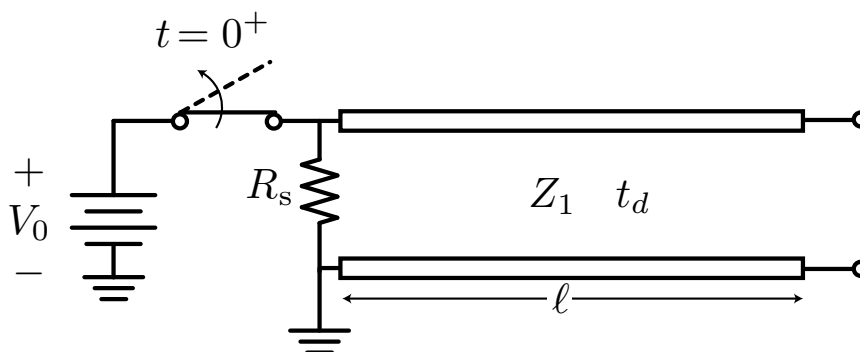


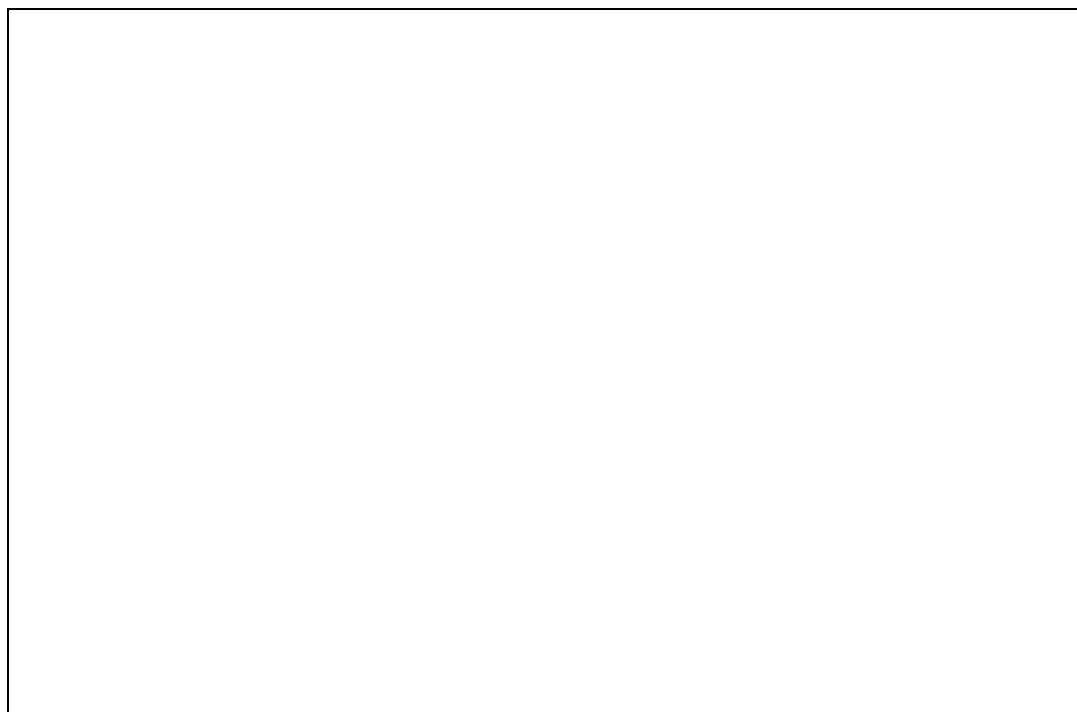
Final Exam(closed book)
Friday, May 21, 2004

Guidelines: Closed book and notes. You may use a calculator. Do not unstaple the exam.
Warning: Illustrations not to scale.

1. (18 points) The initially charged transmission line shown below is suddenly disconnected from the source at $t = 0$. The line has a characteristic impedance of $Z_1 = 50\Omega$ and $R_s = 25\Omega$. The line has a propagation time delay of t_d .

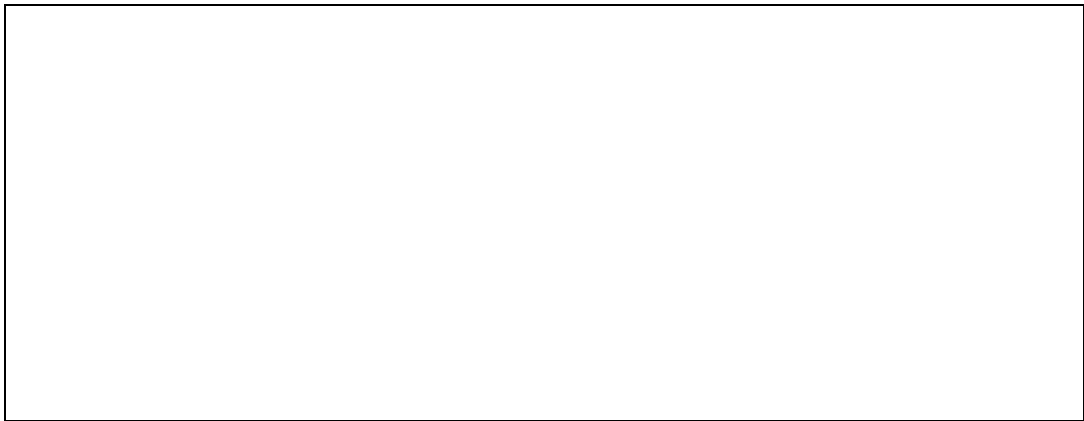


- (a) Draw the bounce diagram for the circuit for $0 < t < 4t_p$.





