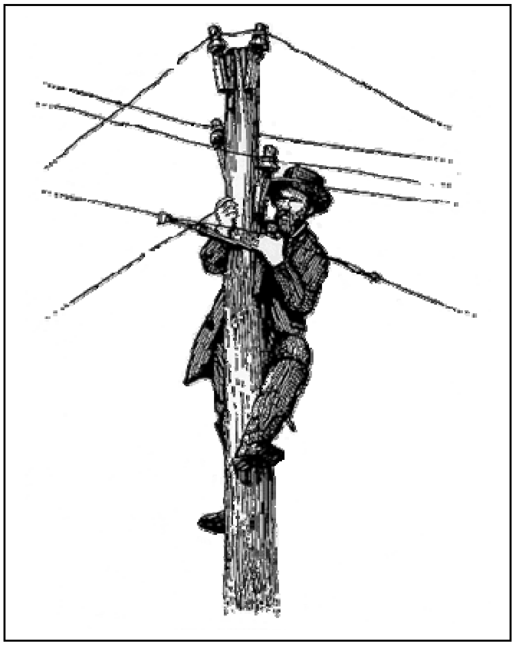
Name ___Solution_________________

Section __Both__________________



Short Answer Questions

1. (18 Pts) ____________
2. (15 Pts) ____________
3. (12 Pts) ____________
4. (5 Pts) ____________

Regular Questions

5. (30 Pts) ____________
6. (20 Pts) ____________

Total

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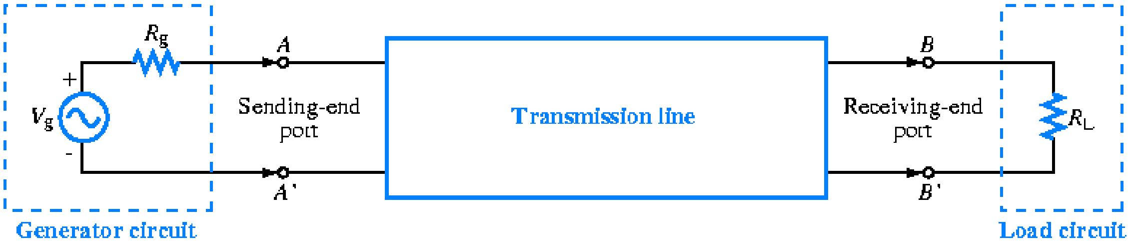
Notes:
1. **Please read over all questions before you begin your work. There may be some information in a later question that helps you with an earlier question.**
2. For short answer questions, you may add some comments to justify your answer.
3. Make sure your calculator is set to perform trigonometric functions in radians & not degrees & use 4 significant digits.

MULTIPLE CHOICE AND SHORT ANSWER QUESTIONS

1. Input Impedance of Lossless Transmission Lines (18 points)



Assume a sinusoidal source is connected to a lossless transmission line, as shown.

a. (6 pts) The transmission line load is an open circuit.

i. For what line lengths will the input impedance observed at the sending point end also be an open circuit? Circle all correct answers.

$0 \quad \lambda/8 \quad \lambda/4 \quad 3\lambda/8 \quad \lambda/2 \quad 5\lambda/8 \quad 3\lambda/4 \quad 7\lambda/8 \quad \lambda \quad 9\lambda/8 \quad 5\lambda/4 \quad 11\lambda/8 \quad 3\lambda/2$

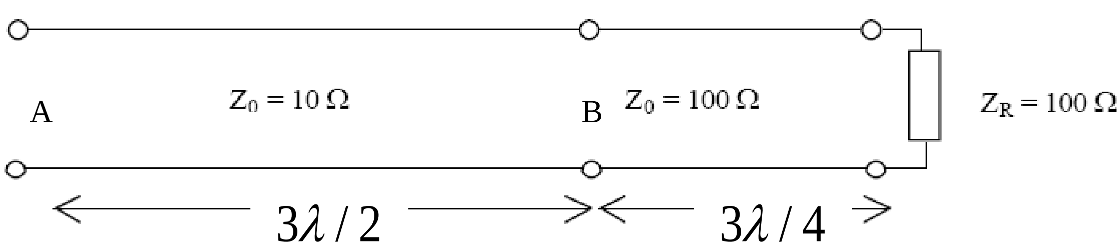
ii. For what line lengths will the input impedance observed at the sending point end be a short circuit? Circle all correct answers.

