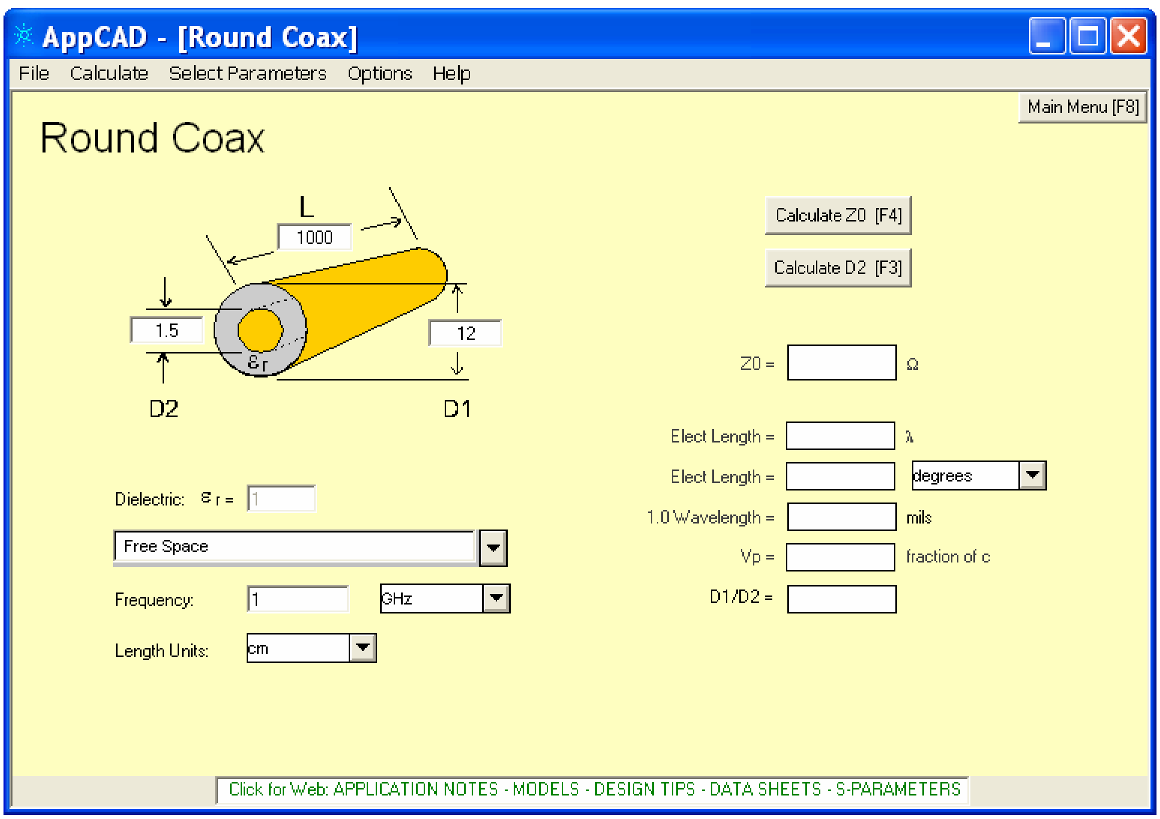
Homework #4
Due 14 March

Before beginning this homework assignment, read over HW4 from Spring 2006. We will be using both the AppCAD software and the spreadsheet approach to electrostatic problem solving in this assignment. AppCAD can be downloaded from