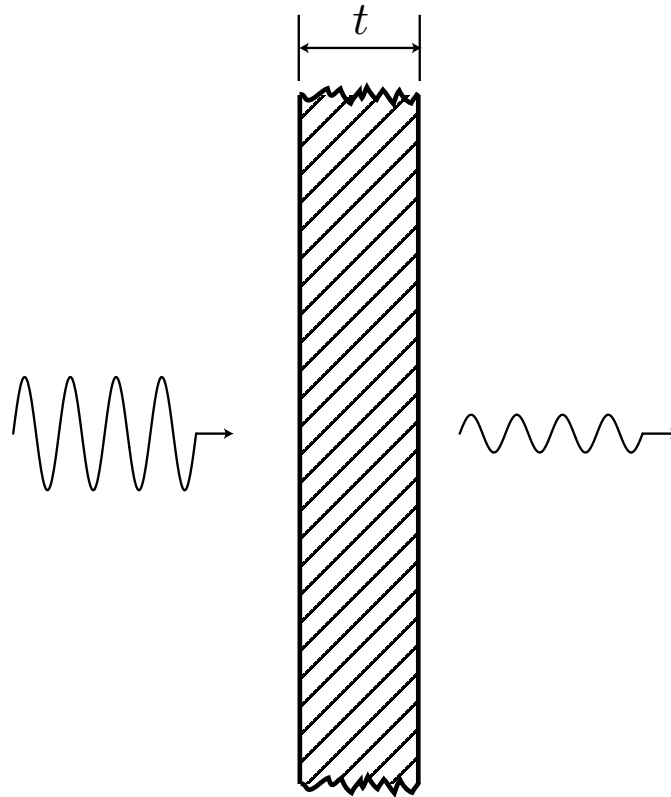
(b) Sketch the voltage waveform at the output.



(c) Sketch the voltage waveform at the input across R_s .

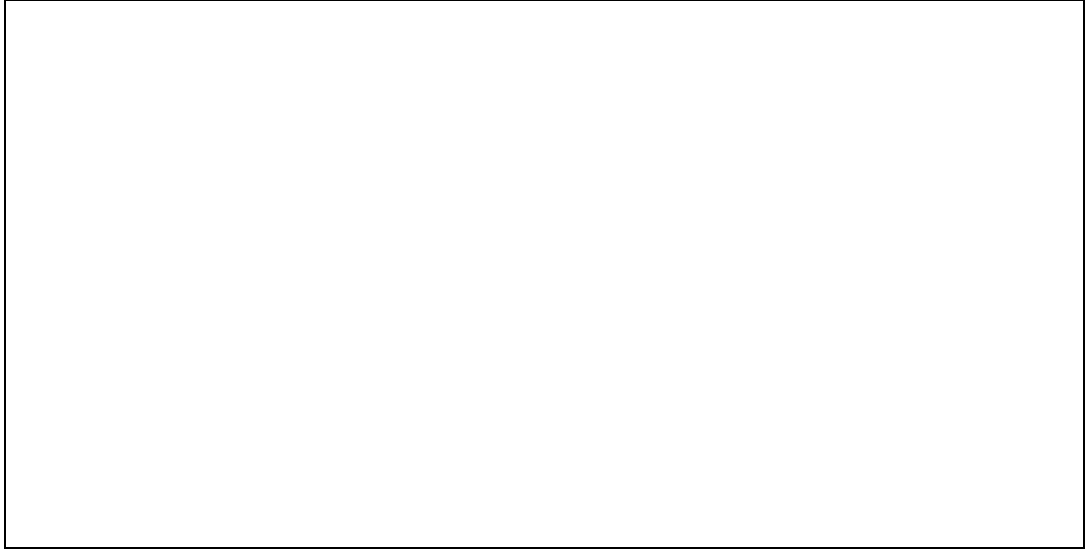


2. (15 points) A top secret government laboratory wishes to isolate its mainframe computer from potential outside eavesdropping. Specify the thickness of walls shown below to prevent outside detection if the minimum detectable signal power is 10 pW/m^2 . The walls are made of a conductive material with resistivity $\rho = 5 \times 10^{-2} \Omega\text{-m}$. The measured electric field strength on the inner surface of the wall is 10 mV/m at a frequency of $f = 1 \text{ GHz}$. You may assume that the computer radiates its power isotropically (equally in all directions) and the incoming radiation onto the surface of the walls is a TEM mode plane wave.

