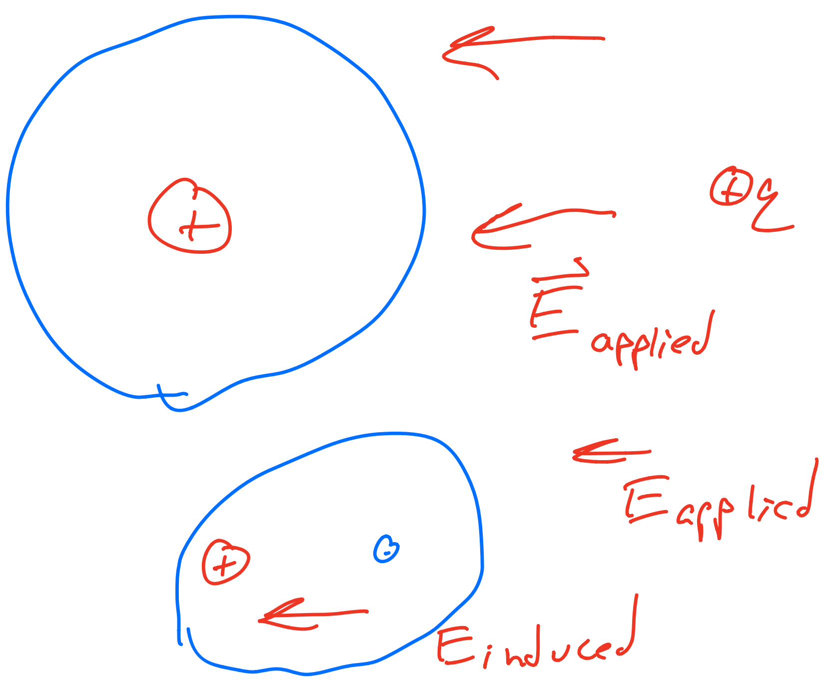
Review of Wed:

- How do charges behave within matter?
  - Charge by contact, tape
- How is neutral matter affected by $\vec{E}$ fields?

Polarization



Electric dipole moment

$p = qs$

$p_{induced} = \alpha E_{applied}$

atomic polarizability

Carbon $\alpha \sim 10^{-40} \frac{Cm}{N/C}$

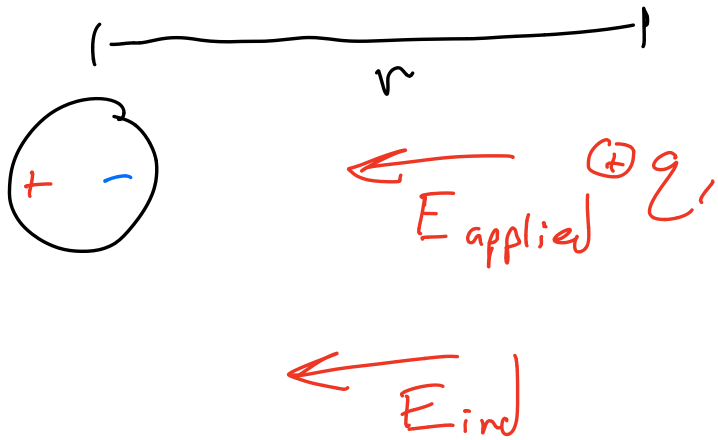
α is tiny but w/ many atoms it adds up

Example

Neutral Atom + pt charge

Force on q_1?

$$|\vec{F}_1| = q_1 E_{induced}$$



E_{ind}?

Dipole on-axis

$$E_{ind} = \frac{1}{4\pi\epsilon_0} \frac{2p_{ind}}{r^3}$$

$$p_{ind} = \alpha E_{applied}$$

$$E_{ind} = \frac{1}{4\pi\epsilon_0} \frac{2\alpha E_{applied}}{r^3}$$

$E_{applied}$?

