

Magnetism (Part I)

In this lecture

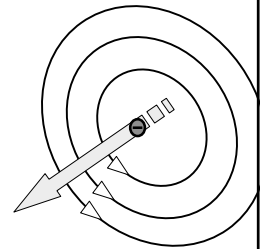
- ★ History of magnetic materials
- ★ Nature of magnetism
- ★ Classification of magnets
- ★ Magnetic susceptibility
- ★ Magnetic laws
- ★ Magnetic poles
- ★ Magnetic Induction

History of Magnetic Materials

- *Magnetite* discovered around 1000BC
- Magnetic oxide Fe_3O_4
- Rod like stone rotates back and forth when suspended on string.
- When it comes to rest it allegedly points the way to water.

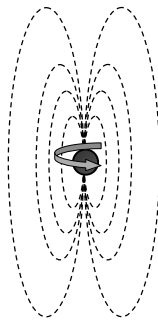
Nature of Magnetism

- Any charged particle in motion creates a magnetic field
- The magnetic field is always perpendicular to the motion of the particle



Nature of Magnetism

- Spinning Charged Particles
- Electron or proton spin creates a magnetic field



Nature of Magnetism

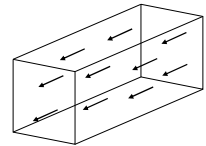
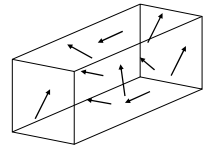
- Lines of magnetic field ALWAYS form a closed loop
- Do not start or end as lines of electric field do
- Such a field is called *bipolar* or *dipolar*
 - Always has a north & south pole

Nature of Magnetism

- Small magnet created by electron or proton spin is called *magnetic dipole*
- Accumulation of many dipoles aligned in same direction creates a *magnetic domain*
- If all magnetic domains in an object are aligned, the object behaves as a magnet

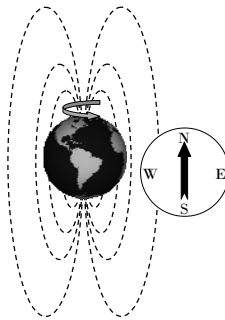
Nature of Magnetism

- Normally magnetic domains are randomly orientated
- When exposed to external magnetic field domains align with field



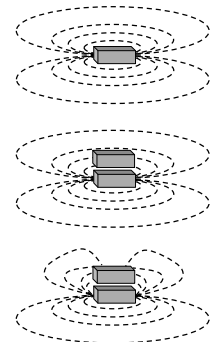
Nature of Magnetism

- Earth has a magnetic field
- Naturally occurring ores (mainly iron) at core
- Which way does a compass needle point at the North Pole?



Nature of Magnetism

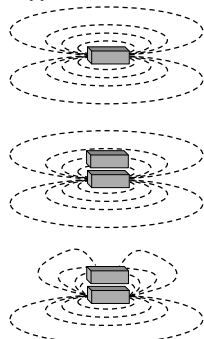
- If a non-magnetic material is brought near magnet no disturbance in fields
- If certain materials (ferromagnetic) are brought near the magnet the field lines deviate and become concentrated into the ferromagnetic material



Nature of Magnetism

Magnetic Permeability

- Permeability μ is a measure of the ease by which a magnetic flux can pass through a material (Wb/Am)
- Can be thought of as the ability of a material to attract the lines of magnetic field intensity
- $\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$



Classification of Magnets

- Three principle types of magnet:
 - Naturally occurring
 - Artificially induced permanent magnets
 - Electromagnets

Natural Magnets

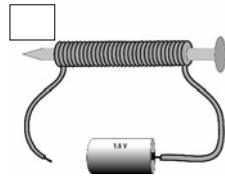
- Example: The Earth
- Earth has a magnetic field because it spins on its axis
- Lodestones of magnetite exhibit strong magnetism because they remained undisturbed in earth's field for a long time

Induced Permanent Magnets

- Permanent magnets can be made by charging them in a strong magnetic field
 - Aligns magnetic domains
- Typically Iron
- Can be demagnetised by heating or shock
 - Causes domains to become misaligned

Electromagnets

- Wire wrapped around iron core
- Current passed through wire produces field
- Field intensity proportional to current



Magnetic Classification

- Materials can be classified by their interaction with magnetic fields
 - Diamagnetic
 - Ferromagnetic
 - Paramagnetic

Diamagnetic

- A material that is unaffected by magnetic fields
- Non-magnetic
- Cannot be artificially magnetised
- Do not experience magnetic force
- Examples:
 - Glass, wood, plastics, ceramics.....

Ferromagnetic

- Strongly attracted by magnets
- Can be permanently magnetised by exposure to magnetic field
- Examples:
 - Iron, cobalt, nickel

Paramagnetic

- Lie between Diamagnetic & Ferromagnetic
- Experience slight magnetic attraction
- Loosely influenced by magnetic fields

- Examples:
 - Gadolinium,
 - Used as contrast agents in MRI

Magnetic Susceptibility

- The degree to which various materials can be magnetized is called the *magnetic susceptibility*
- Plastic placed in magnetic field does not increase field strength: Low magnetic susceptibility

- Iron greatly increase field strength: High magnetic susceptibility

Magnetic Laws

- Magnetic laws have similar form to those for electrostatics
- Similar to those of gravity
- Forces of these three fields are fundamental in nature

- *Grand unified field theory*

Dipoles

- Unlike electricity there is no smallest unit of magnetism

- What happens if you break a magnet in to two?
- Dividing a magnet creates two smaller magnets.

Dipoles

- EVERY magnet has two poles
 - North & South
- Analogous to positive & negative charges

- Unlike electricity, a magnetic monopole can not exist

Attraction & Repulsion

- Like electric charges, magnetic poles attract & repel each other

- Like poles repel
- Unlike poles attract

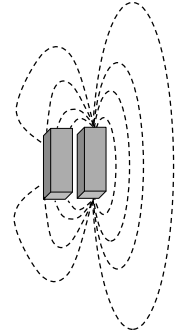
- Field lines also follow convention
 - Leave North pole and return to South pole

Magnetic Induction

- Just as electric charge can be induced from one material to another, a nonmagnetic material can be made magnetic by induction
- Ferromagnetic materials can be made magnetic by induction

Magnetic Induction

- Ferromagnetic material is brought into magnetic field alters field lines
 - Attracted to material
- Material is temporally magnetic
- Where might this be useful in medical imaging?



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Practice Questions

PAM2011: Lecture 7 Problem Sheet

1. List the three types of magnetic material?
2. What is the magnetic property of MRI contrast agents?
3. Where does a compass needle point at the south pole
4. Give an example of how a permanent magnet may become demagnetised
5. Define Magnetic Susceptibility