Department of Physics, Shiv Nadar Institution of Eminence

Spring 2025

PHY102: Introduction to Physics-II

Tutorial – 9

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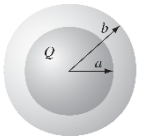
1. A spherical conductor of radius **a** carries a charge Q as shown in the figure. It is surrounded by linear dielectric material of susceptibility χ_e out to radius **b**. Find the energy of this configuration.



2. A thick spherical shell (inner radius a, outer radius b) is made of dielectric material with a "frozen-in" polarization :

$$\vec{P}(\vec{r}) = \frac{k}{r}\,\hat{r}$$

where k is a constant and r is the distance from the center (see **Fig. 1** below). (There is no *free* charge in the problem.) Find the electric field in all three regions by two different methods :

(a) Locate all the *bound charge*, and use the original Gauss's law to calculate the field it produces.

(b) Find $\vec{D}$ from the Gauss's Law analogue for the Displacement, and then get $\vec{E}$ from the defining equation for $\vec{D}$. [Notice that the *second method is much faster*, and it avoids any explicit reference to the bound charges.]

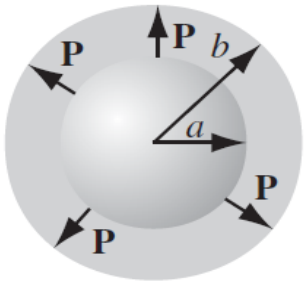
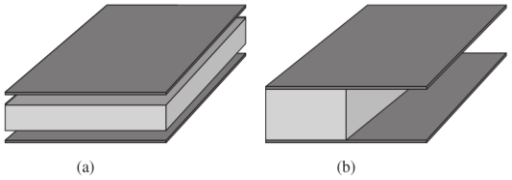


Fig. 1

3. Suppose we half-fill a parallel-plate capacitor in two ways, as shown in the two figures. By what fraction is the capacitance increased when the material is distributed as shown in each case? For a given potential difference V between the plates, find E, D, and P, in each region, and the free and bound charge on all surfaces.



4. A point charge q is placed in a medium whose permittivity $\mathcal{E}$ changes with the distance r from q as $\mathcal{E} = 1 + \frac{A}{r}$ where A is a constant. Show that the potential at any point is given by

$$\varphi(r) = \frac{q}{4\pi A}\ln\left(1 + \frac{A}{r}\right)$$