Government of Tamilnadu

Department of Employment and Training

Course : TNPSC Group II Exam

Subject : Physics

Topic : **Magnetism**

MAGNETISM

Magnetism

- The word magnetism is derived from iron ore magnetite (Fe_3O_4), which was found in the island of magnesia in Greece. Gilbert who laid the foundation for magnetism and had suggested that Earth itself behaves as a giant bar magnet. The field at the surface of the Earth is approximately 10^{-4} T and the field extends upto a height of nearly five times the radius of the Earth.

Causes of the Earth's magnetism

- The exact cause of the Earth's magnetism is not known even today. However, some important factors which may be the cause of Earth's magnetism are:
  1. Magnetic masses in the Earth.
  2. Electric currents in the Earth.
  3. Electric currents in the upper regions of the atmosphere.
  4. Radiations from the Sun.
  5. Action of moon etc.
- However, it is believed that the Earth's magnetic field is due to the molten charged metallic fluid inside the Earth's surface with a core of radius about 3500 km compared to the Earth's radius of 6400 km.

Basic properties of magnets

(i) When the magnet is dipped in iron filings, they cling to the ends of the magnet. The attraction is maximum at the two ends of the magnet. These ends are called poles of the magnet.

(ii) When a magnet is freely suspended, it always points along north-south direction. The pole pointing towards geographic north is called north pole N and the pole which points towards geographic south is called south pole S.

(iii) Magnetic poles always exist in pairs. (i.e) isolated magnetic pole does not exist.

(iv) The magnetic length of a magnet is always less than its geometric length, because the poles are situated a little inwards from the free ends of the magnet. (But for the purpose of calculation the geometric length is always taken as magnetic length.)

(v) Like poles repel each other and unlike poles attract each other. North pole of a magnet when brought near north pole of another magnet, we can observe repulsion, but when the north pole of one magnet is brought near south pole of another magnet, we observe attraction.

(vi) The force of attraction or repulsion between two magnetic poles is given by Coulomb's inverse square law.

Note : In recent days, the concept of magnetic poles has been completely changed. The origin of magnetism is traced only due to the flow of current. But anyhow, we have retained the conventional idea of magnetic poles in this chapter. Pole strength is denoted by m and its unit is ampere metre.

Magnetic moment

- The magnetic moment of a magnet is defined as the product of the pole strength and the distance between the two poles. Magnetic moment is a vector quantity. It is denoted by M. Its unit is A m^2. Its direction is from south pole to north pole.

Magnetic field

- Magnetic field is the space in which a magnetic pole experiences a force or it is the space around a magnet in which the influence of the magnet is felt.

Magnetic induction

- Magnetic induction is the fundamental character of a magnetic field at a point. It is a vector quantity. It is also called as magnetic flux density.

Properties of magnetic lines of force

1. Magnetic lines of forces are closed continuous curves, extending through the body of the magnet.

2. The direction of line of force is from north pole to south pole outside the magnet while it is from south pole to north pole inside the magnet.
3. The tangent to the magnetic line of force at any point gives the direction of magnetic field at that point. (i.e) it gives the direction of magnetic induction ($\vec{B}$) at that point.
4. They never intersect each other.
5. They crowd where the magnetic field is strong and thin out where the field is weak.

Magnetic flux and magnetic flux density

- The number of magnetic lines of force passing through an area A is called magnetic flux. It is denoted by φ. Its unit is weber. It is a scalar quantity.

Tangent law

- A magnetic needle suspended, at a point where there are two crossed magnetic fields acting at right angles to each other, will come to rest in the direction of the resultant of the two fields

$$B_1 = B_2 \tan\theta$$

Magnetic properties of materials

- Classifying the materials depending on their magnetic behavior **Magnetising field or magnetic intensity** The magnetic field used to magnetise a material is called the Magnetising field. It is denoted by H and its unit is A m^{-1}.

Magnetic permeability

- Magnetic permeability is the ability of the material to allow the passage of magnetic lines of force through it.

Intensity of magnetization

- Intensity of magnetisation of a magnetic material is defined as the magnetic moment per unit volume of the material.

$$I = M/V$$

Its unit is A m^{-1}.

