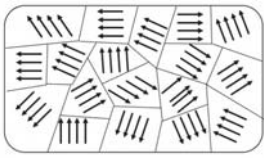
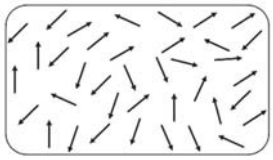
PROPERTIES OF MAGNETIC MATERIALS & HYSTERESIS

Ferromagnetism based on Electron theory

- Like paramagnetic materials, atoms of ferromagnetic materials also possess magnetic moment due to the presence of unpaired electrons.
- Magnetic dipoles interacts strongly with each other and thus, spontaneously align themselves in groups called as domains.



Domain structure in ferromagnetic materials

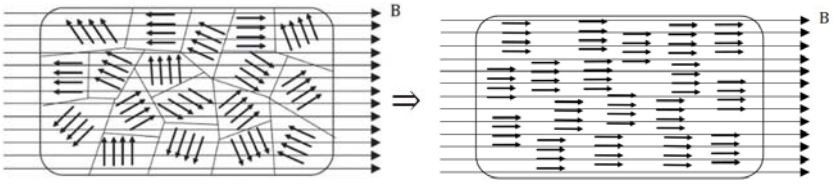


Dipoles in random direction

Case 1: If a strong external magnetic field B is applied

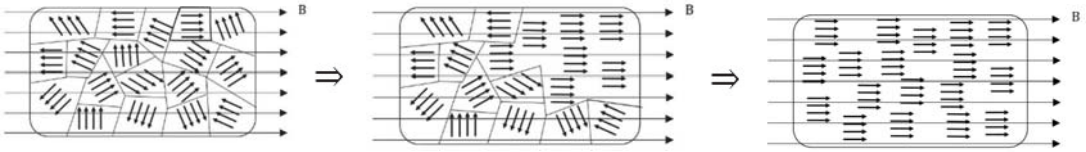
- If the external magnetic field is very strong, then all the domains align themselves along the direction of applied magnetic field. B

Domain alignment with field is shown in the figure



Case 2: If the ferromagnetic material is homogeneous and pure.

- The domains which are already parallel to the external magnetic field expand continually



- Since the dipoles are arranged in groups (domains), very less energy is required to align them along the applied magnetic field. i.e., High Intensity of magnetisation (I) even at low magnetizing intensity (H)

Magnetic Susceptibility (χ_) of Ferromagnetic Materials (Curie – Weiss Law)

For paramagnetic materials $\chi_m \propto \frac{1}{T}$

For Ferromagnetic materials $\chi_m \propto \frac{1}{T-T_c}$

Where T_c = curie temperature

- When a charged particle moves at a right angle to a magnetic field, its kinetic energy stays the same, but its momentum changes because the magnetic force acts perpendicular to the particle's velocity.
- If a unit north pole circles around a wire carrying electric current, work must be done because the magnetic field generated by the current is always non-conservative.
- In a conductor, electrons move freely, but no magnetic force acts on the conductor within a magnetic field because the average thermal velocity of electrons in a conductor is zero.
- The magnetic force between two charges is generally much weaker than the electric force between them because the speeds of charges are much slower than the speed of light in free space.

Properties of Magnetic Materials- Diamagnetic materials

- Diamagnetism is universal property of the substances.
- χ_m is small and negative
- $\mu_r < 1$.

Diamagnetic materials are those that are pushed away by magnets. This happens because they generate negative magnetization. Consequently, the overall magnetic effect is zero in diamagnetic materials. Every element listed in the periodic table exhibits diamagnetic characteristics. However, elements such as copper (Cu), aluminum oxide (Al_2O_3), silicon (Si), and zinc (Zn) show stronger diamagnetic properties.

Properties of Magnetic Materials- Paramagnetic materials

Paramagnetic materials possess a small magnetic effect. This happens because their magnetic influence doesn't fully cancel out. The magnetic moments within paramagnetic substances are arranged in a random manner. Examples of paramagnetic materials include aluminum (Al), chromium (Cr), molybdenum (Mo), titanium (Ti), and zirconium (Zr).

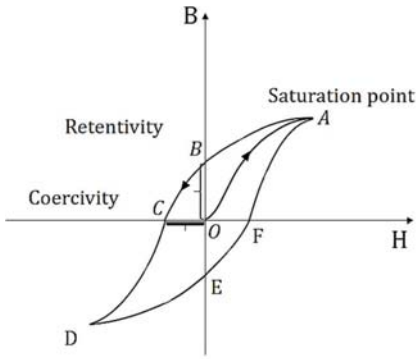
Properties of Magnetic Materials- Ferromagnetic materials

In contrast to certain materials like diamagnets or paramagnets, ferromagnetic substances possess the ability to retain magnetization even after the removal of the magnetic field. This occurrence is termed Hysteresis. Nonetheless, ferromagnetic materials reach a specific temperature known as the Curie point or Curie temperature, beyond which they lose their magnetic properties.

The primary disparity between ferromagnetic and ferri-magnetic materials lies in the arrangement of their magnetic domains. In ferri-magnetic materials, some magnetic domains align in one direction while others align oppositely. Conversely, in ferromagnetic materials, all magnetic domains align in the same direction.

Hysteresis

The phenomenon in which the value of a physical property lags behind changes in the effect causing it.



ABCDEFA:Hysteresis Loop

Energy lost in form of heat during a complete cycle of magnetization and demagnetization.
Area of hysteresis loop $\propto$ Thermal energy developed
Per unit volume of the material in a hysteresis cycle