MAGNETISM

6.MGNETIC MATERIALS

POINTS TO REMEMBER

1. **Properties of magnetic materials :**

a) **Intensity of magnetising field ($\vec{H}$) :**

i) The ratio of magnetic induction produced in vacuum($(\vec{B}_0)$ to the magnetic permeability of vacuum is defined as magnetising field $\vec{H}$ i.e $\vec{B}_0 = \mu_0 \vec{H}$.

ii) H is a vector and its direction is same as that of $\vec{B}$.

iii) SI unit $\vec{H}$ is Am^{-1} and its dimensional formulas is IL^{-1}

iv) $\vec{H}$ does not depend on the nature of medium.

v) When a medium is exposed to a magnetic field of intensity H, it causes an induction B in the medium such that $B = \mu H = \mu_0 \mu_r H$

b) **Intensity of magnetisation (I):**

i) When a magnetic material is magnetized by keeping it in a magnetizing field, the induced magnetic moment per unit volume or induced pole strength per unit area of cross section of that material is known as intensity of magnetisation $I = \frac{M}{V}$ or $I = \frac{m}{A}$

ii) I is a vector quantity having same direction as that of magnetizing field (Ferro, paramagnetic) or opposite to it (dia magnetic).

iii) S I unit of I is same as that of H ie. $A.m^{-1}$

iv) Dimensional formula of I is IL^{-1}

c) **Magnetic susceptibility [χ] :**

i) The ratio of magnitude of intensity of magnetization (I) in a material to that of magnetizing field (H) is called *magnetic susceptibility* of that material.

$\chi = I / H$

ii) The intensity of magnetization inducted in a material by unit magnetizing field is known as magnetic susceptibility.

iii) χ has no units and no dimensions.

iv) For diamagnetic materials χ is low and negative.

v) For paramagnetic materials χ is low but positive.

vi) For Ferro magnetic materials χ is high and positive.

d) **Absolute magnetic permeability (μ) :**

i) The ratio of magnitudes of magnetic induction to magnetizing field is defined as magnetic permeability. $\mu = B/H$

ii) Magnetic permeability of a medium is its ability to allow the magnetic lines of force enter through.

iii) μ value is always positive and is different for different materials.

iv) μ value depends on magnetizing field and temperature (T).

v) For ferromagnetic material μ is high, for paramagnetic materials μ is low and for diamagnetic materials μ is very low.

vi) μ is a scalar. Its S.I unit is H m^{-1} . Its dimensional formula is $MLT^{-1}I^{-2}$.

e) **Relative permeability (μ_r) :**

i) It is the ratio of absolute magnetic permeability of a medium (μ) to the magnetic permeability of free space (μ_0) $\Rightarrow \mu_r = \mu/\mu_0$

ii) μ_γ has no units and no dimensions.

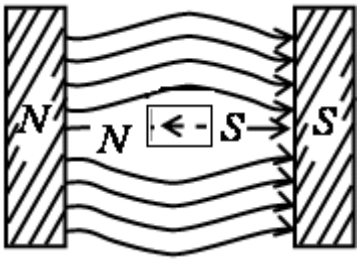
iii) For diamagnetic substances $\mu_r < 1$ (but +ve)

Short Answer Questions

1. How do you distinguish Dia, Para and Ferromagnetisms in matter ?

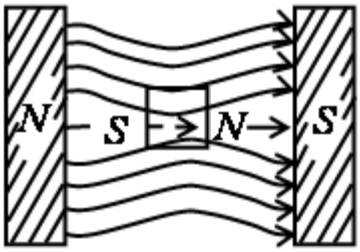
Sol: Properties of Diamagnetic Materials :

Diamagnetic material are repelled by a magnet. The relative permeability is less than one $(\mu_r < 1)$.When the material is kept in an external magnetic field, the lines of force are repelled by the substance and tend to move away from the material. That is these materials move from stronger region to the weaker regions in non-uniform fields. If a diamagnetic liquid is taken in a crucible and placed over two nearby magnetic poles, the liquid gets depressed in the middle, where the field is strong. Similarly, if a rod of a diamagnetic substance is suspended freely in a uniform magnetic field, it comes to rest with its length in a direction perpendicular to the field. The diamagnetic behavior is independent of temperature. All materials show the property of diamagnetism.



Properties of Paramagnetic Materials:

These are feebly attracted by a magnet. The relative permeability of paramagnetic material is greater than one $(\mu_r > 1)$. When a paramagnetic substance is kept in an external magnetic field, the lines of fore are drawn more into the material.

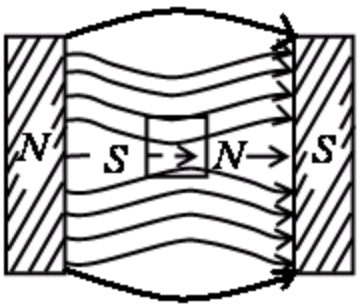


These materials tend to move from weaker to stronger parts in non-uniform magnetic fields. When a paramagnetic liquid taken in a crucible is placed over two close by magnetic pole pieces, it rises in the middle, where the field is strong. Similarly, when a paramagnetic rod is suspended freely in a uniform magnetic field, it comes to rest with its length parallel to the direction of the magnetic field.

If the temperature of a paramagnetic material is increased the magnetic induction through the material decreases.

Properties of Ferromagnetic Material:

Ferromagnetic materials are strongly attracted by magnets. Their relative permeability values are very high $(\mu_r : 10 \, to \, 10,000)$. In other words, they posses all the paramagnetic properties but to a very high degree. When a ferromagnetic material is placed in an external magnetic field, the lines of force through the material will be very large in number



As temperature is increased, the material loses ferromagnetism and at a particular temperature known as Curie temperature the ferromagnetic substance turns paramagnetic in nature.

Magnetic materials gain importance in electrical engineering. They are employed in making electromagnets, transformers, relay systems etc.

Very Short Answer Questions:

1. How do you determine the magnetic nature of a material, given in the form of a rod?

Ans: When the rod is suspended freely in a uniform magnetic field, if it comes to rest with its length in a direction perpendicular to the field, it is diamagnetic. If it comes to rest with its length parallel to the direction of the field, it is paramagnetic.

2. Classify the following substances into Dia, Para and Ferromagnetic materials. i) Manganese, (ii) Bismuth (iii) Cobalt, (iv) Oxygen, (v) Copper and (vi) Aluminium

Ans: i) Manganese – Paramagnetic, ii) Bismuth – diamagnetic, iii) Cobalt – ferromagnetic, iv) Oxygen – paramagnetic v) Copper – diamagnetic vi) Aluminium – paramagnetic.

3. The relative permeability of silicon is 0.999837 and that of palladium is 1.000692. What do you infer about the magnetic nature of silicon and palladium?

Ans: As $\mu_r < 1$ for silicon, it is diamagnetic.

As μ_r is slightly more than 1 ($\mu_r > 1$) for palladium, it is paramagnetic.

ASSESS YOURSELF:

1. What happens to the length of a ferromagnetic rod when it is magnetized?

Ans: The length of the rod slightly increases because of the alignment of the domains in the direction of the external field.

2. What happen to the magnetism of an iron bar magnet when it is melted?

Ans: When an iron bar magnet is melted its temperature will be above Curie temperature

(770 ^{0}C). Hence it loses its magnetism.

3. A rod hot steel needle is suspended along the North-South direction and cooled. What happens?

Ans: A weak magnetic moment is induced parallel to the external field and the needle becomes a weak magnet.