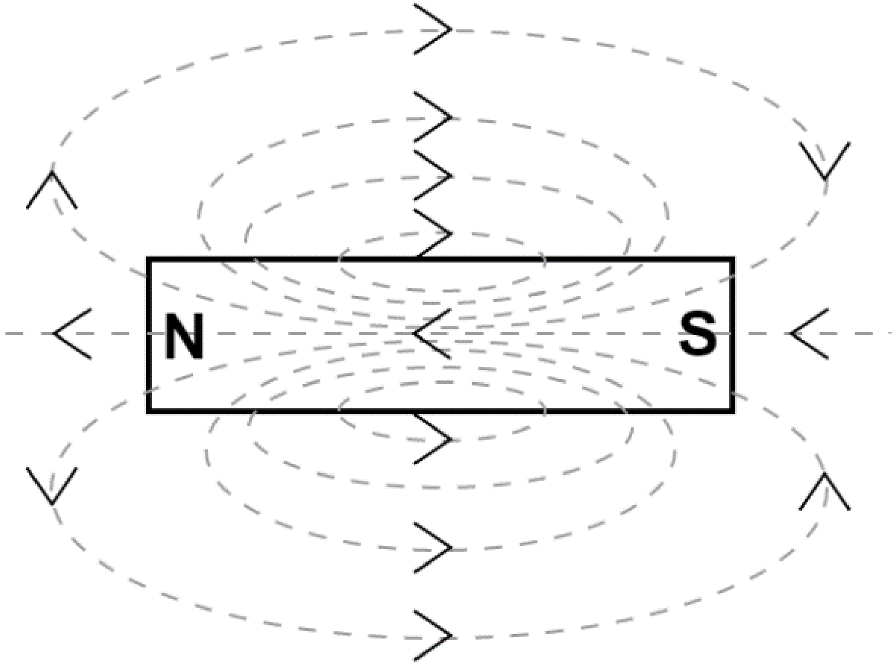
Magnetism

YORK COLLEGE & UNIVERSITY CENTRE

Magnetic Field Lines

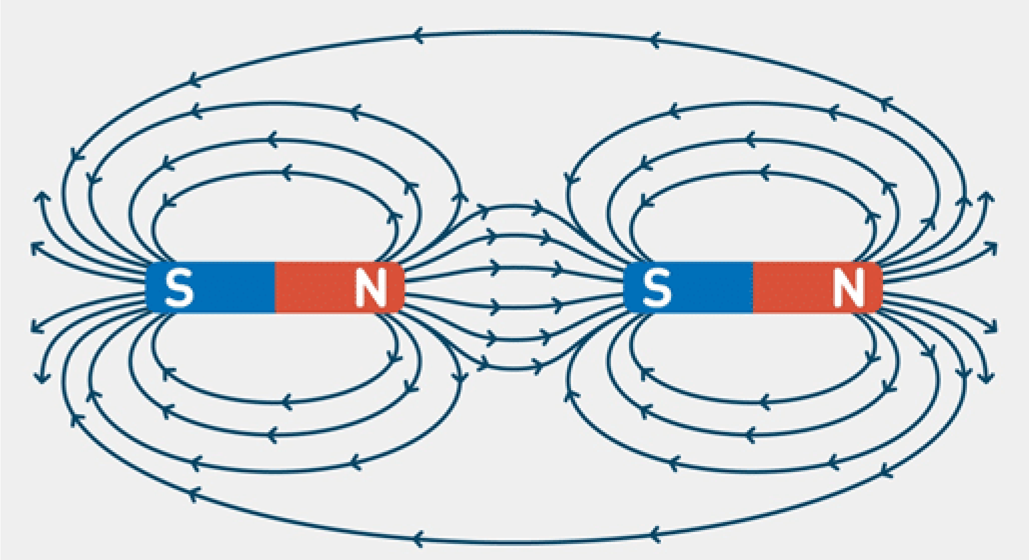
- Magnetic field lines flow from the **positively charged** (north) pole of a magnet to the **negatively charged** (south) pole of a magnet

- Magnetic field lines never cross and never break, this means they also flow through a magnet



