Name: ______________________

SSN: ______________________

ECPE 3025: Electromagnetics
TEST 1 (Fall 2003)

- 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 50 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 social security 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** (24 points)

(a) ____________

True or False: The characteristic impedance, Z_0, represents the amount of power absorbed and converted to heat by a transmission line.

(b) ____________

We cannot use superposition to calculate individual reflections on a transmission line with a diode load, because the diode is a $\boxed{\textit{Answer}}$ device.

(c) ____________

When transmission line reflections cause data-distorting echoes, we call this effect $\boxed{\textit{Answer}}$.

(d) ____________

When coupling of two transmission lines causes signals to propagate on unintended pathways, this effect is called $\boxed{\textit{Answer}}$.

(e) ____________

When a transmission line fans-out to N lines (in parallel) with identical input impedance, the forward-looking reflection coefficient is $\boxed{\textit{Answer}}$.

(f) ____________

When a transmission line fans-out to N lines (in series) with identical input impedance, the forward-looking reflection coefficient is $\boxed{\textit{Answer}}$.

(g) ____________ (1) ____________ (2) ____________ (3)

The reflection coefficients of an open-circuit, closed-circuit, and matched circuit are $\boxed{\textit{Answer 1}}$, $\boxed{\textit{Answer 2}}$, and $\boxed{\textit{Answer 3}}$, respectively.

(h) ____________

A 100 km AC power line with velocity of propagation of 1×10^5 m/s will have a transit time, T, of $\boxed{\textit{Answer}}$.

(i) ____________

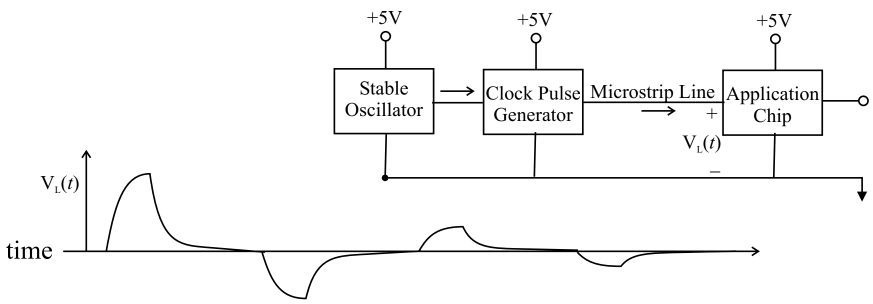
A transmission line with impedance of Z_0 and velocity of propagation v_p will have a per-unit-inductance of $\boxed{\textit{Answer}}$.

(j) ____________

True or False: The VI-characteristic of a resistor is a straight line.

(2) **Descriptive Answer Section** (21 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) **Circuit Diagnosis:** Henry is designing a clock circuit that outputs a short square pulse that drives several microprocessors. When Henry has finished etching his printed circuit board (PCB) and soldering chips onto the board, he finds that the output of his clock, as measured from the input terminals of his application-specific integrated circuit (ASIC) chips, is *not* a clean square pulse; instead, the output looks like the graph below. Using what you know so far about transmission lines, diagnose the problem(s) with this circuit. (**11 points**)



(b) **The Transmission Line Equations:** Below are solutions to a transmission line partial differential equation:

$$v(z,t) = 60\cos(1000t - 5z) - 120\pi \mathrm{u}\left(2t + \frac{z}{100} + 12\right) \text{ V}$$

$$i(z,t) = 2\pi \mathrm{u}\left(2t + \frac{z}{100} + 12\right) + \cos(1000t - 5z) \text{ A}$$

