Lecture 27 outline: 10/21/2020

Chapter 4

- Electric fields in matter
- Polarizability
- Polarization
- Bound Charges
- Gauss's law with bound charges

Electric Fields in Matter

Neutral atoms may be polarized

$\vec{p} = \alpha \vec{E}$ Alpha is called "polarizability"

$\vec{P} = N \vec{p} = N \alpha \vec{E}$ Polarization is dipole moment/volume

To keep things clear

$\vec{P} \stackrel{\text{def}}{=} \epsilon_0 \chi_E \vec{E}$ Chi is called "electric susceptibility"

In case you aren't confused

$\epsilon \stackrel{\text{def}}{=} \epsilon_0 (1 + \chi_E)$ Epsilon is called "permittivity"

$\epsilon_r \stackrel{\text{def}}{=} (1 + \chi_E)$ Epsilon_r is called "relative permittivity" or "dielectric constant"

Units Check

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

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

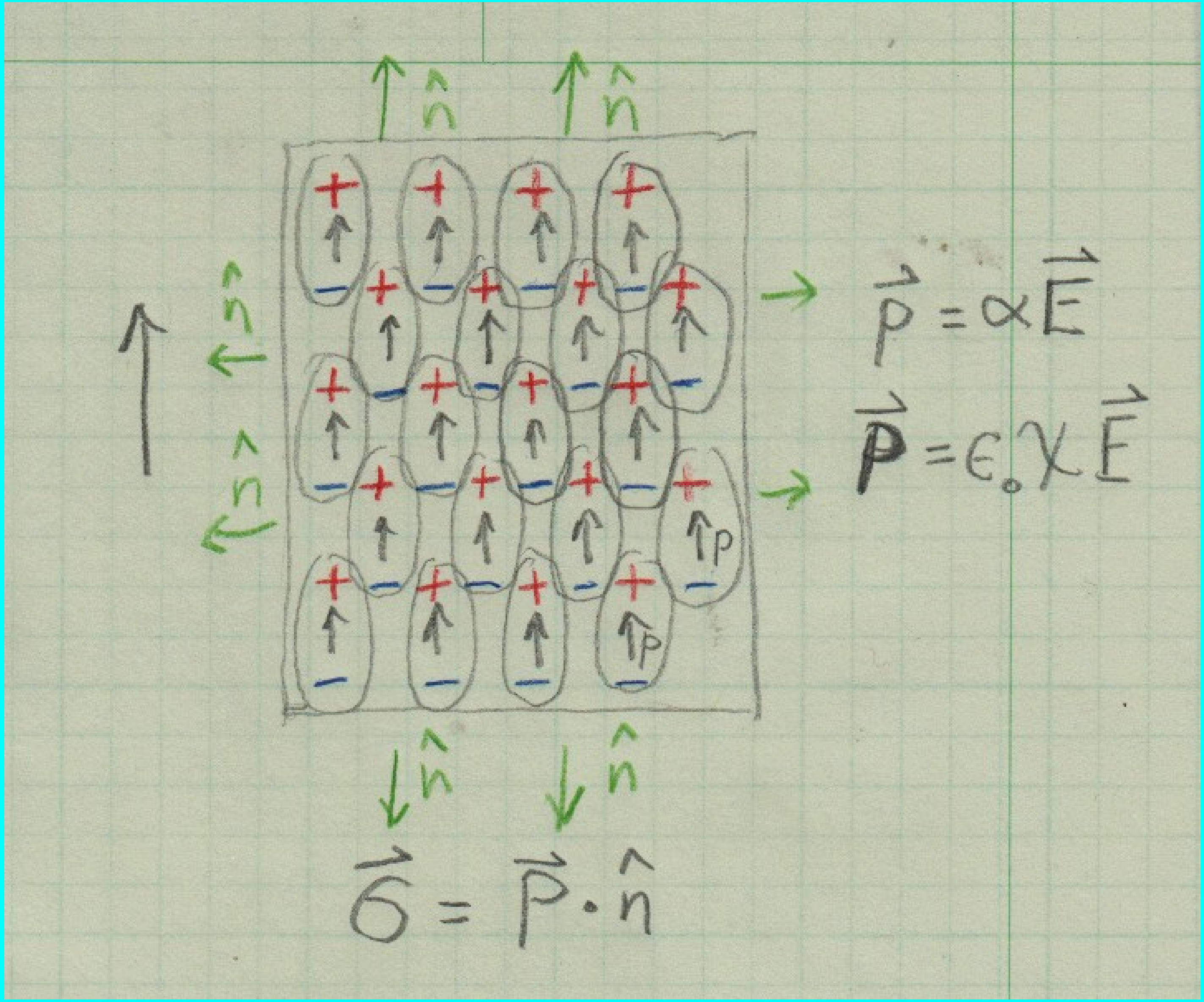
$$\vec{P} \stackrel{\text{def}}{=} \epsilon_0 \chi_E \vec{E}$$

