propto \bar{H} \Rightarrow \boxed{\bar{m} = \chi \bar{H}}$

$\chi \rightarrow$ susceptibility

(iii) Magnetic Susceptibility (χ):

Measure of the ease with which material can be magnetized

Magnetization produced per unit applied magnetic field.

$$\boxed{\chi = \frac{\bar{M}}{\bar{H}}}$$

$\chi \rightarrow$ tensor.

If $\bar{m}$ & $\bar{H}$ have different directions

For isotropic materials, $\bar{m}$ & $\bar{H}$ are in same direction

$\therefore \chi \rightarrow$ scalar quantity.

- Materials with high susceptibility (χ) value are easily magnetized.

(iv) Magnetic Induction ($\bar{B}$):

Magnetic field is ~~pre~~ represented by magnetic field lines. The number of lines passing through a unit area of cross-section is called magnetic flux density

$$\bar{B} = \frac{\text{magnetic flux}}{\text{Area}} = \frac{\phi}{A}$$

Unit of $\bar{B} \rightarrow Wb/m^2$ = tesla. (SI)

CGS unit $\rightarrow$ Gauss $\Rightarrow$ $\boxed{1\ G = 10^{-4}\ T}$

* Rel^n bet^n $\bar{B}$ & $\bar{H}$:

$$\bar{B} = \mu_0 (\bar{H} + \bar{m})$$

$\mu_0 \rightarrow$ permeability of free space = $4\pi \times 10^{-7}$ henry permeter.

$$\bar{B} = \mu_0 (1+\chi)\bar{H} \Rightarrow \underline{\bar{B} = \mu \bar{H}}$$

$\mu \rightarrow$ Absolute permeability of medium.

$$\Rightarrow \underline{\underline{\mu = \mu_0 (1+\chi)}}$$

In free space, $\bar{m} = 0$

$$\Rightarrow \boxed{\bar{B} = \mu_0 \bar{H}}$$

		unit
* Absolute permeability	$\boxed{\mu = \bar{B}/\bar{H}}$	H/m
* Relative Permeability	$\boxed{\mu_r = \mu/\mu_0}$	$= 1+\chi$

* Classification of magnetic Materials:

Based of permeability (μ_r), solids are classified as

(I) Diamagnetic materials $\mu_r < 1$ & $\chi \rightarrow -ve$

(II) Paramagnetic materials $\mu_r > 1$ & $\chi \rightarrow +ve$ & small

(III) ~~Di~~ Ferromagnetic materials $\mu_r >> 1$ & $\chi \rightarrow +ve$ & large.

① Diamagnetic Materials :

- Diamagnetic materials when placed in magnetic field acquire magnetism in opposite direction to applied field direction.

Ex. - Inert gases, majority of metals & many organic compounds.

Hydrogen, air, water, gold, silver & bismuth

* Features of Diamagnetic materials :

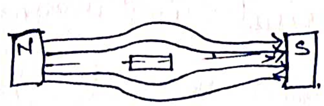
- Magnetization created in material is in opposite direction to applied field. Because of which susceptibility ($\chi = \bar{M} / \bar{H}$) is negative.

χ is very small : of order of 10^{-6}.

- $\chi \rightarrow -ve$ & relative permeability μ_r slightly less than 1.
$\mu_r < 1$

- Materials are repelled by external magnetic field.
If placed in inhomogeneous magnetic field, they tend to mov to weaker field region.

- When a rod of diamagnetic material is ~~kept~~ suspended in external magnetic field, turns in a position perpendicular to field lines. ~~Diagr~~ Diamagnetic material push aside the
- magnetic field lines.

