PH8252 – PHYSICS FOR INFORMATION SCIENCE

UNIT – III

MAGNETIC PROPERTIES OF MATERIALS

Part –A

1. What is meant by magnetic materials? Give examples.

Magnetic materials are the materials which can be easily magnetized due to the application of magnetic field.

Examples: Iron, Ferrites, steel, Nickel, etc...,

2. Define Magnetic flux density.

Magnetic flux density (B) or magnetic induction (B) is defined as the number of magnetic lines of force passing through a unit area of cross section (A).

$$B = \frac{\varphi}{A}$$

Its unit is Wbm^{-2} (or) Tesla.

3. Define Magnetic dipole moment.

Two opposite magnetic poles separated by a distance is called magnetic dipole.

Magnetic dipole moment is the product of magnetic pole strength (m) and the length of the magnet (l). $M = ml$

Its unit is Wb-m.

4. Define Magnetization.

Intensity of magnetization of a material is defined as the magnetic dipole moment per unit volume.

$$I = \frac{M}{V}$$

Its unit is Wbm^{-2}

5. Define 'Magnetic permeability' and 'Relative permeability'.

Magnetic permeability is defined as the ratio of magnetic flux density to the applied magnetic field intensity.

$$\mu = \frac{B}{H} \text{ Henry/metre.}$$

Relative permeability (μ_r) is defined as the ratio of the absolute permeability (μ) of the medium to the permeability of free space (μ_0).

$\mu_r = \frac{\mu}{\mu_0}$

6. Define Magnetic Susceptibility.

Magnetic Susceptibility (χ) is defined as the ratio of the intensity of magnetization (I) to the magnetic field intensity (H).

$$\chi = \frac{I}{H}$$

7. Give the relation between relative permeability (μ_r) and magnetic susceptibility (χ).

When a magnetic material is kept in an external magnetic field, then flux density can be written as,

$B = \mu_0 (H + I)$ ------- (1)

We know, $\mu = \frac{B}{H}$

B = µH ------- (2)

Equating (1) and (2) we get,

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

$\mu_0 \ \mu_r H = \mu_0 (H + I)$ $\{\mu = \mu_0 \ x \ \mu_r\}$

$\mu_r = 1 + \frac{I}{H}$

$\mu_r = 1 + X$ Since, $X = \frac{I}{H}$

Hence proved

8. What is the origin of magnetism in materials?

Magnetism originates from the magnetic moment of the magnetic materials due to the rotational motion of the charged particles. When an electron revolves around the nucleus, orbital magnetic dipole moment arises, due to the spinning of electrons spin magnetic dipole moment arises and due to the nuclear spin nuclear magnetic dipole moment arises.

9. On the basis of spin, how the magnetic materials are classified?

* Diamagnetic materials → No spin

* Paramagnetic materials → Spin with equal magnitude in random direction.

* Ferromagnetic materials → Spin with equal magnitude in parallel direction.

* Antiferromagnetic materials → Spin with equal magnitude in antiparallel direction.

* Ferromagnetic materials → Spin with unequal magnitude in antiparallel direction.

10. Classify the different types of magnetic materials based on magnetic moment.

Based on the presence of magnetic dipole moments, magnetic materials are classified into two types.

(i) Magnetic materials not having any permanent magnetic moments → Dia magnetic material.

(ii) Magnetic materials having permanent magnetic moments → Para magnetic,

Ferromagnetic, Antiferromagnetic and Ferri magnetic materials.

11. Define Bohr Magneton.

The orbital magnetic moment and the spin magnetic moment of an electron in an atom can be expressed in terms of smallest atomic unit of magnetic dipole moment called Bohr magneton.

$$1 \text{ Bohr magneton} = \frac{eh}{4\pi m}$$

$$\mu = 9.27 \times 10^{-24} \text{ Am}^2$$

12. What is Curie temperature?

Curie temperature is the critical temperature below which a material can behave as Ferro magnetic material and above which it can behave as paramagnetic material.

