Introduction

This is a learning as well as an exam preparation video.

At the end of the video are practice assignments for you to attempt.

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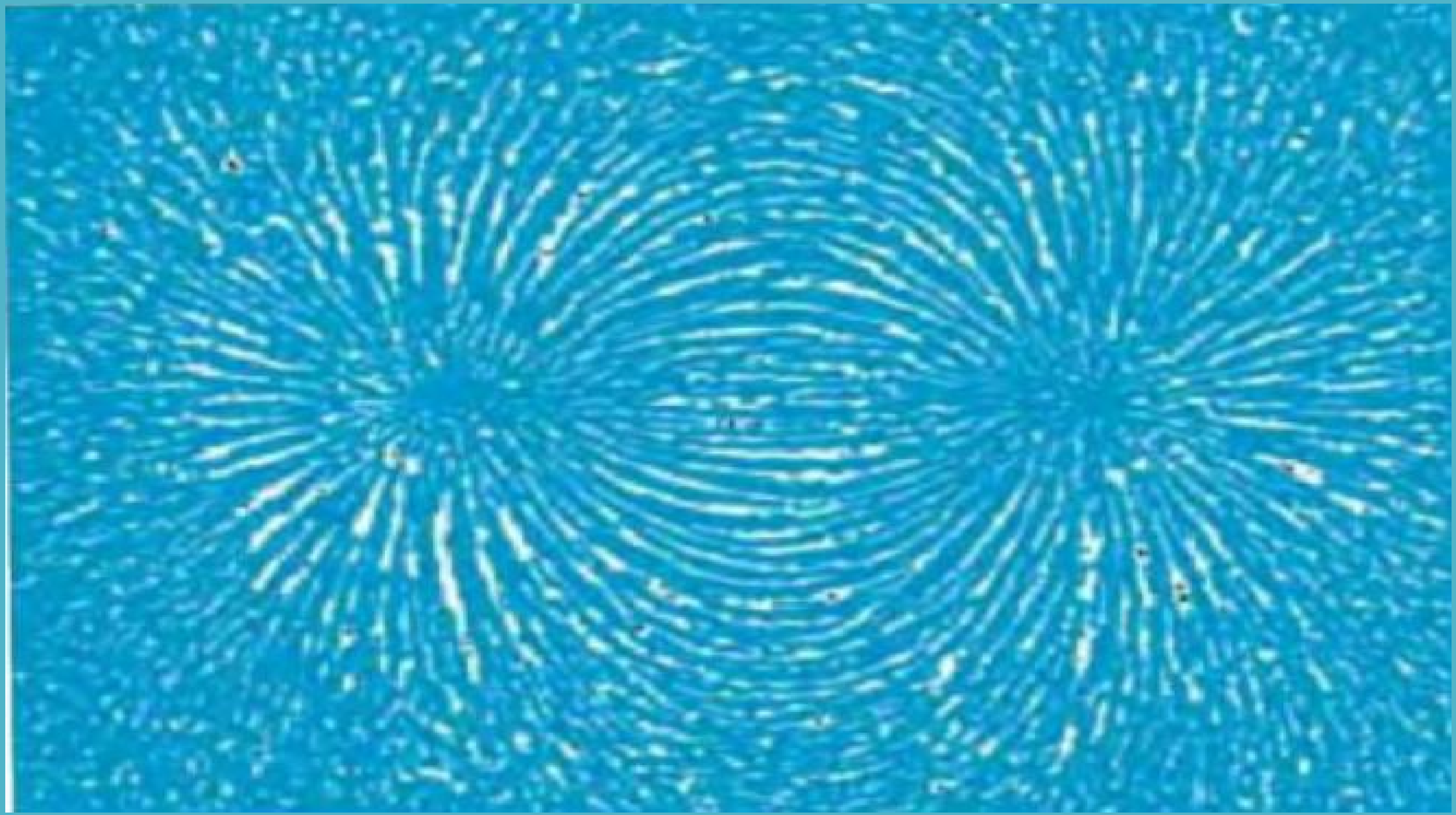
Chapter 5: Magnetism and Matter

Chapter 5: Magnetism and Matter

Bar Magnet



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Bar Magnet:

When iron filings are sprinkled on a sheet of glass placed over a short bar magnet, a particular pattern is formed and following conclusions are drawn

- The bar magnet has poles similar to the positive and negative charge of an electric dipole.
- One pole is designated as north pole and other as south pole.

