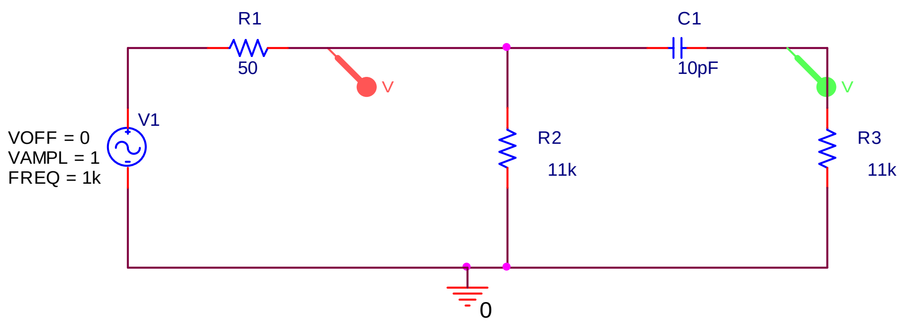
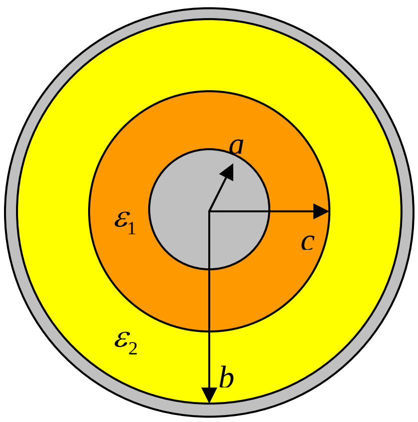
Homework 4
Part Two
Due 21 October at 6:00 pm

4. **Capacitance Measurements** Repeat the experiment done the first day of class where you made a small capacitor from two twisted wires on a protoboard. (Use a length of 20-30cm.) Calculate the capacitance of your configuration (you will have to carefully measure the dimensions of the wires and their separation distance and record the numbers in your solution) and compare with the measurement using the impedance bridge. Remember to take into account the capacitance of the cable you use to connect to your wires. Set up the same circuit you used previously and scan the frequency from *10kHz* to *15MHz*. Take enough data points to show the general form of the frequency dependence of the input and output voltages. Before coming to class, setup the following simulation using PSpice and show it to a TA or instructor at the beginning of your assigned section. Then modify the simulation based on your measured capacitance and run it again. Compare your experimental results with your simulation. Ideally, plot your measured data on the PSpice plot.



5. **Capacitor Design Choices** Assume that we have a limited amount of dielectric material and wish to investigate some choices for how we could use it in a simple capacitor configuration.

   a. Begin by determining the capacitance of the spherical structure below. Note that there are two different dielectric regions. Assume that the inner conductor voltage is V_o and the outer conductor is grounded. You can use either the charge or energy method.



   b. Now assume that the inner region is filled with an insulating material with $\varepsilon_1 = 6\varepsilon_o$ and the outer region is air $\varepsilon_2 = \varepsilon_o$; *a=1cm* and *b=10cm*. Also assume the voltage on the inner conductor is *1000V* and the outer conductor is grounded. Determine the capacitance and energy stored in this configuration. Also, determine the maximum value for the electric field magnitude. Assume that half of the volume between the two conductors is filled with insulator.

   c. Now assume that the outer region is filled with the insulating material so that $\varepsilon_1 = \varepsilon_o$ and $\varepsilon_2 = 6\varepsilon_o$; *a=1cm* and *b=10cm*. Also assume the voltage on the inner conductor is *1000V* and the outer conductor is grounded. Determine the capacitance and energy stored in this configuration. Also, determine the maximum value for the electric field magnitude. Assume that half of the volume between the two conductors is filled with insulator.

   d. Discuss the tradeoffs between the three possible configurations, including the choice to not use the insulating material at all.