13. Give curie – Weiss law and its importance.

Curie – Weiss law is given by

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

Where C → curie constant.

T → Absolute temperature

θ → Curie temperature.

Importance:

* It gives the relation between magnetic susceptibility and absolute temperature.

* If the temperature is less than Curie temperature, a paramagnetic material becomes.

Diamagnetic and if the temperature is greater than Curie temperature, a ferromagnetic material becomes paramagnetic material.

14. What are Ferrites?

Ferrites are the ferromagnetic materials in which the dipoles of adjacent ions are in opposite directions with different magnitudes.

15. Mention the properties of ferrimagnetic materials.

* Ferri magnetic materials possess net magnetic moment.

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

$$\chi = \frac{C}{T \pm \theta}$$

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

* Mechanically, it has pure iron character.

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

16. What is antiferromagnetic? Mention two materials that exhibit antiferromagnetic.

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.

Example: Ferrous oxide, Manganese oxide manganese sulphide, chromium oxide.

17. What is meant by magnetic domain?

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.

18. Mention the energies involved in origin of domains in ferromagnetic material.

The four types of energies involved in the growth of magnetic domains are

(i) Exchange energy

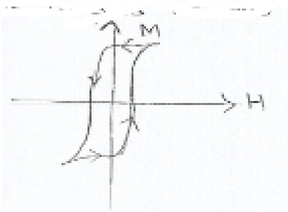
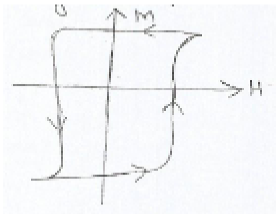
(ii) Anisotropy energy

(iii) Domain wall energy (or) Bloch wall energy.

(iv) Magnetostriction energy.

19. Compare soft and hard magnetic materials on basis of hysteresis loop. Give examples.

Soft Magnetic Materials	Hard Magnetic Materials
1. They can be easily magnetized and Demagnetized	They cannot be easily magnetized and demagnetized.
2. Movement of domain wall is easy and Hence even for a small applied field large	Movement of domain wall is not easy due to the presence of impurities and hence large field is required for magnetization.

Magnetization occurs.	
3. The nature of hysteresis loop is narrow. 	The nature of hysteresis is very broad. 
4. Loop area is less and hence the Hysteresis loss is minimum.	Loop area is large and hence the Hysteresis loss is large.
5. Susceptibility and permeability are high.	Susceptibility and permeability are low.
6. Retentively and coercivity are small.	Retentively and coercively are large.
7. They have low eddy current loss.	They have high eddy current loss.
8. The materials are free from irregularities Like strain or impurities.	The materials have large amount of impurities and lattice defects.
9. <u>Example:</u> Iron, silicon alloys, Ferrites, Garnets, etc…,	<u>Example:</u> Carbon steel, tungsten steel, Chromium steel, cu – Ni – Fe, cu – Ni –co, etc..,

20. Define Hysteresis.

When a Ferromagnetic material is taken through a cycle of magnetization, the intensity of magnetization (I) and the magnetic flux density (B) lags behind the applied magnetic field (H), and this process is known as Hysteresis.

The closed curve obtained during the cycle of magnetization is known as hysteresis loop.

<u>Inference:</u> The area of the loop gives the energy loss during the cycle of magnetization.

21. Define energy product and give its importance in the case of permanent magnets.

The product of retentively and the coercively is known as energy product. It represents the maximum amount energy stored in the specimen.

Importance: It helps in distinguishing a weak and strong magnet. Therefore, for permanent magnets the value of energy product should be very high.

22. What are the required magnetic parameters for recording?

The basic parameters required for recording are

(i) Electromagnetic induction should occur in materials.

(ii) The material should easily acquire magnetism

(iii) It should possess magneto - resistance

(iv) Soft magnets should be used for temporary storage and hard magnets should be Used for permanent storage.