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Bar Magnet:

- When suspended freely, these poles point approximately towards the geographic north and south poles.
- Like poles repel each other and unlike poles attract each other.
- The poles of a magnet can never be separated.

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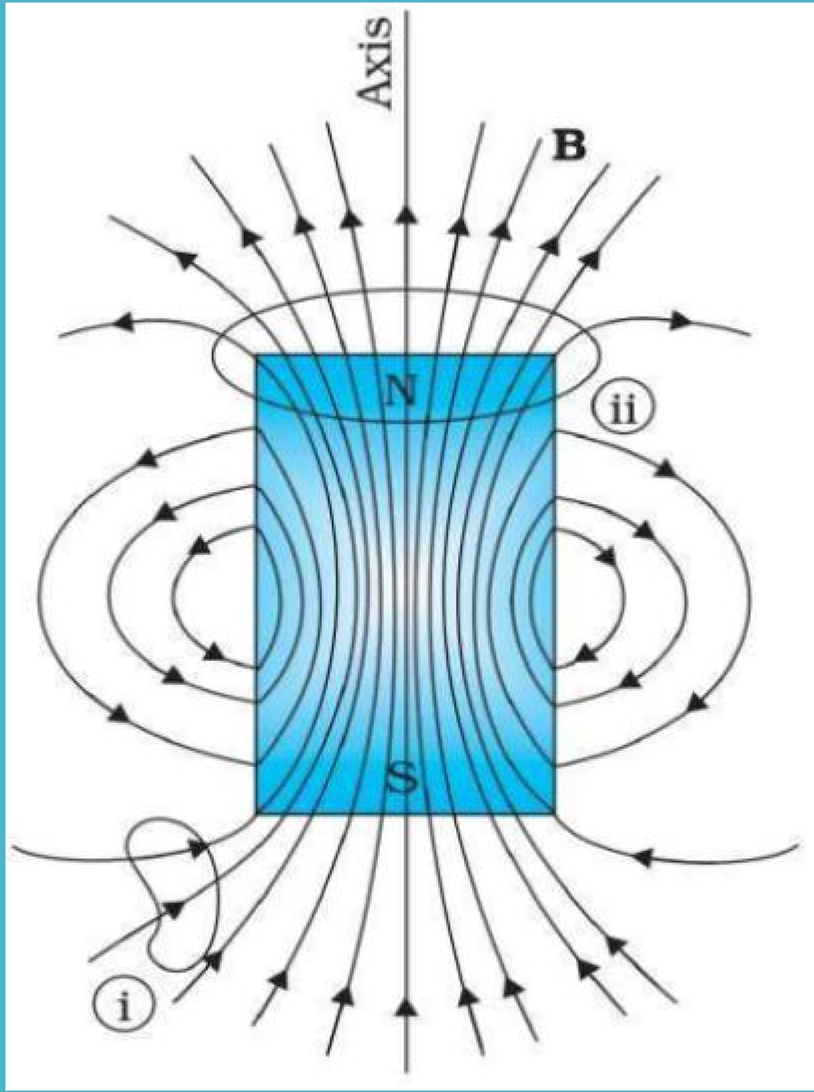
Magnetic Field Lines:



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Magnetic Field Lines:

- Magnetic field line is an imaginary curve, the tangent to which at any point gives direction of magnetic field B at that point.
- The magnetic field lines of a magnet form close-continuous loop.
- Outside the body of magnet, the direction of magnetic field lines are from north pole to south pole.

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Magnetic Field Lines:

- No two magnetic field lines can intersect each other. This is because at the point of intersection, we can draw two tangents. This would mean two directions of magnetic field at the same point, which is not possible.
- Larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field B.

