NAME: ___________________________________

ECE 6340
Fall 2013

EXAM I

INSTRUCTIONS:

This exam is open-book and open-notes. You may use any material or calculator that you wish, as long as it does not have any communication capability. Laptops or other devices that may be used to communicate are not allowed.

- Put all of your answers in terms of the parameters given in the problems, unless otherwise noted.
- Include units with all numerical answers.
- Please circle your final answers.
- Please write all of your work on the sheets attached (if you need more room, you may write on the backs of the pages).

Please show *all of your work* and *write neatly* in order to receive credit.

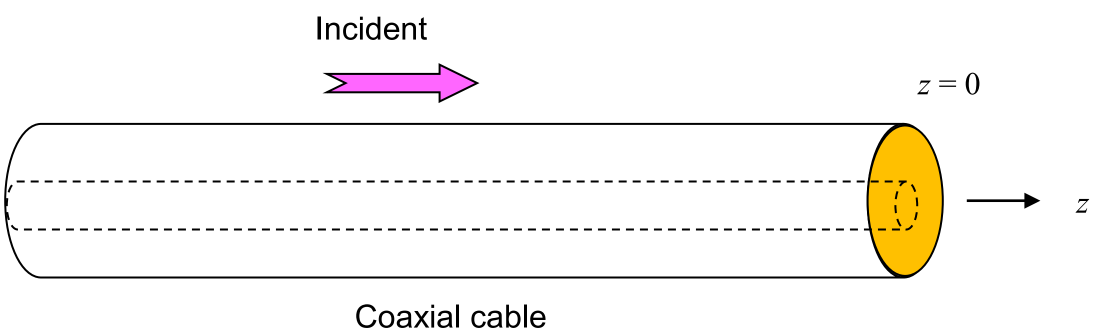
Problem 1 (25 pts)

A coaxial cable is air filled and has an inner radius of a and an outer radius of b. An incident wave at a frequency ω with a voltage of 1.0 [V] is incident on a short-circuit plate at the end of the line, at $z = 0$, as shown below. The incident voltage in the phasor domain is

$$V_{inc}(z) = e^{-jk_0 z} .$$

(Voltage is defined as the voltage on the inner conductor relative to the voltage on the outer conductor, and current is defined as the current in the z direction on the inner conductor.)

Determine the force in the z direction on the short-circuit plate using the Maxwell stress tensor.



ROOM FOR WORK

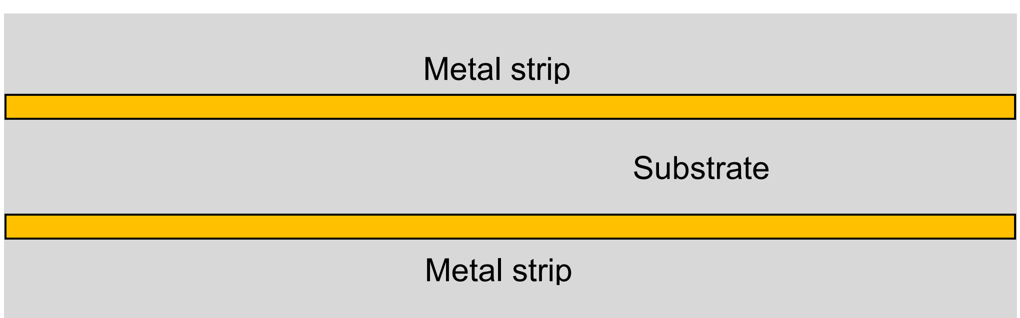
Problem 2 (25 pts)

A transmission line consists of two parallel strips of metal (microstrip lines) that are printed on top of a grounded substrate as shown in part (a) of the figure below (a top view is shown). This transmission line is called a "coplanar strips" transmission line. One of the lines is the "A" conductor and the other one is the "B" conductor. It is thus similar to twin-lead, except that the two conductors are flat strips instead of round wires, and they are printed on a grounded substrate instead of being in free space.

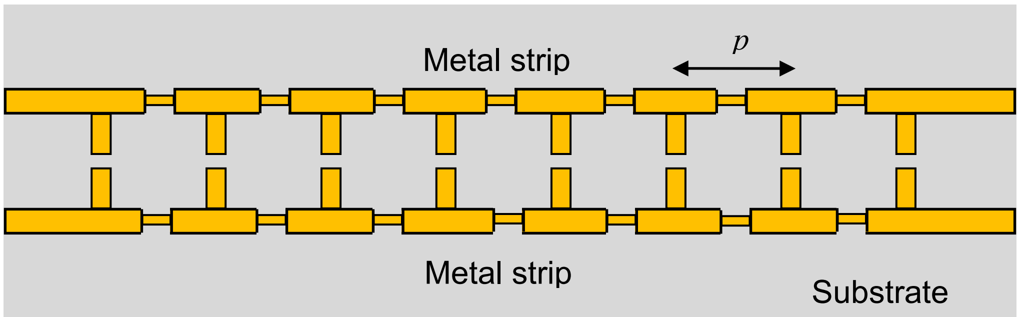
Assume that this transmission line has a known characteristic impedance of Z_0 and a known effective relative permittivity of ε_r^{eff}. (The phase velocity is the speed of light in vacuum (denoted as c) divided by the square root of the effective relative permittivity.) Assume that the mode is quasi-TEM, and thus may be taken as TEM for modeling purposes. Also assume that the structure is lossless.