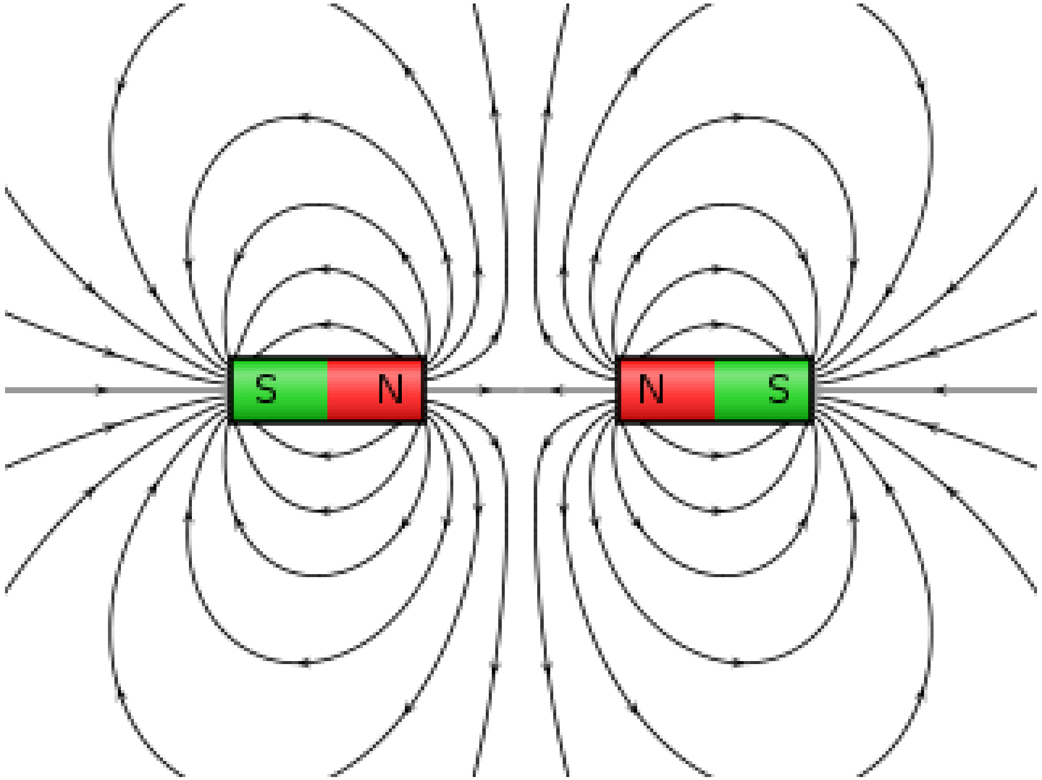
Magnetic Field Lines

- We know magnetic field lines always flow from **north to south** (positive to negative)
- Therefore, if we lay two magnets facing the same way next to each other their **field lines join**
- This is why two magnets will move **attract each other** when put in this configuration



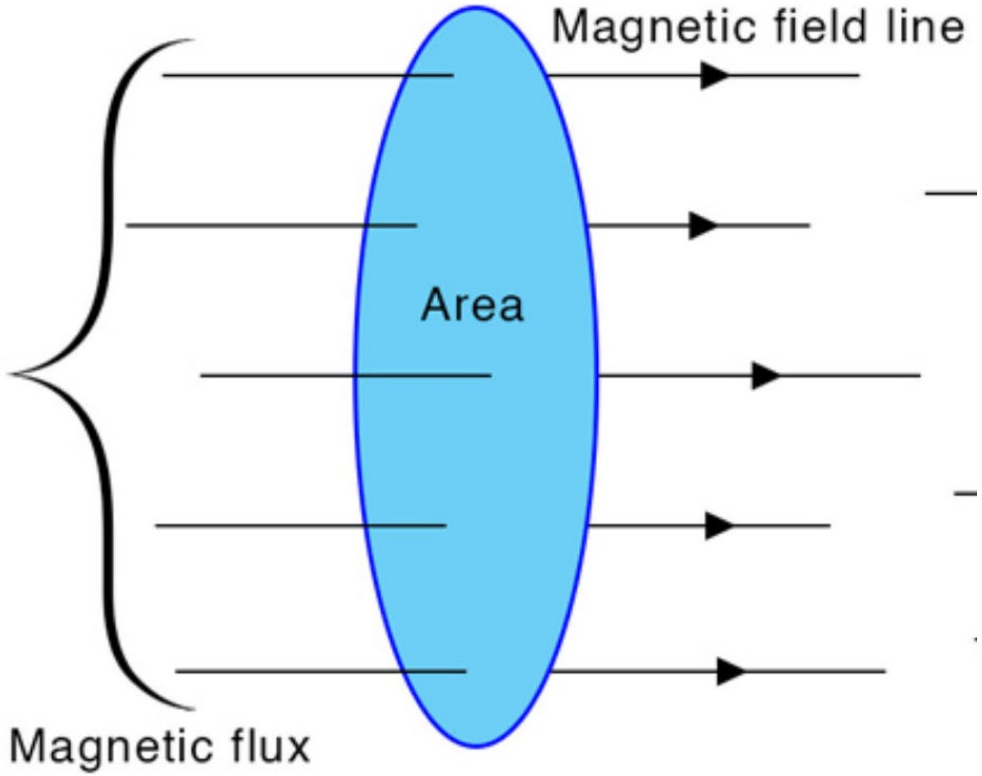
Magnetic Field Lines

- Field lines can't flow between two similarly charged areas (north and north)
- Therefore, if we lay two magnets facing each other their field lines are **squished** due to **repulsion**
- The closer together the magnets get to each other the denser the field lines and thus the **field density increases**