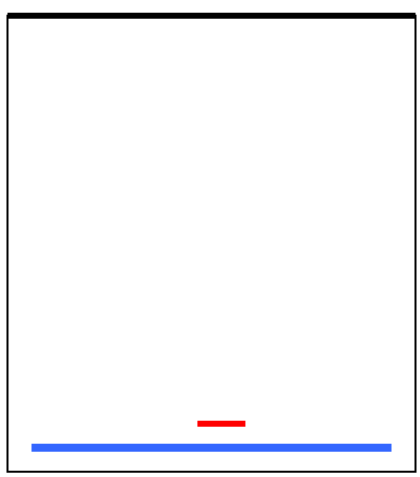
6. **Capacitance Using a Spreadsheet** The device we are going to simulate is a variation of a capaciflector, which was invented by a NASA engineer. This uses a capacitor to determine the distance to a surface, usually as part of a robot obstacle sensor. For our purposes, you should use a 100x100 array (use rows 1to 101 and columns A to CW). The outer boundary cells should be grounded (V=0). The sensor electrode is relatively small (cells AT89 to BD89). There is also a reflector to force the field lines toward the surface to be measured (cells E97 to CS97). Both the sensor and reflector are at the same voltage (choose anything you like, but 10V works). However, we are only to be concerned with the capacitance of the sensor. [In application, the reflector is driven by a voltage follower connected to the sensor.] For your analysis, you can determine the charge on the sensor using the boundary condition method or the flux integral method. The latter should be more accurate, but the differences will not be large. All space is filled with air in this problem.

   a. Determine the charge on the sensor electrode for your choice of voltage. Use this to determine the capacitance of the configuration. Plot the equipotentials for this configuration, adding a few E field lines for clarity. Why are your results reasonable?

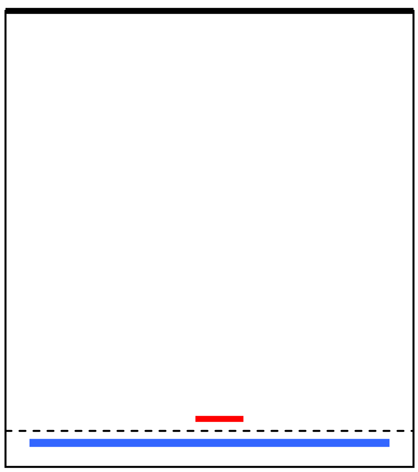
   The object whose position is to be measured is the top of the shield. Now we will move the top plate (add a grounded surface) at other locations to see how the capacitance will change.

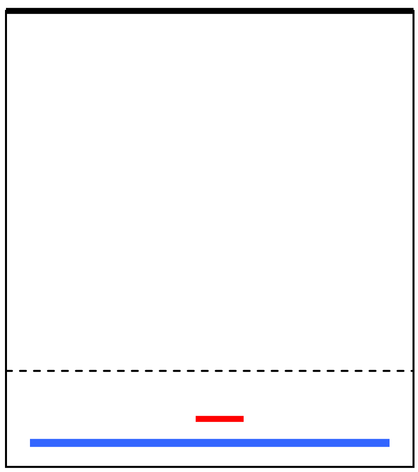
   b. Repeat the calculations of part a for three additional cases: a grounded plane at row 26, 51 and 76, respectively. For each case, plot the equipotentials, adding a few E field lines for clarity. Why are your results reasonable?

   For your analysis, please explain each step, especially if you use the spreadsheet to do most of the work.



Extra Credit: Assume that the purpose of the moveable top plate is to separate a region filled with water from the air filled space just analyzed. Now also assume that the water leaks into the chamber (somehow). Consider two cases: one where the water fills the chamber up to row 95 and one where it fills the chamber up to row 76. Determine the capacitance for both cases. Use a relative permittivity of 81 for water. Only consider the situation where the top of the chamber is in its original position (top row).





Discuss your results.