Field of pt chg

$$E_{app} = \frac{1}{4\pi\epsilon_0}\frac{q_1}{r^2}$$

$$E_{ind} = \frac{1}{4\pi\epsilon_0}\frac{2\alpha}{r^3}E_{app}$$

$$= \left(\frac{1}{4\pi\epsilon_0}\frac{2\alpha}{r^3}\right)\left(\frac{1}{4\pi\epsilon_0}\frac{q_1}{r^2}\right)$$

$$E_{ind} = \left(\frac{1}{4\pi\epsilon_0}\right)^2 \frac{2\alpha q_1}{r^5}$$

$$F_1 = q_1 E_{ind}$$

$$F_1 = \left(\frac{1}{4\pi\epsilon_0}\right)^2 \left(\frac{2\alpha q_1^2}{r^5}\right)$$

Direction?

$+ \; - \qquad \longleftarrow \qquad \bullet\, +q_1$

$- \; + \qquad \longrightarrow \qquad \bullet\, -q_1$

towards the dipole?

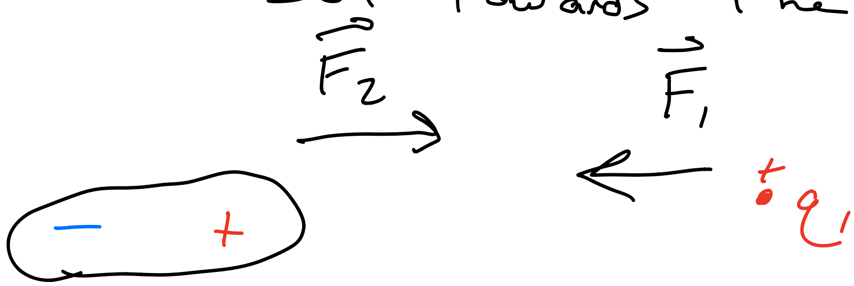
F_1 = Force acting on q_1

What is F_2, force acting on neutral atom?

Newton's 3rd Law

$$\vec{F}_2 = -\vec{F}_1$$

Same magnitude force, but towards the charge



Q: Can a charged object ever repel a neutral object?

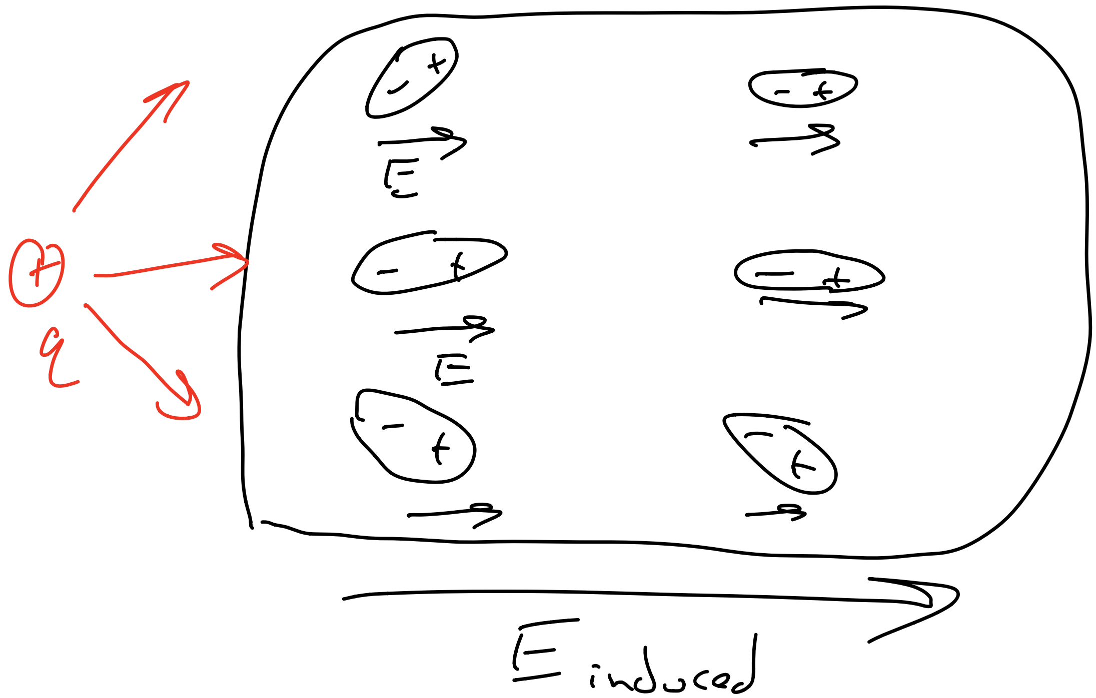
NO!