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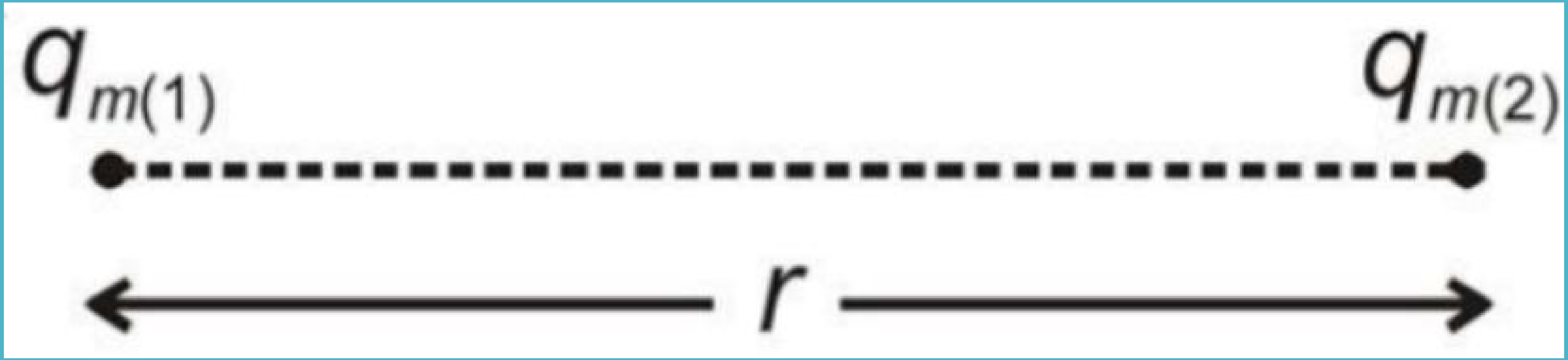
Coulomb's Law of Magnetism:



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Coulomb's Law of Magnetism:

Let pole strength of a monopole be qm, then magnetic force between two isolated poles kept at separation r is.

$$F \propto \frac{q_m(1) \times q_m(2)}{r^2}$$

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Coulomb's Law of Magnetism:

$$F = \frac{\mu_0}{4\pi} \frac{q_m(1) \times q_m(2)}{r^2}$$

This force will be attractive if one pole is North and other is South and force will be repulsive if both poles are of same type (i.e., North-North or South-South).

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Magnetic Field due to a Monopole:

Magnetic field due to monopole at a point is equal to magnetic force experienced by a unit pole strength if kept at that point.

$$B = \frac{\mu_0}{4\pi}\frac{m}{r^2}$$

It is away from pole if it is N-pole and it is towards pole if it is S-pole.

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Magnetic Dipole Moment of a Bar Magnet:

It is equal to the product of any one pole strength and separation between two poles.

$$M = m \times 2l$$

It is directed from South-pole to north-pole.

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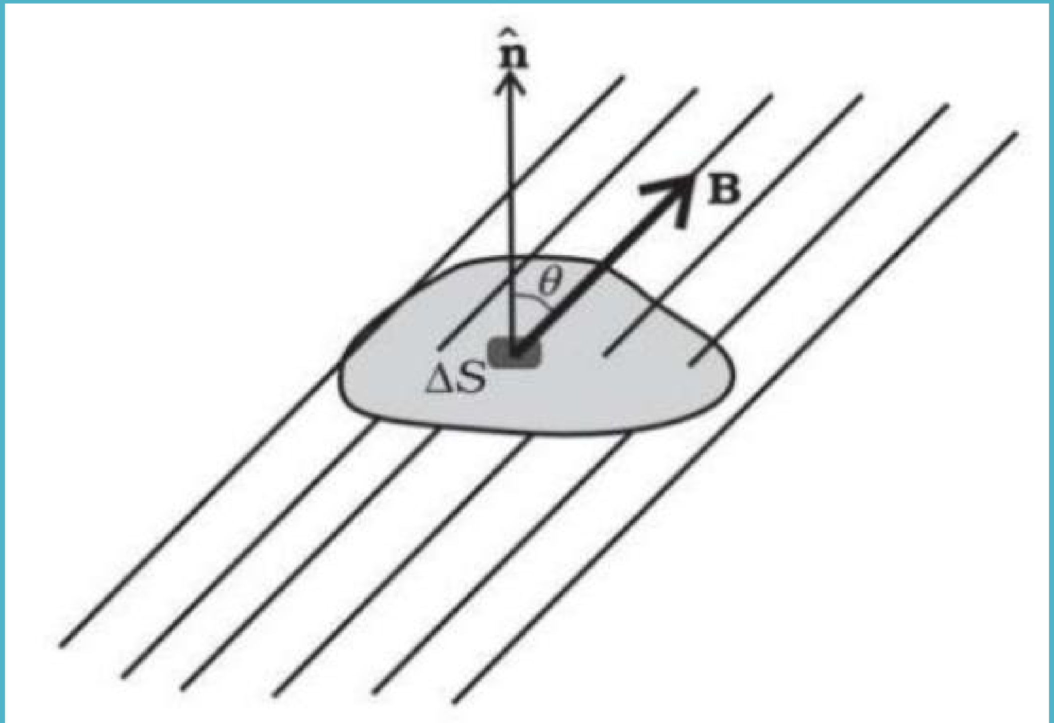
Gauss's Law in Magnetism:



$$\oint \vec{B}.\vec{ds} = 0$$

This law states that "the surface integral of a magnetic field over a closed surface is zero i.e., the net magnetic flux through any closed surface is always zero".