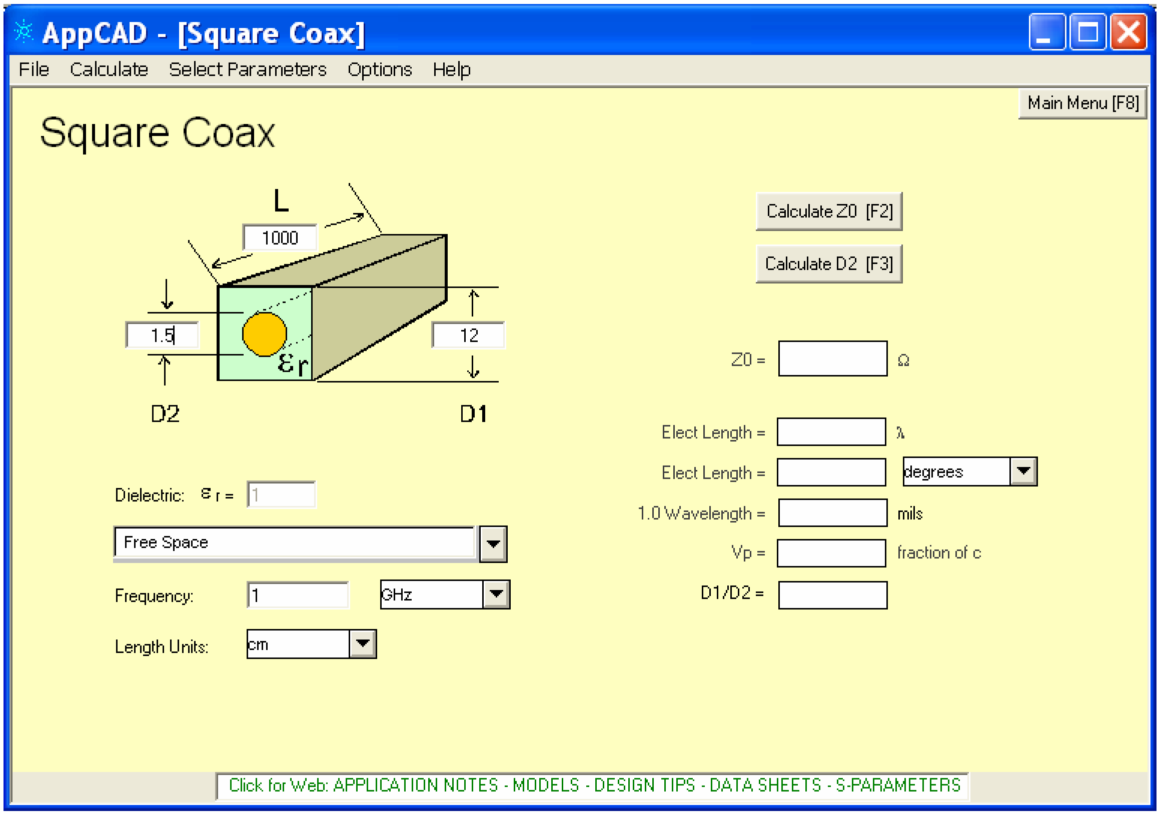
- http://www.hp.woodshot.com/ or
- http://www.rfcascade.com/appcad.html

1. **Using AppCAD to find the Parameters of a Simple Transmission Line**

Begin by using AppCAD to analyze the following two configurations. For each case, we have assumed that the dimensions are as given (these are the dimensions of a standard compact disk). Find the dielectric material for each case that produces a characteristic impedance as close to 50 Ohms as possible. It is likely that you will have to use different materials for the two geometries. Also determine the capacitance for each cable. AppCAD does not give this information directly. You have to figure it out from the information they do give you. *Hint: You will need what you learned about transmission lines.*



Also, calculate the capacitance per unit length for this line using the formulas in the text or class notes. Compare your answer to what is determined by AppCAD.



2. Spreadsheet

Using the spreadsheet finite difference method, determine the capacitance per unit length for the two cases. Compare your answer to the answers determined by AppCAD and analytically (in the case of the coax). Are your answers larger or smaller? Can you explain the difference?

3. Spreadsheet

On the next page, shown sideways, is the spreadsheet setup for a configuration that addresses how capacitance can be used to determine something about the makeup of the insulating materials found between the plates. This is the principle of the stud finder tool used to locate the wooden or metal studs behind a wall when you wish to hang a picture or mount a shelf. This is also the basic idea behind some types of medical imaging modalities that use electrodes to locate objects within a human torso. For this configuration, assume that the structure is 31 cells wide and 31 cells high and that each cell is 1mm by 1mm. The positive electrode is shown in red and the negative electrode is shown in blue. The space between the plates is empty except for the four dielectric blocks. The blocks are 7 cells wide and 5 cells high. The dielectric constant of the blocks is 80. To help you think about how to set up this problem, the color of the cells indicates that a particular type of formula is found there.