- Today we want to take a closer look at how applied electric fields affect matter
  - We've used the example of a neutral atom whose electron cloud is slightly shifted by the applied field
  - Not all atoms keep a tight hold over their outer electrons!
    - This has important effects
  - We need to analyze this type of material separately
- Broadly speaking, we talk about two different types of materials
  - Insulators
  - Conductors

Conductors	Insulators
- Mobile charges free to move throughout material	- Tightly bound electrons; no mobile charge

- So far, we've dealt with insulators
  - Electrons can "shift" (~10^-10 meters) but are not free to move about anywhere

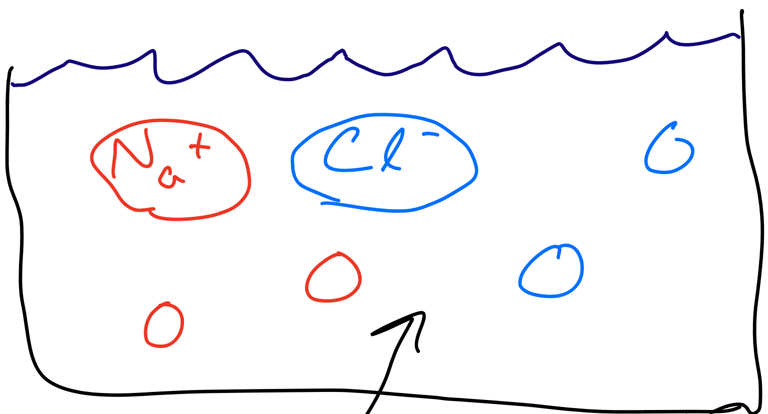
Polarized Insulator



- Excess charge on an insulator:
    - Charge "stays put" doesn't move
    - Do rod demo
        - Like charge to like charge = repel
        - What if I hold up the other end of the rod?
        - Attraction
        - I charged it on one side, but the charges didn't move