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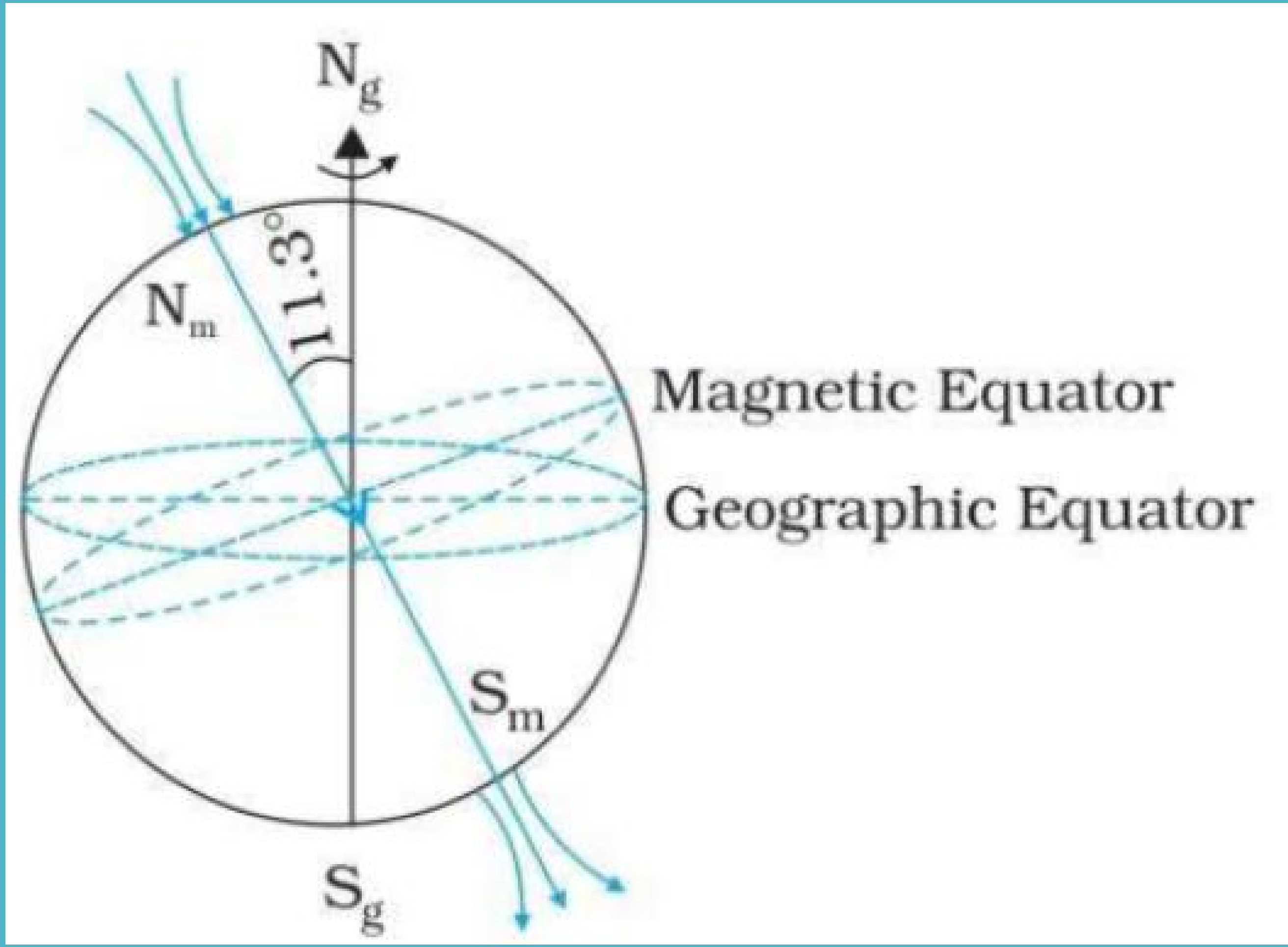
Earth's Magnetism:



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Earth's Magnetism:

1. The earth's magnetism was assumed to arise from a very large bar magnet placed deep inside earth along its rotational axis but main argument against theory is that the interior of earth is too hot to maintain any magnetism.
2. The pattern of earth's magnetic field varies with position as well as time. This is most affected by solar wind.
3. The magnetic field lines of earth appear same as a magnetic dipole located at the center of the earth.
4. The pole near the geographic north pole is called the north magnetic pole and the pole

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Earth's Magnetism:

4. The pole near the geographic north pole is called the north magnetic pole and the pole near the geographic south pole is called the south magnetic pole.
5. Geographic meridian: It is a vertical plane passing through the geographic north-south direction. It contains the longitude circle and axis of rotation of the earth.
6. Magnetic meridian: It is a vertical plane passing through N-S line of freely suspended magnet.

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Magnetic Declination:

It is angle between the true geographic north-south direction and the north south line shown by a compass needle at a place. Its value is more at higher latitude and smaller near equator. The declination in India is small.

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Magnetic Inclination or Dip:

It is angle between axis of needle, (in magnetic meridian) which is free to move about a horizontal axis and horizontal. Thus, dip is an angle that total magnetic field of earth Be makes with the surface of the earth. Angle of dip is maximum δ = 90o at poles. It is zero at magnetic equator.

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Classification of Magnetic Materials:

Magnetic materials are broadly classified as:

Diamagnetic: Diamagnetism is a fundamental property of all matter, although it is usually very weak. It is due to the non-cooperative behavior of orbiting electrons when exposed to an applied magnetic field.

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Classification of Magnetic Materials:

Paramagnetic: This class of materials, some of the atoms or ions in the material have a net magnetic moment due to unpaired electrons in partially filled orbitals.

Ferromagnetic: When you think of magnetic materials, you probably think of iron, nickel, or magnetite. Unlike paramagnetic materials, the atomic moments in these materials exhibit very strong interactions.

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Curie's Law:

Magnetic susceptibility of paramagnetic substance is inversely proportional to absolute temperature T.

$$x_m \propto \frac{1}{T}$$

$$x_m = \frac{C}{T}$$

The constant C is called Curie's constant.

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Curie-Weiss law:

At temperature above the Curie temperature, a ferromagnetic substance becomes an ordinary paramagnetic substance whose magnetic susceptibility obeys the Curie-Weiss law according to which

$$\chi_m = \frac{C}{T - T_c}$$

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Hard and Soft Magnets:

Hard Magnets:

The ferromagnetic material which retains magnetization for a long period of time are called hard magnetic material or hard ferromagnets. Some hard magnetic materials are Alnico (an alloy of iron, aluminium, nickel, cobalt and copper) and naturally occurring lodestone.

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Hard and Soft Magnets:

Soft Magnets:

The ferromagnetic material which retains magnetization as long as the external field persists are

called soft magnetic materials or soft ferromagnets. Soft ferromagnets is soft iron. Such material

is used for making electromagnets.

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Permanent Magnets and Electromagnets:

Permanent Magnets: The substances which at room temperature retain their magnetization for long period of time are called Permanent magnets. Permanent magnets should have.

- High retentivity
- High coercivity.

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Permanent Magnets and Electromagnets:

As the material in this case is never put to cyclic changes of magnetization, hence hysteresis is immaterial. From the viewpoint of these facts, steel is more suitable for the construction of permanent magnets than soft iron. The fact that the retentivity of iron is little greater than that

of steel is outweighed by the much smaller value of its coercivity.

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Permanent Magnets and Electromagnets:

Electromagnets:

An electromagnet is a temporary strong magnet and is just a solenoid with its

winding on a soft iron core which has high permeability and low retentivity.