Magnetic induction

- When a soft iron bar is placed in a uniform magnetising field H, the magnetic induction inside the specimen B is equal to the sum of the magnetic induction Bo produced in vacuum due to the magnetising field and the magnetic induction Bm due to the induced magnetisation of the specimen.

$$B = \mu_o (H + I)$$

Magnetic susceptibility

❖ Susceptibility of a magnetic material is defined as the ratio of intensity of magnetisation I induced in the material to the magnetising field H in which the material is placed

Classification of magnetic materials

❖ On the basis of the behaviour of materials in a magnetising field, the materials are generally classified into three categories namely,

(i) Diamagnetic,

(ii) Paramagnetic

and (iii) Ferromagnetic

Properties of diamagnetic substances

❖ Diamagnetic substances are those in which the net magnetic moment of atoms is zero.

1. The susceptibility has a low negative value. (For example, for bismuth $\chi m = - 0.00017$).
2. Susceptibility is independent of temperature.
3. The relative permeability is slightly less than one.
4. When placed in a non uniform magnetic field they have a tendency to move away from the field. (i.e) from the stronger part to the weaker part of the field. They get magnetized in a direction opposite to the field as shown.
5. When suspended freely in a uniform magnetic field, they set themselves perpendicular to the direction of the magnetic field

Ex: Bi, Sb, Cu, Au, Hg, H_2O, H_2 etc.

Properties of paramagnetic substances

Paramagnetic substances are those in which each atom or molecule has a net non-zero magnetic moment of its own.

1. Susceptibility has a low positive value.
2. Susceptibility is inversely proportional to absolute temperature (i.e) X_m x $\frac{1}{T}$. As the temperature increases susceptibility decreases.

3. The relative permeability is greater than one.
4. When placed in a non uniform magnetic field, they have a tendency to move from weaker part to the stronger part of the field. They get magnetised in the direction of the field When suspended freely in a uniform magnetic field, they set themselves parallel to the direction of magnetic field

Ex: Al, Pt, Cr, O2, Mn, CuSO4 etc.

Properties of ferromagnetic substances

- Ferromagnetic substances are those in which each atom or molecule has a strong spontaneous net magnetic moment. These substances exhibit strong paramagnetic properties.

1. The susceptibility and relative permeability are very large.
   (For example : μr for iron = 200,000)
2. Susceptibility is inversely proportional to the absolute temperature $X_m \text{ x } \frac{1}{T}$. As the temperature increases the value of susceptibility decreases. At a particular temperature, ferromagnetics become paramagnetics. This transition temperature is called curie temperature. For example curie temperature of iron is about 1000 K.
3. When suspended freely in uniform magnetic field, they set themselves parallel to the direction of magnetic field.
4. When placed in a non uniform magnetic field, they have a tendency to move from the weaker part to the stronger part of the field. They get strongly magnetised in the direction of the field.

Ex : Fe, Ni, Co and a number of their alloys

Uses of ferromagnetic materials

(i) Permanent magnets

- The ideal material for making permanent magnets should possess high retentivity (residual magnetism) and high coercivity so that the magnetisation lasts for a longer time. Examples of such substances are steel and alnico (an alloy of Al, Ni and Co).

Electromagnets

- Material used for making an electromagnet has to undergo cyclic changes least hysteresis loss high values of magnetic induction B at low values of magnetising field H. Soft iron is preferred for making electromagnets as it has a thin hysteresis loop and low retentively.

Core of the transformer

- A material used for making transformer core and choke is subjected to cyclic changes very rapidly.

Magnetic tapes and memory store

- Magnetisation of a magnet depends not only on the magnetizing field but also on the cycle of magnetisation it has undergone. Thus, the value of magnetisation of the specimen is a record of the cycles of magnetisation it has undergone. Therefore, such a system can act as a device for storing memory. Ferro magnetic materials are used for coating magnetic tapes in a cassette player and for building a memory store in a modern computer.

Ex: Ferrites (Fe, Fe_2O, $MnFe_2O_4$ etc.).

Fleming left hand rule

- Stretch the thumb, fore finger and middle finger of your left hand such that they are mutually perpendicular. If the forefinger points in the direction of magnetic field and the middle finger points in the direction of current, then the thumb will point in the direction of motion or the force acting on the conductor.

Fleming's right hand rule.

- Stretch the thumb, forefinger and middle finger of right hand so that they are perpendicular to each other. If the forefinger indicates the direction of the magnetic field and the thumb shows the direction of motion of conductor, then the middle finger will show the direction of induced current.