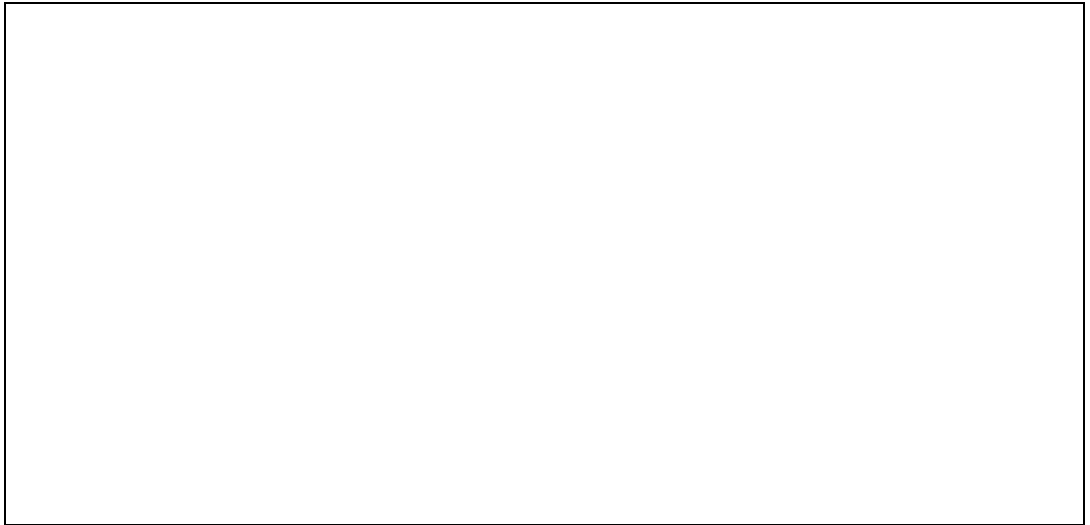


- (a) Calculate the amount of reflected and transmitted field into the conductive walls as a function of t .

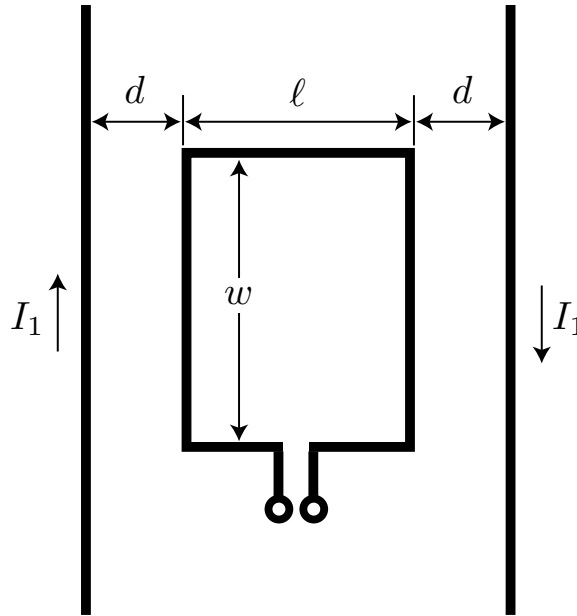




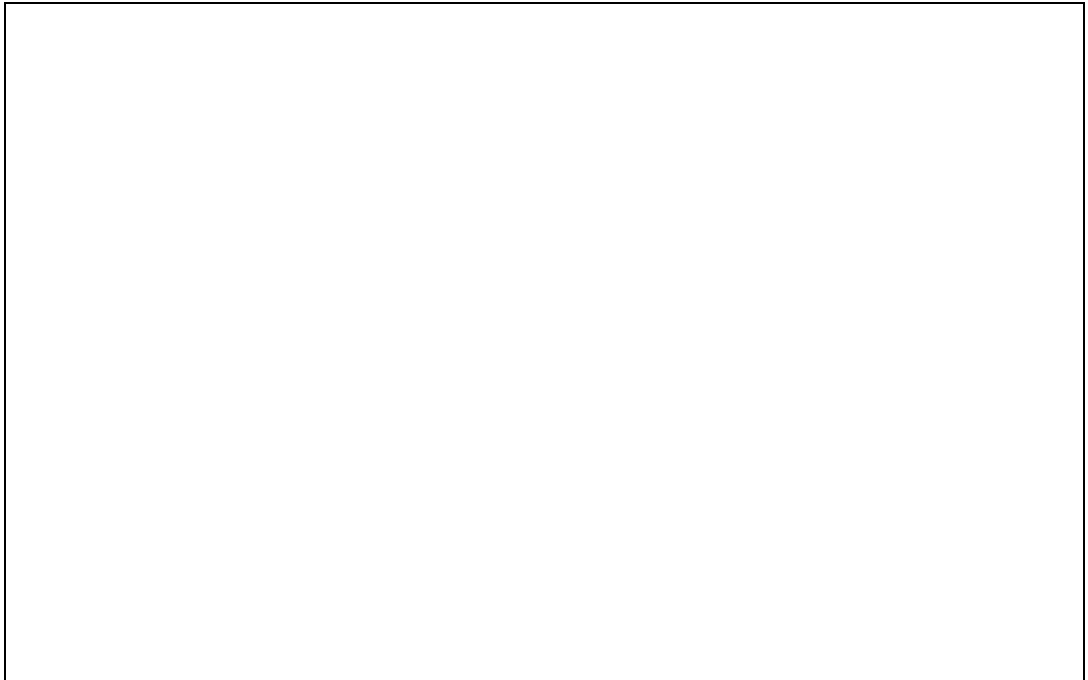
(b) Estimate the thickness t to prevent detection of the leakage radiation.



