Name: ______________________

GTID: ______________________

ECE 3025: Electromagnetics

TEST 1 (Fall 2006)

- Please read all instructions before continuing with the test.
- This is a **closed** notes, **closed** book, **closed** calculator, **closed** friend, **open** mind test. You should only have writing instruments on your desk when you take this test. If I find anything on your desk (excluding the test itself, writing instruments, and life-or-death medication) I will turn you in for an honor code violation. I am serious.
- Show all work. (It helps me give partial credit.) Work all problems in the spaces below the problem statement. If you need more room, use the back of the page. DO NOT use or attach extra sheets of paper for work.
- Work intelligently – read through the exam and do the easiest problems first. Save the hard ones for last.
- All necessary mathematical formulas are included either in the problem statements or the last few pages of this test.
- You have 80 minutes to complete this examination. When I announce a "last call" for examination papers, I will leave the room in 5 minutes. The fact that I do not have your examination in my possession will not stop me.
- I will not grade your examination if you fail to 1) put your name and GTID number in the upper left-hand blanks on this page or 2) sign the blank below acknowledging the terms of this test and the honor code policy.
- Have a nice day!

Pledge Signature: ____

I acknowledge the above terms for taking this examination. I have neither given nor received unauthorized help on this test. I have followed the Georgia Tech honor code in preparing and submitting the test.

(1) **Short Answer Section** (12 points)

(a) ________________

True or False: A forward crosstalk signal is the *derivative* of the original signal on the coupled transmission line.

(b) ________________

As a transmission line under steady state sinusoidal excitation lengthens, its equivalent impedance changes, but will repeat in space every [*Answer*].

(c) ________________

[*Answer*] is a measure of how badly a sinusoidal transmission line load is reflecting signal power.

(d) ________________

A [*Answer*] is a type of transmission line that is made by etching or milling away the top conductor on a conventional printed circuit board (PCB).

(e) ________________

The distance between a constructive voltage peak and the nearest destructive null on a transmission line under steady-sate sinusoidal excitation is [*Answer*].

(f) ________________

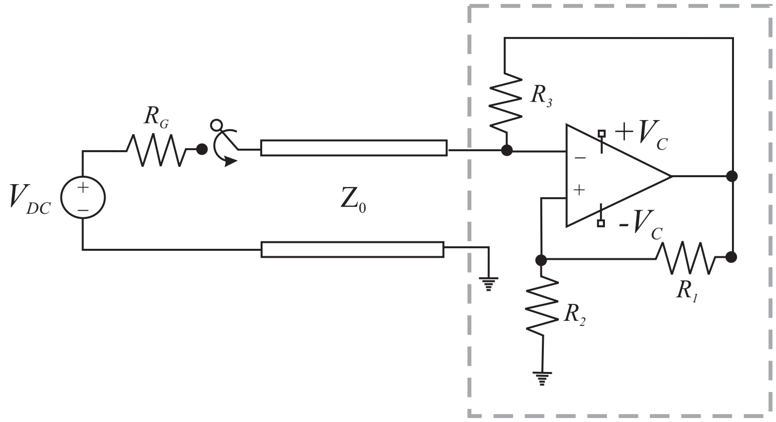
True or False: Nuclear engineers never use transmission lines.

(2) **Descriptive Answer Section** (30 points)

Write a **concise** answer to each question in the spaces provided beneath each problem statement. **Note:** Correct answers that are extremely verbose will be penalized.

(a) **Power Lines:** Towers that carry long-distance, high-voltage power lines are ugly, costly, inconvenient, and bulky. What are some reasons that we cannot bury these lines underground? (**10 points**)

(b) **Active Component Loading:** Here is a peculiar circuit that uses an operational amplifier at the load of a transmission line:



