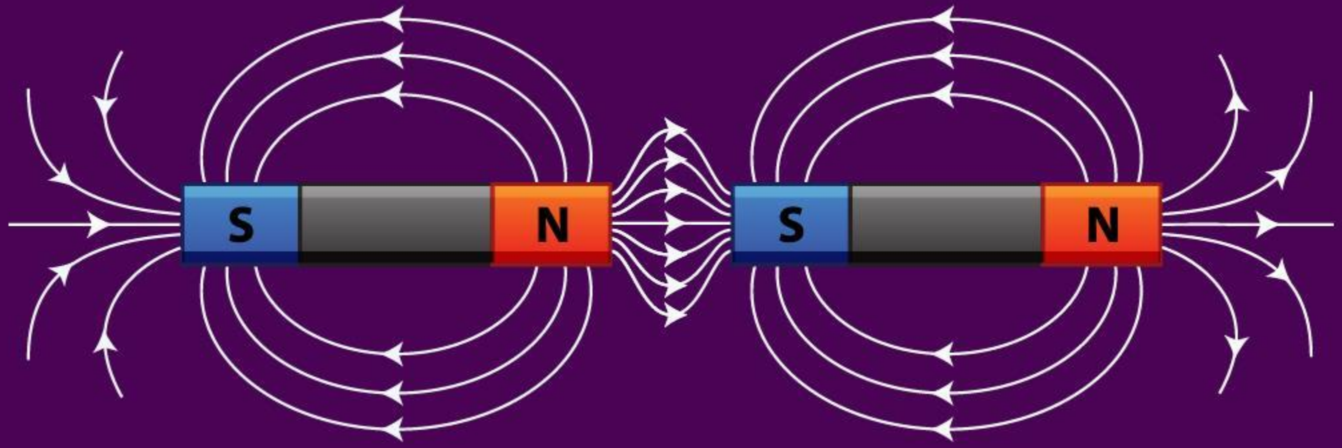
MAGNETISM & MATTER - L2



PHYSICS

ANTHE

AAKASH NATIONAL TALENT HUNT EXAM

Your Gateway To Success

For Class VII to XII

Current Students & Passouts

12TH CLASS | TUESDAY, THURSDAY, SATURDAY
11TH CLASS | MONDAY, WEDNESDAY, FRIDAY

3 PM | 4 PM | 5 PM | 6 PM

VIKAS SIR

CHEMISTRY | 3:00 PM

AKASH SIR

PHYSICS | 4:00 PM

SACHIN SIR

ZOOLOGY | 5:00 PM

PANKHURI MA'AM

BOTANY | 5:00, 6:00 PM

PUSHPENDU SIR

ZOOLOGY | 6:00 PM

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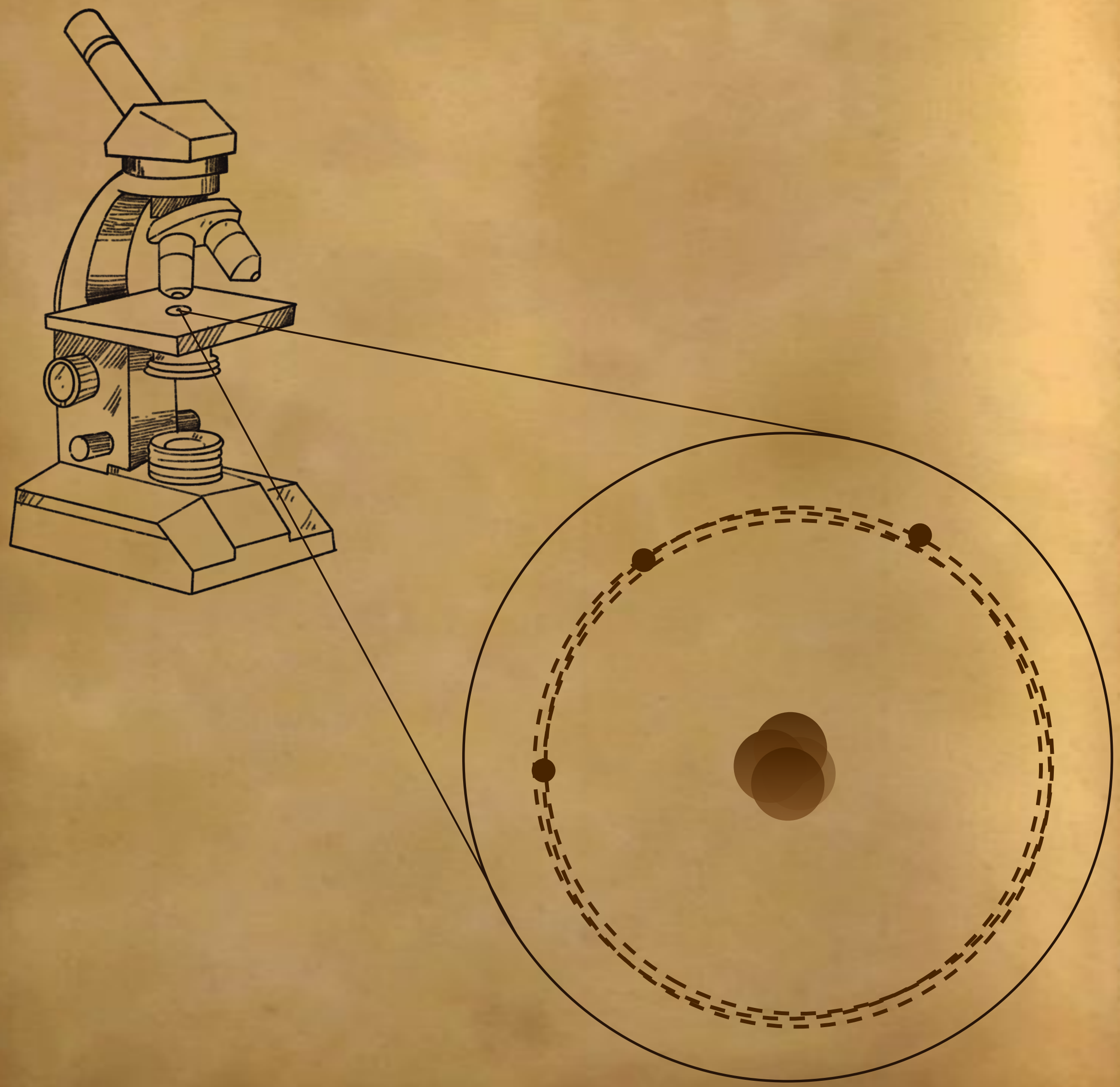
CAUSE OF MAGNETISM IN MATTER



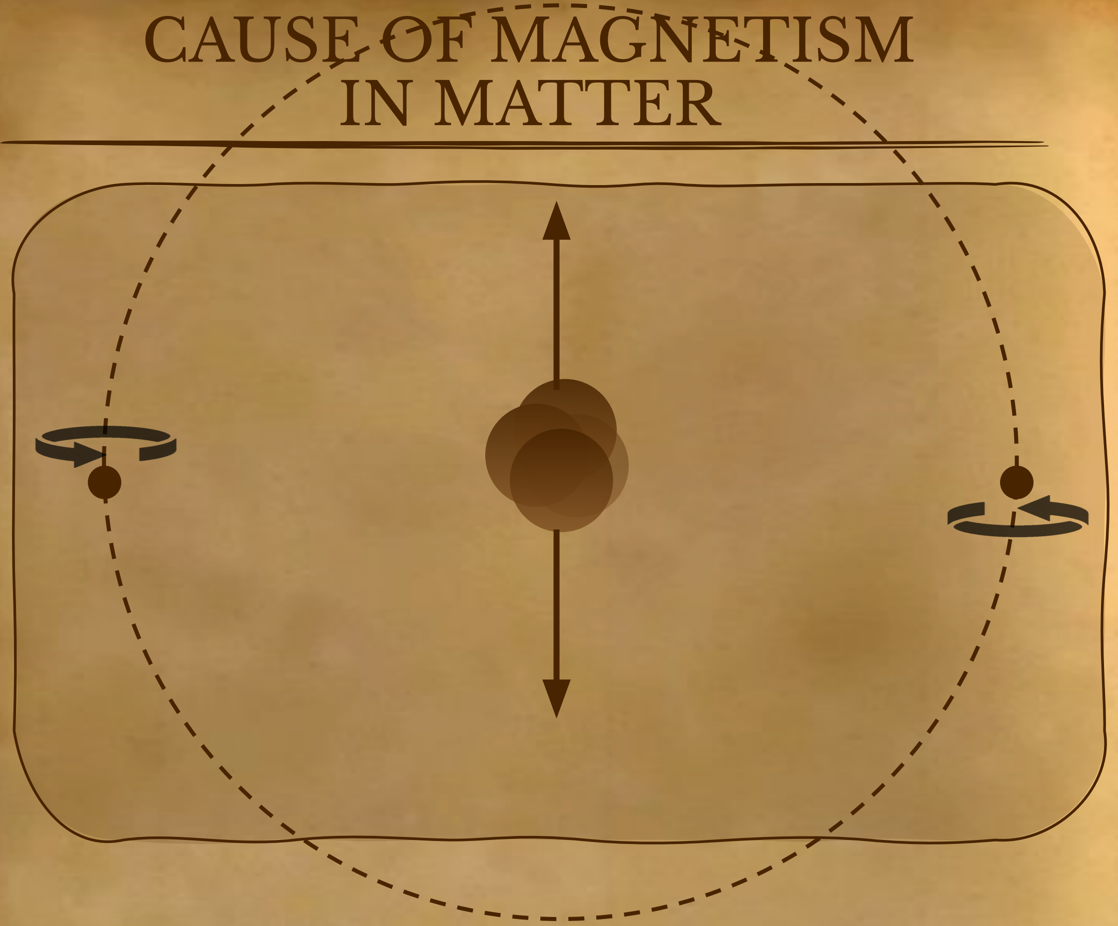
Magnetic moment of an atom is due to:

Major contributing factor

- Orbital motion of e^-
- Magnetic moment due to spin angular momentum of an e^-
- Magnetic moment of nucleus

- Net moment of an atom is a resultant of magnetic moments due to all e^-

CAUSE OF MAGNETISM IN MATTER



- In some elements, the resultant magnetic moment due to electrons gets cancelled.

- In case of Helium, all the e^- are paired. So, their magnetic moment is Zero.

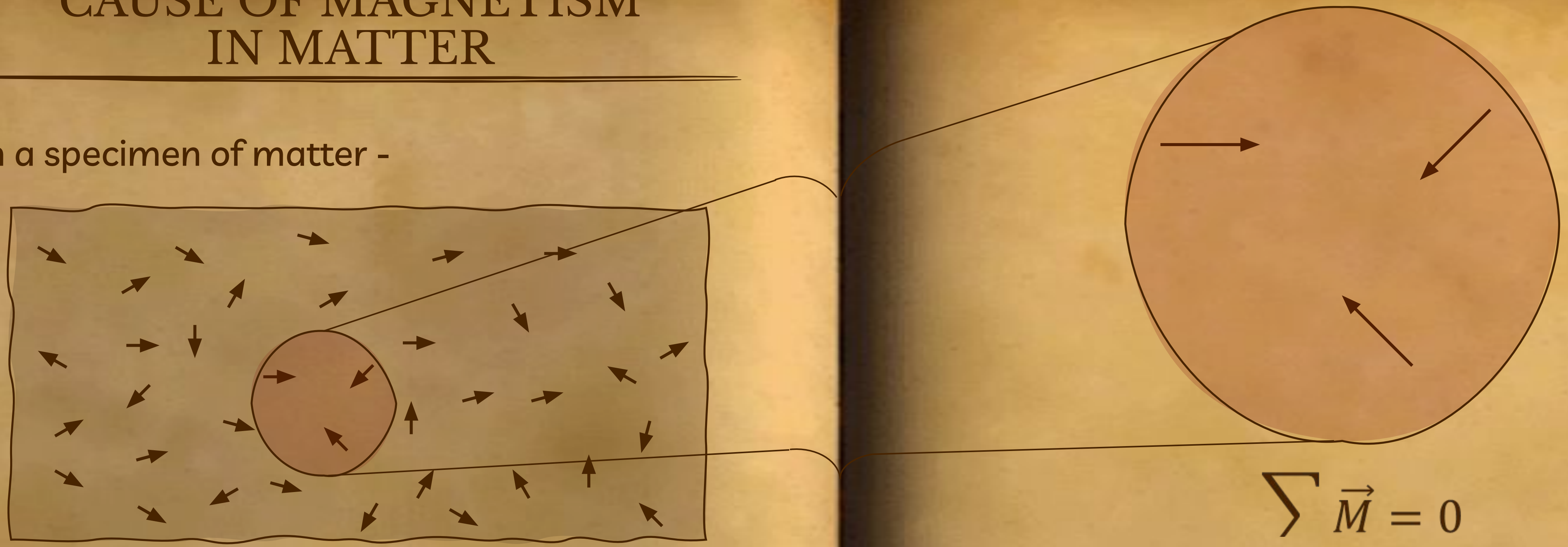
- These materials are known as DIAMAGNETIC MATERIALS.

- In some other materials, moment does not get cancelled due to presence of unpaired e^-.

- These materials are known as PARAMAGNETIC & FERROMAGNETIC MATERIALS.

CAUSE OF MAGNETISM IN MATTER

- In a specimen of matter -

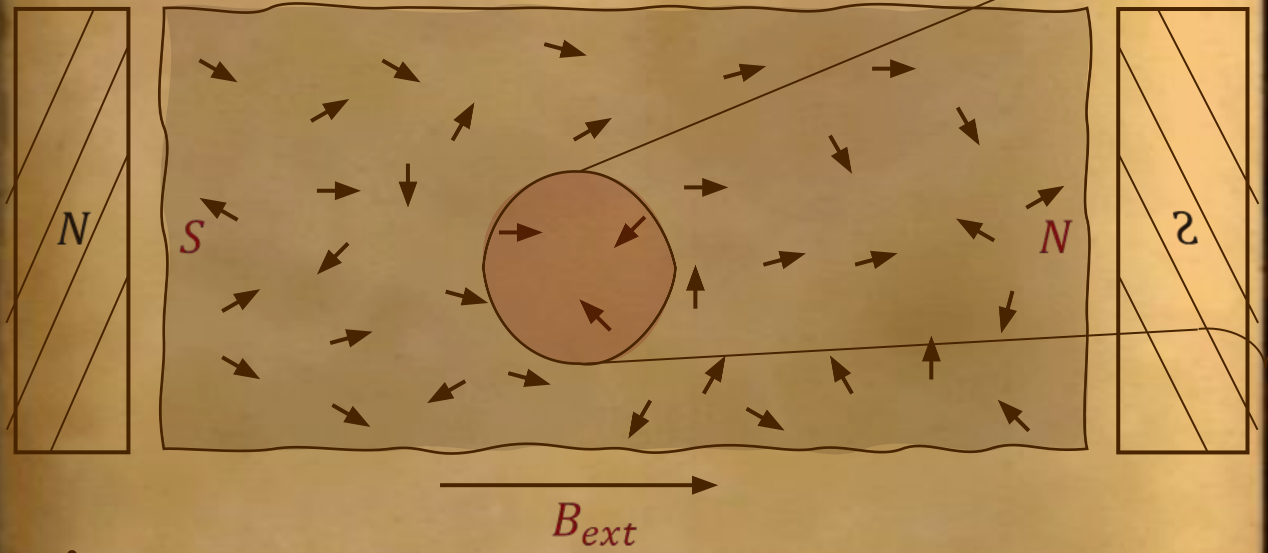


Random alignment of dipoles

- Net magnetic moment ($\vec{M}$) is ZERO.

CAUSE OF MAGNETISM IN MATTER

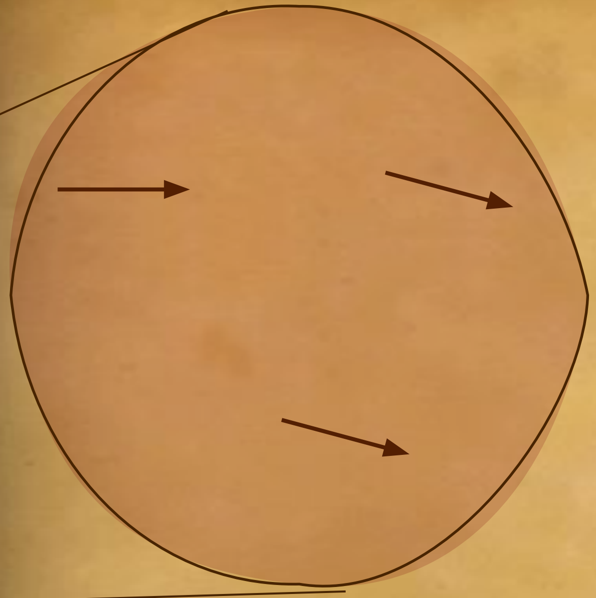
- On application of external magnetic field -



- The matter is now magnetised

- Matter adds its own magnetic field.