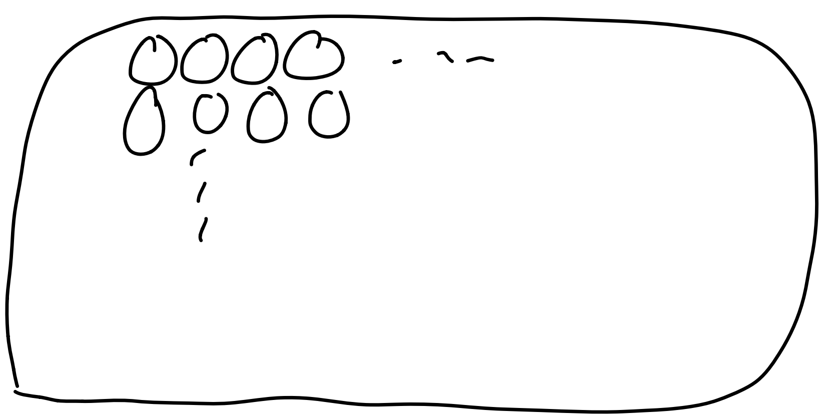
Conductors

Ex: Salt water

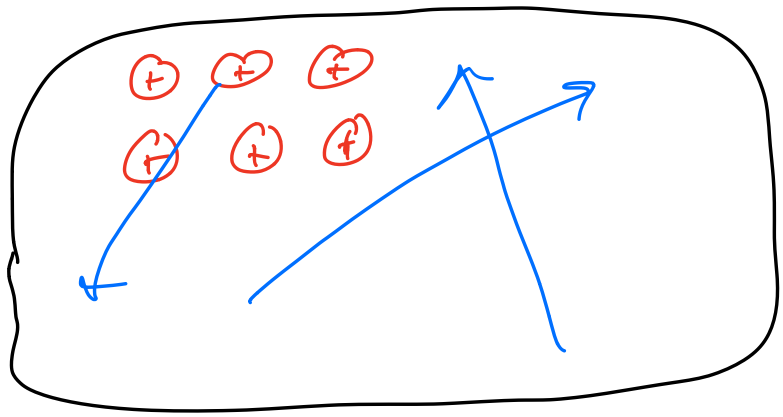


Mobile charges

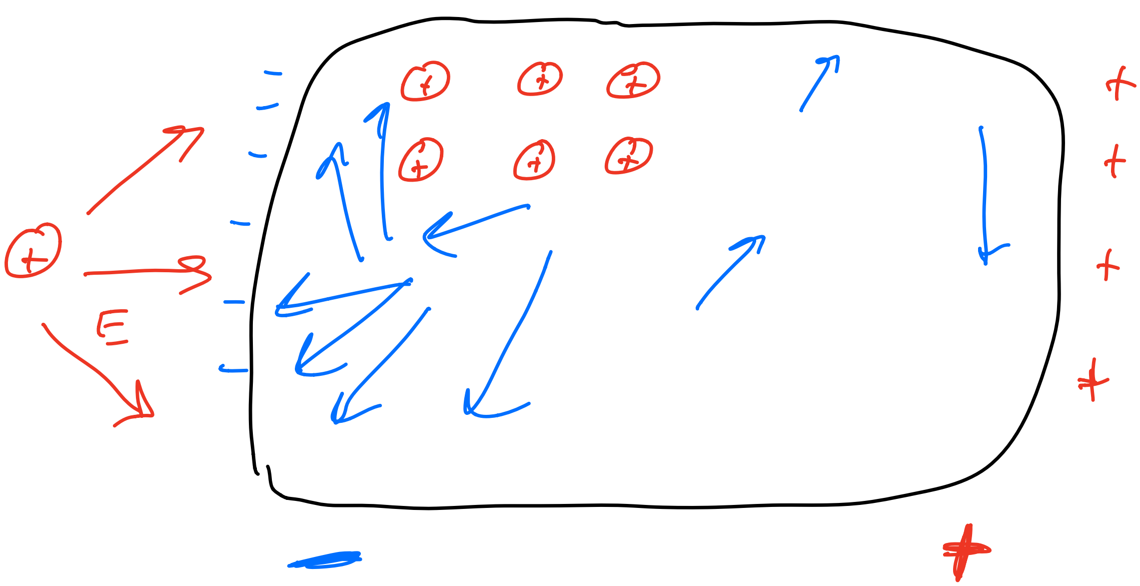
Ex: Metals



Each atom gives up
at least 1 electron



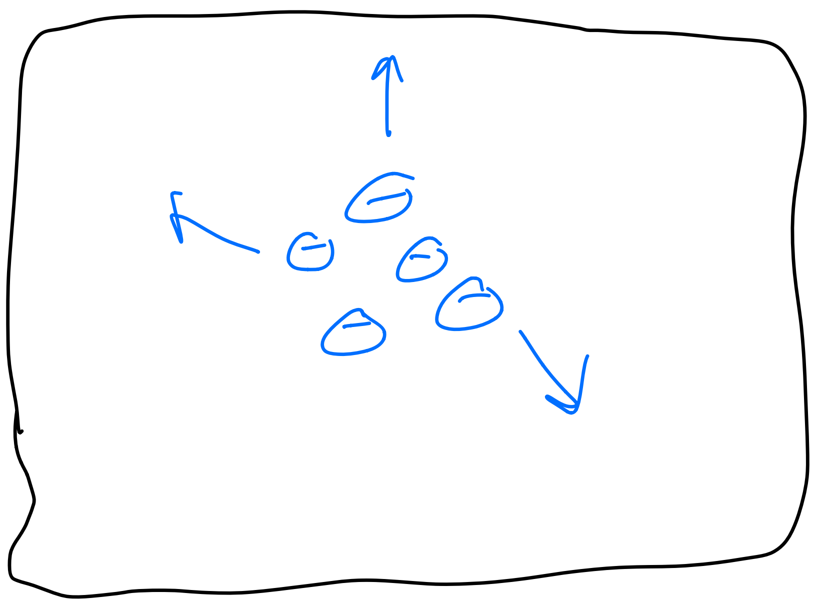
Electron "gas"