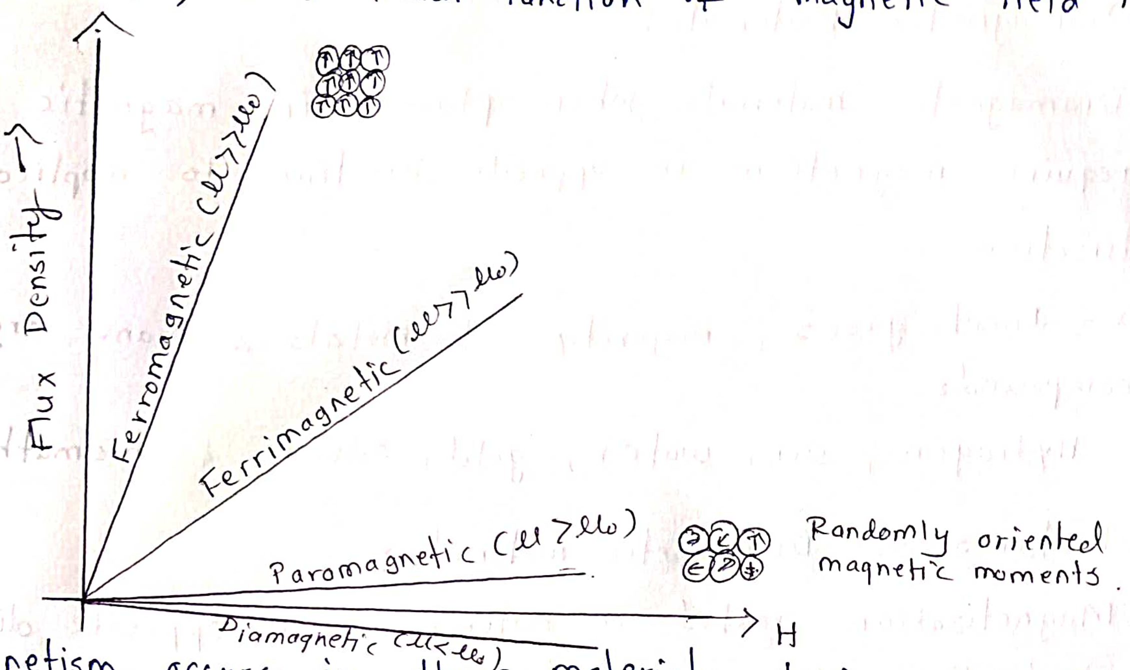


ⓐ Uniform magnetic field.

ⓑ mag. field lines pushed away by diamagnetic material.

- Magnetic susceptibility is independent of temperature.
Pierre Currie discovered independence of χ on temp in 1895.

• Magnetization ($\bar{M}$) is a linear function of magnetic field $\bar{H}$.



• Diamagnetism occurs in those materials having even number of electrons. Electrons of such atoms are paired. Electron in each pair have orbital motion as well as spin motion in opposite sense. Magnetic moment cancel each other & hence resultant magnetic moment of atom ~~cancel each~~ is zero.

• When diamagnetic material is kept in external field, alignment of magnetic dipoles does not occur, as there are no dipoles in material.

• External magnetic field modifies motion of electrons in the orbits.

• Because of which if one electron is accelerated other one will be deaccelerated. Hence, now each electron pair will give rise to a resultant magnetic moment.

Hence resultant magnetic moment is induced in the atom as a whole in the direction opposite to that of external mag field. As a result material is magnetized.

• Strength of induced magnetic moment is proportional to applied field & hence magnetization of material varies with strength of external field.

• When external field is removed magnetization is lost & magnetic moments again orient in random directions.

• magnetic moments are independent of temp hence χ is independent of temp.

* Langevin's Theory of Diamagnetism:

- 1905, Langevin explained diamagnetism in atoms which constist of electrons in motion. 5

In an atom, two forces are acting on electron →
electrostatic force F_c, exterted by nucleus &
& centripetal force due to orbital motion.

$$\therefore \quad F_c = m\omega_0^2 r .$$

$\omega_0 \rightarrow$ Angular frequency of $\bar{e}$ in the orbit.

