Magnetism

Lecture 3

the magnetization

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2nd stage

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2025- 2026

the magnetization

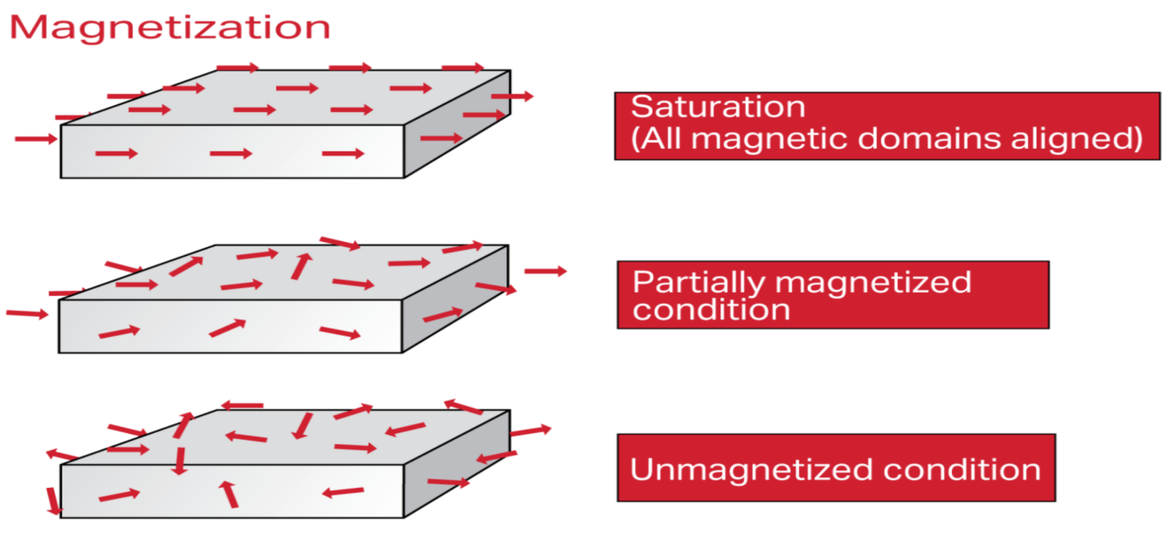
Magnetization is the degree to which a body is magnetized once it is magnetized. Magnetization is the process by which an element acquires magnetic properties, through the application of a magnetic field. A magnetic field is an electrically charged area that possesses a force produced as a result of the traffic of electric charges. Once an element is magnetized, it acquires the force of attraction and repulsion on other objects with the same properties

In classical electromagnetism, **magnetization** is the vector field that expresses the density of permanent or induced magnetic dipole moments in a magnetic material. Accordingly, physicists and engineers usually define magnetization as the quantity of magnetic moment per unit volume.[1] It is represented by a pseudovector **M**.

The magnetization field or **M**-field can be defined according to the following equation:

$$\mathbf{M}=\frac{dm}{dv}$$

Where **dm** is the elementary magnetic moment and **dv** is the volume element;.



Magnetic field intensity

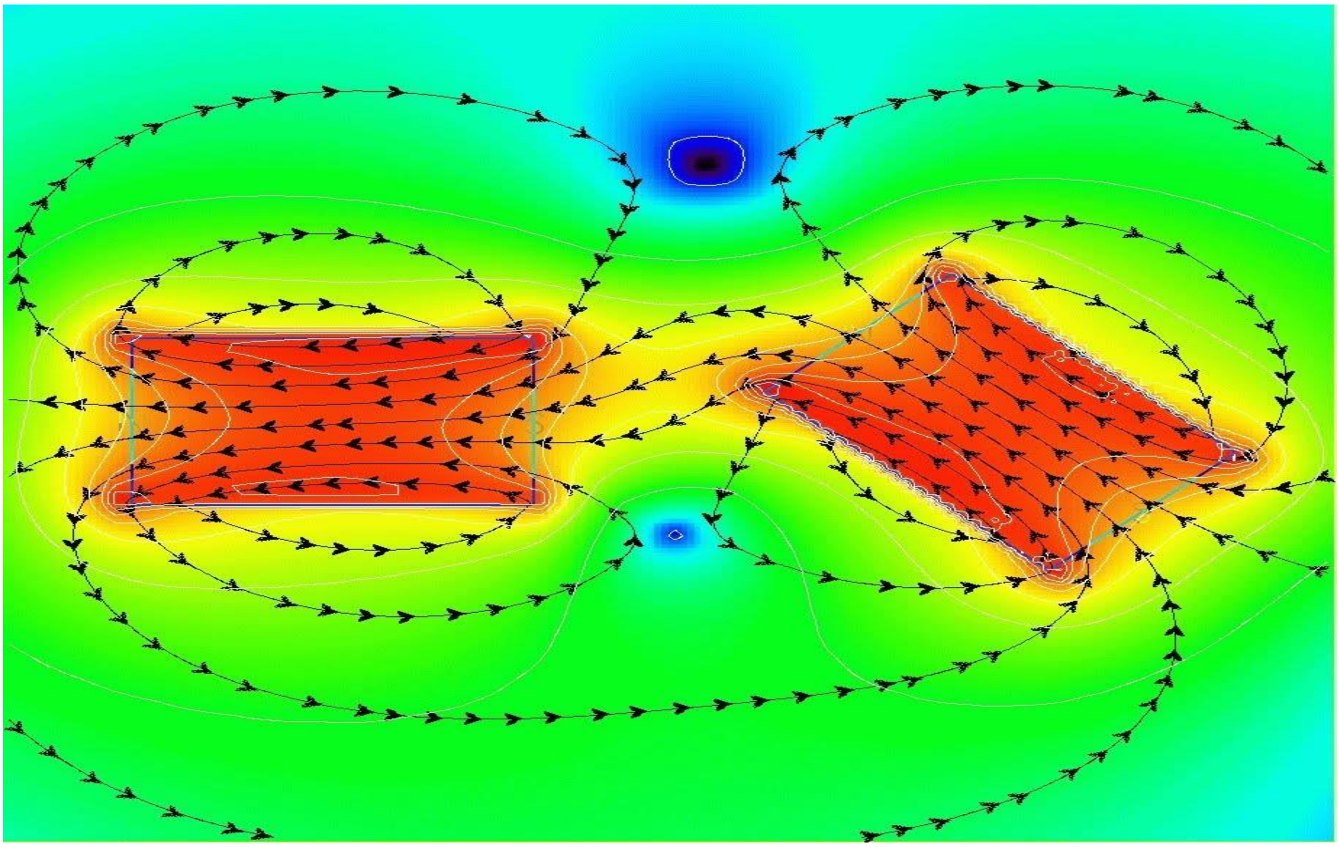
is defined as the degree to which the magnetising field can magnetise a material. The magnetic field which magnetises a material placed in it is known as the **magnetising field**. Magnetic field intensity is denoted by ‘**H**‘ and also known as **intensity of magnetising field** or **magnetising force**.