23. What is meant by eddy current and eddy current losses?

When an alternating magnetic field is applied to the material, it induces an e-m-f and sets up a large current in the material. This current is known as eddy current and the power loss is called eddy current losses.

24. What is meant by Garnet? Give examples.

Garnet is a ferromagnetic material with a typical formula $Me_3 Fe_5 O_{12}$.

Where, $Me_3 \rightarrow$ Trivalent metal ion.

$Fe_5 \rightarrow$ Trivalent Ferric ion.

Examples: Gadolinium Gallium Garnet.

Yttrium Iron Garnet.

Properties:

* They have high resistivity.

* They have low hysteresis loss.

25. What is GMR?

If the charge in electrical resistance is very high compared to the magnetization, it is called as Giant Magneto – Resistance (GMR) and this effect is called GMR effect.

26. What is meant by magnetic bubble? How they are formed?

Magnetic bubbles are soft magnetic materials with magnetic domains of few micrometer in diameter.

Formation:

When a magnetic field is applied to magnetic garnets like Gadolinium Gallium garnet, small cylindrical domain area known as magnetic bubble is formed. These bubbles have a magnetic region of one polarity surmounted by other polarity.

27. Distinguish between magnetic and optical storage devices.

Magnetic Storage devices	Optical Storage Devices
1. Data's are stored using magnetic principle.	Data's are stored using optical principle
2. Writing and reading the data can be done using electro magnets.	Writing and reading the data is made using laser.
3. Access time is slow.	Access time is very fast.
4. Example: Floppy disk.	Example: Compact disk

28. What are the requirements of a transformer core material and electromagnets?

A transformer core material should have high resistivity and low eddy current losses.

An electromagnet should have high initial permeability and low coercively.

29. What are ESD Magnets? Give its properties.

ESD magnets are Elongated single Domain magnets, which are made by very small particles with very high magnetization.

Properties:

* They are highly stable.

* They possess large magnetization.

30. A paramagnetic material has a magnetic field intensity of 10^4A/m. If the susceptibility of the material at room temperature is 3.7×10^{-3} calculate the magnetization and flux density in the material.

Given,

H = 10^4 Am^{-1}

= 3.7×10^{-3}

I =?

B =?

μ_0 = $4\pi \times 10^{-7}$

Solution:

$\chi = \frac{I}{H}$

I = $\chi H = 3.7 \times 10^{-3} \times 10^4$

= 3.7 x 10

= 37 Am^{-1}

Also,

B = μ_0(I + H) = 4π x 10^{-7} (37 + 10^4)

= 0.0126 wb/m^2

31. A magnetic material has a magnetization of 2300 A/m and produces a flux density of 0.00314 wb/m^2. Calculate the magnetization force and the relative permeability of the material.

Given,

I = 2300 Am^{-1}

B = 0.00314 wb/m^2

H =?

μ_r = ?

Solution:

B = μ_0 (I + H)

$\frac{B}{\mu_0}$ = I + H

H = $\frac{B}{\mu_0}$ - I

= $\frac{0.00314}{4\pi\ x\ 10^{-7}}$ - 2300

H = 198.7326 Am^{-1}

Also, = $\frac{I}{H}$ = μ_r -1

μ_r = $\frac{I}{H}$ + 1

= $\frac{2300}{198.7326}$ + 1

μ_r = 12.573

32. The magnetic susceptibility of silicon is -0.4x10^{-5} calculate the flux density and magnetic moment per unit volume when field of intensity 5x10^5 A/m is applied.

Given

χ = -0.4 x 10^{-5}

H = 5 x 10^5 A/m

B =?

I =?

Solution:

(i) Intensity of magnetization I (= χH

= -0.4 x 10^{-5} x5 x 10^{5}

= - 2 x 10^{-5+5} A/m

= -2 A/m

(ii) Flux density B = µH

= (1 + χ) H

= (1 – 0.4 x 10^{-5}) 5 x 10^{5}

= 0.6 x 5 = 3 wb/m^{2}.