# Lecture 29 outline: 10/26/2020

- Discord server exists
- HW06 … break till Wed.
- HW07 change to Friday (10/30)

Chapter 4

- Force and torque on dipole
  - Problem RS 7-07, 7-05
- Electric fields in matter
  - Dielectrics and Electrets
  - Polarization
  - Bound Charges
    - RS 7-09

# Force and Torque on a dipole

$$\vec{N} = \vec{p} \times \vec{E}$$

$$\vec{F} = \left(\vec{p} \cdot \nabla\right) \vec{E}$$

Problem RS 7-07   Force between charge and induced dipole.

# Problem RS 7-05 Torque induced by dipoles on eachother

# Electric Fields in Matter

$$\vec{p} = \alpha \vec{E}$$

Alpha is called “polarizability”

$$\vec{P} = N \vec{p} = N \alpha \vec{E}$$

Polarization is dipole moment/volume

$$\vec{P} \stackrel{\text{def}}{=} \epsilon_0 \chi_E \vec{E}$$

Chi is called “electric susceptibility”

$$\epsilon \stackrel{\text{def}}{=} \epsilon_0 (1 + \chi_E)$$

Epsilon is called “permittivity”

$$\epsilon_r \stackrel{\text{def}}{=} (1 + \chi_E)$$

Epsilon_r is called “relative permittivity” or “dielectric constant”

Units Check

$$\vec{p} = \alpha \vec{E}$$

$$\vec{P} = N \vec{p} = N \alpha \vec{E}$$

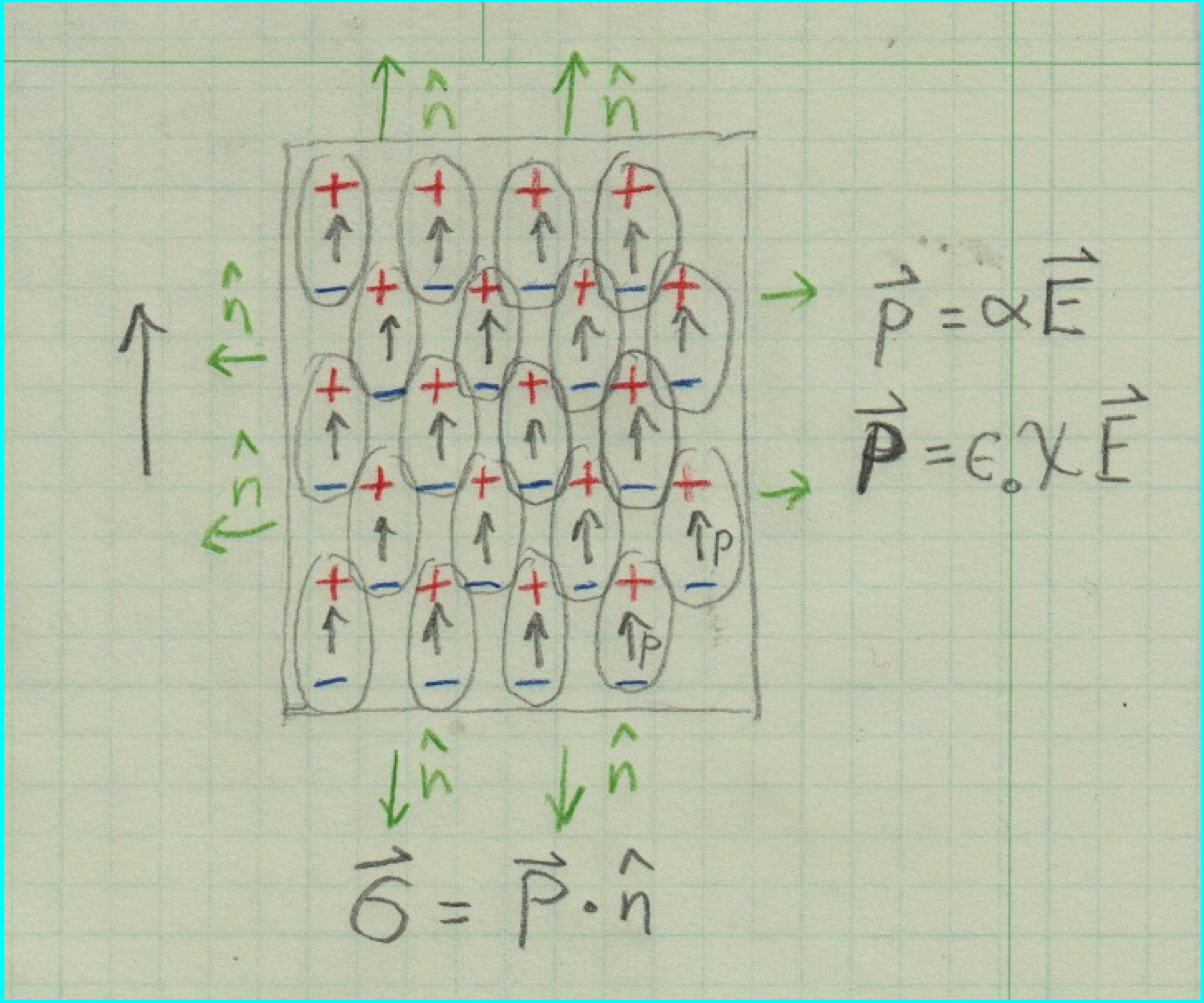
$$\vec{P} \stackrel{\text{def}}{=} \epsilon_0 \chi_E \vec{E}$$