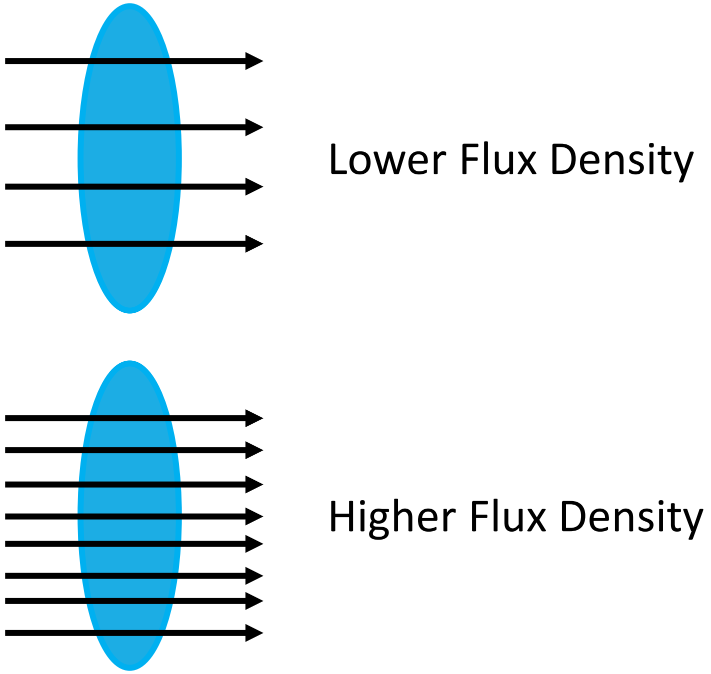
Magnetic Flux

- If we have a given area (say a circle) we can work out how much magnetism is going through it
- The amount of magnetism going through this area is referred to as "flux" which has the symbol Phi "Φ"
- This flux has the unit "wb"



Flux Density

- Flux density is how compact all the field lines are in an area
- Flux density has the symbol B
- It also has the unit T (Tesla)



Relationship Between Flux and Flux Density

- The relationship between flux and flux density is: $B = \frac{\Phi}{A}$
- This can be rearranged to an equation which is found everywhere: $\Phi = BA$
- The units are (Wbm^{-2})

