3.2.5 Summary and Generalization

For all three cases of polarization mechanisms, we had a *linear* relationship between the electrical field and the dipole moment (for fields that are not excessively large):

Electronic polarization	Ionic polarization	Orientation polarization
$\mu_{EP} = 4\pi \cdot \epsilon_0 \cdot R^3 \cdot E$	$\mu_{IP} = \dfrac{q^2}{k_{IP}} \cdot E$	$\mu_{op} = \dfrac{\mu^2}{3kT} \cdot E$

It seems on a first glance that we have justified the "*law*" $P = \chi \cdot E$.

- However, that is not quite true at this point. In the "law" given by equation above, E refers to the *external* field, i.e. to the field that would be present in our capacitor *without* a material inside.
- We have $E_{ex} = U / d$ for our plate capacitor held at a voltage U and a spacing between the plates of d.
- On the other hand, the induced dipole moment that we calculated, always referred to the *field at the place of the dipole*, i.e. the *local* field E_{loc}. And if you think about it, you should at least feel a bit uneasy in assuming that the two fields are identical. We will see about this in the next paragraph.

Here we can only define a factor that relates μ and E_{loc}; it is called the **polarizability** α. It is rarely used with a number attached, but if you run across it, be careful if ϵ_0 is included or not; in other words what kind of unit system is used.

- We now can reformulate the three equations on top of this paragraph into one equation

$$\underline{\mu} = \alpha \cdot E_{loc}$$

- The ***polarizability*** α is a material parameter which depends on the polarization mechanism: For our three paradigmatic cases they are are given by

$$\alpha_{EP} = 4\pi \cdot \epsilon_0 \cdot R^3$$

$$\alpha_{IP} = \frac{q^2}{k_{IP}}$$

$$\alpha_{OP} = \frac{\mu^2}{3kT}$$

- This does not add anything new but emphasizes the proportionality to E.

So we *almost* answered our first basic question about dielectrics - but for a full answer we need a relation between the *local* field and the *external* field. This, unfortunately, is *not a particularly easy problem*

- One reason for this is: Whenever we talk about electrical fields, we always have a certain scale in mind - without necessarily being aware of this. Consider: In a metal, as we learn from electrostatics, there is *no field at all*, but that is *only true* if we do not look too closely. If we look on an *atomic scale*, there are tremendous fields between the nucleus and the electrons. At a somewhat larger scale, however, they disappear or perfectly balance each other (e.g. in ionic crystals) to give no field on somewhat larger dimensions.
- The scale we need here, however, is the *atomic scale*. In the electronic polarization mechanism, we actually "looked" *inside* the atom - so we shouldn't just stay on a "rough" scale and neglect the fine details.

Nevertheless, that is what we are going to do in the next paragraph: *Neglect the details*. The approach may not be beyond reproach, but it works and gives simple relations.

Questionaire
Multiple Choice questions to all of 3.2