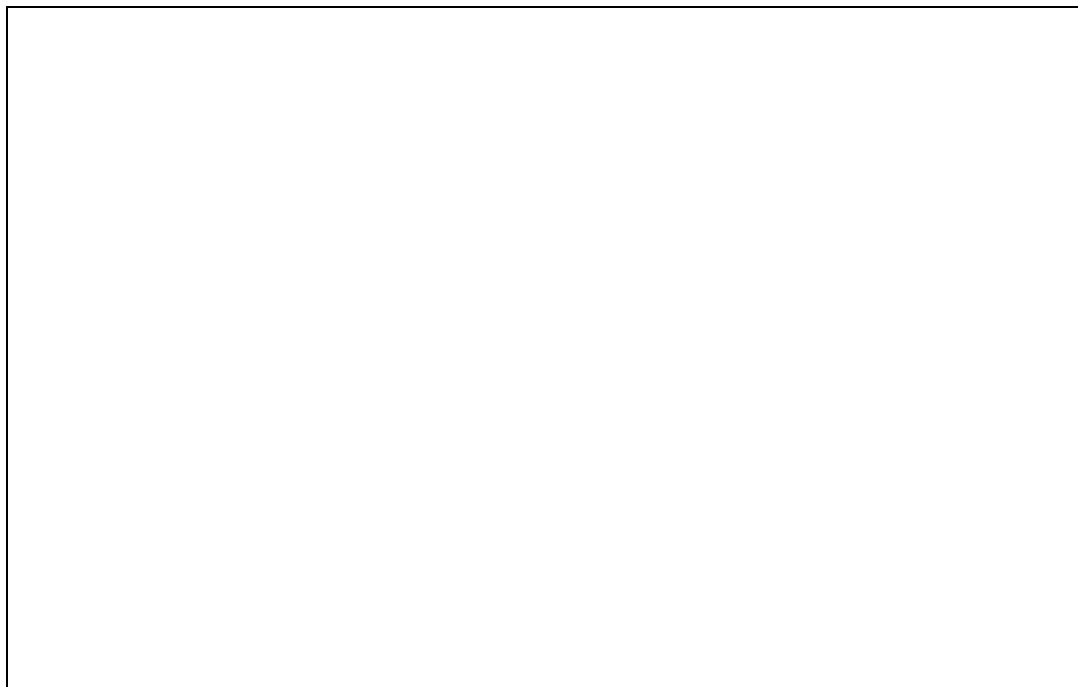
3. (20 points) Two long parallel wires carry an AC current as shown below. A rectangular loop is placed symmetrically in between the wires in the plane of the wires. The inner loop is at a distance $d = 3$ mm from the wires. The loop has a length $\ell = 10$ mm and a width of $w = 15$ mm.



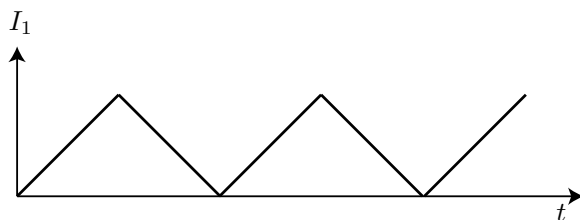
- (a) Calculate the magnetic field in the space between the wires as a function of the current in the parallel lines. The inner loop is terminated in an open circuit as shown.



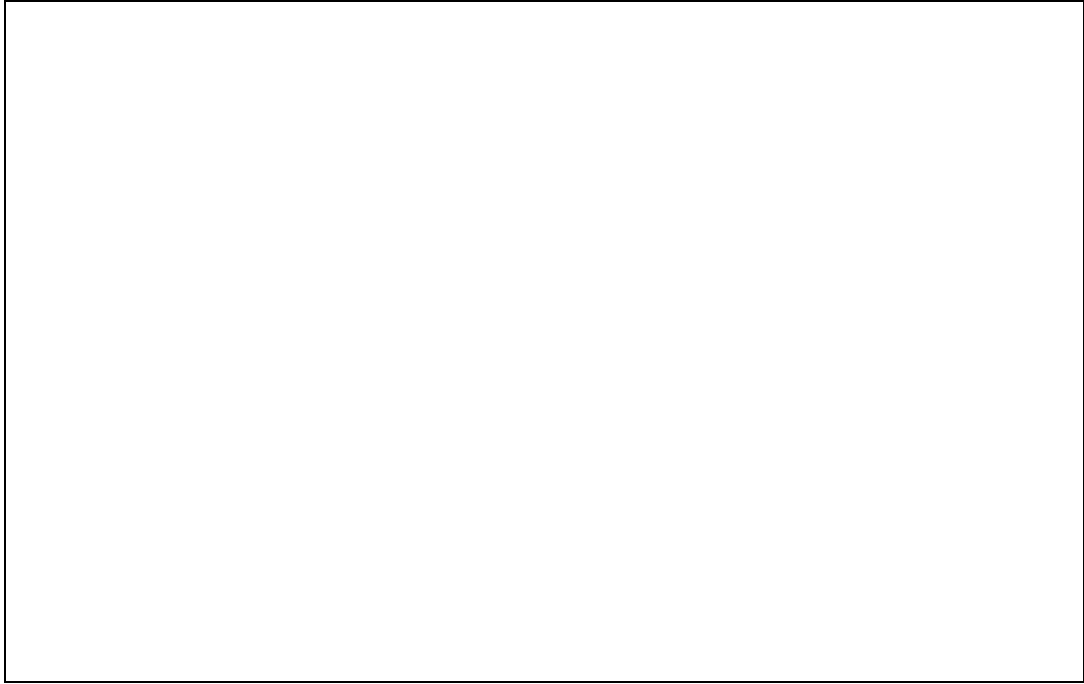
- (b) Calculate the magnetic flux crossing the inner loop and the mutual inductance.