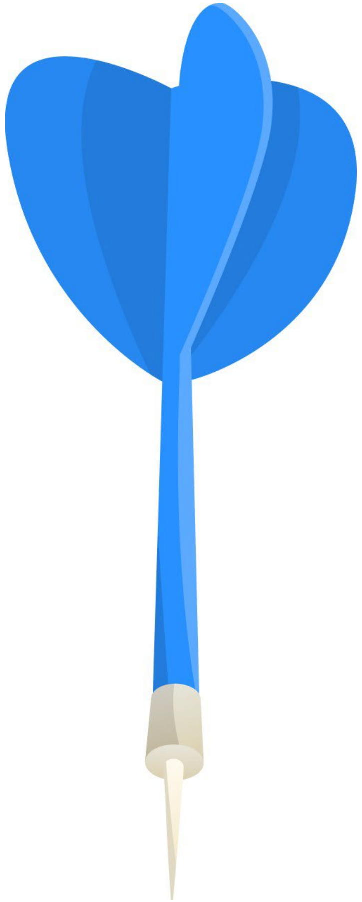
Drawing a 3D system in 2D

- If we need to draw the 3D representation of the system think DARTS

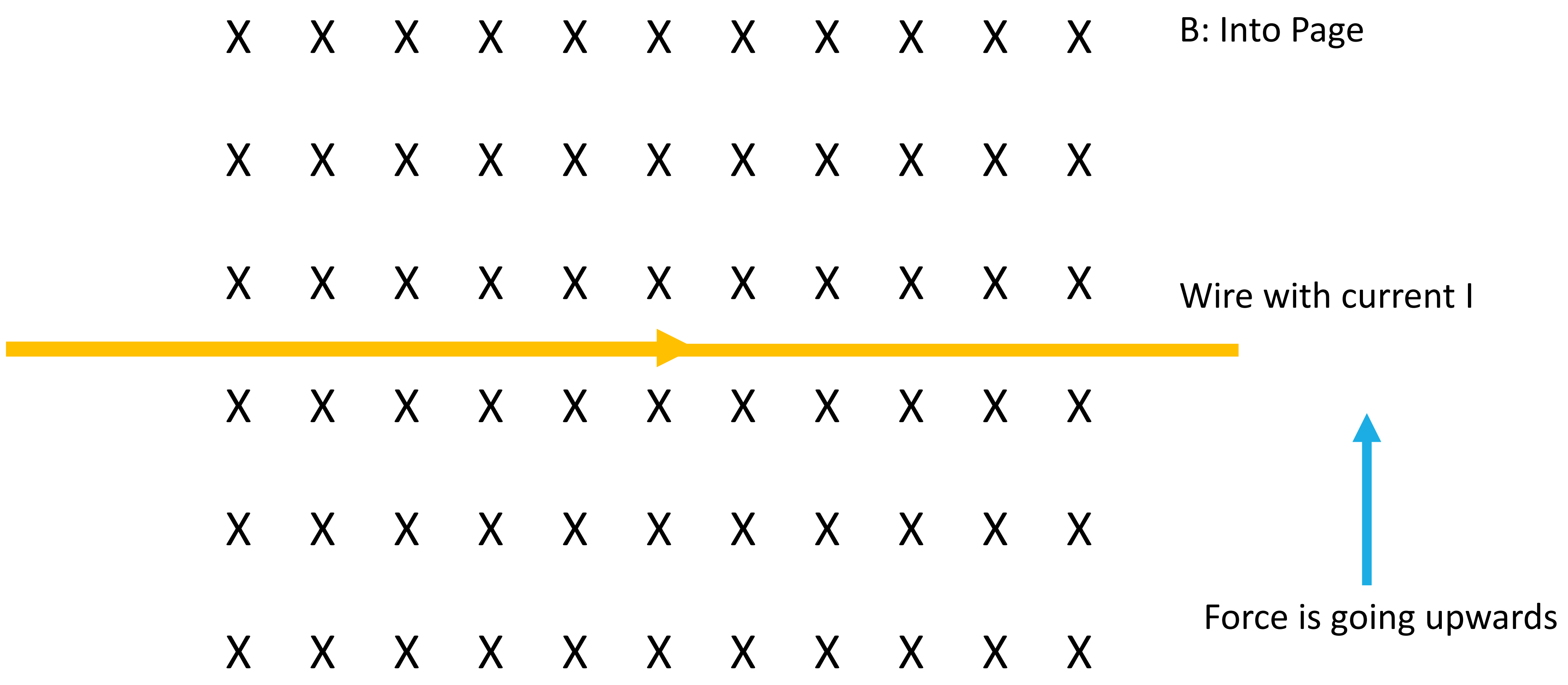
- If the dart is coming for you all you see is a **dot**, if the dart is flying away from you all you see is a **cross**

- A **dot** represents a field coming **out** of the page/plane
- A **cross** represents a field going **into** the page/plane

- Mostly the dot and cross method will be used to display the magnetic field



An example diagram



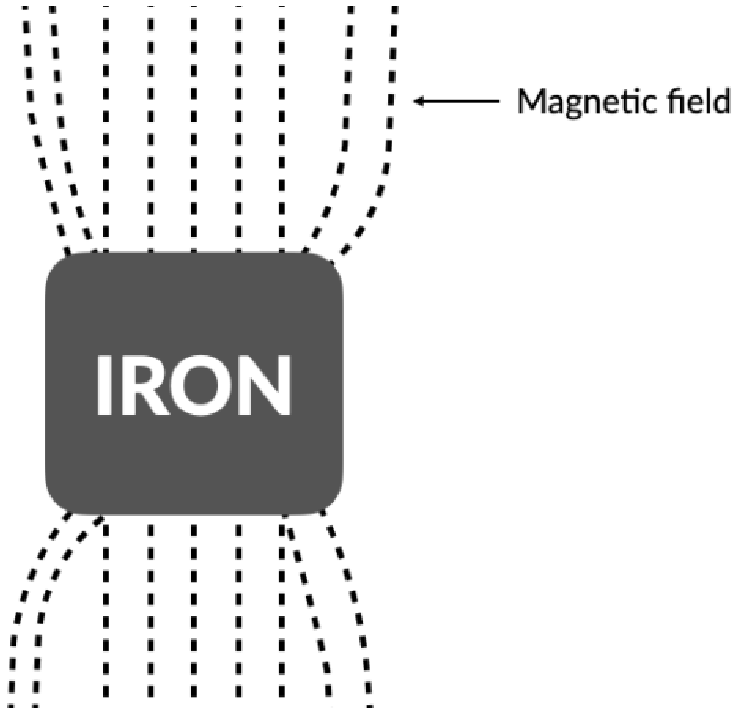
What is permeability

Definition: The ability of a material to support the formation of a magnetic field within itself.