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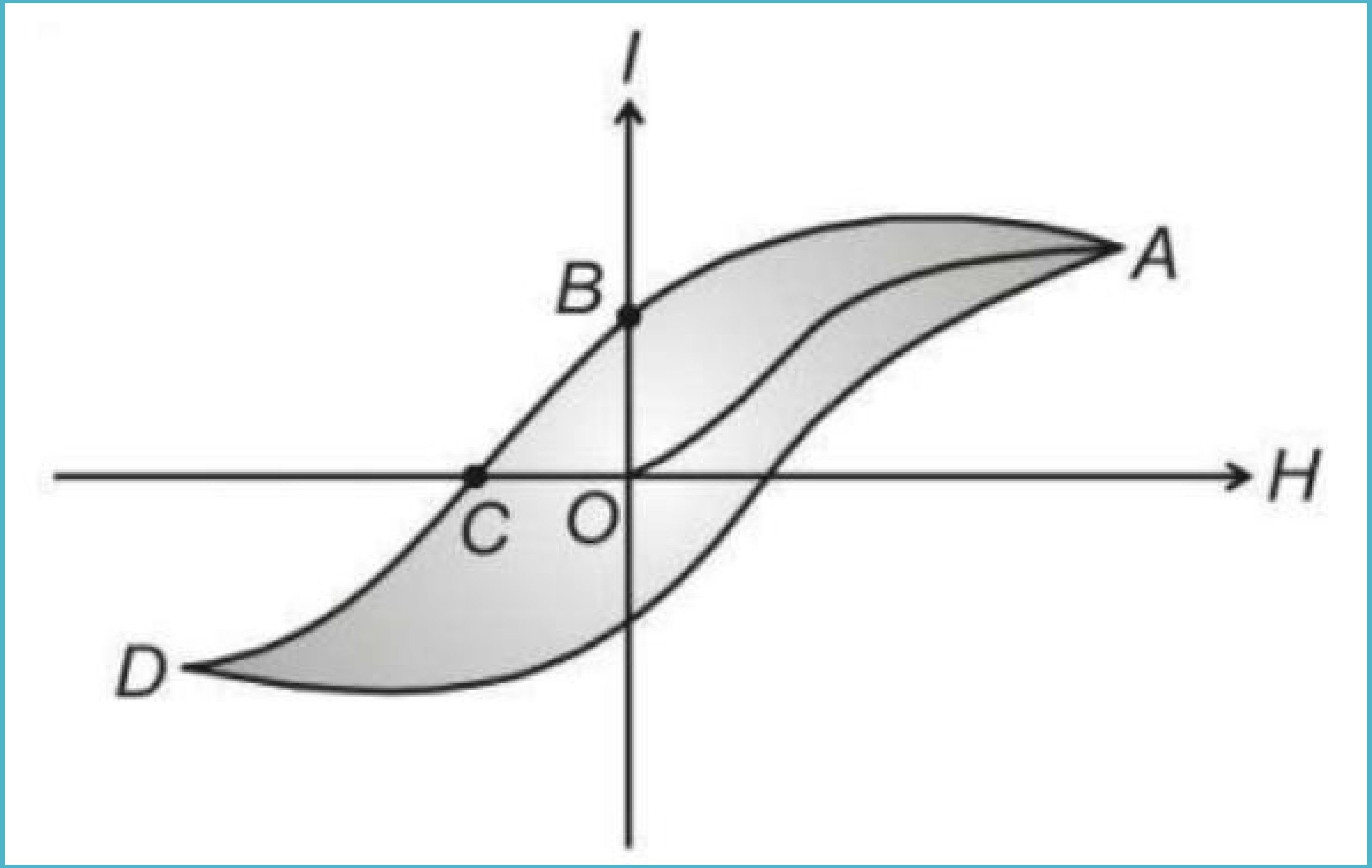
Hysteresis:



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Hysteresis:

- When intensity of magnetization (I) of ferromagnetic substances is plotted against magnetic intensity for a complete cycle of magnetization and demagnetization the resulting loop is called hysteresis loop.

- When intensity of magnetizing field (H) is increased, the intensity of magnetization increases, because more and more domains are aligned in the direction of applied field.

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Hysteresis:

- When all domains are aligned, material is magnetically saturated. Beyond this if intensity of magnetizing field (H) is increased, intensity of magnetization (I) does not increase.
- The value of intensity of magnetization (I) left in the material at H = 0, is called retentivity or remanence.

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Hysteresis:

- Now if magnetizing field is applied in reverse direction and its intensity H is increased, material starts de-magnetizing. The value of magnetizing field needed to reduce magnetization to zero is called coercivity (OC).

- As reverse magnetizing field is increased further, the material again becomes saturated. Now, if the magnetizing field is reduced after attaining the reverse saturation, the cycle repeats itself.

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Hysteresis:

- The area enclosed by the loop represents loss of energy during a cycle of magnetization and demagnetization.

