Dielectrics - Most objects belong to one of two large classes : conductors and insulators / dielectrics. the conductors are the substances that contain an unlimited supply of charges that are free to move about through the material.
In dielectrics, by contrast, all charges are attached to specific atoms or molecules - they're on a tight leash, and all they can do it is move a bit within the atom or molecule. Such microscopic displacements are not as dramatic as the wholesale rearrangement of charge in a conductor, but their cumulative effects account for the characteristic behavior of dielectric materials.

Induced Dipoles - The atom as a whole is electrically neutral, there is a positively charged nucleus and a negatively charged electron cloud surrounding it. these two regions of charge within the atom are influenced by the field : the nucleus is pushed in the direction of the field, and the electrons the opposite way. In principle, if the field is large enough it can pull the atom apart completely. with less extreme fields, however an equilibrium is soon established, for if the centre of the electron cloud does not coincide with the nucleus, these positive and negative charges attract one another, and this holds, the atom together. the two opposite forces - E pulling the electrons and nucleus apart, their mutual attraction drawing them together - reach a balance, leaving the atom polarized. with plus charge shifted slightly one way, and minus the other.

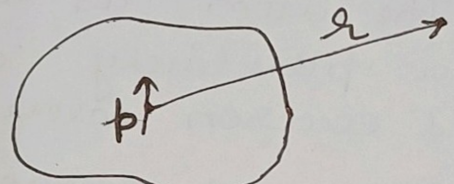
the atom now has a tiny dipole moment p, which points in the same direction as E. the induced dipole moment is approximately $\propto$ to the field.

$$\boxed{\vec{p} = \alpha \vec{E}}$$

the const of proportionality α is called the atomic polarizability.
this value depends on the detailed structure of the atom.

the field of a polarized object -

Bound charges -



If we have a piece of polarized material - an object containing a lot of microscopic dipols lined up. the dipole moment per unit volume is given.
Now we want calculate the field produced by this object.
For a single dipole $\vec{p}$ we have equation-

$$V(\vec{r}) = \frac{1}{4\pi\epsilon_0} \frac{\hat{r}\cdot\vec{p}}{r^2} \quad \text{—(1)}$$

where r is the vector from the dipole to the point at which we are evaluating the potential. We have a dipole moment $\vec{p} = \vec{P}\,d\tau'$ in each volume element $d\tau'$, so the total potential is.

$$V(\vec{r}) = \frac{1}{4\pi\epsilon_0} \int_v \frac{\hat{r} \cdot P(r')}{r^2} d\tau'$$

we know $\nabla'\left(\frac{1}{r}\right) = \frac{\hat{r}}{r^2}$

the differentiation is with respect to the source coordinates (r') we have,

$$V = \frac{1}{4\pi\epsilon_0} \int_v \vec{P} \cdot \nabla'\left(\frac{1}{r}\right) d\tau'$$

Now integrating by parts, we get.

$$V = \frac{1}{4\pi\epsilon_0} \left[\int_v \nabla' \cdot \left(\frac{\vec{P}}{r}\right) d\tau' - \int_v \frac{1}{r} (\nabla' \cdot P) \, d\tau' \right]$$

using the divergence theorem,

$$V = \frac{1}{4\pi\epsilon_0} \oint_S \frac{1}{r} \vec{P} \cdot d\vec{a}' - \frac{1}{4\pi\epsilon_0} \int_v \frac{1}{r} (\nabla' \cdot \vec{P}) \, d\tau' \quad -(2)$$

In this eq.(2) first term looks like the potential of a surface charge.

$$\boxed{\sigma_b = \vec{P} \cdot \hat{n}} \quad -(3)$$

while the second term looks like the potential of a volume charge $\boxed{\rho_b = -\nabla \cdot P}$ $-(4)$

So the eq. (2) becomes

$$V(r) = \frac{1}{4\pi\epsilon_0} \oint_S \frac{\sigma_b}{r} da' + \frac{1}{4\pi\epsilon_0} \int_v \frac{\rho_b}{r} d\tau' \quad -(5)$$

It means that the potential of a polarized object is the same as that produced by a volume charge density $\rho_b = -\vec{\nabla} \cdot \vec{P}$ plus a surface charge density $\sigma_b = \vec{P} \cdot \hat{n}$.

Scanned by Scanner Go