- Net magnetic field inside > External magnetic field



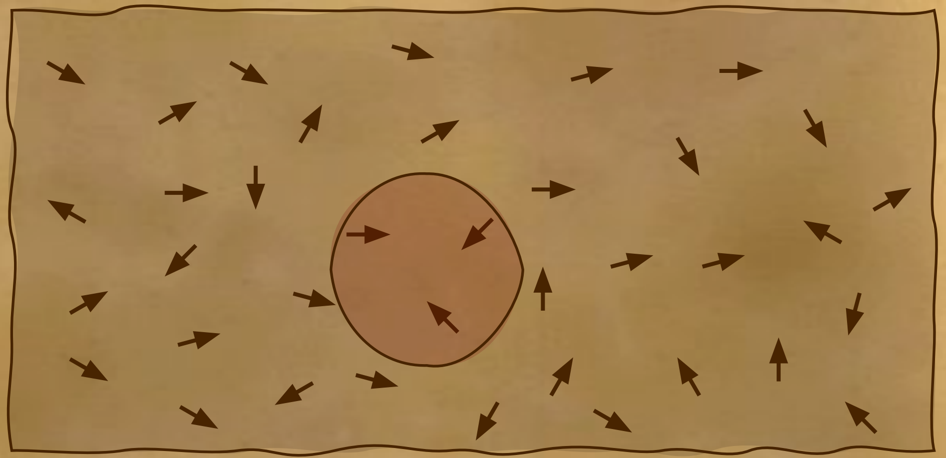
$$\sum \vec{M} \neq 0$$

CONTENTS

MAGNETISATION & MAGNETIC INTENSITY

MAGNETISATION VECTOR ($\vec{I}$)

- It's defined as NET MAGNETIC MOMENT per unit volume



$$\vec{I} = \frac{\sum \vec{M}_{net}}{V}$$

- S.I. Unit is $Ampere\ m^{-1}$

PROBLEM

For a bar magnet with pole strength m, length $2l$ and cross sectional area A. Calculate the value of magnetisation vector I

(a) $\frac{m}{Al}$

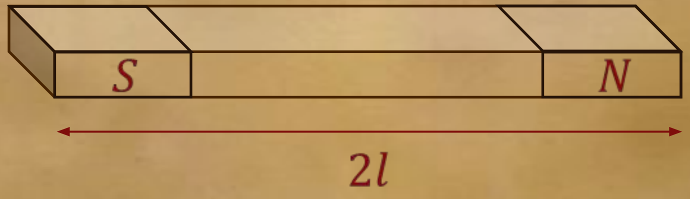
(b) $\frac{m}{A}$

(c) $\frac{2m}{A}$

(d) $\frac{m}{2A}$

SUMMARY

For a bar magnet with pole strength m, length $2l$ and cross sectional area A. Calculate the value of magnetisation vector I



$$M = m \times 2l$$

$$I = \frac{M}{[illegible]}$$

$$I = \frac{m \times 2l}{[illegible]} = \frac{m}{[illegible]}$$

PROBLEM

For a bar magnet with pole strength m, length $2l$ and cross sectional area A. Calculate the value of magnetisation vector I

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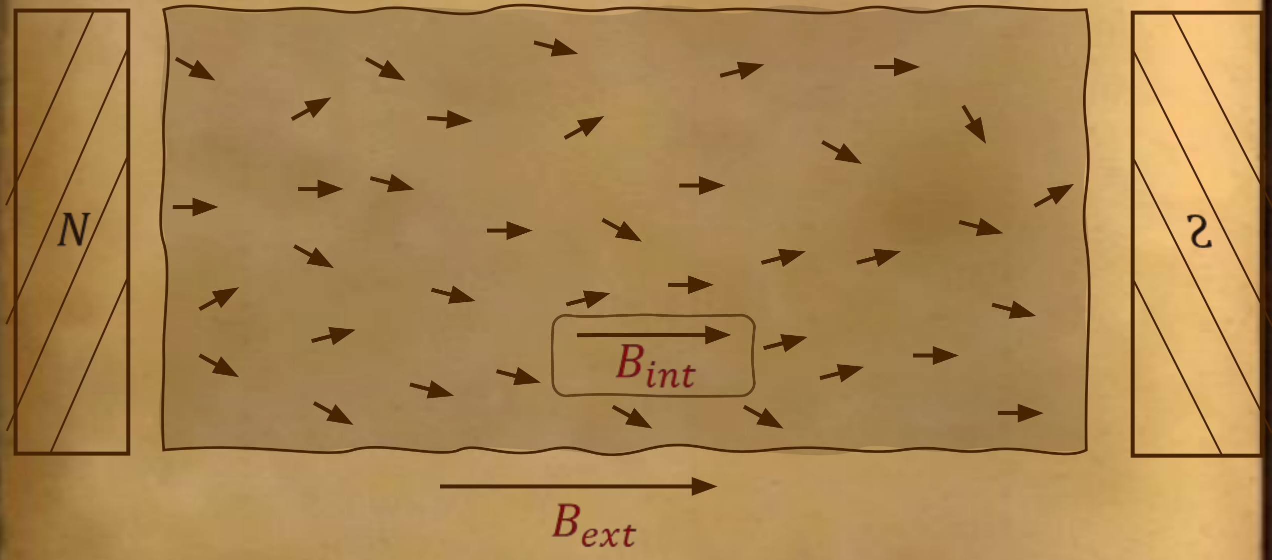
MAGNETISATION & MAGNETIC INTENSITY

RELATION BETWEEN $\vec{I}$ & $\vec{H}$

- Internal factor is proportional to external factor



$$\vec{I} \propto \vec{H}$$

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

Magnetic susceptibility (Dimensionless constant)

Magnetic susceptibility (χ) of a material is defined as the ratio of $\vec{I}$ & $\vec{H}$

- χ indicates how much a substance gets

MAGNETISATION & MAGNETIC INTENSITY

RELATION BETWEEN $\vec{I}$ & $\vec{H}$

- Internal factor is proportional to external factor

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

$$\vec{B}_{net} = \mu_0(1+\chi)\vec{H}$$

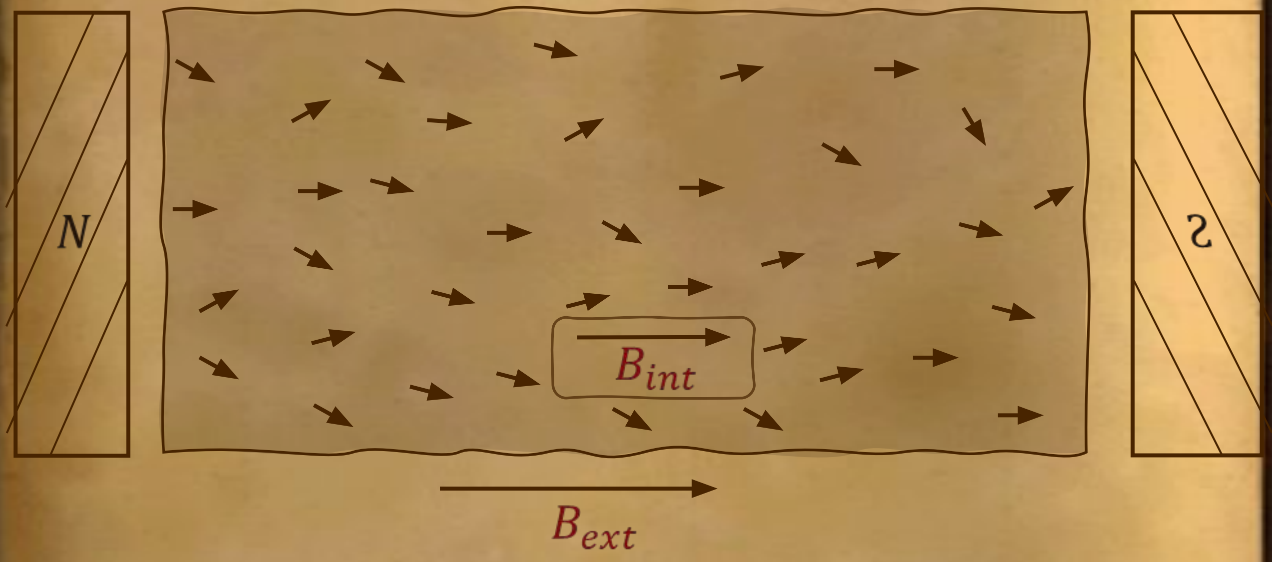
$$\vec{B}_{net} = \mu \vec{H}$$

μ: Permeability of material

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

MAGNETISATION & MAGNETIC INTENSITY

RELATION BETWEEN $\vec{I}$ & $\vec{H}$



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

- If there is no material ($\vec{I} = 0$)

$$\vec{B}_0 = \mu_0 \vec{H}$$

μ_0: Permeability of vacuum

- If there is a material ($\vec{I} \neq 0$)

$$\vec{B}_m = \mu_0 \vec{H} + \mu_0 \vec{I}$$

$$\vec{B}_m = \mu_0(1 + \chi)\vec{H}$$

$$\vec{B}_m = \mu \vec{H}$$

RELATIVE PERMEABILITY

- Factor by which magnetic field increases when a material is introduced.