Symbol: Represented by μ (Greek letter "mu").

Formula: $B=\mu H$

where B is magnetic flux density and H is magnetic field strength.



Types of permeability

- **Absolute Permeability (μ)** – Measured in Henries per meter (H/m).
- **Relative Permeability (μr)** – Ratio of a material's permeability to that of free space (μ0).
- **Permeability of Free Space (Vacuum):** $\mu 0 = 4\pi \times 10^{-7}$ H/m.

Relative permeability

- $\mu_r = \frac{\mu}{\mu_0}$
- Air (μr ≈ 1)
- Iron (μr ≈ 1000-5000)
- Soft Ferrites (μr ≈ 10-1000)

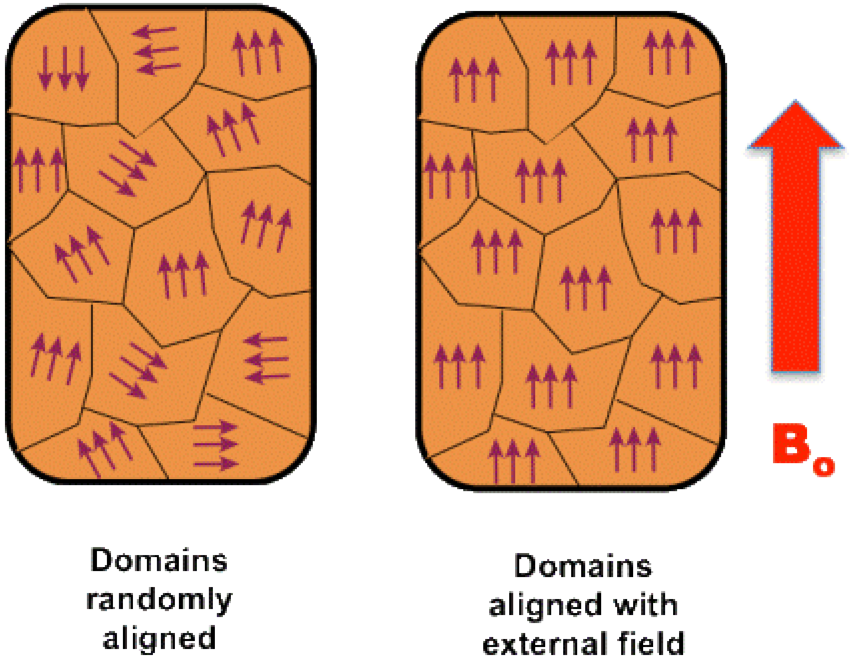
Material	Magnetic Permeability (H/m)
Air	$1.25663753 \times 10^{-6}$
Bismuth	1.25643×10^{-6}
Copper	1.256629×10^{-6}
Iron (pure)	6.3×10^{-3}
Nickle	1.26×10^{-4} – 7.54×10^{-4}
Carbon Steel	1.26×10^{-4}
Hydrogen	1.2566371×10^{-6}
Water	1.256627×10^{-6}
Wood	$1.25663760 \times 10^{-6}$

Your Turn

- **Complete question 1 to 10 on the worksheet**
- **B=μH**
- $\boldsymbol{\mu_r = \frac{\mu}{\mu_0}}$

