**Objective:** To study the capacitance of a parallel plate capacitor, its dependence on the physical properties of the capacitor, and the laws for combinations of capacitors.

**Apparatus:** Capacitance meter, wire connectors, a parallel plate capacitor with adjustable plate separation, plastic slab and two capacitors.

**Theory:** Any arrangement of two conductors which stores charge is called a capacitor. If applying a potential difference $\Delta V$ across the arrangement produces charges $\pm Q$ on the two conductors, then the capacitance of the arrangement is $C = \frac{Q}{\Delta V}$. The units of $C$ are farad (F), $1 \text{ F} = \frac{1 \text{ coulomb}}{\text{volt}}$, or more commonly, the microfarad, $1 \mu \text{F} = 10^{-6} \text{ F}$, and the picofarad (or micro-microfarad) $1 \text{ pF} = 10^{-12} \text{ F}$. For two parallel plates of area $A$ separated by distance $d$ in a vacuum:

$$C_0 = \frac{\varepsilon_0 A}{d}.$$

The introduction of a dielectric between the plates of an isolated capacitor tends to reduce the electric field between the plates and hence reduces $\Delta V$ with $Q$ staying constant. Therefore, we expect $C$ to increase with the dielectric in place. If $C$ is the capacitance with a dielectric between the plates, then $\kappa = \frac{C}{C_0}$, where $\kappa$ is called the dielectric constant. Typical values of $\kappa$ range from 1.0054 for air to 78.6 for water at 25°C.

When two capacitors are connected in parallel, the total capacitance is the sum of the individual capacitances:

$$C_{\text{total}} = C_1 + C_2.$$

When two capacitors are connected in series:

$$\frac{1}{C_{\text{total}}} = \frac{1}{C_1} + \frac{1}{C_2}.$$

**Procedure:**

1. **Data Acquisition**
   Construct an Excel spreadsheet like the attached template. This will be used to record data from the three experiments below. The shaded areas of the spreadsheet indicate where data will be recorded.

2. **Capacitance of a Parallel Plate Capacitor:**
   With the leads removed, and the meter on its most sensitive scale, zero the capacitance meter. Now connect the two leads to the capacitance meter. These two wires are conductors and therefore have a capacitance. Set the meter on the most sensitive scale and notice the value of the capacitance of the wires. Move the wires around to see how the capacitance changes with separation and configuration. Record the range of capacitance you observe.

   When we connect the wires to the parallel plate capacitor, the resulting arrangement will
really be two capacitors in parallel: the parallel plate capacitor plus the capacitance meter leads. Since we expect a parallel combination to be the sum of the two capacitances, we must subtract the capacitance of the wires to obtain the true capacitance of the parallel plate capacitor when we measure the latter with our meter.

Use the Vernier caliper to measure the plate separation of the parallel plate capacitor when the slide scale reads 1.0 cm. The difference between the measured value and 1.0 cm is a correction factor for the capacitor’s distance scale. It will be necessary to add this distance to the scale value to obtain the true separation, \(d\). Measure and record the diameter of the plates. Also record the uncertainty in the measurements of the diameter and the plate separation.

For a series of 10 measurements, record the capacitance as a function of the plate separation (as indicated from the sliding scale).

Since the capacitance varies as \(\frac{1}{d}\), if you pick ten equally spaced points, most of your data points will end up clustered together. You should pick your points so as to evenly space them between \(\frac{1}{1\text{ cm}}\) and \(\frac{1}{12\text{ cm}}\).

Note any fluctuations in the meter reading and include them with the uncertainty.

3. Dielectric Constant of a Plastic Slab

Insert the plastic slab between the plates of the capacitor and gently push the plates flush against it. Record the plate separation and the capacitance. Carefully remove the slab. If the plates move, return them to their position before the slab was removed and record the new capacitance.

Insert two dielectric slabs against each other and flush with the plates. Again, record the plate separation and capacitance, remove the slabs and record the new capacitance.

4. Combinations of Capacitors

For the two small capacitors provided, measure the capacitance of each. Connect the capacitors in series and then in parallel, recording the capacitance of each combination.

PROBLEMS

Calculate the equivalent capacitances for the following arrangements of four capacitors, each of 8.0 pF capacitance.
REPORT:
1. From your measurements in Part 2 above, plot a graph of capacitance versus the inverse of the plate separation. Don't forget to subtract the capacitance of the leads and add the zero value of the plate separation. Use Excel’s **Add Trendline** function to obtain the equation of the best-fit straight line through the data and its $R^2$ value. Use Excel’s **LINEST** array function to find the standard error of the slope. From the slope of the line and the diameter of the capacitor plates, use Maple’s Scientific Error Analysis function to compute the permittivity constant, $\varepsilon_0$ and its standard error.

2. From the measurements of the capacitance with and without the plastic slab, find the dielectric constant of the slab. Compare the value you obtain for one slab with that of two slabs. What is the percentage difference?

3. Compute the value of the capacitance of the combinations of the capacitors and compare the results with what you would expect from the equations given in the **Theory** section of this exercise. What might cause the discrepancy?

4. Your lab report should consist of the following:
   (1) the completed spreadsheet and associated graph,
   (2) the error propagation analysis of $\varepsilon_0$ discussed above,
   (3) the answers to the three equivalent capacitance problems above, and
   (4) an abstract describing this experiment.