- External magnetic field is ~~app~~' applied perpendicular to plane of orbit.

$$\therefore \quad F_c \pm F_m = m\omega^2 r .$$

magnetic field will change only the velocity of e^- but not radius of orbit.

$$\therefore \quad F_m = e V \bar{B} = e\omega r \bar{B} .$$

$$\therefore \quad m\omega_0^2 r \pm e\omega r \bar{B} = m\omega^2 r .$$

$$\therefore \quad m\omega_0^2 \pm e\omega\bar{B} = m\omega^2 .$$

$$\therefore \quad \pm e\omega\bar{B} = m(\omega^2 - \omega_0^2)$$

$$= m(\omega + \omega_0)(\omega - \omega_0)$$

$$(\omega - \omega_0) \approx \Delta\omega \quad \& \quad (\omega + \omega_0) \approx 2\omega$$

$$\therefore \quad \pm e\omega\bar{B} = m\, 2\omega \,.\, \Delta\omega .$$

$$\therefore \quad \Delta\omega = \pm \frac{e\bar{B}}{2m} .$$

- Revolving electron behaves as a current loop & have mag moment.

$$\therefore \quad \mu_m = e\left(\frac{\omega}{2\pi}\right)\pi r^2 = \underline{\frac{1}{2} e\omega r^2}$$

- change in angular velocity produces the change in magnetic moment & ~~magneti~~ magnitude of induced magnetic field is

$$\Delta \mu_m = \frac{e^2 r^2 \bar{B}}{4m}$$

- If there are 'i' atoms in a material, atom,

$$\sum_i \Delta \mu_m = \frac{e^2 \sum_i r_i^2}{4m} \bar{B}$$

- If there are 'N' atoms per unit volume of the material magnitude of magnetization:

$$M = \frac{N e^2 \sum_i r_i^2}{4m} \mu_0 H$$

μ_m & H are in opposite direction.

$$\therefore \bar{M} = - \frac{\mu_0 N e^2 \sum_i r_i^2}{4m} \bar{H}$$

$$\therefore \chi_{dia} = \frac{\bar{M}}{\bar{H}} = - \frac{\mu_0 N e^2 \sum_i r_i^2}{4m}.$$

As all i electrons orbits may not be perpendicular to applied magnetic field $\therefore$ R.H.S. $\times$ 2/3.

$$\therefore \boxed{\chi_{dia} = - \frac{\mu_0 N e^2 \sum_i r_i^2}{6m}.}$$

* It is found that,

- Diamagnetic susceptibility is negative.
- Diamagnetic susceptibility is independent of temperature.
- It is directly proportional to atomic number.
- χ_{dia} is larger, if atom is bigger.

* Paramagnetic Materials :-

- Paramagnetic materials are those when placed in external magnetic field, ~~produces~~ acquire magnetis in the direction of external field.

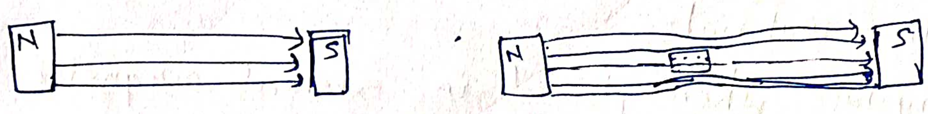
Ex. - Oxygen, sol^n of iron salts, Copper chloride, chromium, platinum.

* Features of Paramagnetic materials :

- Exhibit positive magnetic susceptibility as the direction of magnetization & applied field is same. susceptibility is of order of 10^{-6}.

- Relative permeability (μ_r) is slightly greater than unit ($\mu_r > 1$)

When placed in external field, field lines are pulled towards the material & permeate through it.



- When a rod of paramagnetic material is freely suspended in a magnetic field, aligns itself along lines of induction

In non uniform field, paramagnetic substances are attracted towards stronger field

When taken in U shaped tube, & one leg is placed in magnetic field, level in that rises.

- Magnetization, $\bar{M}$ is a linear function of the magnetic field $\bar{H}$ If field is not too strong.

- Para magnetic susceptibility is strongly dependent on temperature

Pierre Curie discovered in 1895 & χ_{para} is inversely proportional to temperature.

$$\boxed{\chi_{para} = \frac{C}{T}} \quad \text{.... Curie Law}$$

$C \rightarrow$ Curie constant.

- Molecules of paramagnetic material possess a net ~~per~~ ~~manat~~ permanent magnetic moment even in absence of external magnetic field.

