

Magnetism & matter

Disclaimer : This PPT will NOT help you learn physics concepts. It is intended only as a quick revision of formulas, definitions, theorems and concepts before examinations. No physics can be learnt just by watching a few videos or going through a few slides of PPT.

Magnetism and matter

M, H, B relations

Diamagnetic materials

Paramagnetic materials

Ferromagnetic materials

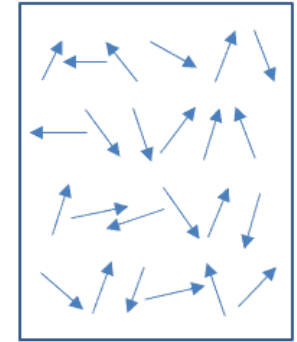
Hysteresis loop

Magnetism & matter

- Intensity of magnetization ($\vec{M}$): Magnetic moment per unit volume.

$$\vec{M} = \frac{\vec{m}_{\text{net}}}{V}$$

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$\vec{M}$ is a vector quantity.

Its SI unit is Am^{-1} .

- Magnetic field in a solenoid containing a magnetic material is given by

$$\vec{B} = \vec{B}_o + \vec{B}_m$$

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where B_o is due to the current in the solenoid (source) and B_m is due to magnetization of material in the solenoid.

- B_m is directly proportional to magnetization, therefore

$$\vec{B}_m = \mu_o \vec{M}$$

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Magnetism & matter

❑ Magnetic intensity (H) is defined as

$$\bar{H} = \frac{B}{\mu_0} - M$$

❑ Relation between magnetic intensity (H) and intensity of magnetization (M).

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

$$\bar{H} = \frac{\bar{B}}{\mu_0} - \chi \bar{H}$$

$$\frac{\bar{B}}{\mu_0} = (1 + \chi) \bar{H}$$

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

Relation between total magnetic field induction (B) and magnetic field intensity (H) is therefore

$$\bar{B} = \mu \bar{H}$$

Where μ is permeability of the medium given by the relation

$$\mu = (1 + \chi) \mu_0$$

Relative permeability of the medium is related to susceptibility as

$$\mu_r = (1 + \chi)$$

Diamagnetic materials

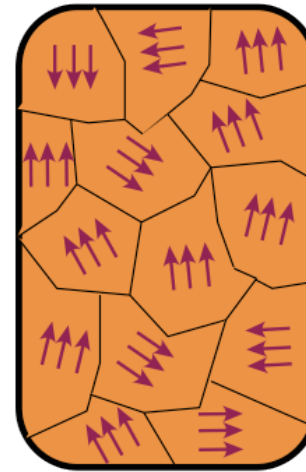
- ❑ Move from region of stronger to weaker magnetic field
- ❑ They are repelled by magnets
- ❑ Susceptibility is small and negative
- ❑ Resultant magnetic moment of an atom of a diamagnetic material is zero.
- ❑ Eg: Cu, Pb, Si, H₂O, NaCl
- ❑ Diamagnetism is present in all materials, however it is masked by relatively stronger effects in certain materials.
- ❑ Meissner effect : Perfect diamagnetism exhibited by superconductors.
- ❑ For superconductors : $\chi = -1$ and $\mu_r = 0$

Paramagnetic materials

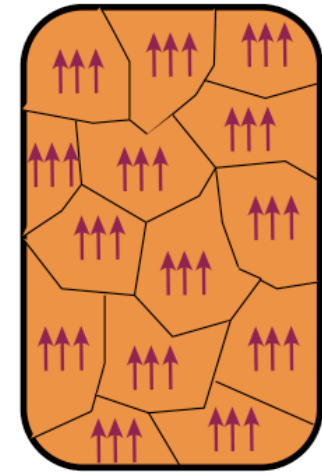
- ❑ Move from region of weaker to stronger magnetic field
- ❑ They are weakly magnetized and weakly attracted to magnets
- ❑ Susceptibility is small and positive
- ❑ Resultant magnetic moment of an atom is not zero. (though net magnetic moment is zero due to random orientations)
- ❑ Eg: Al, Na, Ca
- ❑ Experimentally it is found that $M = C \frac{B_o}{T}$
- ❑ Curie's law $\chi = C \frac{\mu_o}{T}$
- ❑ Curie's law is not applicable at very low temperature (or at very high magnetic field) at which dipoles are completely aligned and further magnetization is not possible

Ferromagnetic materials

- ❑ Move from weaker to stronger magnetic field regions (strongly)
- ❑ They are strongly magnetized and strongly attracted to magnets
- ❑ Susceptibility is large and positive
- ❑ Resultant magnetic moment of each atom is not zero.



Domains
randomly
aligned



Domains
aligned with
external field

- ❑ Domains : Regions having spontaneous alignment in the same direction. Domains generally have random direction of magnetizations.
- ❑ Under influence of external magnetic field, further orientation takes place and size of domain increases.

Ferromagnetic materials

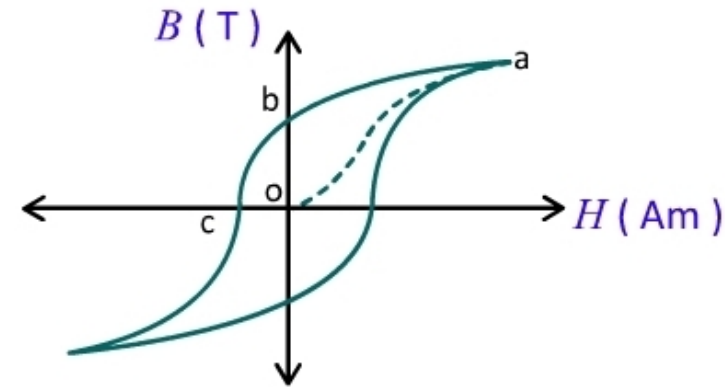
- ❑ Soft ferromagnets: They lose their magnetization when external field is removed.
Relative permeability can be > 1000
Eg : iron, cobalt, nickel, gadolinium
- ❑ Hard ferromagnets: They retain the magnetizations even when external field is removed.
Eg : alnico, cobalt steel and ticonal
- ❑ At high temperature, ferromagnets become a paramagnetic as the domain structure disintegrates
- ❑ Curie temperature: Temperature at which ferromagnet becomes paramagnetic.
- ❑ Above Curie temperature, susceptibility is given by

$$\chi = \frac{C}{T - T_0}$$

Hysteresis loop

It is plot of magnetic field induction (B) as a function of magnetic intensity (H)

Hysteresis loop is obtained by placing the magnetic material inside a solenoid and subjecting it to magnetic field of the solenoid in repeated cycles using a.c.



Initially the material is unmagnetized (at point o). As H is increased the material gets magnetized indicated by increasing B (oa). When H is decreased to zero, B decreases but does not become zero.

Retentivity or remanence: It is the value of B at $H = 0$

When the direction of H is increased in opposite direction B is found to decrease further (as the alignment atomic dipoles deteriorates)

Coercivity : Value of H when $B = 0$

Power loss: Area of a hysteresis loop indicates the power loss in execution of each cycle.

Hysteresis loop

Permanent magnets are made up of materials that have high *coercivity* and high *retentivity*.

Temporary magnets (electromagnets) are made up of materials that have *low coercivity* and *low retentivity*.

Transformer cores are made up of materials that have narrow hysteresis loop. This ensures to minimum loss of energy during prolonged operation time.