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AG40

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	100	100	100	100	100	100	100	100	100	100	100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
2	-0.6	-26	-32	-33	-34	-34	-34	-34	-34	-34	15.8	28.2	31.2	31.9	32.1	32.1	32.1	32.2	32.2	32.4	32.5	-17	-30	-33	-34	-34	-34	-34	-34	-34	-34
3	-1.1	-7.4	-11	-12	-12	-12	-12	-12	-12	-13	-0.3	5.74	7.74	8.41	8.61	8.68	8.71	8.75	8.87	9.21	9.47	-2.9	-9	-11	-12	-12	-12	-12	-12	-12	-12
4	-1.7	-3.2	-4.4	-5	-5.3	-5.4	-5.5	-5.6	-5.7	-5.8	-2.9	-1	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	0.05	1.13	-1.6	-3.7	-4.8	-5.2	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4
5	-2.2	-2.6	-3	-3.3	-3.4	-3.5	-3.6	-3.7	-3.8	-3.9	-3.3	-2.9	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-2.5	-1.8	-2.3	-2.9	-3.3	-3.4	-3.5	-3.5	-3.5	-3.5	-3.4	-3.4
6	-2.8	-2.9	-3	-3.1	-3.2	-3.3	-3.3	-3.4	-3.5	-3.6	-3.5	-3.4	-3.7	-3.7	-3.6	-3.6	-3.6	-3.6	-3.6	-3.3	-3	-3	-3.1	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2
7	-3.3	-3.3	-3.4	-3.4	-3.5	-3.5	-3.6	-3.7	-3.7	-3.8	-3.8	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.6	-3.6	-3.6	-3.6	-3.5	-3.5	-3.5	-3.4	-3.4	-3.4	-3.4
8	-3.8	-3.8	-3.8	-3.9	-3.9	-4	-4	-4.1	-4.1	-4.2	-4.1	-4	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-4	-4.1	-4.1	-4.1	-4.1	-4	-4	-3.9	-3.9	-3.8	-3.8	-3.8
9	-4.3	-4.3	-4.3	-4.3	-4.4	-4.5	-4.5	-4.6	-4.6	-4.7	-4.6	-4.5	-4.4	-4.3	-4.3	-4.3	-4.3	-4.3	-4.4	-4.5	-4.6	-4.6	-4.6	-4.6	-4.5	-4.4	-4.4	-4.3	-4.3	-4.2	-4.2
10	-4.7	-4.7	-4.7	-4.8	-4.9	-5	-5.1	-5.1	-5.2	-5.2	-5.2	-5.1	-5	-5	-4.9	-4.9	-4.9	-5	-5	-5.1	-5.2	-5.2	-5.2	-5.1	-5	-5	-4.9	-4.8	-4.7	-4.7	-4.7
11	-5.1	-5.1	-5.2	-5.2	-5.4	-5.5	-5.6	-5.7	-5.8	-5.8	-5.8	-5.7	-5.6	-5.6	-5.5	-5.5	-5.5	-5.6	-5.6	-5.7	-5.8	-5.8	-5.7	-5.7	-5.6	-5.5	-5.3	-5.2	-5.1	-5.1	-5.1
12	-5.5	-5.5	-5.5	-5.7	-5.8	-6	-6.2	-6.3	-6.4	-6.4	-6.4	-6.3	-6.3	-6.1	-6.1	-6	-6.1	-6.1	-6.3	-6.3	-6.4	-6.4	-6.4	-6.3	-6.2	-6	-5.8	-5.6	-5.5	-5.5	-5.5
13	-5.8	-5.8	-5.9	-6	-6.2	-6.5	-6.8	-7	-7	-7	-7	-7	-6.9	-6.7	-6.5	-6.5	-6.5	-6.7	-6.9	-7	-7	-7	-7	-6.9	-6.8	-6.5	-6.2	-6	-5.8	-5.8	-5.8
14	-6	-6	-6.1	-6.3	-6.6	-7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.2	-6.9	-6.9	-6.9	-7.2	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-6.9	-6.5	-6.3	-6.1	-6	-6
15	-6.2	-6.2	-6.3	-6.4	-6.7	-7.1	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.3	-7.1	-7.1	-7.1	-7.3	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.1	-6.7	-6.4	-6.2	-6.1	-6.1
16	-6.2	-6.2	-6.3	-6.5	-6.8	-7.2	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.4	-7.2	-7.1	-7.2	-7.4	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.2	-6.8	-6.5	-6.3	-6.2	-6.2
17	-6.2	-6.2	-6.3	-6.4	-6.7	-7.1	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.3	-7.1	-7.1	-7.1	-7.3	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.1	-6.7	-6.4	-6.2	-6.1	-6.1
18	-6	-6	-6.1	-6.3	-6.6	-7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.2	-6.9	-6.9	-6.9	-7.2	-7.7	-7.7	-7.7	-7.7	-7.7	-7.7	-7.6	-6.9	-6.5	-6.3	-6.1	-6	-6
19	-5.8	-5.8	-5.9	-6	-6.2	-6.5	-6.8	-7	-7	-7	-7	-7	-6.9	-6.7	-6.6	-6.5	-6.6	-6.7	-6.9	-7	-7	-7	-7	-6.9	-6.8	-6.5	-6.2	-6	-5.8	-5.8	-5.8
20	-5.5	-5.5	-5.5	-5.7	-5.8	-6	-6.2	-6.3	-6.4	-6.4	-6.4	-6.4	-6.3	-6.2	-6.1	-6.1	-6.1	-6.2	-6.3	-6.4	-6.4	-6.4	-6.4	-6.3	-6.2	-6	-5.8	-5.6	-5.5	-5.5	-5.5