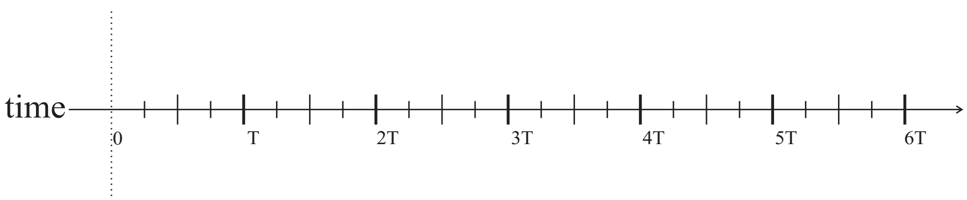
Because an operation amplifier is an active device, it is often capable of supplying more power than it absorbs from the signaling network. For example, the Thevenin equivalent of the load above is actually a pure resistance with *negative* $\left(-\frac{R_2 R_3}{R_1+R_2}\right)$ Ohms. Using basic principles of transmission line theory, explain qualitatively how this circuit will behave when the switch is thrown. (**10 points**)

(c) **Crosstalk:** List 5 things that an electrical engineer can do to a high-frequency printed circuit board and layout to minimize crosstalk. (**10 points**)

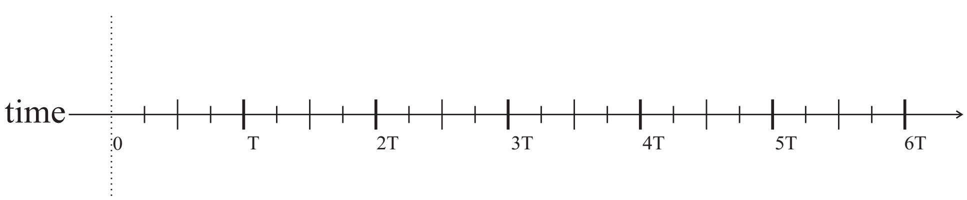
(3) **Reflection Sketches:** There is an uncharged transmission line with transit time T, length D, and reflection coefficients $\Gamma_G = -\frac{1}{2}$ and $\Gamma_L = \frac{1}{2}$. At $t = 0$ a DC source is connected to the line and 16 Volts DC begins to travel down the line. Please sketch and label the amplitudes of the time-domain waveforms that would be measured at the locations listed below. (**24 points**)

a. The voltage observed at the load side of the transmission line:

b. The voltage observed at the source side of the transmission line:

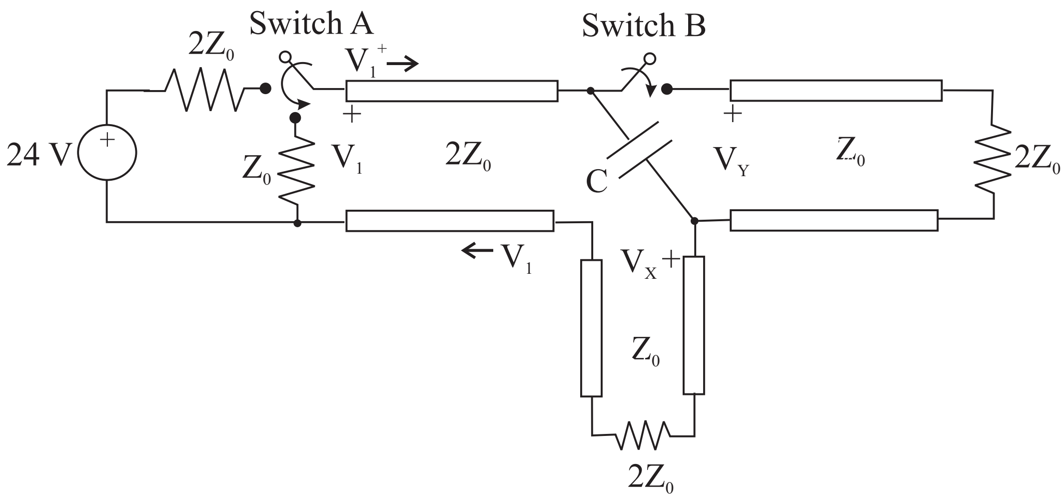


c. The voltage observed exactly **three-quarters** ($z = \frac{3D}{4}$) down the transmission line:



(4) **Switching Network:** The circuit below represents a high-speed digital interconnect that is switched according to the following states:

- State 0: Both switches are open and both lines are uncharged.
- State 1: Immediately after switch A is closed onto the DC source.
- State 2: Switch A has been closed for a while.
- State 3: Immediately after switch B is closed.
- State 4: Switch B has been closed for a while.
- State 5: Immediately after switch A closes onto the stand-alone Z_0 resistor.