Randomly distributed
No net charge



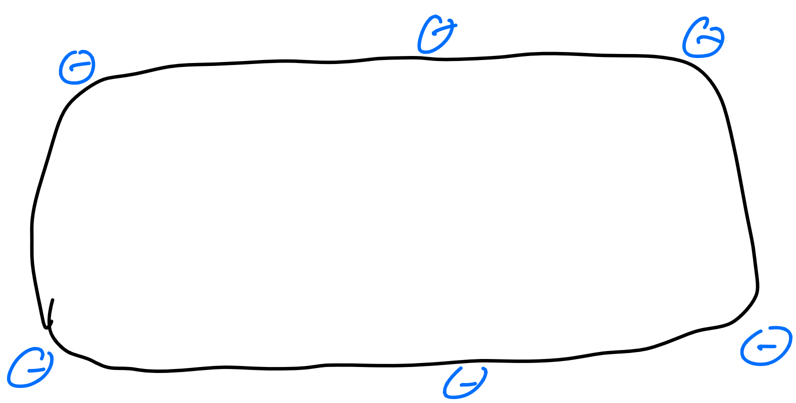
Polarization

- Shift in mobile charges

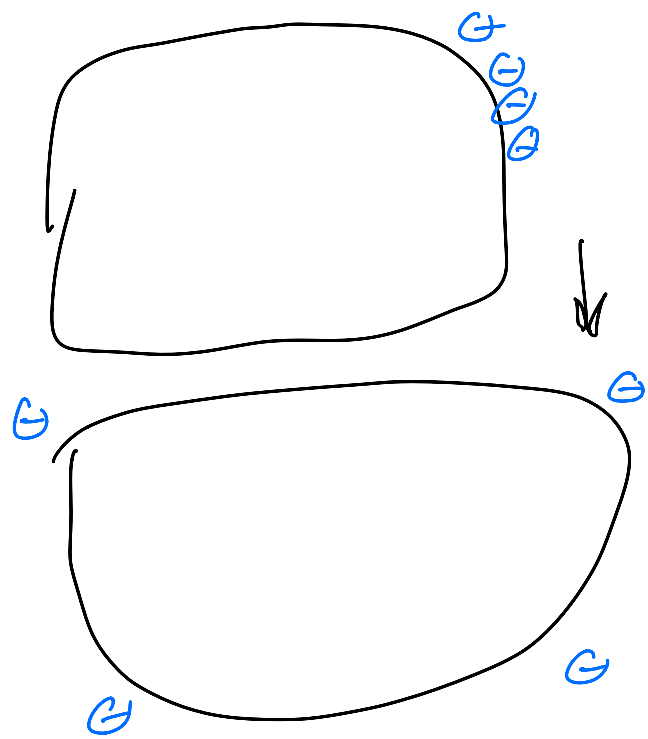
Excess Charge



Scatter!



No excess charge in interior
– only on surface



We will quantify this next week.
Read 14.6 – 14.7 !