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

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

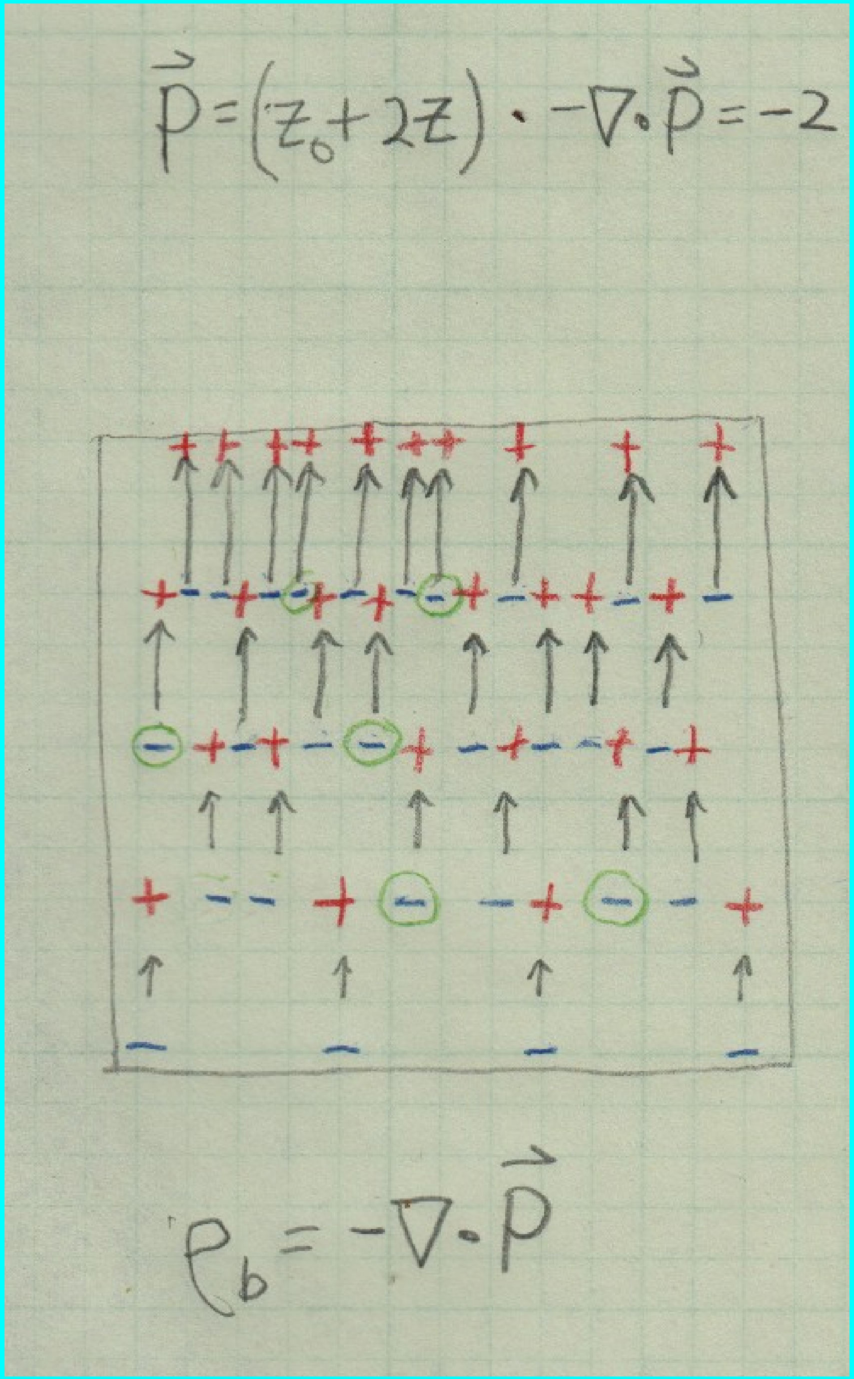
Polarization = Dipole moment per Volume

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



Polarization = Dipole moment per Volume

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

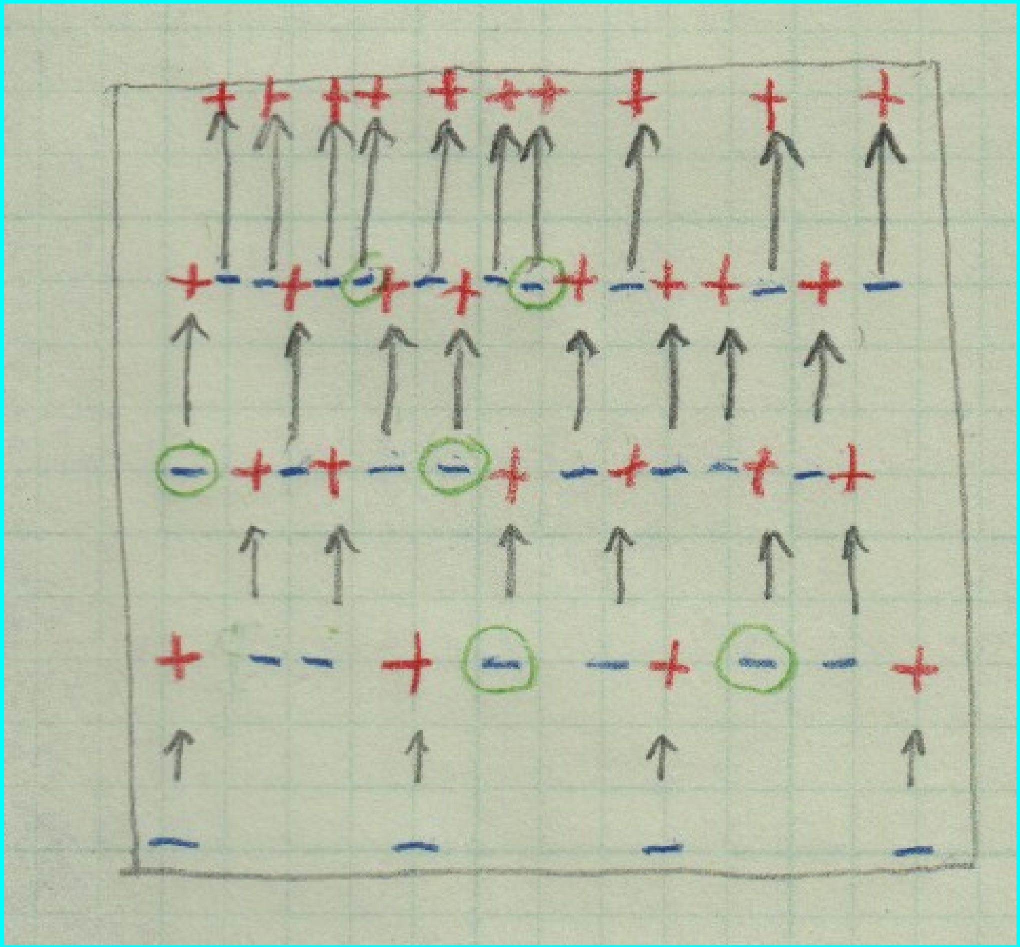


Imagine a cube centered at origin with polarization $\vec{P} = kyx\,\hat{x}$

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

Gauss with Free and Bound Charge

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



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

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

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

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

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

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

$$\nabla \cdot \vec{D} \stackrel{\text{def}}{=} \rho_F$$