$$\vec{B}_m$$

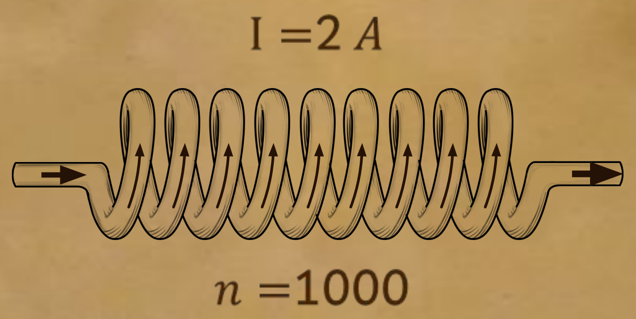
$$\mu_m \vec{H}$$

$$\mu_r = \frac{\mu_m}{}$$

PROBLEM

A solenoid has a material of relative permeability 400. If solenoid has 1000 turns per meter and carries a current of $2\ A$. Find

1) H
2) B_{net}
3) I



SOLUTION

A solenoid has a material of relative permeability 400. If solenoid has 1000 turns per meter and carries a current of $2\ A$. Find

1) H
2) B_{net}
3) I

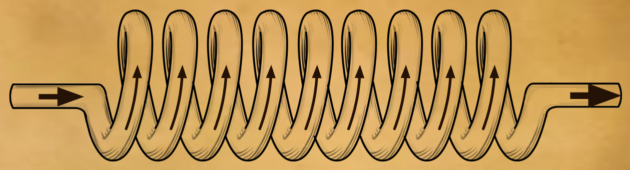
$$B_0 = \mu_0 n I$$

$$B_m = \mu_m H = \mu_r \mu_0 H$$

$$I = \chi H$$

$$\mu_r = 1 + \chi$$

$\mathrm{I} = 2\ A$

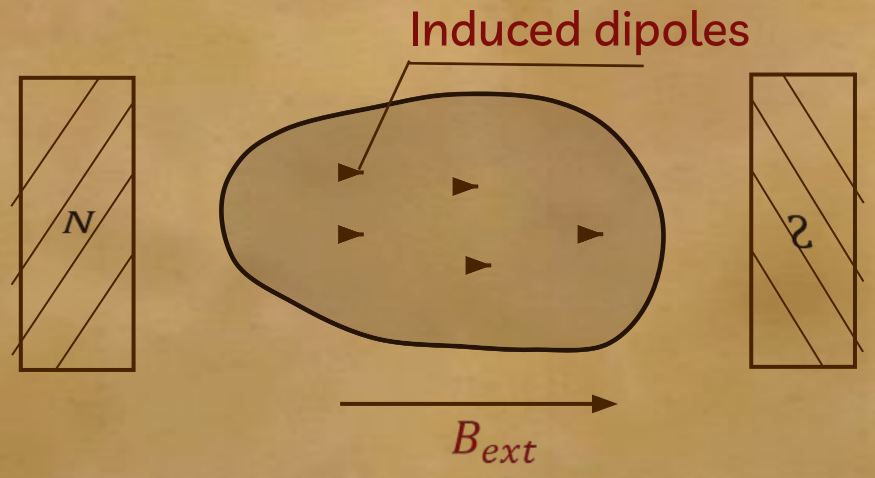


$n = 1000$

CONTENTS

DIAMAGNETISM

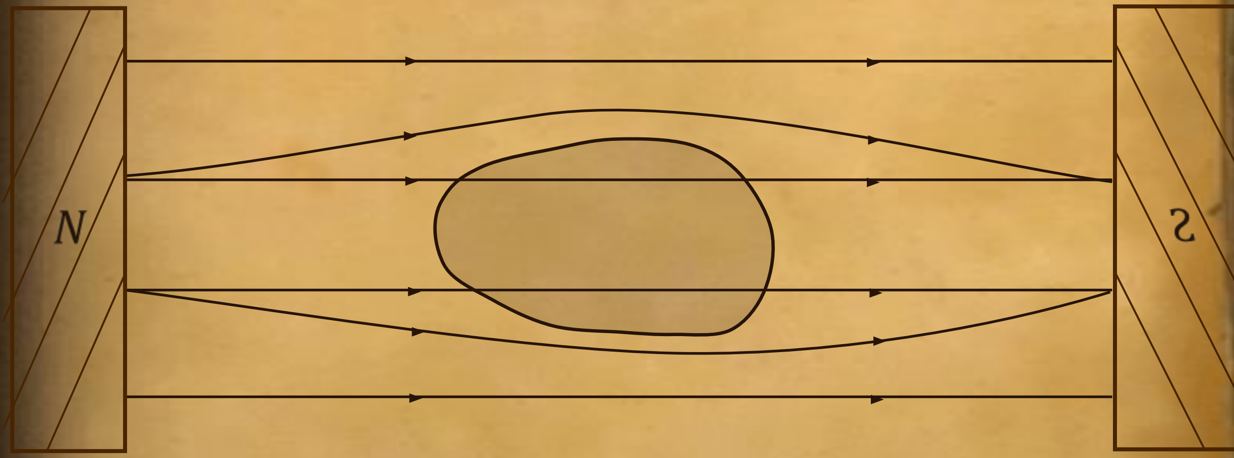
- Dipoles are INDUCED in any substance on application of external magnetic field. (Lenz's law)



- This induction is VERY SMALL.
- In diamagnetic substances, these induced dipoles cause a WEAK REPULSION.
- Magnetic susceptibility is SMALL and NEGATIVE.

χ is –ve and $\mu_r < 1$

- Magnetic field lines are REPELLED from diamagnetic substances



- Examples: N_2 (At STP), Water, $NaCl$, Cu

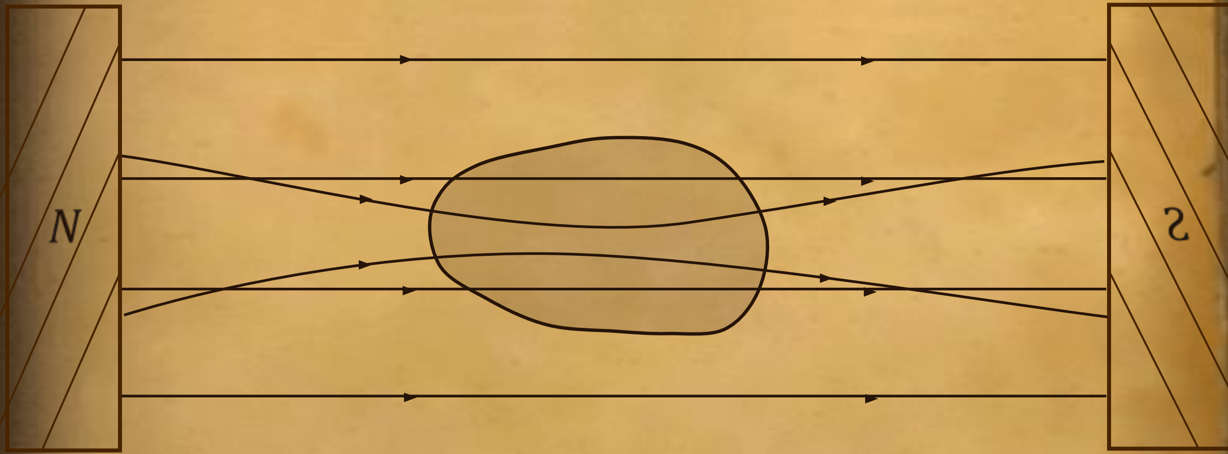
PARAMAGNETISM

- Atomic dipoles are **REALIGNED** in the presence of external magnetic field.