$0 \quad \lambda/8 \quad \lambda/4 \quad 3\lambda/8 \quad \lambda/2 \quad 5\lambda/8 \quad 3\lambda/4 \quad 7\lambda/8 \quad \lambda \quad 9\lambda/8 \quad 5\lambda/4 \quad 11\lambda/8 \quad 3\lambda/2$

b. (6 pts) A transmission line has length $\lambda/4$, characteristic impedance $Z_o = 100\Omega$ and load $Z_L = j100\Omega$. What is the input impedance?

$$Z_{IN} = \frac{Z_o^2}{Z_L} = \frac{100^2}{j100} = -j100$$

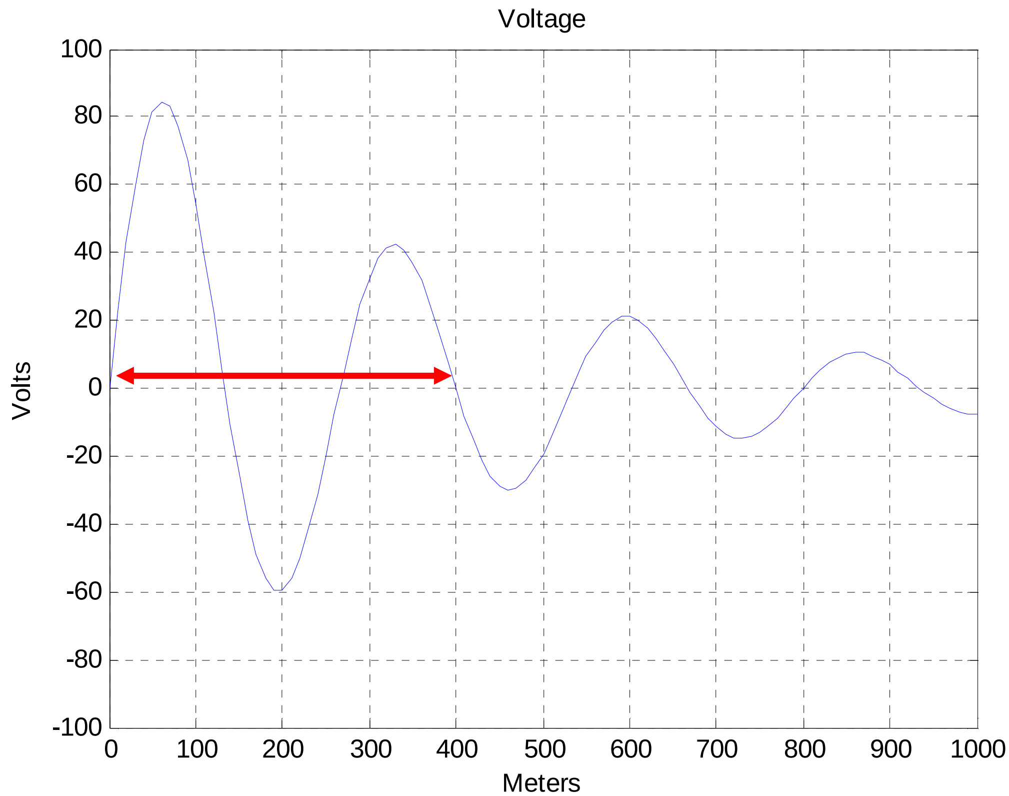
c. (6 pts) What is the input impedance of the network below? Z_{IN} =



At B, $Z_{IN} = Z_o = 100\Omega$ *because the second line is matched. At A,* $Z_{IN} = Z_L = 100\Omega$ *because the first line is a multiple of a half wavelength.*

2. Lossy Transmission Line (15 points)

A sinusoidal voltage wave is propagating on a low loss transmission line. The voltage as a function of position appears as shown below. From this plot, determine the damping coefficient $\alpha =$ 0.0026 and the propagation constant $\beta =$ 0.0236



The red line in the figure shows the distance equal to $1.5\lambda = 400$ *so that* $\lambda = \dfrac{800}{3} = 266.7$

$$\beta = \frac{2\pi}{\lambda} = \frac{3\pi}{400} = 0.0236 \ \ and \ \ 100e^{-\alpha 200} = 0.6 \ \ or \ \ \alpha = 0.0026$$

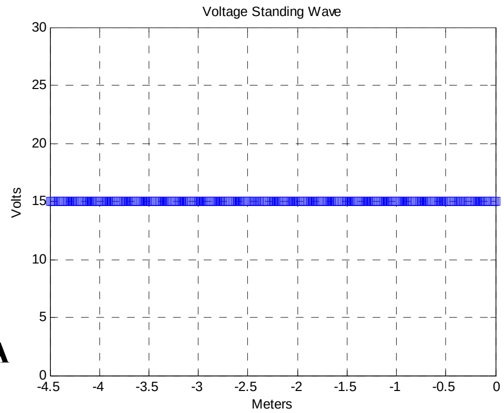
If the measurements above were taken at in a transmission line with a propagation constant of *70%* and capacitance per unit length of *31.75pF/m*, what are the characteristic impedance, the inductance per unit length and the resistance per unit length of the line?

$$u = 0.7x3x10^8 = 2.1x10^8 = \frac{1}{\sqrt{lc}} \quad Z_o = \sqrt{\frac{l}{c}} \ \ or \ \ c = \frac{1}{uZ_o} \ \ or \ \ Z_o = \frac{1}{uc} = 150$$