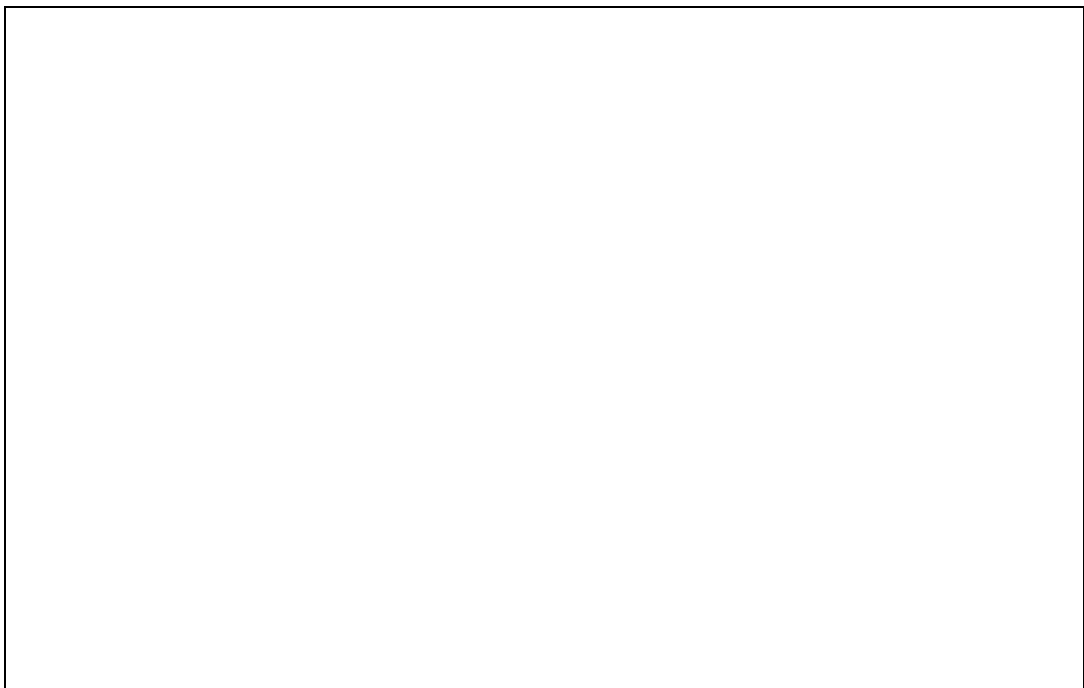
- (c) Calculate the voltage pickup in the inner loop if the wires carry the AC current waveform shown below. The maximum excursion of the current $I_1 = 1$ A and the period of oscillation is $1 \mu\text{s}$.



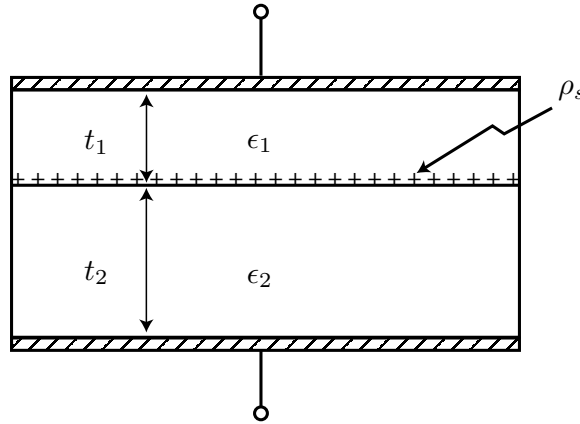
- (d) Calculate the peak force on the inner loop if a DC current of 1 mA is forced into the inner loop while the current in the long wires is of the triangular form described above but mismatched by 5%.



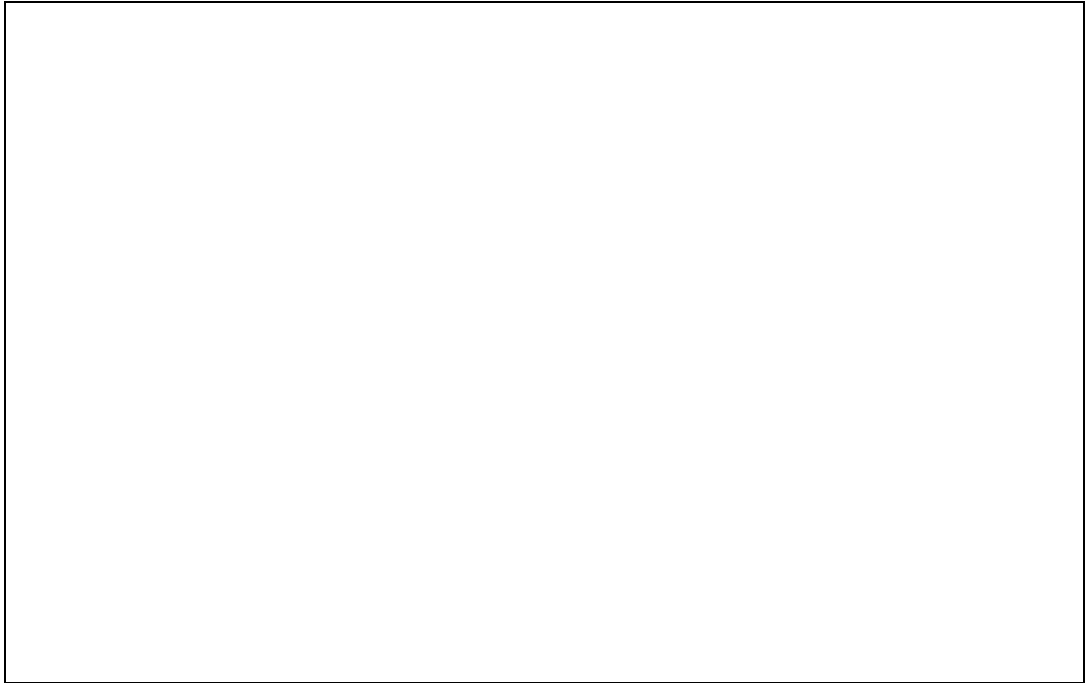
- (e) If the loop is terminated in a resistive load, indicate the direction of current flow in the loop relative to the phase of the current in the long wires. Explain.