- The alignment is **PARTIAL.**
- In paramagnetic substances, there is a **WEAK ATTRACTION** in external magnetic field
- Magnetic susceptibility is **SMALL** and **POSITIVE.**

χ is +ve and $\mu_r > 1$

- Magnetic field lines get denser inside paramagnetic substances.



- Examples: O_2(at STP) , FeO, Al, Na, Ca

PARAMAGNETISM

CURIE'S LAW

- Magnetisation ($\vec{I}$) of a paramagnetic substance is inversely proportional to absolute temperature (T)

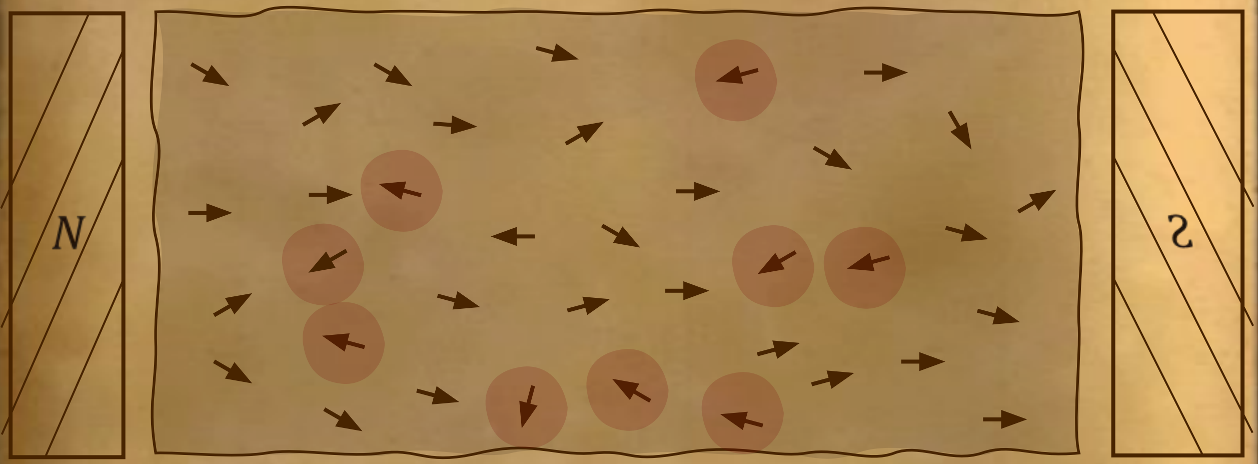
At normal temperature

At higher temperature

PARAMAGNETISM

CURIE'S LAW

- Magnetisation ($\vec{I}$) of a paramagnetic substance is inversely proportional to absolute temperature (T)



When temperature is increased, magnetisation reduces

$$I \propto \frac{B_0}{}$$

$$I = C\frac{B_0}{}$$

Curie's constant

$$\chi H = C\frac{\mu_0 H}{}$$

$$\chi = C\frac{\mu_0}{}$$

χ = Magnetic susceptibility

μ_o = Permeability of free space

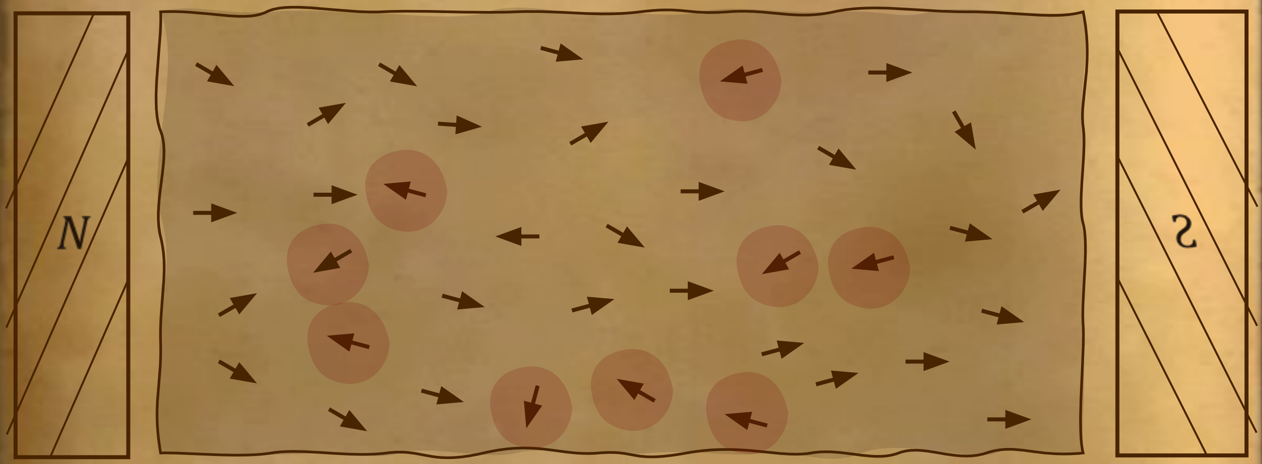
C = Curie's constant

T = Absolute temperature

PARAMAGNETISM

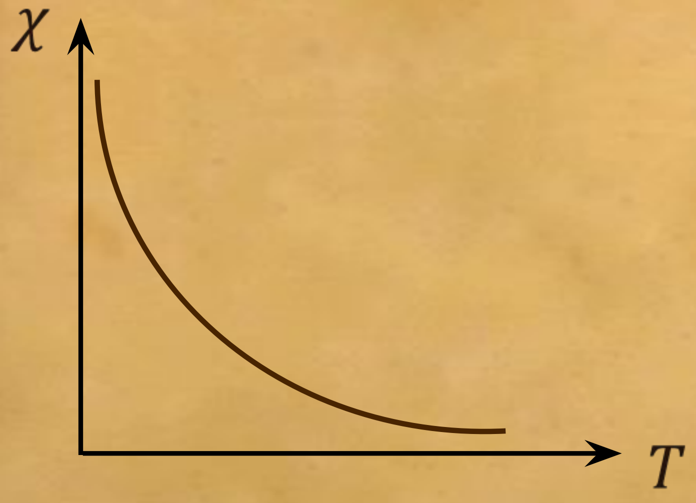
CURIE'S LAW

- Magnetisation ($\vec{I}$) of a paramagnetic substance is inversely proportional to absolute temperature (T)



When temperature is increased, magnetisation reduces

$$\chi = C\frac{\mu_0}{}$$



FERROMAGNETISM

- In ferromagnetic substances, atomic dipoles interact with each other to align in same direction. These small volumes are called DOMAINS.

- On application of external magnetic field, these domains align themselves in the direction of magnetic field.

- Domains usually are of $1\,mm$ size & contain around 10^{11} atoms

- Domains aligned in the direction of magnetic field also grow in size. (Domain Growth)

- Magnetic susceptibility χ is +ve and very large, $\mu_r \gg 1$.

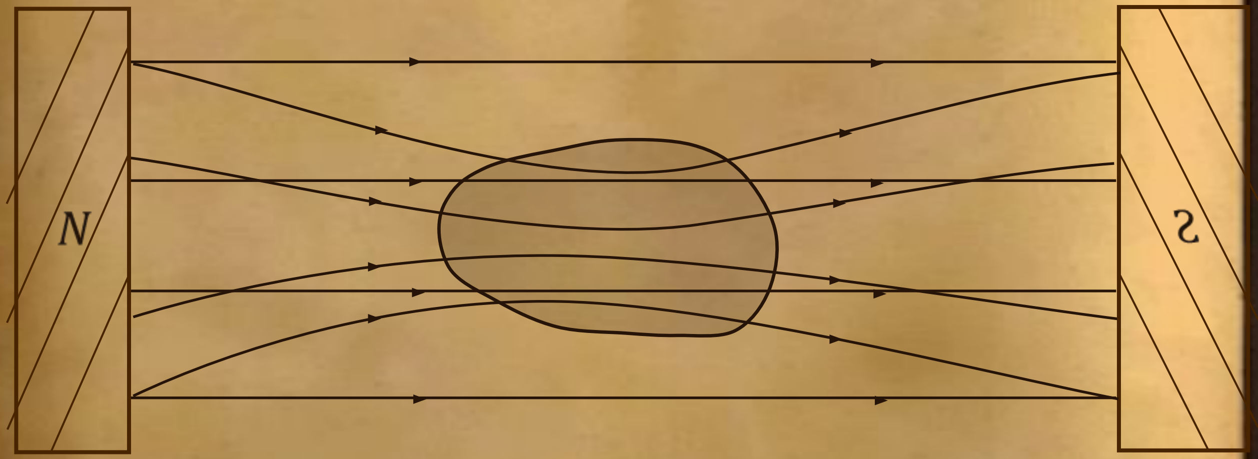
FERROMAGNETISM

- In ferromagnetic substances, atomic dipoles interact with each other to align in same direction. These small volumes are called DOMAINS.