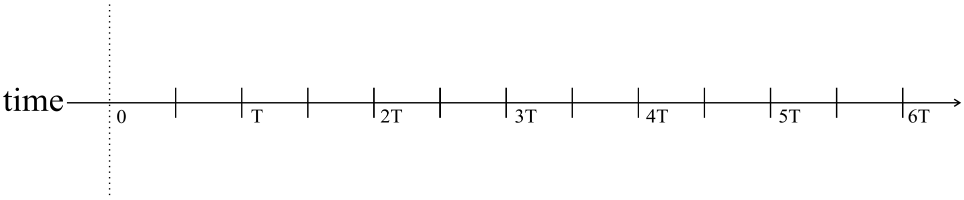
Answering the following questions about this solution. (**10 points**)

- Write the the forward-propagating voltage waveform: ________________
- Write the the backward-propagating current waveform: ________________
- The characteristic impedance for this line is ________________
- The velocity of propagation for this line is ________________
- What is the total voltage at $t = 0$ at the front of the line ($z = 0$)?

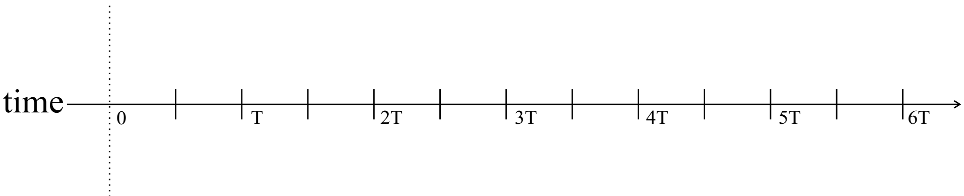
____

(3) **Reflection Sketches:** There is a transmission line with transit time T, length D, and reflection coefficients $\Gamma_G = -0.8$ and $\Gamma_L = 0.8$. At $t = 0$, an impulse enters the source-side of the line. Sketch the following functions of time in the space provided below. You do not need to label the amplitudes of your pulses but the diagrams should show the appropriate modulus (sign) and relative increasing/decreasing behavior of amplitudes. (**15 points**)

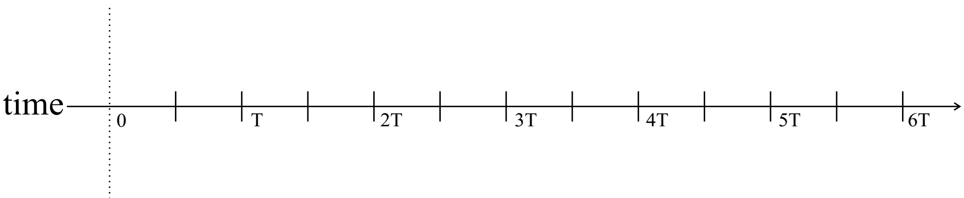
a. The voltage observed at the transmission line load:



b. The voltage observed at the transmission line source:

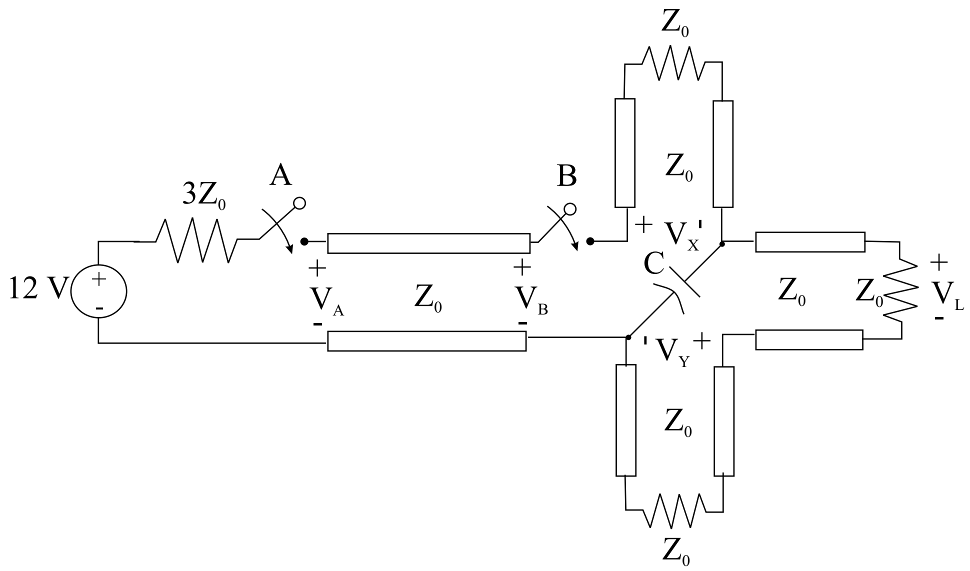


c. The voltage observed exactly halfway down the transmission line:



(4) **Switching Network:** The circuit below 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.
- 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.