- But magnetic moments are randomly oriented in absence of external field. Therefore net magnetization inside the material is zero.
- When kept in external magnetic field, magnetic dipoles tend to align in the direction of field. & material becomes magnetized
- Thermal motions opposes the magnetic dipole alignment along direction of external field, hence as we increase the temp. due to increased thermal motions magnetization is reduced. Hence susceptibily decreases as the temperature is increased.

$$\left(\chi_{para} \propto 1/T \right)$$

* Ferromagnetic materials:

- Metalic crystals when placed in external magnetic field become strongly magnetized in the direction of field.
- Iron, Nickel & some steels. are the examples.
- Expt. of Einstein & de Haas showed that the spin magnetic moments of electrons are responsible for Ferromagnetism
- Ferromagnetic materials possess spontaneaous magnetic moment even in absence of external magnetic field.
- Internal magnetic field has an induction that is hundreds & thousands of times greater than the induction of external magnetic field producing magnetization. $\rightarrow M >> H$.

$$\bar{B} \cong \mu_0 \bar{M}$$

- Features of ferromagnetic materials:
- Exhibit very high values of magnetic susceptibility & relative permeability

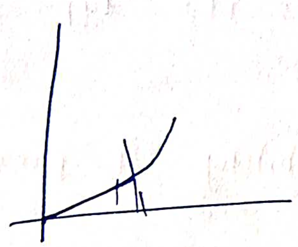
  Susceptibility as large as 10^6 & relative permeability of order of thousands.
- When a ferromagnetic material is kept in a magnetic field

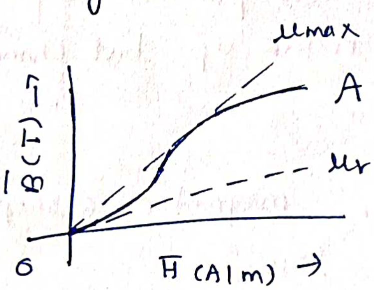
field lines crowd into the material.

- If material is taken in a shell form, magnetic lines are concentrated mainly in the shell without penetrating ~~through~~ into the cavity, means that a shell made of a ferromagnetic material acts as a magnetic shield which does not allow magnetic field to penetrate into the space enclosed by the shell. ∴ Ferromagnetic materials conduct magnetic flux much as metals conduct electric current.

- Magnetization of a ferromagnetic material does not vary linearly with the applied field $\bar{H}$. It is complex non linear function of field strength.

Initially, $\bar{M}$ (& hence $\bar{B}$) increases very fast with a small increase in $\bar{H}$. Then its increase slows down & at large ~~scale~~ enough values of $\bar{H}$, magnetic saturation is reached in which magnetization becomes ~~part~~ practically independent of the strength of magnetizing field.





- magnetization proceeds along curve OA in case of an initially non magnetized ferromagnetic substance

Curve OA → initial magnetizing curve.

- Because of non-linear rel^n bet^n $\bar{B}$ & $\bar{H}$, permeability of ferromagnetic material does not have a constant value. μ is measured either from initial permeability or from max permeability.

- Ferromagnetic properties of crystals are found to be dependent on the direction of magnetization. the magnetization is more easily obtained along certain crystallographic axes than along others. The direction in which magnetization is strongest for a given value of field is called 'Direction of easy magnetization' while direction corresponding to lowest magnetization for a given field is called direction of 'Hard magnetization'

- Ferromagnetic material are characterized by definite temperature (T_c) curie temperature, above which ferromagnetic behaviour disappears.

The saturation magnetization is maximum at 0K in the material, diminishes gradually as temperature is increased & abruptly drops to zero at curie temperature

Ferromagnetic behaviour vanishes ~~at~~ beyond T_c & material transforms into a paramagnetic material. It is reverseble transformation. When material is cooled back through T_c, ferromagnetic character reappears.

- Transformation is not accompained by changes in the crystal lattice. Lattice is not broken up but changes it's type of symmetry.