- On application of external magnetic field, these domains align themselves in the direction of magnetic field.
- Domains usually are of $1\,mm$ size & contain around 10^{11} atoms
- Domains aligned in the direction of magnetic field also grow in size. (Domain Growth)
- Magnetic susceptibility χ is +ve and very large, $\mu_r \gg 1$.

FERROMAGNETISM

- Ferromagnetic substances are strongly attracted in external magnetic field



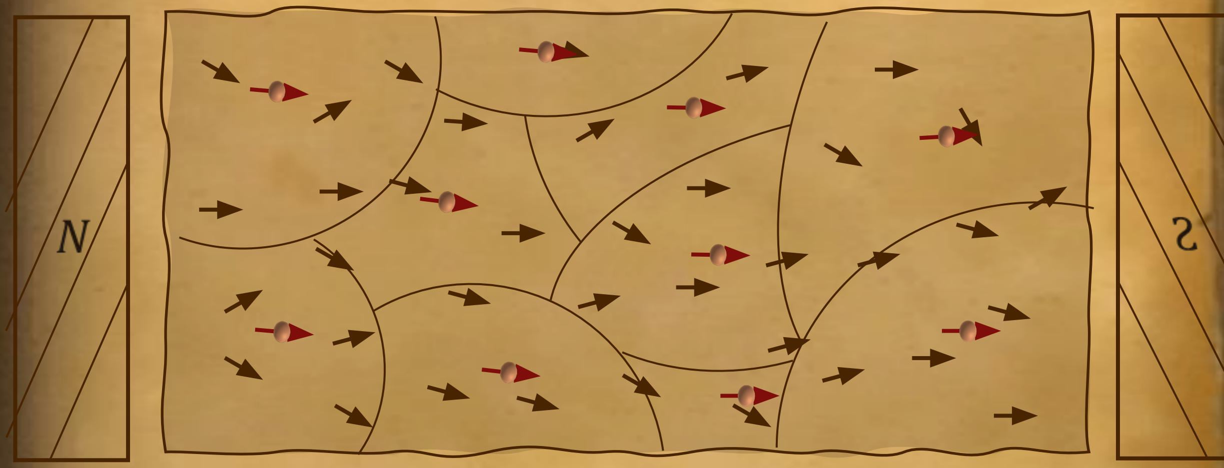
On removal of external magnetic field

- Magnetisation persists:
  Hard ferromagnetic materials
  (Ex. Alnico)
- Magnetisation disappears:
  Soft ferromagnetic materials
  (Ex. Soft iron)

FERROMAGNETISM

CURIE TEMPERATURE

At normal temperature



At higher temperature

FERROMAGNETISM

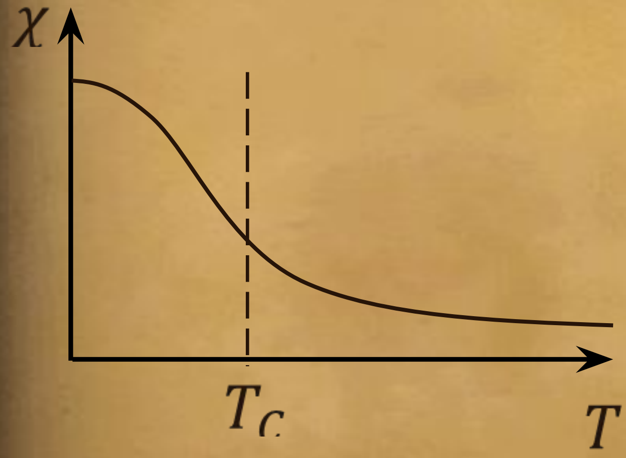
CURIE TEMPERATURE

- On increasing temperature, ferromagnetic property DECREASES.
- At a certain temperature, materials lose their ferromagnetic properties and become PARAMAGNETIC.
- The domain structure disintegrates.
- This transition temperature is called CURIE TEMPERATURE (T_C).

- The susceptibility above Curie temperature in paramagnetic state is given by :

$$\chi = C\frac{\mu_0}{T - T_C}$$

T_c = Curie temperature



CONTENTS

CLASSIFICATION OF MATERIALS

BASED ON MAGNETIC PROPERTIES

DIAMAGNETIC :

- Susceptibility (χ) is negative.
- Permeability of material (μ) is less than permeability of vacuum (μ_0)
- Relative permeability (μ_r) is between 0 and 1.

$$\mu_r = 1 + \chi$$

PARAMAGNETIC :

- Susceptibility (χ) is small and positive.
- Permeability of material (μ) is slightly greater than permeability of vacuum (μ_0)
- Relative permeability (μ_r) is slightly greater than 1.

$$\mu_r = 1 + \chi$$

FERROMAGNETIC :

- Susceptibility (χ) is large and positive.
- Permeability of material (μ) is greater than permeability of vacuum (μ_0)
- Relative permeability (μ_r) is greater than 1.

$$\mu_r = 1 + \chi$$

CLASSIFICATION OF MATERIALS

BASED ON MAGNETIC PROPERTIES

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

Diamagnetic	Paramagnetic	Ferromagnetic

- ε is a small positive number introduced to quantify paramagnetic materials.

PROBLEM

The magnetic susceptibility is negative for

(a) Ferromagnetic materials only.

(b) Paramagnetic and ferromagnetic materials

(c) Diamagnetic material only.

(d) Paramagnetic material only.

SOLUTION

The magnetic susceptibility is negative for

(a) Ferromagnetic materials only.

(b) Paramagnetic and ferromagnetic materials

(c) Diamagnetic material only.

(d) Paramagnetic material only.

NEET 2016

PROBLEM

If a diamagnetic substance is brought near north or south pole of a bar magnet, it is

(a) Attracted by the poles.

(b) Repelled by the poles.

(c) Repelled by the north pole and attracted by the south pole.

(d) Attracted by the north pole and repelled by south pole.

SOLUTION

If a diamagnetic substance is brought near north or south pole of a bar magnet, it is

(a) Attracted by the poles.

(b) Repelled by the poles.

(c) Repelled by the north pole and attracted by the south pole.

(d) Attracted by the north pole and repelled by south pole.

NEET 2009

PROBLEM

The magnetic moment of a diamagnetic atom is.

(a) Much greater than one.

(b) 1

(c) Between zero and one.

(d) Equal to zero.

SOLUTION

The magnetic moment of a diamagnetic atom is.

NEET 2010

(a) Much greater than one.

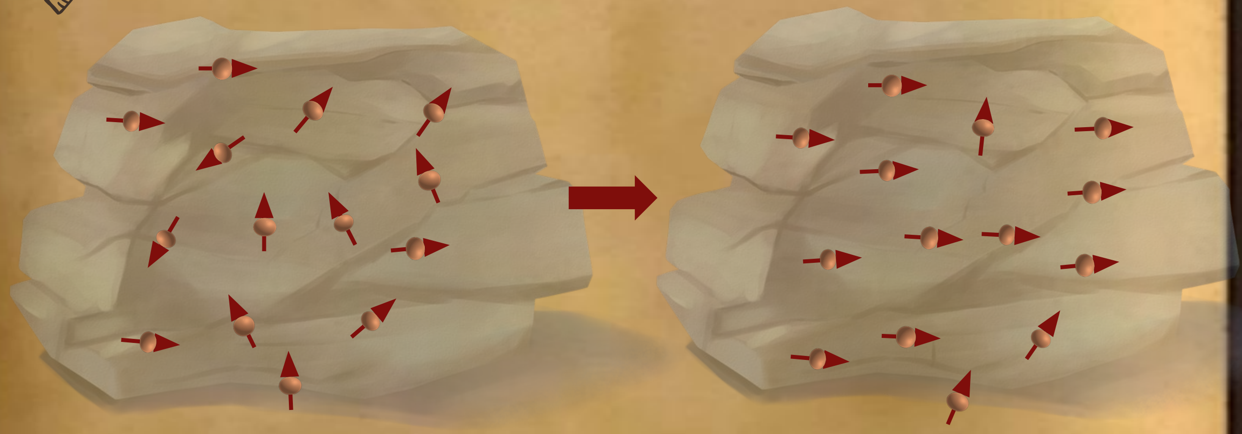
(b) 1

(c) Between zero and one.

(d) Equal to zero.

I-H CURVE

What is magnetization (I)?