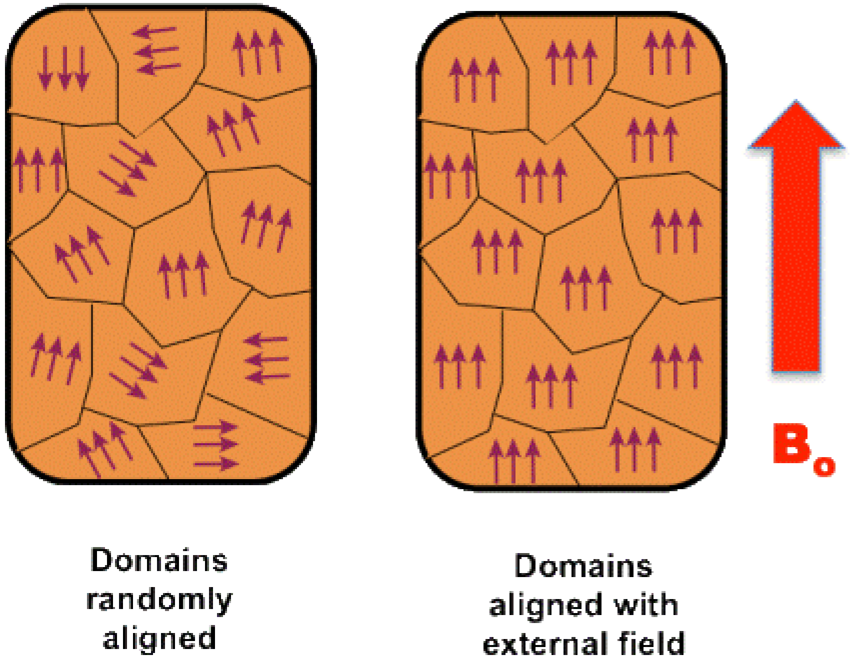
Ferromagnetic Materials

- They are materials that exhibit strong magnetic properties due to magnetic domain alignment.
- Magnetic domain alignment refers to the process in which the microscopic magnetic regions (domains) within a material orient themselves in the same direction under the influence of an external magnetic field.



Ferromagnetic Materials Properties

- High permeability (easily magnetized).
- Exhibit hysteresis (retain magnetism after an external field is removed).
- Can be permanently magnetized.



Examples of Ferromagnetic materials

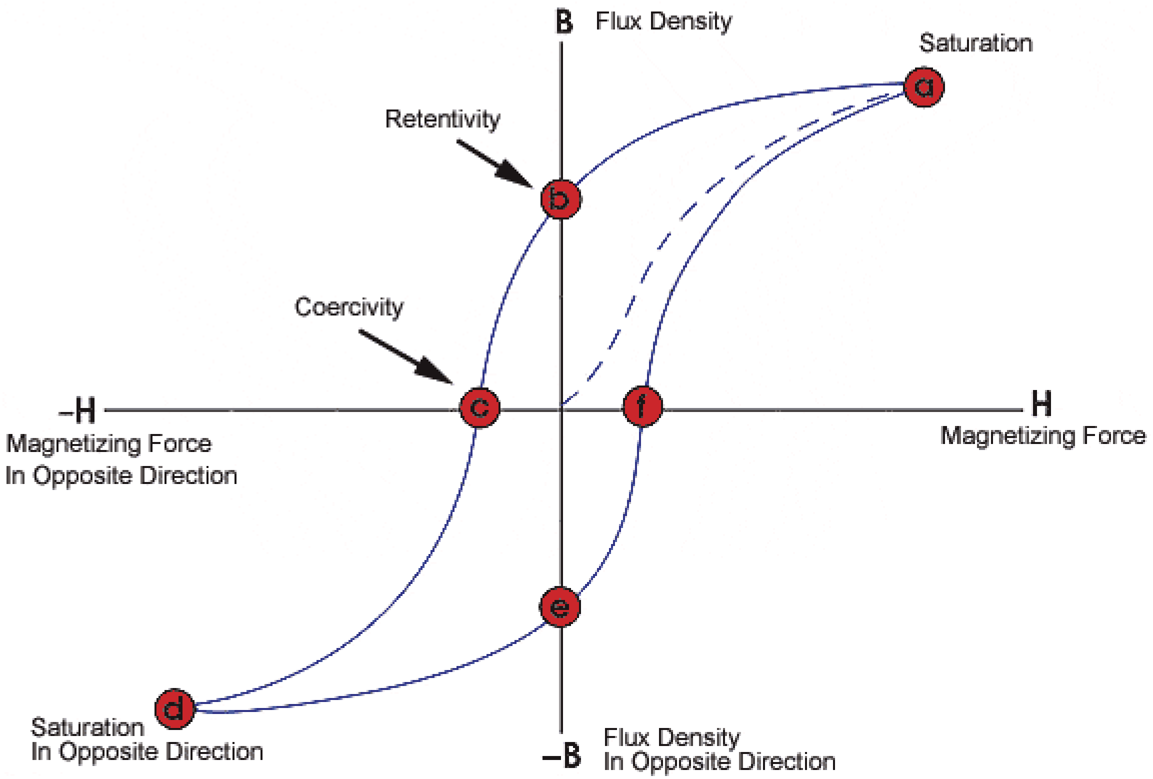
- Iron (Fe)
- Nickel (Ni)
- Cobalt (Co)
- Steel (an alloy mainly of iron)

- Used in transformers, electromagnets, and electric motors.