- Above curie temperature, magnetic susceptibility of paramagnetic state obeys Curie-Weiss law :

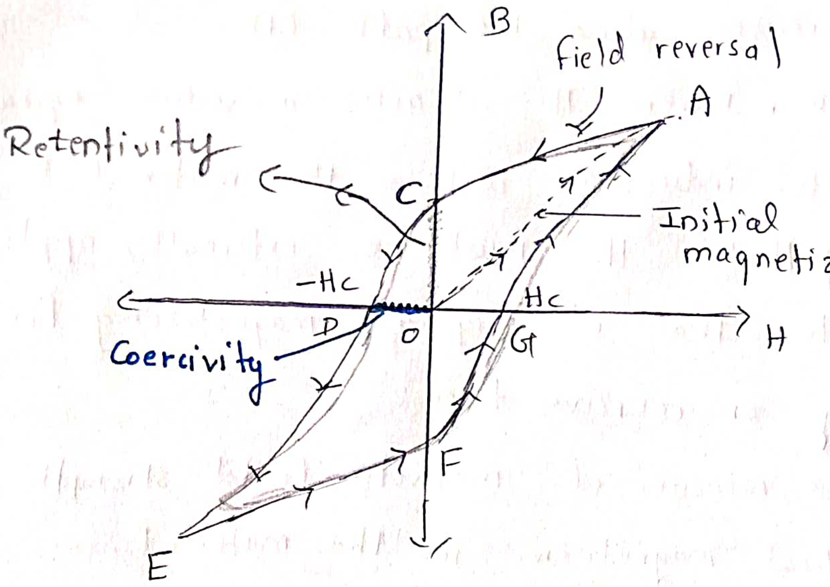
$$\chi = \frac{C}{T-\theta} \quad ; \quad T > T_c$$

* Hysteresis, retentivity & corecivity :

- Typical property of ferromagnetic materials. → Hysteresis.

Lag in the changes of magnetization behind the variation of magnetic field.

- Magnetization of ferromagnetic materials depend on not only on strength of magnetizing field but also on magnetization history of the material.



* ACDEFGA → Hysteresis loop

- If unmagnetized specimen of ferromagnetic material is subjected to increasing or decreasing magnetic fields, magnetic induction $\bar{B}$ varies as a function of $\bar{H}$ along a closed loop called 'Hysteresis Loop'
- Curve begins at 'O'. As H increased B begins to increase slowly, then more rapidly & finally attaining a saturation value of $\bar{B}$ in saturation flux density B_s & corresponding magnetization is saturation magnetization M_s
- If we decrease H, B also decreases. but follows path AC instead of path AO. ⇒ B lags behind H
- If we make external field (H) zero, B does not become zero. but has value equal to OC. Magnetic flux density remaining in material (even if H = 0) is called residual magnetism.

⇒ Material remains magnetized even in absence of external magnetic field. H.

The power of retaining magnetism is called retentivity or remanence of material.

"Retaintivity or Remanence of material is a measure of magnetic flux density remaining in the material when magnetizing field is removed."

- If magnetic field H is increased in reverse direction, the

value of $\bar{B}$ decreases along the path CD.
It becomes zero, when H attains a value equal to OD.
To reduce magnetic induction within the material to zero, a field of magnitude H_c must be externally applied in direction opposite to that of original magnetizing field.
H_c → ~~core~~ coercivity or coercive force.
Coercivity is a measure of magnetic field strength required to destroy residual magnetism in the material.
If we increase H further in negative direction, saturation is ultimately reached in the reverse direction.
If we reverse variation of H, a curve similar to ACDE is traced through points EFGA, yeilding negative remanence ($-B_r$) & +ve coercivity $+H_c$.
At points C & F, where specimen is magnetized in absence of any external magnetic field, it is said to become a permanent magnet.
The closed curve ACDEFGA represents a cycle of ~~magnetiza~~ magnetization of specimen & known as 'Hysteresis loop' of specimen.