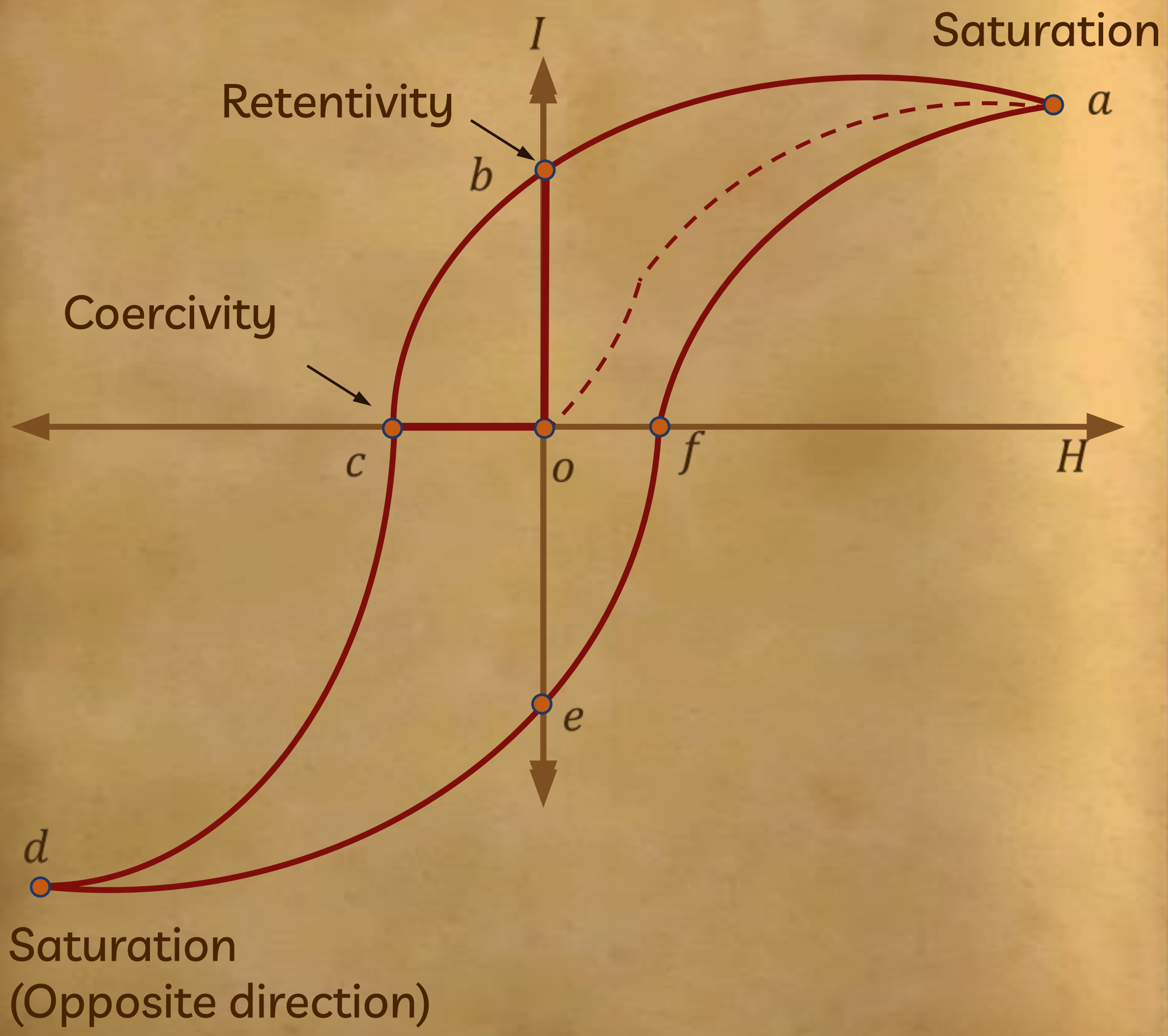


What is magnetic intensity (H)?

Hysteresis loop (Hysteresis Curve)

- A hysteresis loop (also known as a hysteresis curve) is a four-quadrant graph that shows the relationship between the induced magnetic flux density (B) and the magnetizing field (H).
- Hysteresis is characterized as a lag of magnetic flux density behind the magnetic field strength.

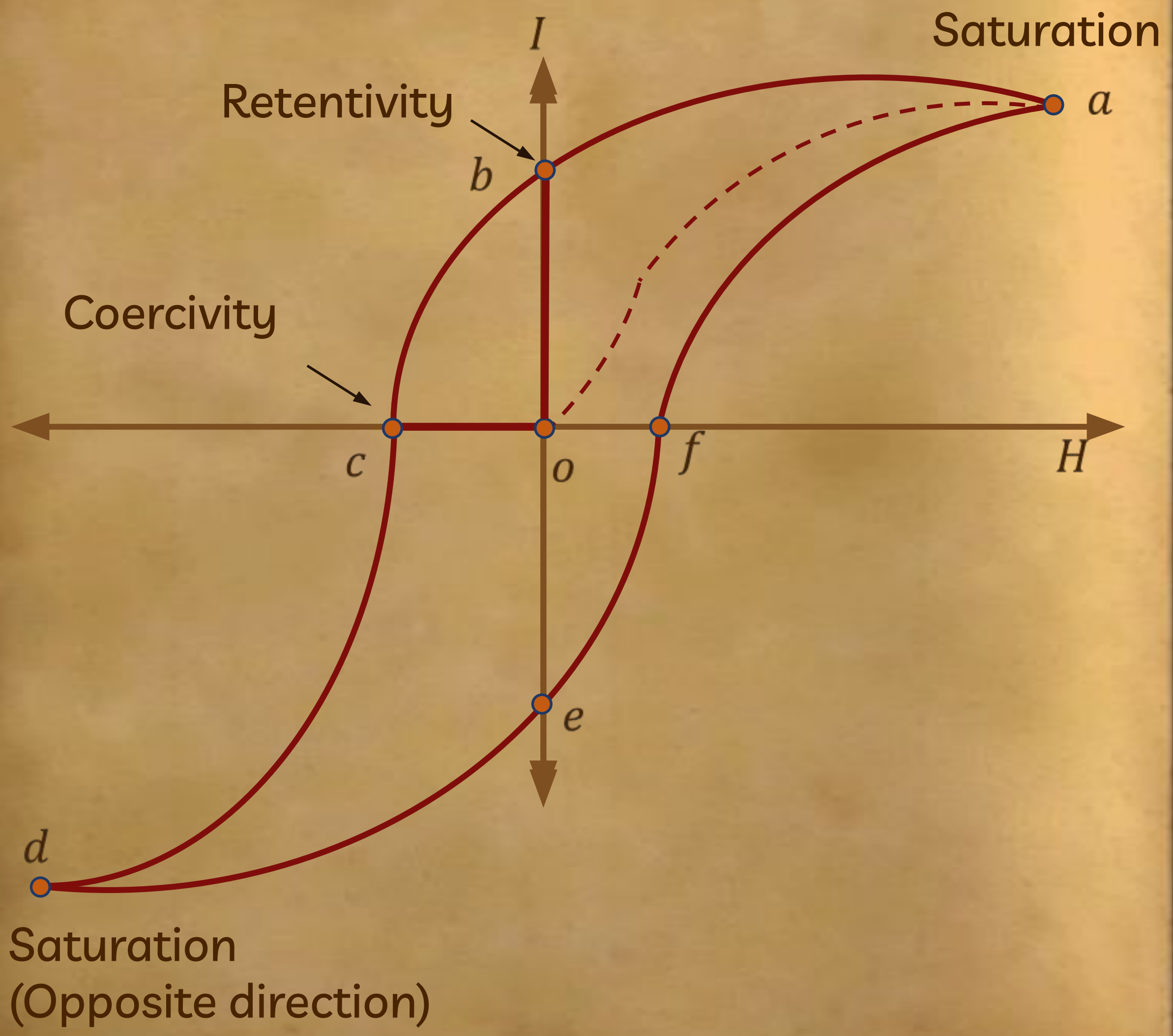
I-H CURVE



- Hysteresis loop (Hysteresis Curve)
- It is the path $(a \to b \to c \to d \to e \to f \to a)$ in which a ferromagnetic substance is taken through a cycle of magnetisation and de-magnetisation.

Magnetised (a) → De-magnetised (c) → Magnetised (d) → De-magnetised (f) → Magnetised (a)

I-H CURVE



- **Retentivity:**

  It is the capacity of a substance to retain its magnetism even when the magnetizing field has ceased to act.

- **Coercivity:**

  It is an amount of magnetic intensity required to demagnetize a material.