$$\epsilon \stackrel{\text{def}}{=} \epsilon_0 (1 + \chi_E)$$

$$\epsilon_r \stackrel{\text{def}}{=} (1 + \chi_E)$$

# Polarization = Dipole moment per Volume

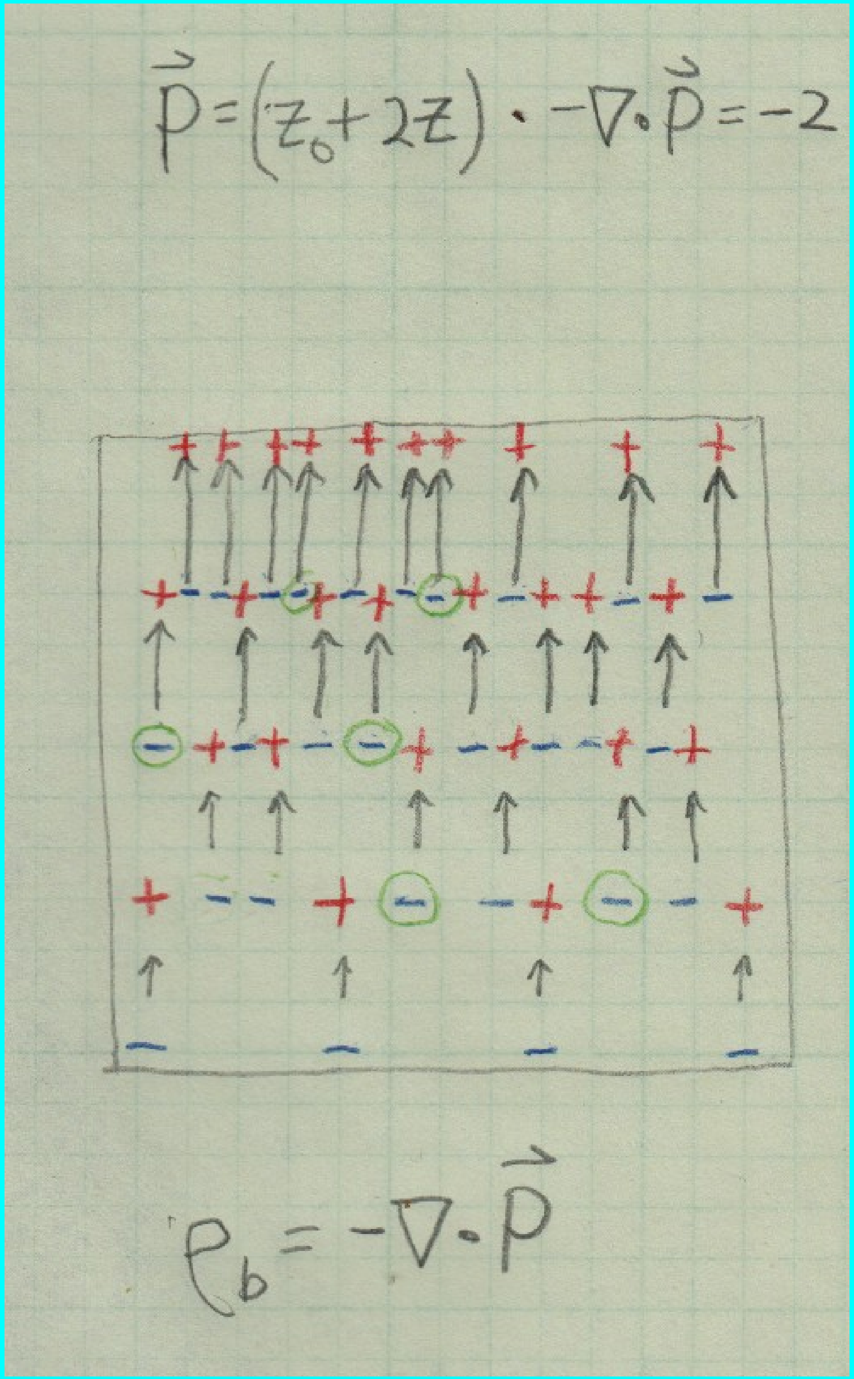
$\sigma_B = \vec{P} \cdot \hat{n}$



# Dielectrics and Electrets

# Polarization = Dipole moment per Volume

$$\rho_B = -\nabla \cdot \vec{P}$$



Real similar to RS 7-09

Imagine a cube centered at origin with polarization $\vec{P} = P_0 y x \hat{x}$

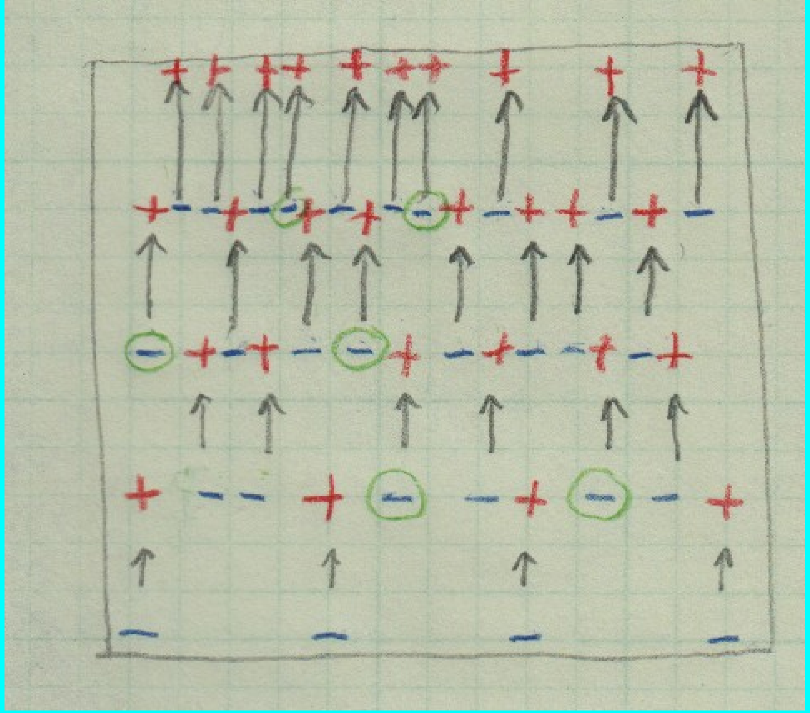
The cube has side “a”

What is the bound surface and volume charge on the cube?

$$\rho_B = -\nabla \cdot \vec{P}$$

$$\sigma_B = \vec{P} \cdot \hat{n}$$

# Gauss with Free and Bound Charge



$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

$$\rho = \rho_{Free} + \rho_{Bound}$$

$$\rho_{Bound} = -\nabla \cdot \vec{P}$$

$$\epsilon_0 \nabla \cdot \vec{E} = \rho_F - \nabla \cdot \vec{P}$$

$$\nabla \cdot \epsilon_0 \vec{E} = \rho_F - \nabla \cdot \vec{P}$$

$$\nabla \cdot (\epsilon_0 \vec{E} + \vec{P}) = \rho_F$$

$$(\epsilon_0 \vec{E} + \vec{P}) \stackrel{def}{=} \vec{D}$$

$$\nabla \cdot \vec{D} = \rho_F$$

$$\int \vec{D} \cdot d\vec{A} = Q_{Free}$$