BOUND CHARGES IN A DIELECTRIC

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Reference: Griffiths, David J. (2007) Introduction to Electrodynamics, 3rd Edition; Prentice Hall - Problem 4.14.

We've seen that potential due to the polarization density in a dielectric can be represented as bound charges which divide into a volume charge distribution and a surface charge distribution. The relation between these charge distributions and the polarization density **P** is

$$\sigma_b = \mathbf{P}\cdot\hat{\mathbf{n}} \tag{1}$$

$$\rho_b = -\nabla\cdot\mathbf{P} \tag{2}$$

where $\hat{\mathbf{n}}$ is the unit normal to the surface of the dielectric.

Since a dielectric is neutral, the polarization results from moving around charge within it, not from adding or removing charge, so the total charge should remain as zero. This follows directly from the divergence theorem, since

$$\int_A \mathbf{P}\cdot\hat{\mathbf{n}}d^2\mathbf{r} = \int_V \nabla\cdot\mathbf{P}d^3\mathbf{r} \tag{3}$$

where the first integral is over the surface of the dielectric and the second is over its volume. From that relationship, we see that the total surface charge is equal and opposite to the total volume charge, so their sum is always zero.

In the special case (such as we've considered in the last few posts) where the polarization inside the volume is uniform, $\nabla\cdot\mathbf{P}=0$ everywhere inside the dielectric, so the total surface charge must also be zero.

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