$B - H$ AND $I - H$ CURVES FOR THE MAGNETIC MATERIALS

Relationship between Magnetic field (B) and Magnetization (M):

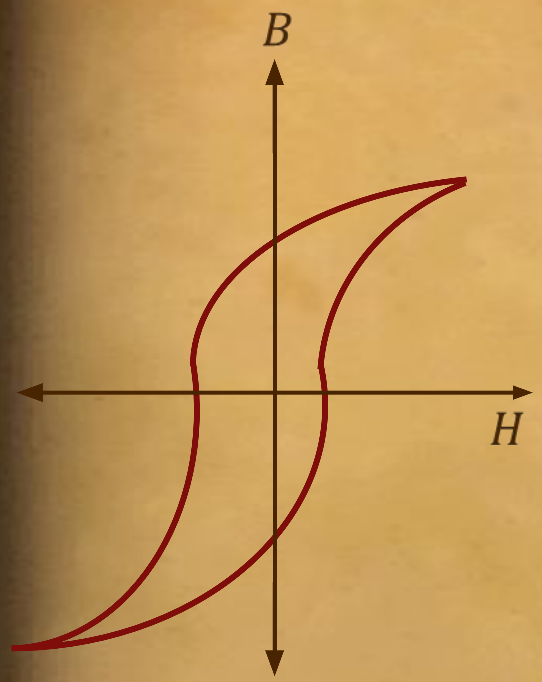
$$\vec{B} = \mu_o(\vec{H} + \vec{I})$$

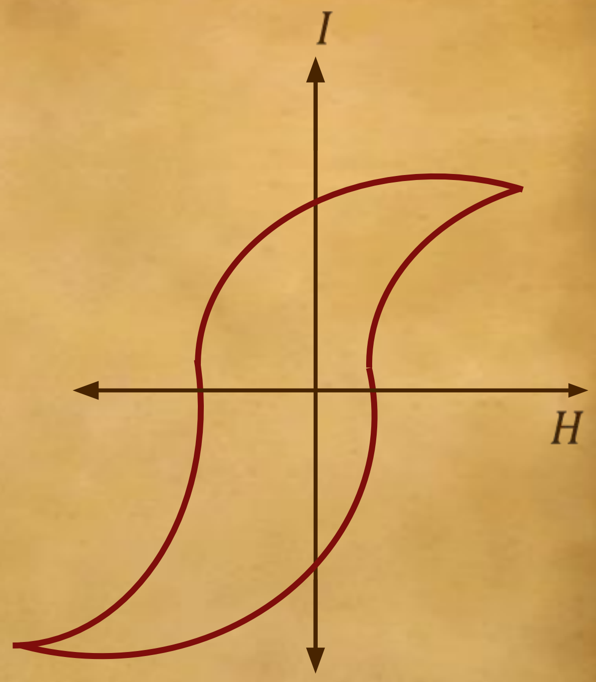
$\vec{B}$ = Magnetic field vector

μ_o = Permeability of free space

$\vec{H}$ = Magnetic field strength

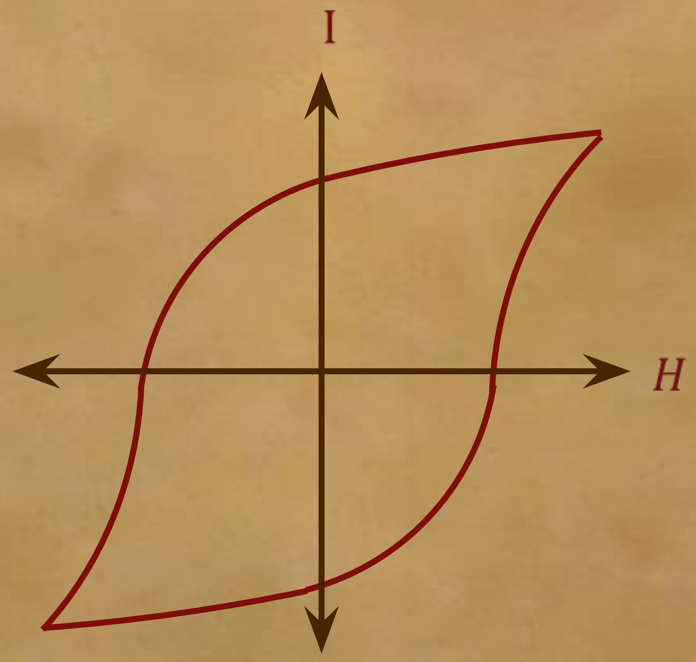
$\vec{I}$ = Magnetization vector





HYSTERESIS LOSS

The area enclosed by the hysteresis loop $\propto$ Energy supplied per unit volume of material in each cycle which is lost as heat

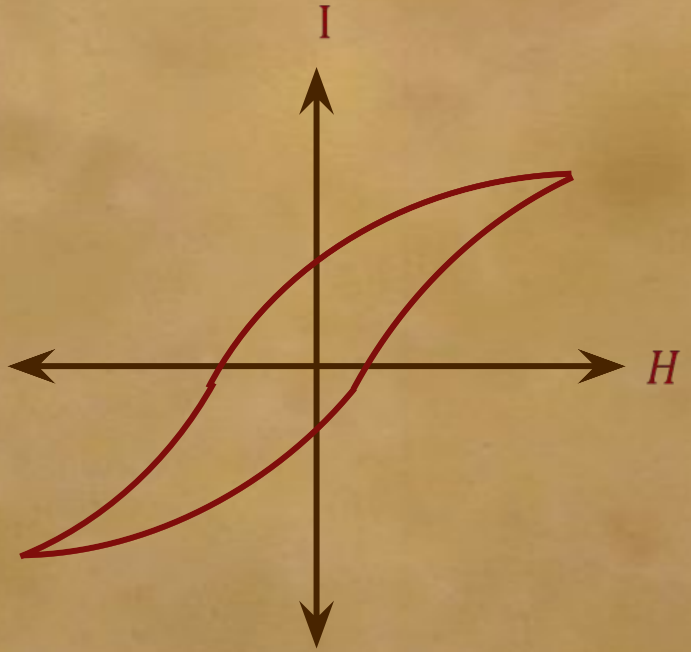


For permanent magnet

- High saturation magnetisation
- High Retentivity
- High Coercivity

HYSTERESIS LOSS

The area enclosed by the hysteresis loop $\propto$ Energy supplied per unit volume of material in each cycle which is lost as heat



For electromagnet

- High saturation magnetisation
- Low Retentivity
- Low Coercivity

PROBLEM

Which material is better for use in a coil of the generator or the core of a transformer.

a. Soft iron

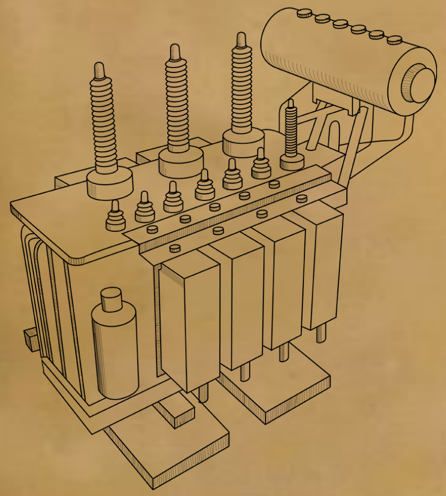
b. Mild steel

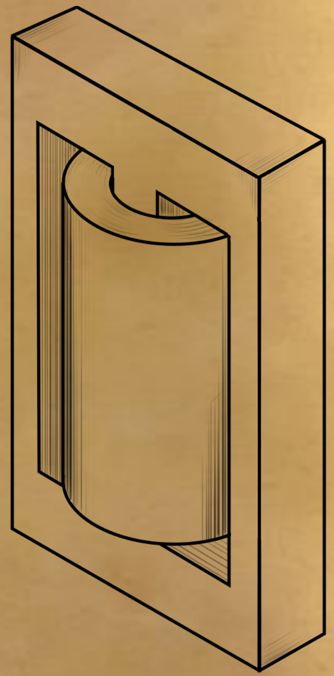
c. Stainless steel

d. Hard iron

SOLUTION

Which material is better for use in a coil of the generator or the core of a transformer.





Soft Iron

Transformer

Transformer core

Material to be used in core of transformer should have :

- Low Retentivity
- Low Coercivity
- Small Area of hysteresis loop

PROBLEM

Which material is better for use in a coil of the generator or the core of a transformer.

a. Soft iron

b. Mild steel

c. Stainless steel

d. Hard iron