Fill out the following table according to these switching states (skip state 3). Assume all backwards propagating waves are measured from the right-most side of the transmission line. Assume all forward propagating waves are measured from the left-most side of the transmission line. (**34 points**):

	V_1	V_X	V_Y	V_1^+	V_1^-
State 0	0	0	0	0	0
State 1		0	0		0
State 2					
State 4					
State 5					

Formula Sheet

$$\frac{\partial^2 v(z,t)}{\partial z^2} = LC\frac{\partial^2 v(z,t)}{\partial t^2} \qquad \frac{\partial^2 i(z,t)}{\partial z^2} = LC\frac{\partial^2 i(z,t)}{\partial t^2} \qquad Z_0 = \sqrt{\frac{L}{C}} \qquad v_p = \frac{1}{\sqrt{LC}}$$

$$\lambda f = v_p \qquad \omega = 2\pi f \qquad \beta = \frac{2\pi}{\lambda} \qquad \text{Reflection: } \Gamma_{L,G} = \frac{Z_{L,G} - Z_0}{Z_{L,G} + Z_0} \qquad \text{Transmission: } 1 + \Gamma_{L,G}$$

$$\text{Phasor Transform: } A\cos(2\pi f t + \phi) \longrightarrow A\exp(j\phi)$$

$$\text{Reverse Transform: } \tilde{x} \longrightarrow \text{Real}\left\{\tilde{x}\exp(j2\pi f t)\right\}$$

$$v(z,t) = V^+ f\left(t - \tfrac{z}{v_p}\right) + V^- g\left(t + \tfrac{z}{v_p}\right) \qquad \tilde{v}(z) = V^+\exp(-\gamma z) + V^-\exp(+\gamma z)$$

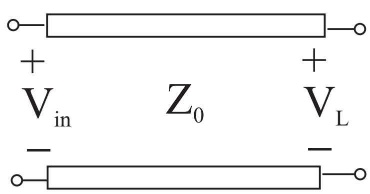
$$i(z,t) = \tfrac{V^+}{Z_0} f\left(t - \tfrac{z}{v_p}\right) - \tfrac{V^-}{Z_0} g\left(t + \tfrac{z}{v_p}\right) \qquad \tilde{i}(z) = \tfrac{V^+}{Z_0}\exp(-\gamma z) - \tfrac{V^-}{Z_0}\exp(+\gamma z)$$

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)} \qquad Z_{in} = Z_0\frac{Z_L + jZ_0\tan\beta D}{Z_0 + jZ_L\tan\beta D}$$

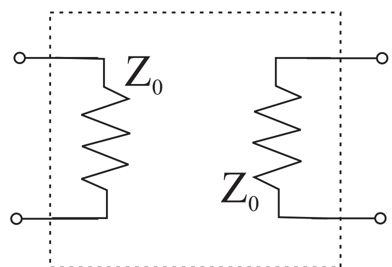
$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1 + |\Gamma_L|}{1 - |\Gamma_L|}$$

$$V^+ = \frac{V_L + I_L Z_0}{2} \qquad V^- = \frac{V_L - I_L Z_0}{2}$$

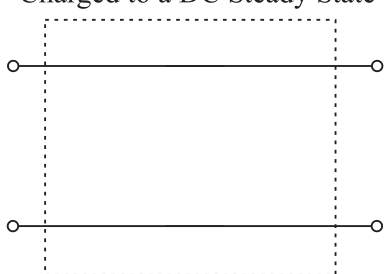
Useful Equivalent Circuits for T-lines



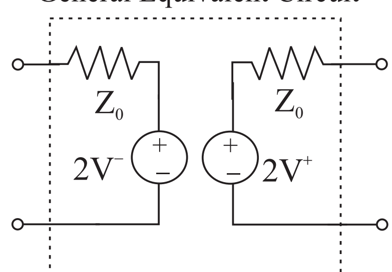
Completely Discharged Line



Charged to a DC Steady State



General Equivalent Circuit



$$\mu = \mu_r\mu_0 \qquad \mu_0 = 4\pi\times 10^{-7}\ \text{H/m} \qquad \epsilon = \epsilon_r\epsilon_0 \qquad \epsilon_0 = 8.854\times 10^{-12}\ \text{F/m}$$