Fill out the following table according to these switching states (**40 points**):

	V_A	V_B	V_L	V_X	V_Y
State 0	0	0	0	0	0
State 1					
State 2					
State 3					
State 4					

Formula Sheet

$$\frac{\partial^2 v(z,t)}{\partial z^2} = LC\frac{\partial^2 v(z,t)}{\partial t^2} \qquad \frac{\partial^2 i(z,t)}{\partial z^2} = LC\frac{\partial^2 i(z,t)}{\partial t^2}$$

$$Z_0 = \sqrt{\frac{L}{C}} \qquad v_p = \frac{1}{\sqrt{LC}}$$

$$\lambda f = v_p \qquad \omega = 2\pi f \qquad \beta = \frac{2\pi}{\lambda} \qquad D = T v_p$$

$$\text{Reflection: } \Gamma_{L,G} = \frac{R_{L,G} - Z_0}{R_{L,G} + Z_0} \qquad \text{Transmission: } 1 + \Gamma_{L,G}$$

$$\text{General I/O: } V_L(t) = (1+\Gamma_L)\sum_{n=0}^{\infty}(\Gamma_G\Gamma_L)^n f\left(t - [2n+1]T\right)$$

$$\mu = \mu_r\mu_0 \qquad \mu_0 = 4\pi \times 10^{-7}\ \text{H/m}$$

$$\epsilon = \epsilon_r\epsilon_0 \qquad \epsilon_0 = 8.854 \times 10^{-12}\ \text{F/m}$$

Electrical Properties of Common Transmission Lines

	L	C	Z_0	v_p
Parallel Plate	$\frac{\mu d}{w}$	$\frac{\epsilon w}{d}$	$\sqrt{\frac{\mu}{\epsilon}}$	$\frac{1}{\sqrt{\mu\epsilon}}$
Coaxial Cable	$\frac{\mu}{2\pi}\ln\left(\frac{b}{a}\right)$	$\frac{2\pi\epsilon}{\ln\left(\frac{b}{a}\right)}$	$\ln\left(\frac{b}{a}\right)\sqrt{\frac{\mu}{\epsilon}}$	$\frac{1}{\sqrt{\mu\epsilon}}$
Stripline	–	–	$\frac{1}{2\pi}\sqrt{\frac{\mu}{\epsilon_{\text{eff}}}}\ln\left(\frac{8b}{a}+\frac{a}{4b}\right)$ for $a < 2b$ $\sqrt{\frac{\mu}{\epsilon_{\text{eff}}}}\frac{1}{1.393+\frac{a}{b}+\frac{2}{3}\ln\left(\frac{a}{b}+\frac{13}{9}\right)}$ for $a > 2b$	$\frac{1}{\sqrt{\mu\epsilon_{\text{eff}}}}$

$$^*\epsilon_{\text{eff}} = \epsilon_0\left[\frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\sqrt{1+12b/a}\right]$$

General solution for charging a first-order reactive circuit (RC or RL) between steady state 1 (V_1 volts DC) and steady state 2 (V_2 volts DC):

$$V(t) = V_1 + (V_2 - V_1)\left[1 - \exp\left(-\frac{t-t_0}{\tau}\right)\right]\ \text{u}(t-t_0)$$

where t_0 is the moment of excitation and τ is the circuit time constant.

$$\tau = RC \text{ or } \frac{L}{R}$$