21	-5.1	-5.1	-5.2	-5.3	-5.4	-5.5	-5.6	-5.7	-5.8	-5.8	-5.8	-5.8	-5.7	-5.6	-5.6	-5.6	-5.6	-5.6	-5.7	-5.8	-5.8	-5.8	-5.8	-5.7	-5.6	-5.5	-5.3	-5.2	-5.1	-5.1	-5.1
22	-4.7	-4.7	-4.7	-4.8	-4.9	-5	-5.1	-5.2	-5.2	-5.2	-5.2	-5.2	-5.1	-5.1	-5	-5	-5	-5.1	-5.1	-5.2	-5.2	-5.2	-5.2	-5.1	-5.1	-5	-4.9	-4.8	-4.7	-4.7	-4.7
23	-4.3	-4.3	-4.3	-4.3	-4.4	-4.5	-4.6	-4.6	-4.7	-4.7	-4.7	-4.6	-4.5	-4.5	-4.4	-4.4	-4.4	-4.5	-4.5	-4.6	-4.7	-4.7	-4.7	-4.6	-4.5	-4.5	-4.4	-4.3	-4.3	-4.2	-4.2
24	-3.8	-3.8	-3.8	-3.8	-3.9	-4	-4	-4.1	-4.2	-4.2	-4.2	-4.1	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-4.1	-4.2	-4.2	-4.1	-4.1	-4	-3.9	-3.9	-3.8	-3.8	-3.8	-3.8
25	-3.3	-3.3	-3.3	-3.3	-3.4	-3.4	-3.5	-3.6	-3.6	-3.7	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.7	-3.6	-3.6	-3.5	-3.4	-3.4	-3.3	-3.3	-3.3	-3.3
26	-2.8	-2.8	-2.8	-2.8	-2.8	-2.9	-3	-3	-3.1	-3.2	-3.4	-3.6	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.6	-3.4	-3.2	-3.1	-3	-3	-2.9	-2.8	-2.8	-2.8	-2.8	-2.8
27	-2.2	-2.2	-2.2	-2.3	-2.3	-2.3	-2.4	-2.5	-2.6	-2.7	-3	-3.3	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.3	-3	-2.7	-2.6	-2.5	-2.4	-2.3	-2.3	-2.3	-2.2	-2.2	-2.2
28	-1.7	-1.7	-1.7	-1.7	-1.7	-1.8	-1.8	-1.9	-2	-2.2	-2.4	-2.9	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-2.9	-2.4	-2.2	-2	-1.9	-1.8	-1.8	-1.7	-1.7	-1.7	-1.7	-1.7
29	-1.1	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2	-1.3	-1.4	-1.5	-1.7	-2	-2.3	-2.4	-2.5	-2.5	-2.5	-2.4	-2.3	-2	-1.7	-1.5	-1.4	-1.3	-1.2	-1.2	-1.2	-1.1	-1.1	-1.1	-1.1
30	-0.6	-26	-32	-33	-34	-34	-34	-34	-34	-34	-34	-34	-34	-35	-35	-35	-35	-35	-34	-34	-34	-34	-34	-34	-34	-34	-34	-34	-34	-34	-34
31	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
32																															
33																															

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The red and blue cells are electrodes so they contain fixed voltages. Also the white and yellow cells contain the formula for the average of the near neighbors. The purple cells contain the formulas for the open edge of the region with no conductors. The orange and pink cells contain the formulas for the boundary between two dielectric media. For each of the following configurations, you normally would be free to use either the charge on the positive plate or the charge on the negative plate to find the capacitance. However, for completeness and to see that similar methods can give different results, you are to find the capacitance both ways here. That is, find the charge on the positive plate and use it to find C and then find the charge on the negative plate and use it to find C. Remember also that you are really finding the charge and capacitance per unit length. When you have finished calculating all of these capacitances, discuss the differences in the values you have obtained. Do they make sense and why?

a. First find the capacitance of this structure for the case where the entire internal region is empty (no dielectric blocks)

b. Second find the capacitance for the four cases where there is one dielectric block, addressing each possible location separately. If you have done this correctly, two of your answers should be the same.

c. Third, find the capacitance for the case where all four blocks are included.