Hysteresis Loop

- Describes the relationship between the magnetic field strength (H) and the magnetic flux density (B) in a ferromagnetic material as it is magnetized and demagnetized

- This relationship can be mapped out on a graph like the one on the left



Key points of Hysteresis Loop

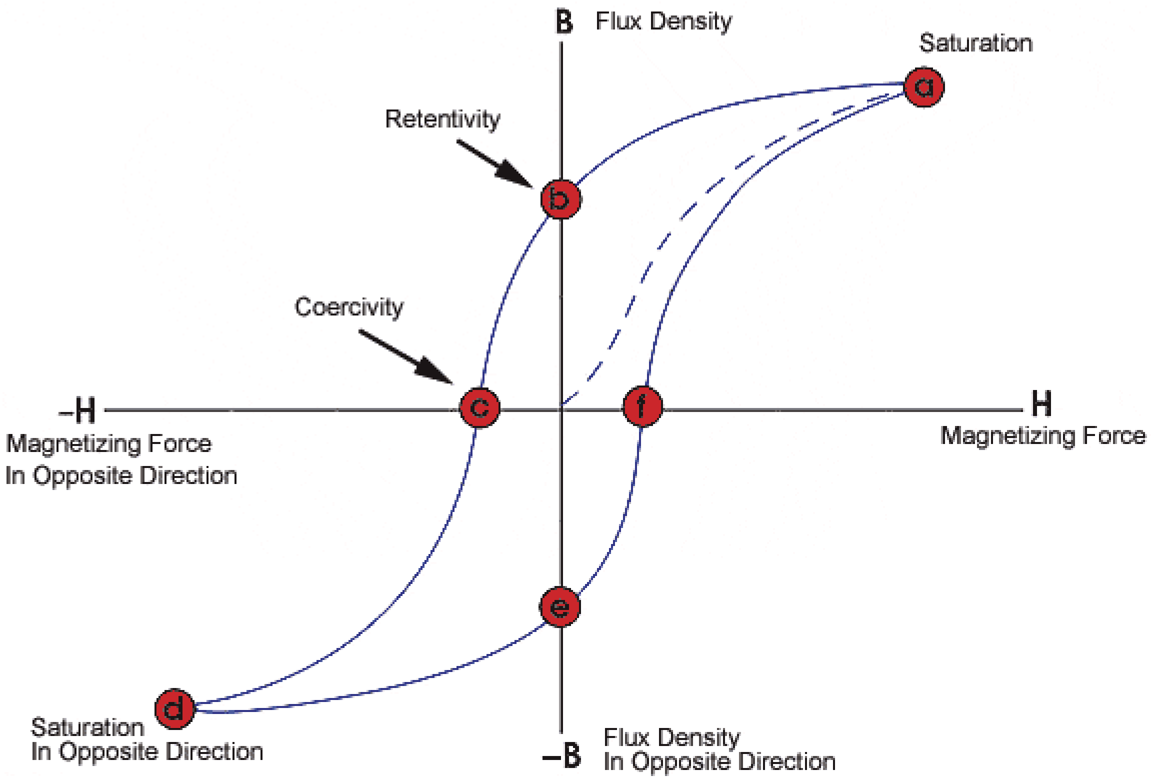
Magnetization (Increasing Field Strength): As an external magnetic field is applied, magnetic domains align, increasing the material's magnetic flux density.

Saturation: When all magnetic domains are aligned, the material reaches saturation, and increasing the field doesn't increase flux density.

Removal of Field (Demagnetization): After the external field is removed, residual magnetization (remanence) remains in the material.

Coercivity (Hc): The magnetic field strength required to demagnetize the material is known as coercivity.