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Relation Between Horizontal and Vertical Component:

Squaring and adding equation (1) and (2), we get

$$B_H^2 + B_V^2 = B_e^2(\cos^2\delta + \sin^2\delta)$$

$$B_e = \sqrt{B_H^2 + B_V^2}$$

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Relation Between Horizontal and Vertical Component:

Dividing equation (2) by (1)

$$\frac{B_V}{B_H} = \tan\delta$$

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Relative Permeability (μr):

It is the ratio of permeability of a medium to that of permeability of free space.

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

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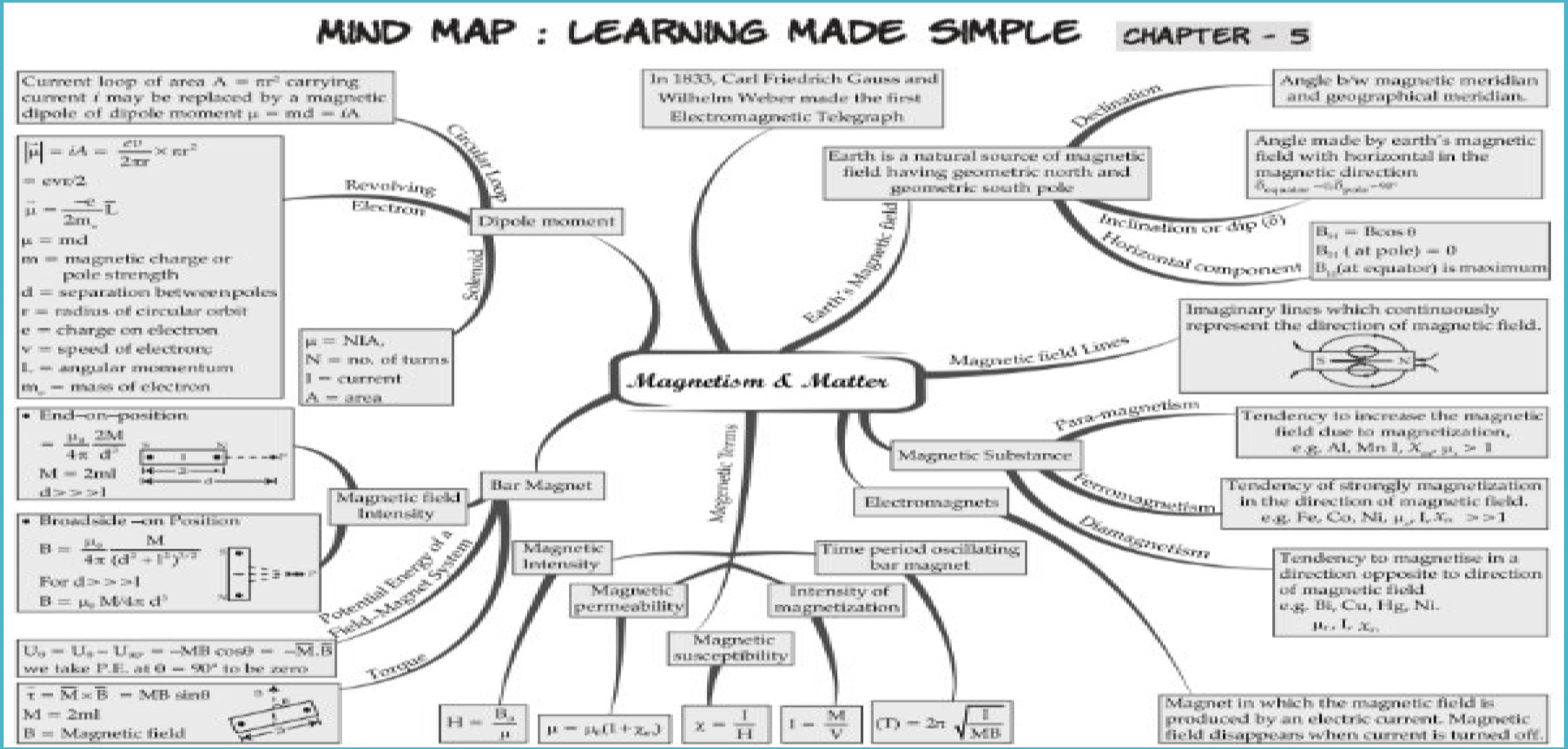

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