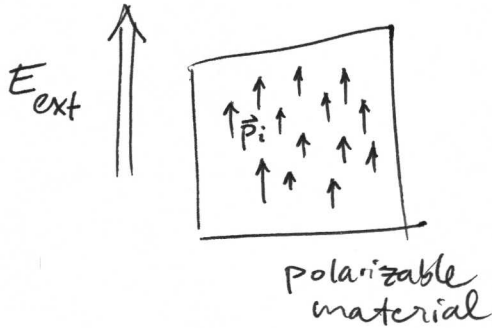
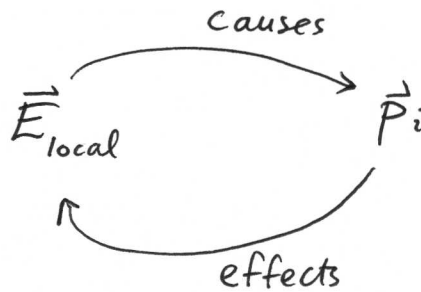


POLARIZABLE MATERIALS

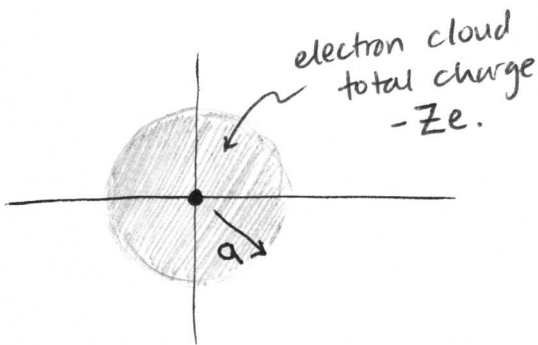


The microscopic dipoles are sensitive to the local E-field, \vec{E}_{local} , which is a combination of \vec{E}_{ext} and \vec{E} from neighboring dipoles

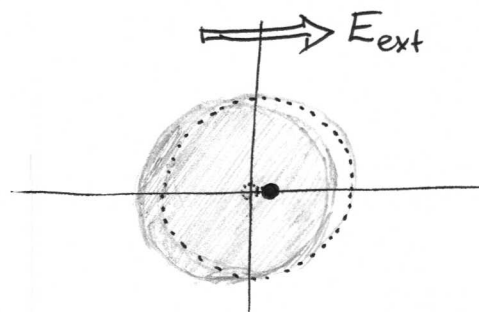


In the next few days we will develop ways to calculate self-consistent solutions.

MICROSCOPIC ORIGIN OF DIPOLES



Nucleus has charge $+Ze$



center of electron cloud shifts left
nucleus shifts to right
"d" is the equilibrium separation distance.

Model electron cloud as a uniform charge density $\rho_0 = \frac{Q_{tot}}{Volume}$

②
Calculate E-field generated by ρ_0 inside the electron cloud.

Gauss's Law $4\pi r^2 E_{\text{cloud}}(r) = \frac{Q_{\text{enc}}}{\epsilon_0} = \frac{\frac{4}{3}\pi r^3 \rho_0}{\epsilon_0}$

$\Rightarrow E_{\text{cloud}}(r) = -\frac{Zer}{4\pi\epsilon_0 a^3}$ for $r < a$.

Equilibrium when

$\vec{E}_{\text{ext}} = -\vec{E}_{\text{cloud}}(r=d)$

$|E_{\text{ext}}| = \frac{Zed}{4\pi\epsilon_0 a^3}$

note: Zed is the dipole moment of the atom.

$= \frac{|p|}{4\pi\epsilon_0 a^3}$

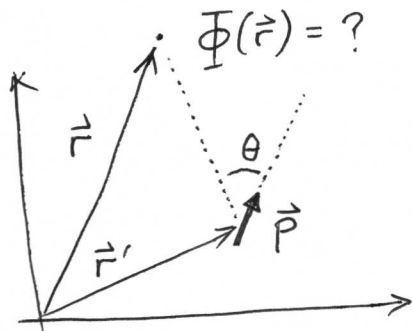
$|p| = \underbrace{4\pi\epsilon_0 a^3}_{\text{atomic polarizability}} |E_{\text{ext}}|$

atomic polarizability.