* Soft & Hard Magnetic Materials:
• Based on area of Hysteresis loop, magnetic materials are classified as: soft & Hard magnetic materials.
• Area within a hysteresis loop represents a magnetic energy loss per unit Volume of material per magnetization-Demagnetization cycle.
Because of this energy loss, heat is generated in the specimen.
Hence, when using magnetic material in the applications where ac fields are applied, materials having narrow

& small area hysteresis loop are to be used.
Materials having narrow hysteresis loop are soft magnetic ~~materitas~~ materials.
Core of rotating electrical machines are made from soft magnetic materials.

- In the applications where magnetization of material is to be retained on permanent basis materials with large hysteresis loop are used.
Materials with large area hysteresis loop are called hard magnetic materials.
Permanent magnets, magnetic tapes & disks used in entertainment & computer ~~dis,~~ industries are made from hard magnetic materials.

* Applications of Magnetic Materials :-

* Magnetic Devices :-

① Transformer Cores

- Transformer are comprised of a number of parts, each working in conjunction with the others to ensure safe & effective transmission of energy.
- The core makes up the bulk of a transformer.
A magnetic core is a piece of magnetic material with a high permeability used to confine & guide magnetic fields in electrical devices.
- Composition of transformer core depends on such factors as Voltage, current & frequency. Generally made of ferromagnetic metal such as iron or ferrimagnetic compounds as ferrites.
- Inside the core there is higher permeability than air hence magnetic field lines are concetrated inside core material.
- Around the core, there is coil of wire which carries current Which ~~cre~~ create the magnetic field.

- Due to presence of core magnetic field of wire increases by several thousand over what be without the core.
- Different ranges of cores: as steel laminated, solid, toroidal, pot & planar cores.

* Steel laminated cores :-

- Steel laminated cores have high level of permeability & hence used for transmitting voltage at audio frequency level)
- Unlaminated steel cores have a high level of eddy los current loss, & it results in core heating.
- Although thin laminations are hard to manufacture & are more expensive, they are effective in high frequency transformers.
- Several designs are available, out of which E shaped core is affordable to manufacture, but tend to have more energy loss.

A & C type core, offers reduced resistance because of metal grains are parallel to energy flux.

* Solid Cores :-

- Solid cores particularly powdered iron cores are used in circuits have high magnetic permeability as well as electrical resistance.
- Work best for transmission levels above main frequencies.

* Toroidal cores:

- Cores are circular in structure with rest of the transformer built around the core ring.

Materials used are steel, coiled permalloys, powdered iron, ferrites.

* Magnetic Storage :-

- Two types of storage devices available :-

semiconductor memories in which flip-flops are storage element & magnetic memories in which magnetic domains are storge element. Semiconductor memories are volatile where as magnetic memories are permanent & non-volatile.

- Most common form of storage technology is magnetic storage.
- In the computing field, magnetic storage term is used & in the audio & video ~~field~~ production field magnetic recording term is used.
- Storage media are called a disk or a cartridge

Process of storing data in a memory unit is called as writing & process of retrieving data from memory is called reading.

Medium used in magnetic storage devices is coated with iron oxide. which is ferromagnetic material.

Mostly these magnetic storage ~~device~~ uses a drive, which is mechanical device that connects to the computer.

Media which is the part that actually stores the information, is inserted into the drive.

Ex. - 1.44 MB floppy-disk drives use 3.5-inch diskettes.

Drive uses a motor to rotate media at a high speed, & it accesses (reads). the stored information using small devices called heads.

Each head has a tiny electromagnet, which consists of an iron core wrapped with wire.

Electromagnet applies a magnetic flux to the oxide on the media, that oxide permanantly 'remembers' the flux it sees.

While writing, data signal is sent through the coil of wire to create magnetic field in the core.

At the gap magnetic flux forms a fringe pattern

This pattern bridges the gap & flux magnetizes the

the oxide on the media
When data is read by drive, ~~dri~~ read heads pulls a varying magnetic field across the gap, which creates varing magnetic field in core & hence a signal in the coil.
This signal is then sent to the computer as binary data.