4. (15 points) Consider the following capacitor sandwich structure with $\epsilon_1 \neq \epsilon_2$. The interface between the dielectrics is charged with a fixed surface charge $\rho_s = 10 \text{ mC/m}^2$. The thickness of the structure is negligible in comparison with the width and so you may neglect fringing fields.



- (a) Calculate the electric fields in region 1 and region 2 when an external voltage $V_s = 10 \text{ V}$ is applied to the structure.



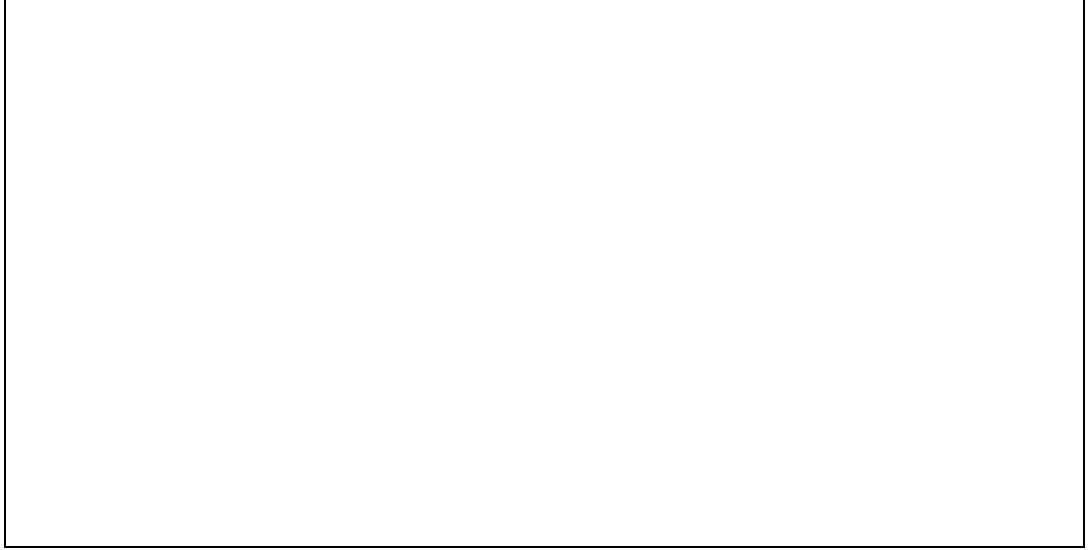
(b) What's the charge density induced on the top and bottom plates?



(c) Show that the charge density q on the top plate can be expressed with an equation similar to a capacitor $q = Cv + q_0$, where q_0 is a fixed charge density. Calculate C and q_0 .



- (d) Alternatively, we can interpret the fixed charge as producing a threshold voltage for the capacitor, such that $q = C(v - v_t)$. Calculate v_t .

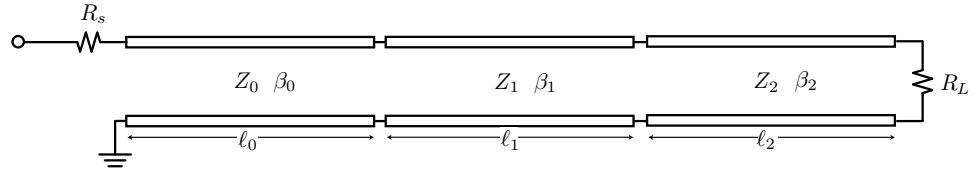


- (e) Calculate the electrostatic energy in the volume of the capacitor structure for $V_s = 0$. How does this compare with the value calculated from circuit theory? Explain.



5. (20 points) Calculate each question succinctly.

- (a) Calculate the SWR on each transmission line ($Z_0 = 48\Omega$, $Z_1 = 24\Omega$, $Z_2 = 6\Omega$, $R_s = 48\Omega$, $R_L = 3\Omega$, $\beta_0 = 2\pi$, $\beta_1 = \pi$, $\beta_2 = 2\pi$, $\ell_0 = 100\text{m}$, $\ell_1 = 1.5\text{m}$, $\ell_2 = .75\text{m}$).

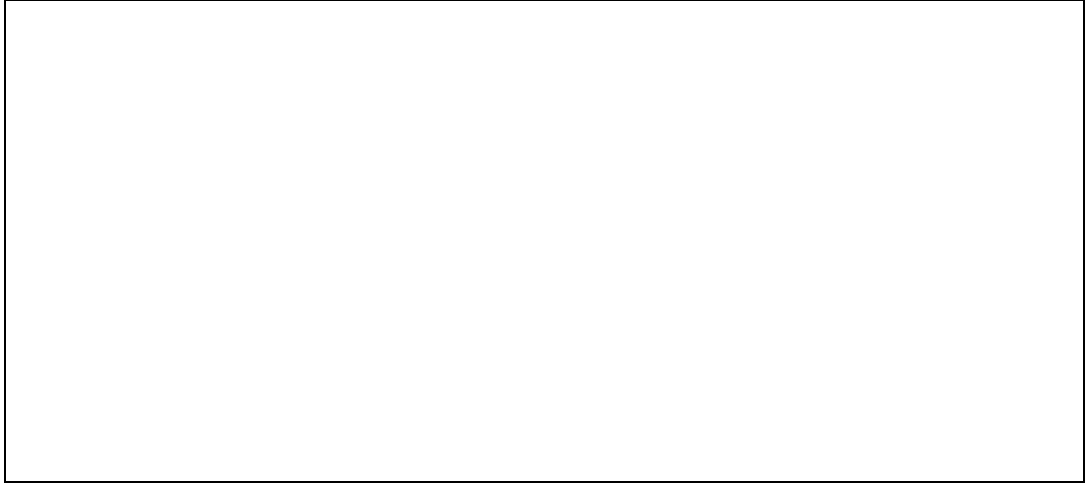


- (b) Write down five inductive termination impedances $Z_L = R + jX$ ($X > 0$) which result in an SWR of 3 on a 50Ω transmission line.

