

I realized over the weekend when writing up last recitation's notes and from questions in course center that I was far overzealous in trying to cover the general properties of conductors and linearly polarizable insulators in ten minutes. There's not much to say about them, really, but the book's explanation uses several models that are incompatible on small scales which make them unsatisfactory for microscopic models. Let me explain some of the assumptions that come into play here and the models, and suggest a general method for evaluating these models.

Universal Assumptions:

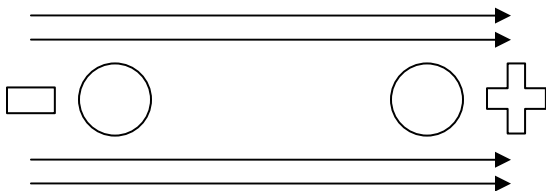
Charge is infinitely divisible: There is no minimum quantity that charge comes in. If you have one electron, there's nothing wrong with spreading it evenly along the entire surface.

Infinite charge is available: There is no maximum amount of charge that you can pull out of a neutral object, as long as you leave behind the opposite charge. Charge is always conserved.

Electrostatic Case: For all of these descriptions, there is no current or moving charge anywhere. This is a critical assumption, as many of the things that I will say below are not true in the dynamic case.

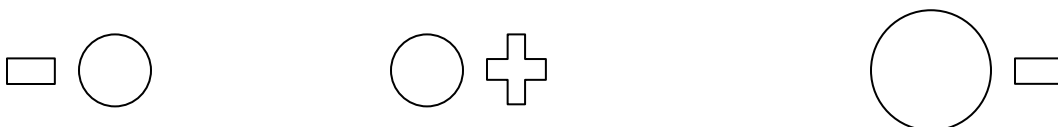
Dipoles

Model 1: A Dipole as Two Charge Cores in a Uniform Electric Field



Because here we are dealing with the electrostatic case, *there must be no net electric field at either charge here.* This means that the electric field on the positive charge due to the negative charge on the positive charge must be exactly opposite the uniform electric field, as well as the electric field on the positive charge due to the negative charge. Otherwise, there would be motivation for the dipole to spread out more.

Model 2: A Dipole as Two Charge Cores in a non-Uniform Electric Field

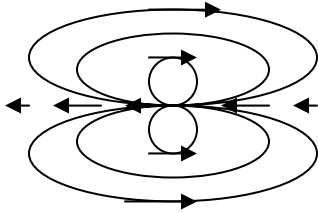


In this model, however, there will be overall motion due to the changing electric field. In order to make this workable we invoke Model 1 and say that the dipole takes some polarization which is a function of the electric field at the center. This model is linearly polarizable, making the dipole moment $\vec{p} = \alpha \vec{E}$.

Model 3: Ideal Dipole

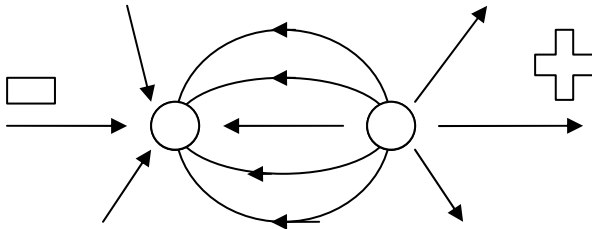
It is important to notice that an ideal dipole has no charge at all. The field diverges at its center, and there is no "between" area between the charges to speak of. Its electric field

takes the form $\frac{1}{4\pi\epsilon_0} \frac{p}{r^3}$ along its axis, but takes a more complex form that I omit here because this is only an introductory description off of that axis. Its field looks like:



Model 4: Real Dipole

A real dipole's field is not at all like the ideal dipole's, which only works at large separations. Its field is exactly like that of two point charges of a given separation and charge, which is not uniquely given by the dipole moment. Its field looks similar, like



and it makes slightly more sense to talk about the behavior of the field microscopically inside it.

Conductors

Facts:

In the static case, there is no electric field inside the mass of the conductor: A conductor is a perfectly polarizable material. All charges inside of it are free to move around inside, and so will arrange themselves in such a way as to cancel completely all electric fields inside. If this was not the case, there would be some point at the conductor with an electric field that could act on the free electrons inside it so that they would move, contradicting the assumption that this was a static case.