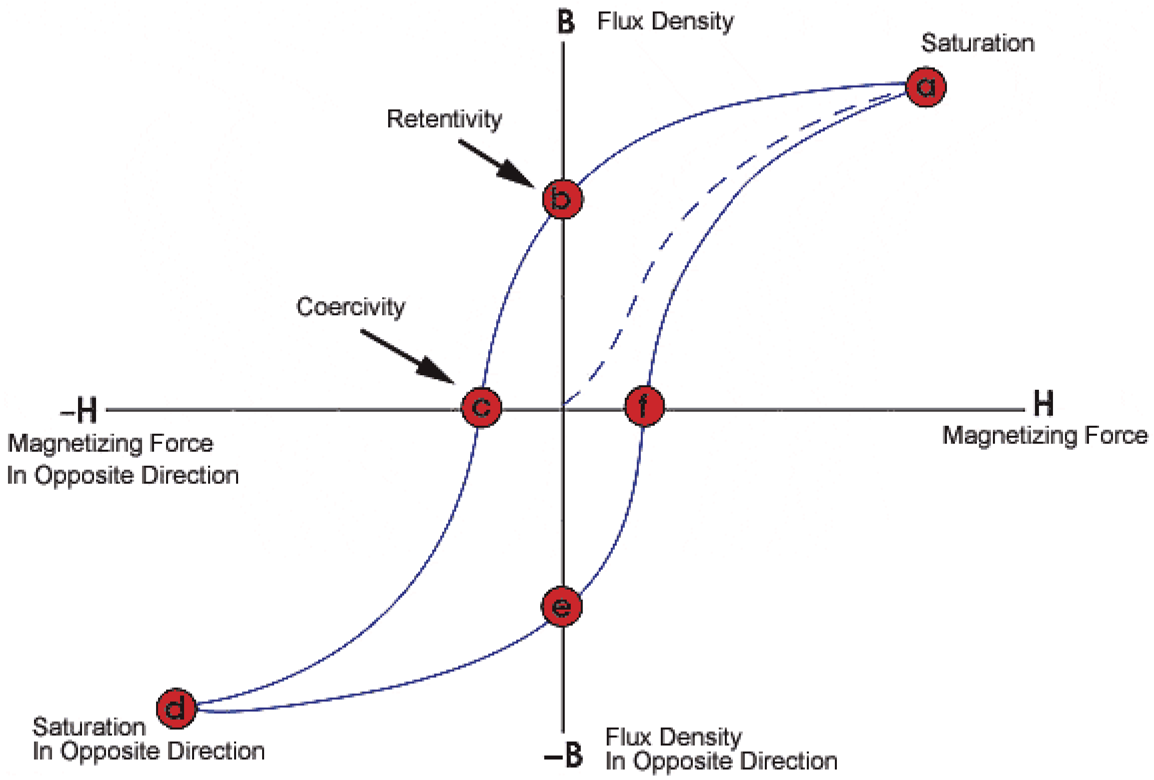
Reversing the Field: When the field is reversed, the flux density follows a different path, completing the loop.



Energy Loss

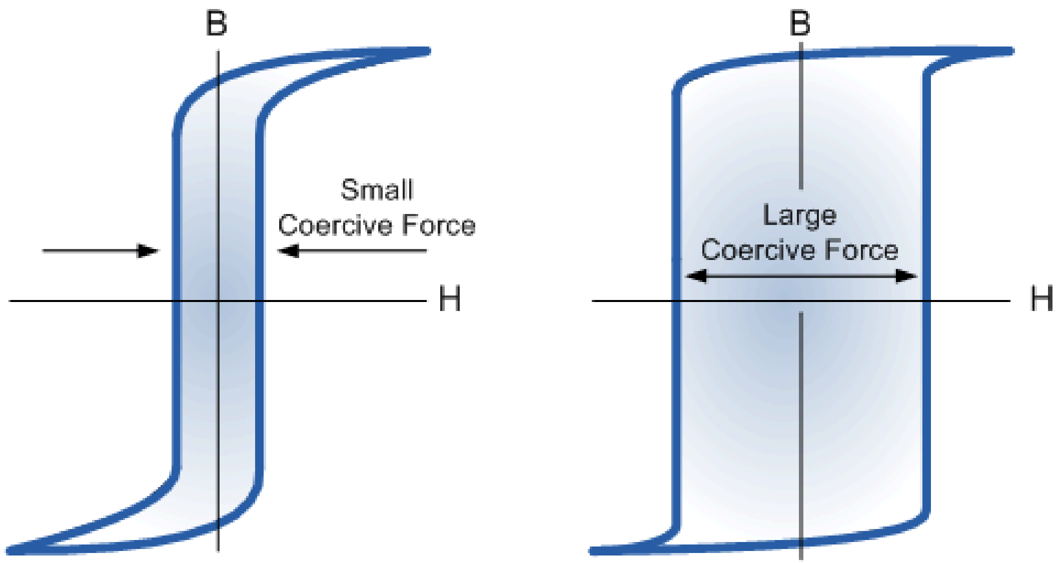
- The area inside the hysteresis loop represents the energy loss due to hysteresis during one complete cycle of magnetization and demagnetization. This energy loss occurs primarily as heat within the material.

- As the external magnetic field changes, the domains in the material must move to realign with the changing field. Some energy is lost due to **friction** between these domain movements, which manifests as **heat**.



Soft vs Hard Hysteresis Loops

- The wideness of the loop shows us how much coercive force is needed
- Softer materials will be narrower
- Harder materials will be wider



"Soft" Ferromagnetic Material

"Hard" Ferromagnetic Material

Factors affecting energy loss

- Material: Hard magnetic materials (like permanent magnets) have larger hysteresis loops and higher energy losses because their domains are harder to move. Soft magnetic materials (like iron or steel) have smaller loops and lower energy losses.

- Frequency of Magnetization: The faster the material is cycled (i.e., the higher the frequency), the greater the energy loss.

Your Turn

- **Please complete the rest of the questions on the worksheet**