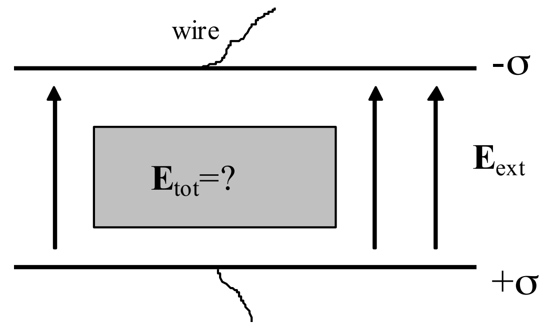
✭ "LEC-TORIAL:" SQUINTING CLOSELY AT PLASTIC ✭
Polarization & Bound Charge

Part 1 – Polarization and Bound Charge

A slab of plastic is placed within a charged capacitor. Before inserting the plastic, there is a uniform electric field inside the capacitor, $\mathbf{E}_{ext}$. Let's explore the properties of a dielectric to find the (total) electric field $\mathbf{E}_{tot}$ inside the plastic.



i. (Together as a class:) *Extreme close-up!* At right, sketch a cartoon of the first few rows of atoms inside the plastic. Think of many negative charges "-*q*," each bound to a fixed positive core "+*q*," with a spring constant *k*. Each "-*q*" charge is displaced from the core by a distance Δz.

   a. Write an expression for the magnitude of the dipole moment **p** of each "atom":

ii. (Together as a class:) *Not-so-extreme close-up.* Back to a model with smooth, continuous charge distributions…. Draw a sketch of the plastic showing where the net charge is positive, negative, and zero.

iii. (In your groups:) If there are *N* atoms per unit volume in the plastic (each with a +*q* and a –*q* charge) write simple expressions for:

   a. the volume charge densities ρ^+ (this is some sort of "smeared" average volume charge density arising just from the +q's) and ρ^-

   b. the volume dipole moment density (total dipole moment per unit volume), a.k.a. the *polarization* **P. (Note:** this is a vector! Which way does it point here?)

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iv. (In your groups:) When using a continuous model of charge densities, you should have found that the top surface of the plastic has an overall net charge found within a thin layer of area A and thickness Δz just inside the surface. Find the *surface charge density* of this thin layer.

v. (In your groups:) The surface-charge density you found above is called the *bound-charge density,* σ_B. Rewrite your expression so that it is in written in terms of **P.**

vi. (Together as a class): Is your result for **P** consistent with the relationship $\boxed{\sigma_B = \vec{P} \cdot \hat{n}}$? Be sure to check **all surfaces** (top, bottom, and sides) of the plastic!

Part 2 – Electric Fields in Dielectric Materials (or Insulators)

(All parts together as a class.) For our purposes here, there are *three* (!) E-fields to keep track of:

- The uniform electric field $\mathbf{E}_{ext}$ inside the capacitor before we inserted the plastic.
- The induced electric field $\mathbf{E}_{ind}$ caused by the bound charge densities in the plastic.
- The total electric field $\mathbf{E}_{tot}$.

i. Write a *vector* equation relating all three fields:

ii. Write a separate *vector* expression for the induced electric field, $\mathbf{E}_{ind}$, inside the plastic slab in terms of **P**. (*Hints:* How is $|\mathbf{E}_{ind}|$ related to σ_B? How is its direction related to that of **P**?)

iii. Combine your results from parts i and ii to write a *vector* equation relating $\mathbf{E}_{ext}$, $\mathbf{E}_{tot}$ and **P.**

iv. Griffiths defines a quantity $\boxed{\mathbf{D} = \varepsilon_o \mathbf{E} + \mathbf{P}}$ **,** where **D** is the called the "electric displacement field," or simply the "D field." Look at your answer to part iii – think about how you might interpret the meaning of **D**.

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