You have two large parallel conducting plates, one of which has charge $+Q$ and the other $-Q$. Each plate has a total area A and they are separated by distance d. Your task is to calculate the potential difference between the plates.

1. Determine the electric field between the plates, assuming the dimensions of the plates are much larger than d.

2. By integrating $-\mathbf{E}\cdot\mathbf{ds}$ from one plate to the other, show that the potential difference between the plates is given by:

   $$\Delta V = \frac{1}{C}Q$$

   where,

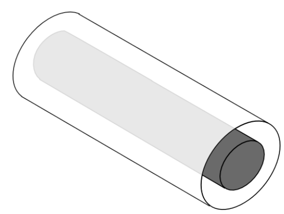
   $$C = \frac{A\varepsilon_0}{d} .$$

C is called the capacitance of the plates. Whenever you have two conductors (with any geometry) that have equal and opposite charge, the potential difference between to the two conductors will be proportional to the charge on each conductor. These two conductors are called a *capacitor*. We can think of a capacitor as a device for storing charge, and the capacity of charge that can be stored on each conductor for a given potential difference between the conductors is called the *capacitance*. If a potential difference ΔV exists between the plates, then the charge on each plate will be:

$$Q = C\Delta V .$$

We will discover that the capacitance depends only on the geometry of the capacitor.

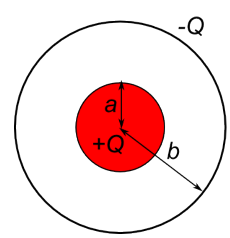
3. Show that:
   a. The capacitance of a cylindrical capacitor of length L with an inner conductor of radius a and an outer conducting shell of radius b is equal to:

   $$C = \frac{2\pi\varepsilon_0 L}{\ln(b/a)}$$

   Assume L is much larger than the separation of the conductors.

   b. The capacitance of a spherical capacitor with an inner conductor of radius a and an outer conducting shell of radius b is equal to:

   $$C = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)$$

   The approach for both these problems is just like the parallel plate capacitor. First, determine the electric field between the two conductors when they have charge $+Q$ and $-Q$, and then calculate the potential difference between the conductors by integrating $-\mathbf{E}\cdot\mathbf{ds}$ from one conductor to the other.

4. For the case of a spherical capacitor, show that as the outer sphere gets infinitely far away, the potential difference between the two spheres becomes:

   $$\Delta V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{a}$$

   What is the significance of this result (hint: you have see this expression before!)

5. For the parallel plate capacitor, use Gauss's law to show that all the charge on each plate resides on the surface facing the other plate (i.e., there is no charge on the surface facing "outside".)