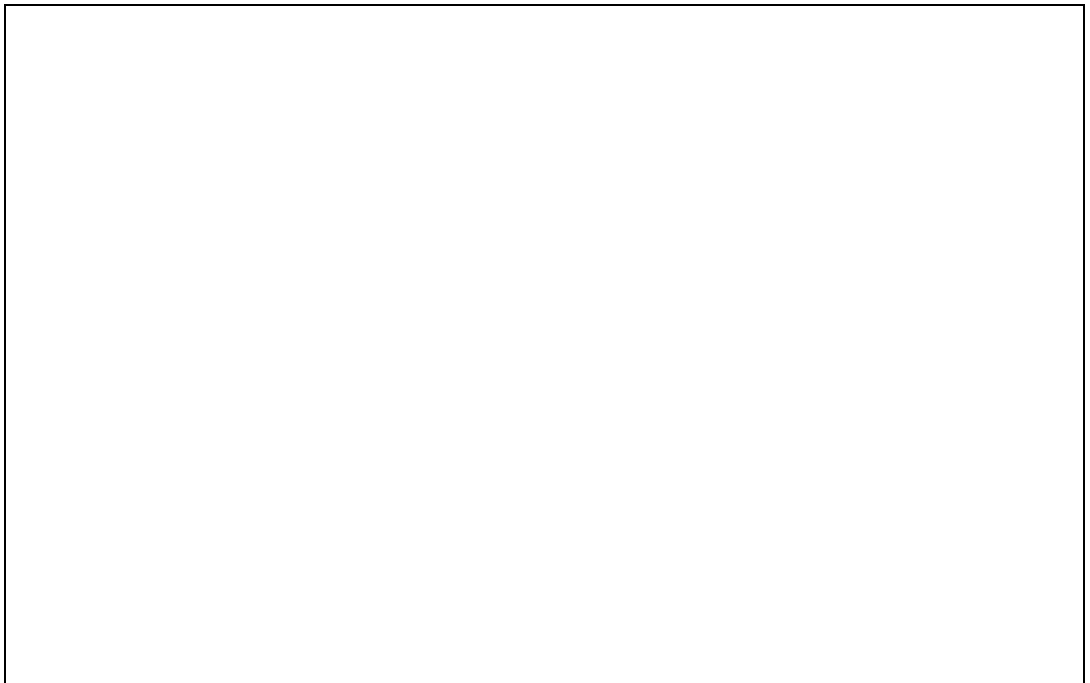
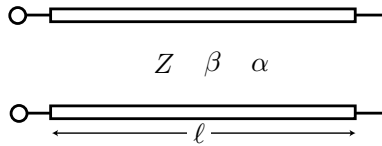
- (c) The current density in a circular conductor of radius r_0 is given by

$$J(r) = J_0 \frac{r}{r_0}$$

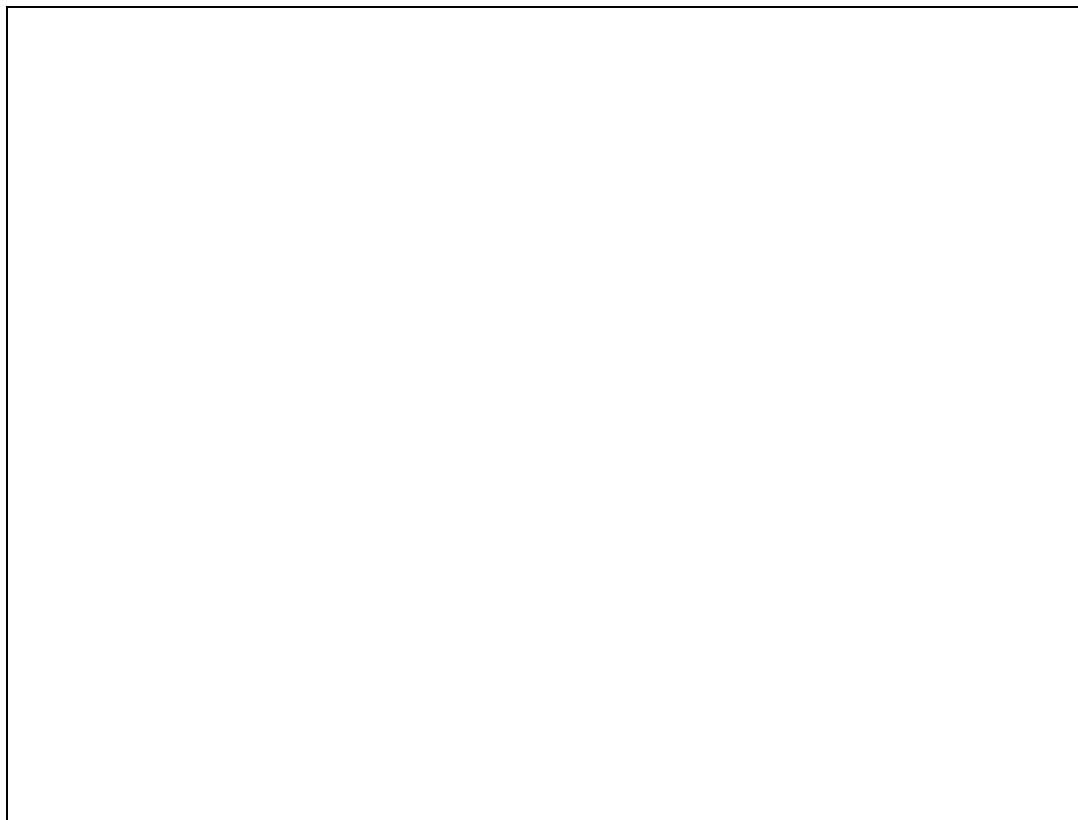
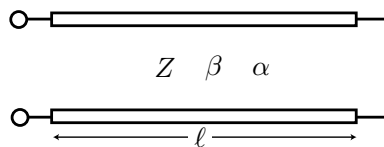
Calculate the conductive loss per unit length per unit Ampère of current in the wire.



