Exam 2 Practice

(no due date; just for practice)

1. Impedance Matching and Smith Charts

(Note: This somewhat challenging Smith Chart problem is not quite the same as to what you will see on Exam 2 – Exam 2 problems will ask you to perform the computations described in the Core Skills. However, this problem is excellent practice for understanding the subtleties of Smith Charts.)

Your television is not matched to your cable TV line, causing reflection and losses. Your TV cable has a characteristic impedane of 75 Ω and a velocity factor of 0.7c.

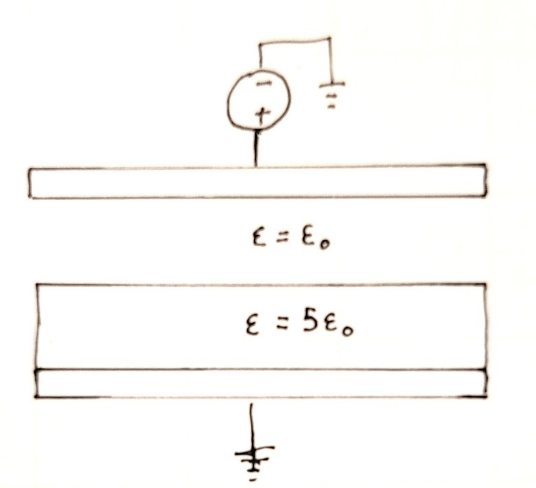
a.) You find a juncture box in the cable at a distance of 10m (in terms of cable length) from the TV. You use a network analyzer to determine that at 600 MHz, the reflection coefficient at this point has a magnitude of 0.707 and a phase angle of 135 degrees. What input impedance does this correspond to? Represent this as both a normalized and non-normalized impedance and show it on a Smith Chart (either the Smith Chart widget or the printable Smith Chart.)

b.) Convert the 10m cable length to wavelengths at 600Mhz. What is the load impedance at the TV?

c.) Suppose that you want to block the 600MHz channel by connecting a parallel open-circuit stub to the 10m cable line. You may attach this stub at any distance from the load. What length of stub should you use? Does it matter what distance from the load you choose?

2. Capacitance

Consider the parallel plate capacitor shown below. The top and bottom plates are conductors, and half the space between them is filled with a dielectric. The plates are 10cm long and 10cm wide, and the width of the gap between them is 2cm. (1cm is free space and 1cm is dielectric). Assume that there is never any surface charge at the interface between the air gap and the dielectric.



a.) Sketch the electric field lines between the two plates for this problem. Assume that this is an ideal parallel plate capacitor with no fringing field.

b.) Calculate the electric field inside both regions of the gap between the plates if the charge on the top plate is +1nC and the charge on the bottom plate is -1nC. *(Hint: Remember that if this capacitor had only air and no dielectric in the gap between the plates, the field would be $E=\sigma/\varepsilon_{0}$.)*

c.) Calculate the voltage between the two plates.

d.) Calculate the stored energy and capacitance.

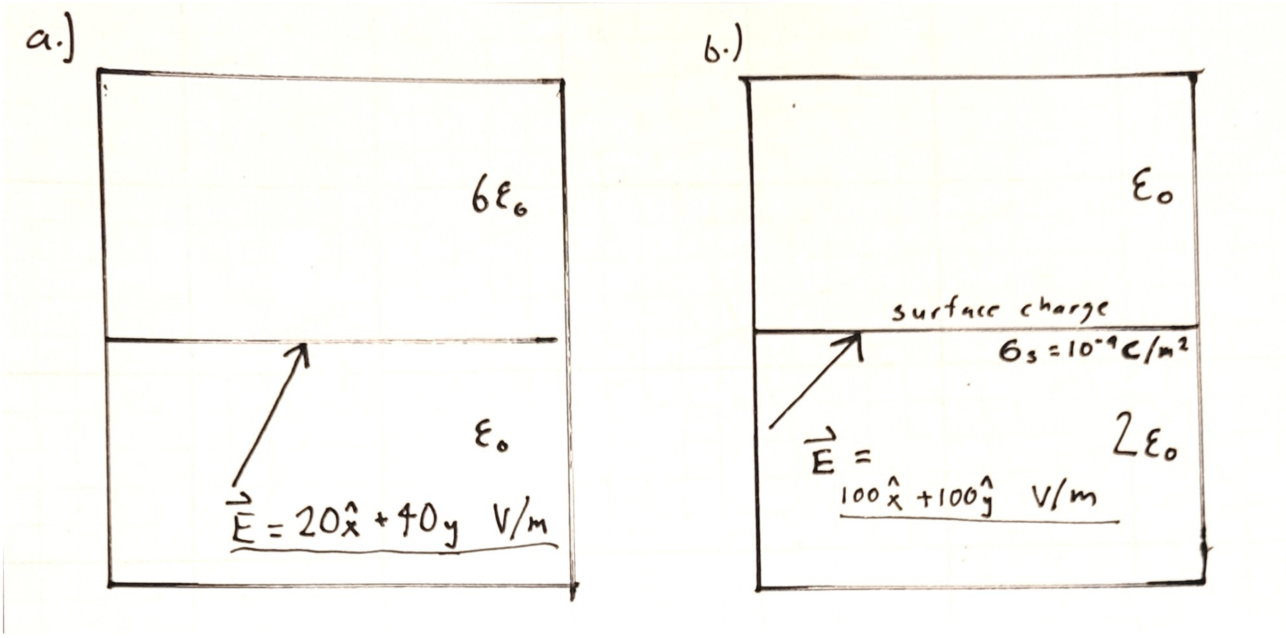
e.) Let's say that the air gap region width is cut in half. Calcualate the electric field, capacitance, and stored energy again.

f.) Show that Laplace's equation applies for the region between the plates.

g.) If the two plates are moved a substantial distance apart, will the E field expression be the same? Will the capacitance expression have the same form? Why or why not?