* Hard Disks:
Magnetic disk memories provide large storage capabilities with moderate operating speed.
A magnetic disk is a flat, circular plate called 'platter' which has a surface coated with magnetic iron oxide particles.
Has a read-write head that hovers over surface to read data.
Hard Disk composed of one or more platters & their associated read-write heads.
Platter rotates with very high speed of order of 3600 rpm
Magnetic heads are mounted on access arms in which ~~in~~ information is stored.
Information is recorded in the form of bands.
Each band of information on a particular disk is called a track
Tracks are divided into sectors
Before using the disk tracks & sectors must be formed
Tracks & sectors are formed (created) when hard disk is first formatted.
Tracks are arranged in concentric rings so that software can jump from "file 1" to "file 19" ~~wt~~ without having fast forward through fiel 2 to 18.
There will be several thousand data tracks on one side of disk in which bits are recorded in a track at a density of order of 20,000 to 1,00,000 bits/inch.

• Outer tracks have more circumference than that of inner tracks hence outer tracks contain more bits than the inner track.

Disk or cartridge spins like a record & a head move to correct track, providing 'direct-access storage'

• Total time taken by head to begin reading or to begin writing on a selected track is called access time.

Time taken to position a head on selected track is called seek time ~ order of milliseconds.

• Time required for desired data to reach magnetic head after positioning of head is called rotational delay. ~ order of few milliseconds.

∴ Total access time is sum of seek time & rotational delay

The number of bits transferred per second once reading or writing begins is called 'transfer rate' of disk.

• When magnetic disk rotates, thin but resilient layer of air rotates along with the disk.

Shape of ~~disk~~ head is designed is such a way that it rides on this layer of air causing disk to maintain separation from head.

It flots of air cushion a fraction of millimeter above surface of disk.

Drive is inside a sealed unit because even a speck of dust could cause heads to crash.

Storage capacity can be increased by mounting several disks on a common drive unit known as "disk Pack"

Magnetic disk memories are relatively inexpensive, have low acess time & high disk transfer rate.

In latest PCs, hard disks of size 80 to 250 GB are common.

* **Advantages :-**

(I) Very fast access of data. Data can be read ~~randomly~~ directly from any part of disk (Random access).

(II) Access speed is about 1000 KB per second.

* **Floppy Disks:**

- Small flexible direct access magnetic storage device.
- Made up of very thin & flexible mylar (plastic) material.
- Surface of disk is coated with a thin magnetic film. It is permanently ~~t~~ packed in a square jacket for protective purpose.
- Index hole → A reference point for all tracks on disc.
- During data processing disk rotates & when two holes (one hole in jacket & inner hole in disk) are aligned a beam of light ~~shind~~ ~~shiting~~ shining ~~from~~ on one side of disk is sensed from other side & used for timing funcn.

The surface of floppy disc is divided into a ~~m~~ number of concentric circles called tracks & information is stored in tracks.

Tiny magnetic spots are used to record a ~~logical~~ logic states 1 or 0, for 1 it is magnetized in one direction & for 0 it is magnetized in opposite direction.

As disk rotates at 360 rpm within fixed jacket, read/write head makes contact through access window & moves to specific position along length of slot.

The write protect notch is used to protect stored information.

A typical $5\frac{1}{4}$ inch floppy disk is organized into 77 tracks & is divided into 26 sectors. Hence each track is divided into 26 equal sized sectors.

$5\frac{1}{4}$ inch disk available with double density & high density with storage capacity of 360 KB & 1.2 MB.

- Floppy disks are no longer used because of their low ~~ca~~ capacity range. & hence now most of computers are made without floppy disk drive.

* Advantages:
  - Very cheap to buy & floppy disk drive are very common.

* Diadvantages:
  - Easily physically damaged if unprotected & magnetic fields can damage the data.
  - Slow to access, as it rotates far slowly than hard discs, at only 6 revolutions per sec. & start spinning only when requested. Access speed is about 36 KB/sec.

* Magnetic Tapes :-
  - A type of backup storage device used to copy data on a hard disk.

    generally, thin flexible plastic tapes with thin coating of hard magnetic material on one side.
  - magnetic material must have high remanent magnetizt. & least sensitivity for self-demagnetization

Data on the tape is arranged as a long sequence, begining at one end & stretching to the other end.

- Hence, tape is sequential storage device while floppy & hard disks are random access storage devices.