In the static case, electric fields at the conductor's surface are always perpendicular to the surface normal: In other words, if the electric field wasn't pointing straight out of or into the conductor at the surface, there would be some field pushing the free charges at the surface along the surface of the conductor. This motion contradicts the static assumption.

Extra charge on the conductor will distribute itself in such a way as to cancel all of its own electric fields inside. On spherical conductors, this is an even distribution. On other shapes, it may not distribute evenly.

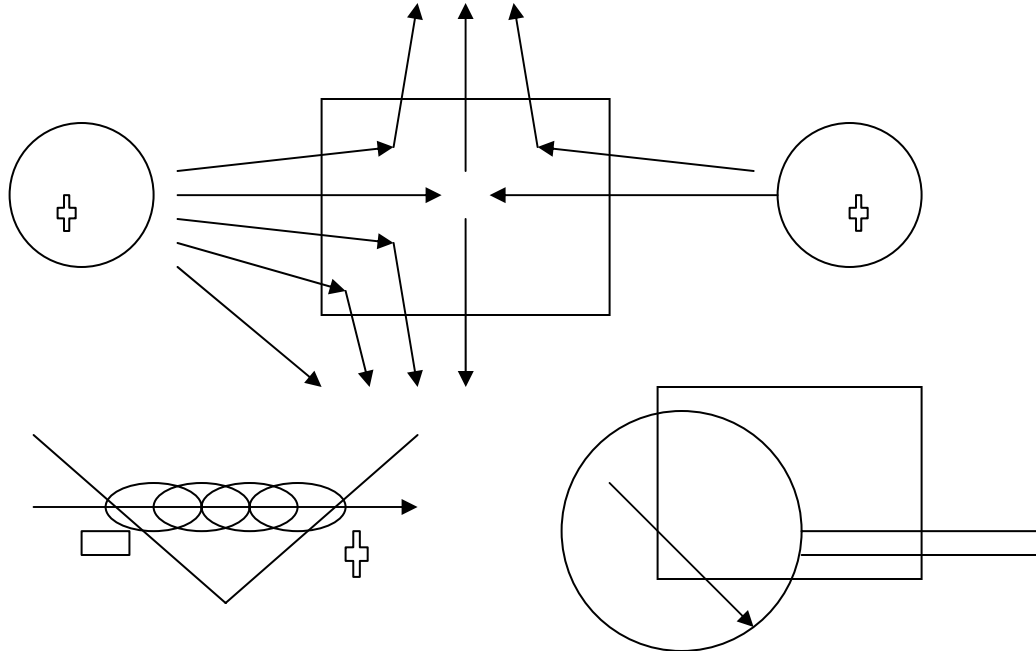
Falsehoods:

The conductor does not "block" or "absorb" electric field: All of the charges in a conductor are only arranged as to cancel the electric field in the metal parts. If there is a hollow hole in the conductor or something on the other side, it may well still have electric field which will be warped somewhat by the conductor's surface charges. The superposition principle always holds.

Linearly Polarizable Insulators

Facts:

The insulator responds to electric fields by making each of its constituent atoms into a dipole depending on the field it sees. Using $\vec{p} = \alpha\vec{E}$, we see that the dipoles will oppose the electric field (but possibly not cancel it completely) and point in the opposite direction. e.g.



You can see above how you can induce a surface charge in the insulating square using two charged spheres. The dipoles line up opposing the electric field, so that their ends cancel except for the little negative end where the field line entered and the little positive end where the field line exits.

A General Method

In order to make the most sense out of these diagrams without math, here's a procedure: First, draw all "real" charges in. This means any present net positive or negative charge. This will always die off as the inverse square of the radius, and will likely have the largest effect on the rest. Next, draw field lines due to this. Add a slight negative charge wherever they enter an insulator and a slight positive where they exit. Where they enter a conductor, make the field lines perpendicular and add an opposing charge on the opposite side (you'll have to estimate what a charge distribution to cancel these fields would look like.) Now estimate all forces, with preference given to the "real" charges' effect, and then to the induced charges' effect. Remember that the superposition principle always holds.

We also worked on homework problems today, which I have not included here because you should work on them as homework.