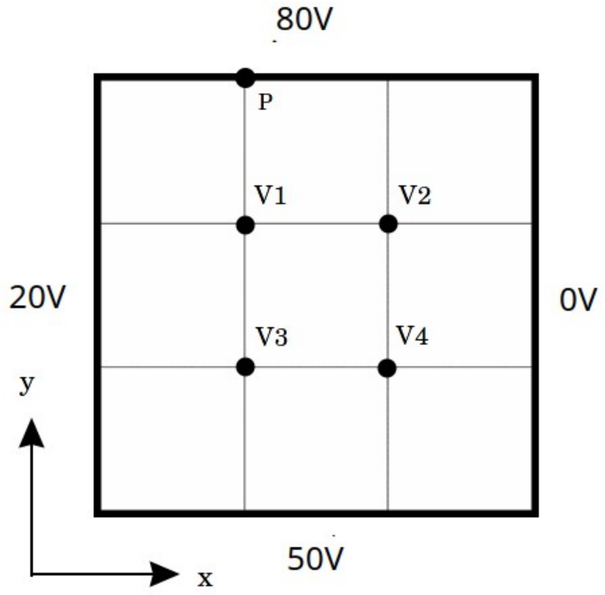
3. Boundary Conditions

For each of the problems below, you are shown a boundary between two materials and given an electric or field vector in the lower material. Calculate what the corresponding electric field would be in the upper material.



4. Finite Difference

A square region of free space is bounded by 100V on top, 0V on the bottom, 50V on the left and 30V on the right. *(We wlll treat this as a two-dimensional problem in the x-y plane. Neglect z by assuming the fields and potentials involved are uniform in z.)* Consider the four equidistant points shown in the diagram below. Assume that each of the 9 square cells that make up this square region are 10cm on each side.

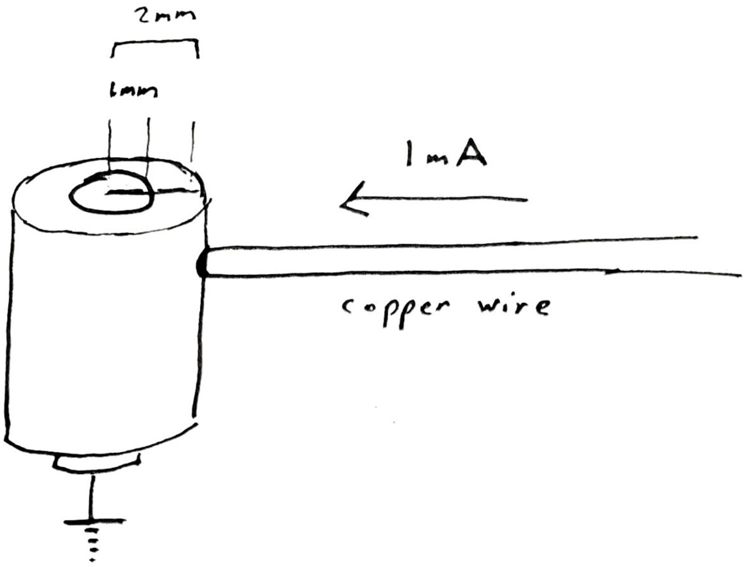


a.) (6 pts) Use the finite difference method to estimate the voltage at the four points. Use 0V as your initial guess for all four points, then perform two iterations.

b.) (3 pts) Using your results from part a, estimate the electric field at point P.

c.) (3 pts) Explain two things that could be done to improve the accuracy of the finite difference calculation at these four points.

5. Capacitance part 2



You have a cylindrical capacitor consisting of an inner, grounded conductive cylinder with radius 1mm and an outer conductive shell at radius 2mm. The cyclindrical capacitor is 5mm tall. A copper wire of 0.5mm radius is connected to the outer conductive shell. A current of 1 mA flows through the copper wire into the outer shell of the capacitor.

a.) What is the current density and electric field magnitude inside the copper wire? Use 5.9×10^7 S/m as the conductivity of copper. Assume that the current is DC.

b.) Suppose that the 1mA current continues to flow into the capacitor at a constant rate. f the capacitor contains a dielectric with a relative permittivity of 3 and a breakdown field strength of 300kV/cm, how much time will elapse before the capacitor fails due to dielectric breakdown? Ignore the effect of frinding field at the capacitor’s edges.

6. Conducting Plane

A 2 nC sphere of negative charge hovers 1cm above a very large (essentially infinite) flat conducting plane. Does the 2 nC sphere experience a force? If so, what is its magnitude and direction?

Online Exercises

Vector Analysis

Electrostatics

Charges in Adjacent Dielectrics (widget)
- This widget allows you to visualize electric field lines, equipotential lines, and the way these are affected by dielectrics.

Charges near a Conducting Sphere (widget)
- This widget allows you to visualize the accumulation of surface charge on a conductor.