Access time is measured in seconds for tapes, floppy & hard disk it was milliseconds.

Tape drives have good storage capacity

Most of tape drives can backup 1GB data in 15-20 minutes.

But it is not suitable for daily tasks because it is too slow to be computers main storage device.

Tape is tighten by two tension arams around it.

Tension arms are movable & when tape is suddenly driven past the heads by ~~capta~~ capstan, mechanism gives a buffering supply of tape.

A servo mechanism is used to drive upper & lower reels to maintain sufficient tape reels.

Output signals from read heads are generally in range of 0.1 to 0.5 V.

- Recording density → few hundred bits / inch to several thousand bits / inch.

- Data are ~~stored~~ recorded on magnetic tape by using some coading system. one character is stored per row along the tape.

* Advantages :-

Relatively cheap & tape cassettes can store very large quantites of data (typically 26 GB)

* Disadvantages :-

Accessing data is very slow & we can not go to an item of data on the tape as we can do with disc. We need to start from begining & search for data as tape goes past the heads. (Serial access).

* Magneto-optical Recording :-

- Compact discs are classified based on storage tech. & capabilities as CD-ROM (Read only Memory), CD-WORM (Write once Read many), CD-R/W (Read / write) etc...

Use different material but data is written & read using a laser beam.

In case of CD (R/W), we can write the data, read & rewrite after ensure.

Erasability implies, recording media can undergo a very large number of write / erase operations without any loss in recording / reading quality.

Two main media designs for rewritable optical systems: MO (magneto-optical) media & phase change media.

* MO systems → write magnetically & read optically.

* Principle :-

- Laser medium is used for writing, reading & erasing data on a MO mediam.
- Eveen a weak laser generates high local temperatures when focused at a small spot on the medium.

All magnetic materials have Curie temp.

Materials used in MO are selected with curie temp of order of 200°C. Above curie temp. magnetic materials loses magnetization due to complete disordering of magnetic domains in it. Also coercivity drops at higher temperature, Hence when material is heated, its coercivity is low, magnetization can be changed by applying weak magnetic field When material is cooled to room temp, its coercivity rises back to such a high level that magnetic data can not be easily affected by magnetic fields during regular daily activities.

* Writing :-

- When disk is inserted in drive, label side will face the magnet & transperent side will face the laser.
  Direction of magnetization in the thin magnetic film is perpendicular to the surface.
  Atomic magnets are oriented in upward direction ⊥lar to film.
  When focused laser beam falls on film, strong localized heating occurs.
  At high temperature, domain reversal takes place due to action of downward magnetic field & atomic magnets turn downward.
  The magnetized areas can not be seen in regular light, but can be seen only in polarized light.

* Reading :

- MO systems use polarized light to read the data from disk.
  There is change in the light polarisation in presence of magnetic field on the surface of disk. → known as Kerr effect.
  When a beam of polarized light reflects from a magnetized surface, polarization of reflected beam changes slightly. If magnetization is revesed change in polarization is also reversed.
  Change in direction of magnetization could be associated with numbers 0 or 1., making it useful for binary data storage.

* MO Erasing :-

To erase the data, magnetic field is applied in upward direction.

Focused laser pulse causes local heating which ~~ass~~ assists atomic magnets to turn in upward direction.

* Design of MO disk:

Thin film of amorphous Terbium iron cobalt (TbFeCo) magnetic film is coated on a substrate. It is active medium. Active magneto-optical layer is enclosed bet^n dielectric layers. ← These layers act as antireflection layers & increase light absorption by the active layer.

On top of these layers thin Al - layer is coated, which Acts as light reflector & a heat sink to minimize lateral heating of active layer.

* Material for MO recording should meet following major criteria :-

- Have amorphous structure (smooth surface & domain's boundries to decrease system's noise)
- Low thermal conductivity (to limit lateral heating)
- High mp at about 200°C - 300°C (media stability, accidental data loss prevention)
- Rapid drop of coercivity near curie temp (sharp recording threshold)
- High coercivity at R.T.
- Chemical stability & Vertical anisotropy.