NAME: _____

ELEE 6340
Fall 2002

EXAM I

INSTRUCTIONS:

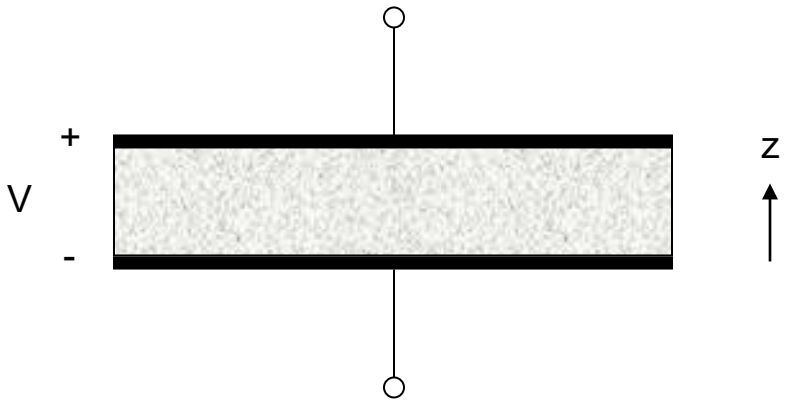
This exam is open-book and open-notes. You may use any material or calculator that you wish. Please show *all of your work* and *write neatly* in order to receive credit. Put all of your answers in terms of the parameters given in the problems, unless otherwise noted. Include units with all answers in order to receive full credit.

Problem 1 (30 pts)

A parallel-plate capacitor is filled with saltwater. At a frequency of 10 GHz, the water has $\hat{\varepsilon} = \varepsilon_0 (60 - j35)$ [F/m] and $\sigma = 4$ [S/m]. A voltage phasor V = 1.0 exists across the capacitor (see the figure below). The capacitor has a 1.0 [cm] separation between the plates. The area of each plate is 100 [cm^2]. Assume that the electric field is uniform inside the capacitor.

Determine the following:

1. The complex relative permittivity ε_{rc}.
2. The electric field vector $\boldsymbol{E}$ inside the capacitor.
3. The $\boldsymbol{D}$ vector inside the capacitor (leave the answer in terms of ε_0).
4. The conduction current density $\boldsymbol{J}^c$ inside the capacitor.
5. The charge density ρ_s on the bottom plate of the capacitor (leave the answer in terms of ε_0).
6. The polarization current $\boldsymbol{J}^p$ that is due to the polarized molecules.
7. The equivalent current $\boldsymbol{J}^{eq}$ that completely replaces the capacitor in terms of producing the same external fields when it radiates in free space.



ROOM FOR EXTRA WORK

Problem 2 (20 pts)

The characteristic impedance of a certain transmission line is $Z_0 = 50$ [Ω] when it is filled with air. The transmission line is then filled with a lossy Teflon material, having $\varepsilon_r = 2.2$ and a loss tangent of $\mathrm{Tan}\delta = 0.001$. Assume that the transmission line is made of perfect conductors.

1. Determine the parameters R, L, G, C after the line is filled with the lossy Teflon.

2. Determine the attenuation constant α [np/m] (after the line is filled with the Teflon) for a signal at a frequency of 1.0 GHz.

ROOM FOR EXTRA WORK

Problem 3 (30 pts)

A transmission line consists of perfectly conducting wires in air. The characteristic impedance is Z_0^A. The line is then filled with a lossy nonmagnetic material having a loss tangent Tanδ. The line then has loss (because G > 0), and also dispersion. In order to eliminate the dispersion, a series resistance per unit length R [Ω/m] is added to the line.

Show that the dispersion is eliminated if

$$R = k_0 Z_0^A \operatorname{Tan}\delta .$$

ROOM FOR EXTRA WORK

Problem 4 (20 pts)

When a certain waveguide is air filled, is has a cutoff frequency f_{c0}. This waveguide is then filled with a lossy material, having a complex relative permittivity ε_{rc}. Show that the propagation wavenumber of the filled waveguide at any frequency is

$$k_z = k_0 \left(\varepsilon_{rc} - \left(\frac{f_{c0}}{f} \right)^2 \right)^{1/2} .$$

Explain all of your steps carefully.

ROOM FOR EXTRA WORK