Magnetic field intensity (H) is equal to the ratio of the magnetic flux density (B) to the permeability of the material. The SI unit of magnetic field intensity is **Am^{-1}**.

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

Where : $\mu = \mu_o \mu_r$

μ_o is known as absolute permeability of vacuum or free space and $\mu_o = 4\pi \times 10^{-7}$ TmA^{-1}



Magnetic Permeability

also referred to as **permeability in electromagnetism**, is a property of a magnetic material which supports the formation of a magnetic field. The term was coined by Oliver Heaviside in the year 1885. Magnetic permeability is a property that basically allows magnetic lines of force to pass through a material.

In other words, the magnetic permeability of a material can also be said to be its magnetisation capability. This helps in determining how much magnetic flux can the material support, which will pass through it.

Magnetic Permeability Definition

Magnetic permeability is defined as the ratio of the magnetic induction to the magnetic intensity. It is a scalar quantity and is denoted by the symbol μ. Magnetic permeability helps us measure a material's resistance to the magnetic field or measure the degree to which a magnetic field can penetrate through a material.

If the material has greater magnetic permeability, the greater will be the conductivity for magnetic lines of force.

Factors Affecting Magnetic Permeability

Permeability also depends on several factors, such as the nature of the material, humidity, position in the medium, temperature, and frequency of the applied force. Magnetic permeability is always positive and can vary with a magnetic field. On the other hand, the opposite of magnetic permeability is magnetic reluctivity.

Magnetic Permeability Formula

The magnetic permeability formula is given as follows;

Magnetic permeability (μ) = B/H

Where B = magnetic intensity and H = magnetising field.

The SI unit of magnetic permeability is henry per meter (H/m) or newton per ampere squared ($N \cdot A^{-2}$).

Types of Permeability

The different types of permeability include the following:

1-Permeability of Free Space

It is the ratio of magnetic intensity in a vacuum and magnetising field. The permeability of free space, also known as the permeability of air or vacuum, is represented by :

$$\mu_0 = B_0/H.$$

2-Permeability of Medium

It is the ratio of magnetic intensity in the medium and magnetising field. It is expressed as,

$$\mu = B/H$$

3-Relative Permeability

Relative permeability is a dimensionless quantity. It is the ratio of two quantities with the same units, so relative permeability has no unit. The relative permeability of free space is 1.Its expression is given as:

$$\mu_r = \mu/\mu_m$$

Relative permeability = (number of lines of magnetic induction per unit area in a material)/(number of lines per unit area in a vacuum).

What is Magnetic Susceptibility?

Magnetic susceptibility is a dimensionless proportionality constant that indicates the degree of magnetization of a material in response to an applied magnetic field. It is caused by the interactions of electrons and nuclei with the externally applied magnetic field.

In electromagnetism, magnetic susceptibility is defined as:

The measure of how much a material will be magnetized in an applied magnetic field.

It is denoted by χ.

Magnetic Susceptibility Formula

The mathematical definition of magnetic susceptibility is the ratio of magnetization to applied magnetizing field intensity. This is a dimensionless quantity. Where:

$$\chi = M/H$$

χ: magnetic susceptibility **M:** magnetization **H:** field intensity

Relation between Relative Permeability and Magnetic Susceptibility

The relation between magnetic susceptibility and relative permeability is described as follows:

$$\chi_m = \mu_r - 1$$

If the magnetic susceptibility of a material is $\chi_m = 3.5$, calculate the relative permeability μ_r of the material.

Solution:

Using the relation:

$$\mu_r = 1 + \chi_m$$

Substitute the value:

$$\mu_r = 1 + 3.5 = 4.5$$

$$\mu_r = 4.5$$

A magnetic material has a relative permeability $\mu_r = 0.9997$.
Calculate the magnetic susceptibility χ_m,
and determine whether the material is **paramagnetic** or **diamagnetic**.

Solution:

Use the formula:

$$\chi_m = \mu_r - 1 = 0.9997 - 1 = -0.0003$$

Since:

$$\chi_m < 0 \Rightarrow \text{The material is diamagnetic}$$

- $\chi_m = -0.0003$
- **Material type: Diamagnetic**