The line is then modified by adding narrow series segments and shunt capacitive gaps as shown in part (b) of the figure below, with a period of p for the unit cell length. Assume that each narrow segment acts as a series inductance of L_e [H] and each shunt segment adds a shunt capacitance of C_e [F]. You can neglect the length of the series segments, since they are small compared to the unit cell length p; a series segment is thus equivalent to an ideal series inductance of L_e that has no length.

Calculate R, defined as the ratio of the phase constant on the structure relative to that on the unmodified (coplanar strips) structure. You should carry out the algebra to the point where it is obvious that this ratio R is not a function of frequency, but only depends on c, Z_0, L_e, C_e, p and ε_r^{eff}.



(a) Coplanar strips transmission line



(b) Modified transmission line

ROOM FOR WORK

Problem 3 (25 pts)

A shallow dish of water is placed in a microwave oven as shown below. The radian frequency of the oven is $\omega = 2\pi f$. The volume of the water is V. Immediately above the water, in the air region, the electric field is perfectly vertical (in the z direction) and uniform, and is given (in the time domain) by

$$\underline{\mathscr{E}}_0 = \underline{\hat{z}}\, A_0 \cos(\omega t)\,.$$

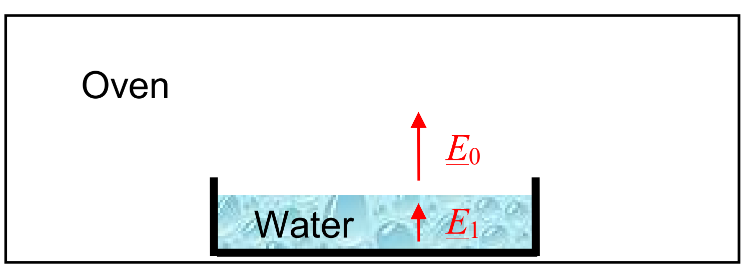
Assume that the electric field $\underline{\mathscr{E}}_1$ inside the water is also uniform and vertical (but is not necessarily the same as the electric field $\underline{\mathscr{E}}_0$ above the water). The water has a complex relative permittivity given by

$$\varepsilon_r = \varepsilon_r' - j\varepsilon_r''\,.$$

Also, the water has salt dissolved in it so that it has a conductivity σ. Hence, the water has a complex effective relative permittivity ε_{rc}.

(a) Derive a formula for the power being dissipated inside the water. Your final answer should be in terms of V, A_0, ω, ε_0, ε_{rc}', and ε_{rc}'' .

(b) Assume that the conductivity of the water is high so that the loss due to polarization is negligible compared to the loss from the conductivity. Solve for what the conductivity σ should be in order to maximize the power being dissipated within the water at a fixed frequency ω. Your answer should be in terms of ω, ε_0 and ε_{rc}'.



ROOM FOR WORK

Problem 4 (25 pts)

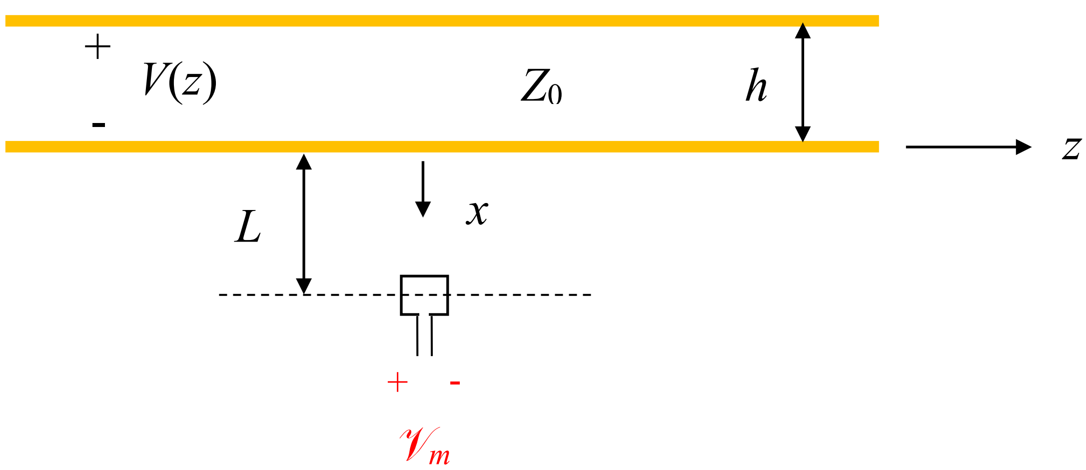
Two lossless narrow parallel wires form an infinite twin-lead transmission line in air. The separation between the centers of the wires is h. The lower wire has its axis aligned with the z axis. The characteristic impedance of the twin-lead transmission line is Z_0. A small rectangular loop of wire is located next to the transmission line as shown below. The area of the loop is A, and the center of the loop is located at $z = 0$ and $x = L$. The size of the loop is small compared with the distance L. The loop is connected to an ideal voltmeter (not shown) so that the loop is open-circuited.

Assume that a sinusoidal steady-state voltage signal propagates down the line, with a phasor voltage given by

$$V(z) = V_0 \, e^{-jk_0 z} \, .$$

Assume that the frequency is low enough that the wavelength is very large compared with the distance to the loop and the distance between the wires. Therefore, the magnetic field produced by each wire in the time domain at any time t may be found by treating the current on each wire as a uniform DC current, with the value of the DC current being that of the actual sinusoidal current at that time t.

Determine the voltage reading on the voltmeter $\mathcal{V}_m(t)$ as a function of time.



ROOM FOR WORK