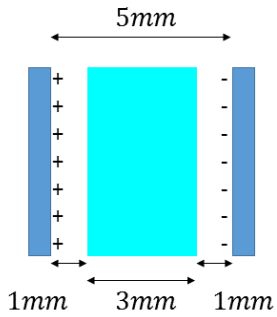
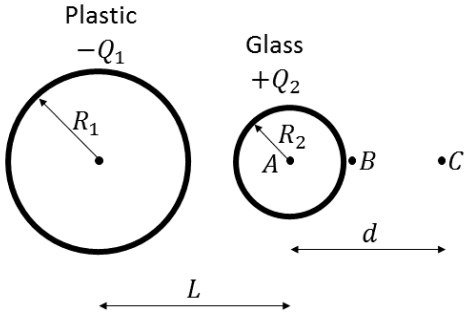
Homework 3: Non conducting materials and dielectrics

1. An isolated large-plate capacitor (not connected to anything) originally has a potential difference of $800\,V$ with an air gap of $5\,mm$. Then a plastic slab $3\,mm$ thick, with dielectric constant $\varepsilon_r = 6$, is inserted into the middle of the air gap as shown in the figure below.

Calculate the potential differential between the two conducting plates ΔV

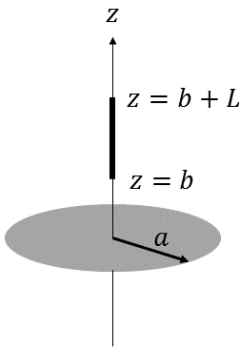


2. A thin spherical shell of radius R_1 made of plastic carries a uniformly distributed negative charge $-Q_1$. A thin spherical shell of radius R_2 made of glass carries a uniformly distributed positive charge $+Q_2$. The distance between centers is L, as shown in the figure below.

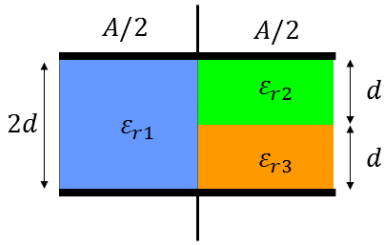


a) Find the potential difference $V_B - V_A$. Location A is at the center of the glass sphere, and location B is just outside the glass sphere.
b) Find the potential difference $V_C - V_B$. Location B is just outside the glass sphere, and location C is a distance d to the right of B.
c) Suppose the glass shell is replaced by a solid metal sphere with radius R2 carrying charge $+Q_2$. What is the new potential difference $V_B - V_A$ is true?

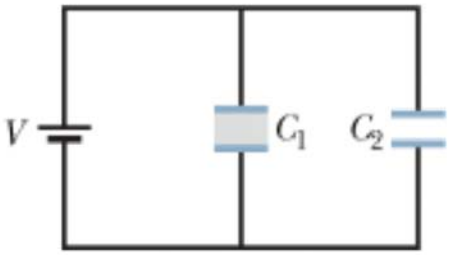
3. A uniformly charged (thin) non-conducting rod is located on the central axis a distance b from the center of an uniformly charged non-conducting disk. The length of the rod is L and has a linear charge density λ. The disk has radius a and surface charge density σ. Calculate the total force among these two objects.



4. The figure below shows a parallel-plate capacitor of plate area A and plate separation $2d$. The left half of the gap is filled with material of a relative dielectric constant $\varepsilon_{r1} = 12$; the top of the right half is filled with material of a relative dielectric constant $\varepsilon_{r2} = 20$; the bottom of the right half is filled with material of a relative dielectric constant $\varepsilon_{r3} = 30$. What is the capacitance in terms of ε_0, A, and d?



5. In the figure below, how much charge is stored on the parallel-plate capacitors by the 10 V battery? One is filled with air, and the other is filled with a dielectric for which $\varepsilon_r = 2.0$; both capacitors have a plate area of $2.00 \times 10^{-3} m^2$ and a plate separation of $1.00\ mm$.



6. Show that the individual dipole moment $\vec{p}$ of a carbon tetrachloride (CCl_4) molecule in an electric field $|\vec{E}| = 10^7\ volts/m$ is $1.78 \times 10^{-31} C - m$, given the data: molecular weight $= 156$, density = $1.6\ g/cm^3$, $\varepsilon_r = \varepsilon/\varepsilon_0 = 2.24$, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$ and Avagadro number = 6.02 × 1023. The number of molecules per unit volume is given by $(Avagadro\ number \times density)/mol.wt.$

7. Consider a point charge $+q$ in a homogeneous isotropic medium of infinite extent. The dielectric medium is linear and dielectric constant is ε_r. Calculate the electric field $\vec{E}$ and the polarization $\vec{P}$.

8. A disk of radius R has a surface charge distribution given by $\sigma = \sigma_0 R/r$ where σ_0 is a constant and r is the distance from the center of the disk.

(a) Find the total charge on the disk.

(b) Find an expression for the electric potential at a distance *x* from the center of the disk on the axis that passes through the disk's center and is perpendicular to its plane.