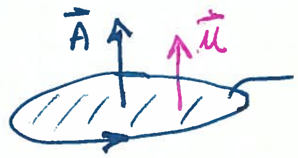
8.02 E+M w/ Lewin | LECTURE 21 | 3/24/2020

Magnetism: Dia, Para, Ferro

- External electric fields can induce electric dipoles
- External magnetic fields can induce magnetic dipoles (atomic level)
    - Magnetic object affects external field

Magnetic Dipole Moment



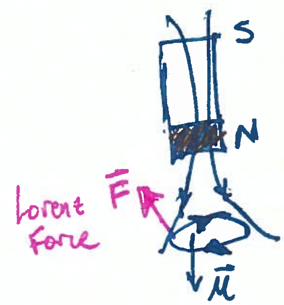
$\vec{\mu} = I\vec{A}$

All materials, when exposed to external magnetic field, will to some degree oppose mag. field. They will generate an EMF at atomic level... note NOT Lenz's Law! (need quantum to really understand this!) } Dia Magnetism

Materials w/ magnetic dipoles but not permanent magnets. when external magnetic field is applied it aligns dipoles. no net mag. field } Para Magne

Paramagnetic materials are attractive

Diamagnetic materials repel applied field



Ferromagnetism

Atoms in material have permanent dipole moments, but, unlike paramagnetism where dipoles are randomly aligned, here they are aligned in one direction so there is a net magnetic field! ($K_m \simeq \chi_m$)

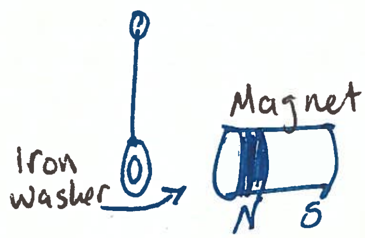
$K_m < 1$ Diamagnetic

$K_m > 1$ Paramagnetic

$\vec{B} = K_m \vec{B}_{vaccuum}$ — $\vec{B}$: B-field inside material; K_m: relative permeability

$K_m = 1 + \chi_m$ — χ_m: Magnetic Susceptibility; K_m: Relative Permeability

Demonstration

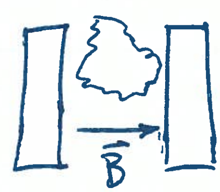


Iron washer (ferrous material) on wire is attracted to the magnet bc ferromagnetism. When heated, the washer becomes paramagnetic and magnetic force is lower and not attracted to magnet

Paramagnetic materials have low attractive forces
ferromagnetic materials have high attractive forces

Demonstration

Showed that liquid oxygen is paramagnetic and is suspended between plates in strong magnetic field. Liquid Nitrogen does not do the same!



lecture over

Magnetic Permeability: the ability of a material to respond to how much electromagnetic flux it can support to pass through it AKA it's the degree of magnetization capability

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

magnetic permeability (μ) is the ratio of magnetic flux density (B) to its electromagnetizing force (H)

Magnetic Susceptibility: the measurement of the extent to which a substance can be magnetized by applying an external mag. field.

$$\chi = \frac{M}{H}$$

magnetic susceptibility (χ) is the ratio of magnetic dipole moment (M) to magnetic field strength (H)