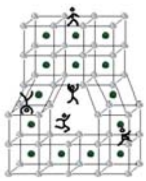
Dielectrics & Magnetism



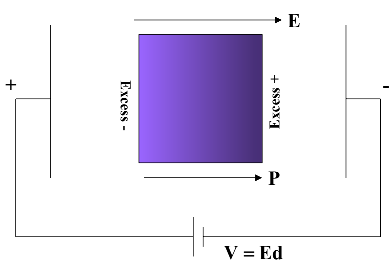
Monday,
Nov. 17, 2003

MATS275: INTRODUCTION TO MATERIALS SCIENCE

- An Insulator in a Field
- Magnetic Fields and Inductions
- Magnetic Materials
  - Diamagnetic
  - Paramagnetic
  - Ferromagnetic

In an E Field

- Put a material in an external E Field:



Polarization & Field

- The polarization will be related to the field…

$$\mathbf{P} = \mathbf{N}\mathbf{p} = \underbrace{\chi_e}_{\text{Susceptibility}}\varepsilon_0 \mathbf{E}$$

recall

$$\mathbf{E} = \frac{\sigma}{\varepsilon_0}$$

- Define the Displacement

$$\vec{\mathbf{D}} = \varepsilon_0 \vec{\mathbf{E}} + \vec{\mathbf{P}}$$

The Electric Displacement

- The displacement is related to the field:

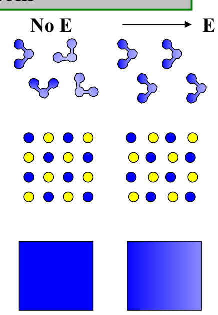
$$\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$$
$$= \varepsilon_0 \vec{E} + \chi_e \varepsilon_0 \vec{E}$$
$$= (1 + \chi_e)\varepsilon_0 \vec{E}$$
$$= \varepsilon_r \varepsilon_0 \vec{E}$$

$$P = \chi_e \varepsilon_0 E = (\varepsilon_r - 1)\varepsilon_0 E$$

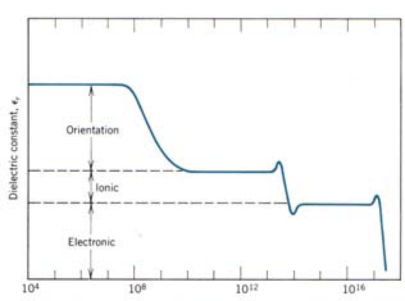
Dielectric constant → **Related to how easily polarized the material is**

Polarization
Where it come from

- Orientation
  – example - ice
- Ionic
  – example - AgCl
- Electronic
  – example - metals



Frequency Dependence

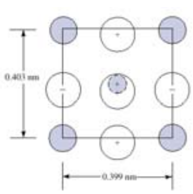


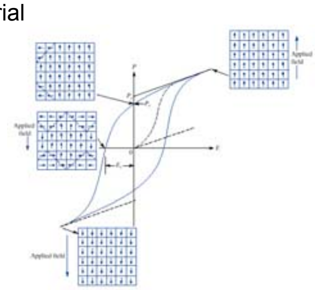
Dielectric Constants

	60 Hz	1 MHz	Strength
Titanates	-	15-10,000	>2 MV/m
Mica	-	5.4-8.7	>40
Silica	4.0	3.8	9.8
Nylon	4.0	3.6	15

$BaTiO_3$

- Ferroelectric Material





The Magnetic Field

- Applied Field - H (A-turn/m)
- Magnetic Induction - B (T= Wb/m^2)

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

- Example - solenoid...

$$B = \mu_0 n I \qquad H = nI$$

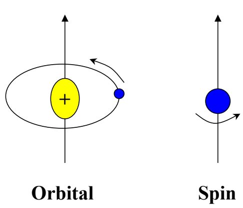
Magnetization

$\vec{B} = \mu \vec{H}$ $\qquad\qquad$ $\vec{B} = \mu_0 \left(\vec{H} + \vec{M} \right)$

$$\vec{M} = \chi_m \vec{H}$$
$$\vec{B} = \mu_0 \vec{H} + \mu_0 \chi_m \vec{H}$$
$$\vec{B} = \mu_0 (1 + \chi_m) \vec{H}$$
$$\vec{B} = \mu_r \mu_0 \vec{H}$$

Magnetization
Where it comes from

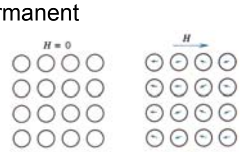
- Magnetic fields created by moving charges:



$$\mu_B = 9.27 \times 10^{-24}\, \text{A} \cdot \text{m}^2$$

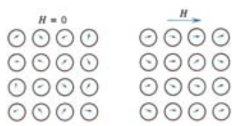
Type of Magnetic Material

- Diamagnetic
  - no unpaired spins
  - χm<0, μr slightly less than 1
  - magnetization opposes applied field
  - not permanent



Type of Magnetic Material

- Paramagnetic
  - unpaired spins
  - $\chi_m>0$, μ_r slightly more than 1
  - magnetization adds to applied field
  - non-permanent



Type of Magnetic Material

- Ferromagnetic
  - unpaired spins
  - $\chi_m>>0$, μ_r much more than 1
  - magnetization adds to applied field
  - history dependent

Hysteresis