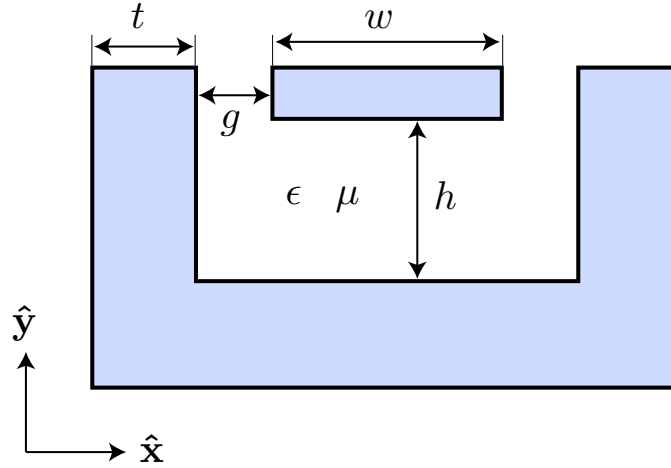
- (d) Demonstrate that in the low frequency limit, a short section of a shorted transmission line shown below can be modeled as an equivalent resistor R_{eq} . Compute the value of R_{eq} in terms of the distributed line parameters R' , G' , L' , C' .



- (e) Draw an equivalent circuit for small frequency offsets from the frequency $f = 100$ MHz. Assume the wave velocity on the line is $c = 1 \times 10^8$ m/s and $\ell = 1$ m. *Do not* calculate the equivalent lumped parameter values but simply draw an equivalent circuit.



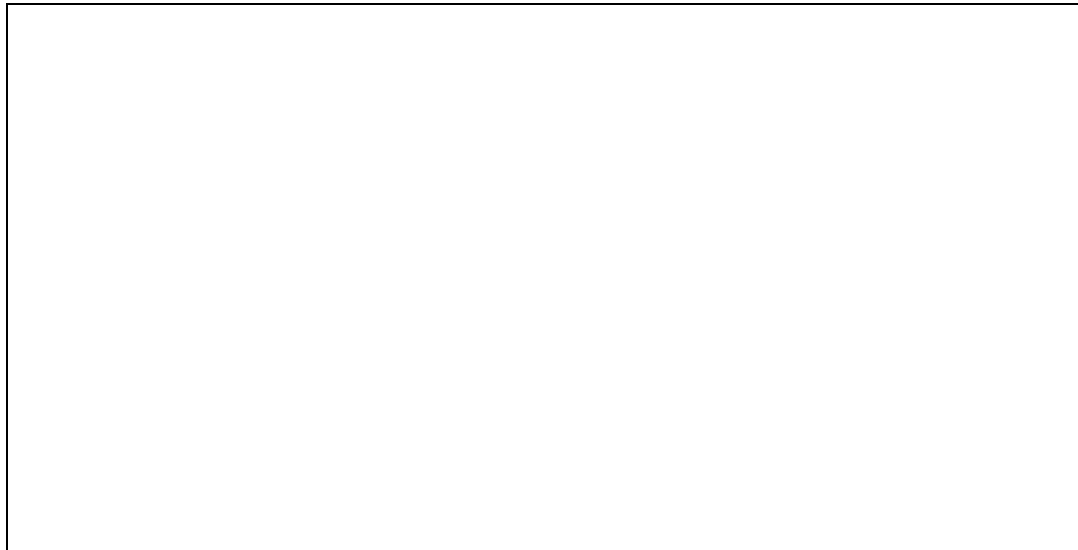
6. (12 points) For the cross-section shown below, we wish to find the propagation characteristics of a TEM wave. Assume that the conductors have zero resistance and the dielectric and magnetic losses are negligible at the frequency of operation.



- (a) Setup the equations for the electrostatic potential in the cross-section of the plane by writing $\phi(x, y) = f(x)g(y)$. What boundary conditions must be satisfied?

- (b) What's the propagation constant and wave impedance?

- (c) Assume that we have determined the electrostatic potential from part (a) and in rectangular coordinates, denote this potential as $\phi(x, y)$. Write the magnetic and electric fields in terms of the potential function $\phi(x, y)$.



Smith Chart