This toy model of atomic polarizability is quite accurate. Full Quantum Mech calculation gives the same relationship with small correction to the ~~proportionality factor~~ 4π numerical factor.

(3)

DIPOLES DISTRIBUTED THROUGHOUT SPACE



$$\Phi(\vec{r}) = \frac{1}{4\pi\epsilon_0} \frac{p \cos \theta}{|\vec{r} - \vec{r}'|^2}$$

$$= \frac{1}{4\pi\epsilon_0} \frac{\vec{P} \cdot (\vec{r} - \vec{r}')}{|\vec{r} - \vec{r}'|^3}$$

Now, if there is a continuous distribution of dipoles

chop up space, ~~into~~ one dipole per pixel.

$$\Phi(\vec{r}) = \int_{\text{all space}} \frac{(\vec{P}(\vec{r}') d^3\vec{r}') \cdot (\vec{r} - \vec{r}')}{4\pi\epsilon_0 |\vec{r} - \vec{r}'|^3}$$

- $\vec{P}(\vec{r}')$ is the "polarization of the material."

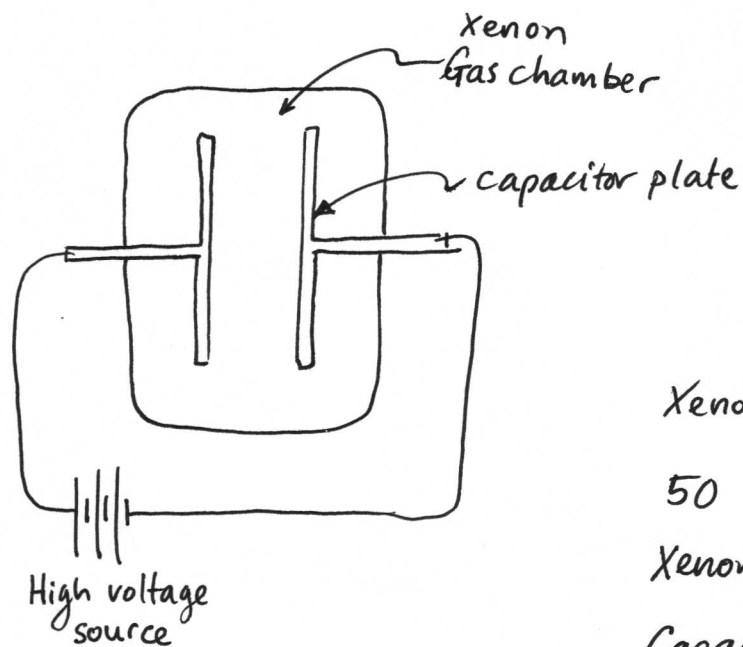
- $(P(\vec{r}') d^3\vec{r}')$ is the dipole moment of a pixel.

Compare to monopoles

charge in one pixel

$$\Phi(\vec{r}) = \int_{\text{all space}} \frac{\rho(\vec{r}') d^3\vec{r}'}{4\pi\epsilon_0 |\vec{r} - \vec{r}'|}$$

- $P(\vec{r}')$ is the sum of atomic dipoles per unit volume.



Xenon has an atomic radius $\sim 0.2 \text{ nm}$.
 50 mol (300×10^{23} atoms) of
 Xenon are placed in a 1 m^3 chamber.
 Capacitor plates inside the chamber
 are charged up so that the ~~the~~ spatially
 averaged \vec{E} -field near the center of
 the chamber reaches 10^6 V/m .

Estimate the polarization of the gas, \vec{P} , near the center
 of the chamber. Note, \vec{P} has units of $\frac{\text{C}\cdot\text{m}}{\text{m}^3}$.