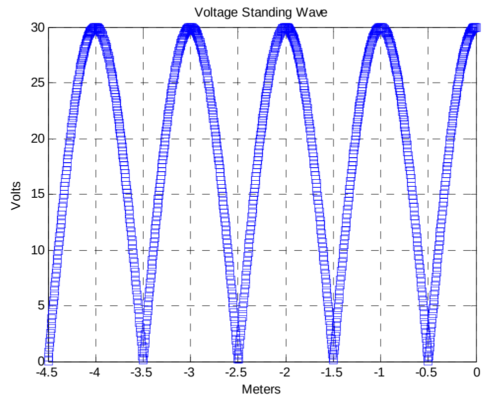
$$l = cZ_o^{\ 2} = 0.7\mu H/m \quad r = 2Z_o\alpha = 0.77\Omega/m$$

3. Standing Waves (12 points)

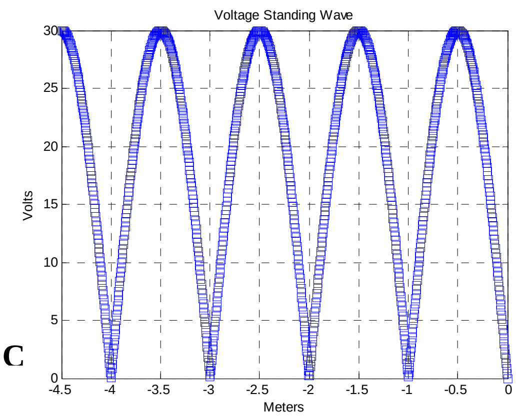
For all of the following questions, assume that a lossless transmission line has a characteristic impedance of $Z_o = 300\Omega$.



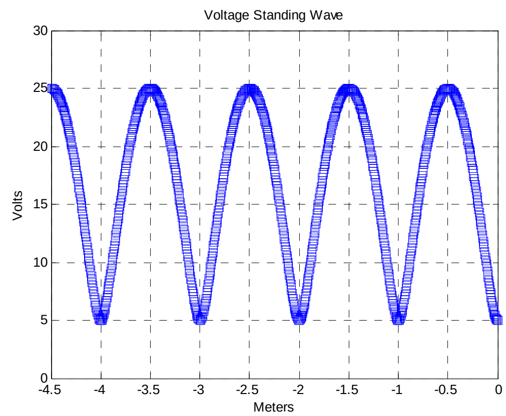
A



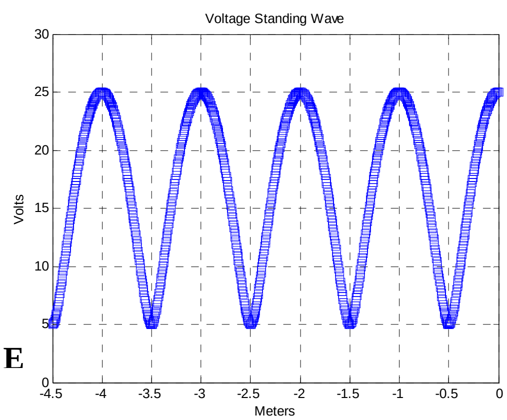
B



C



D



E

	A	B	C	D	E
Z_L	*300*	∞	*0*	*60*	*1500*
Γ_L	*0*	*1*	*-1*	*-2/3*	*2/3*
SWR	*1*	∞	∞	*5*	*5*

a. (10 pts) For each of the five standing wave plots shown above, determine the load impedance Z_L, the reflection coefficient Γ_L and the standing wave ratio *SWR*. Place the values you determine in the table.

b. (2 pts) Which of the standing wave plots looks like the current standing wave pattern for a short circuit load?

B (open circuit V)

Which of the standing wave plots looks like the current standing wave pattern for an open circuit load?

C (short circuit V)

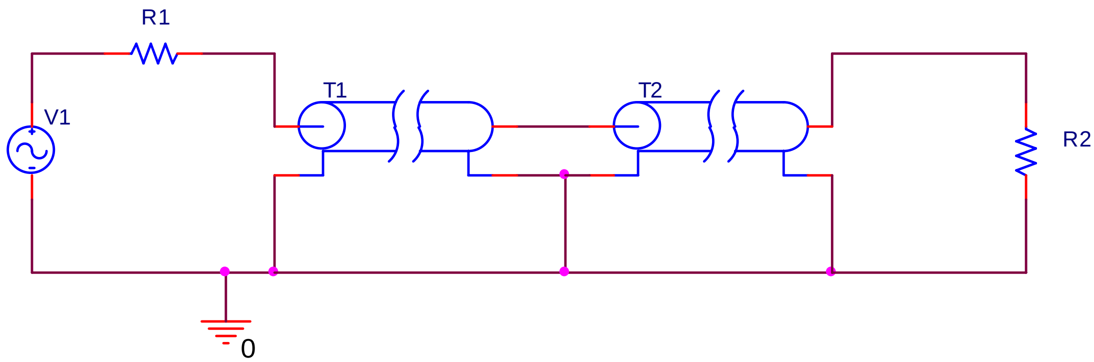
4. Cultural Question (5 points)

What is the name of the organization that awarded the badge shown below for telegraphy in 1925? *Hint: It is not the Boy Scouts. Ans: Girl Scouts*

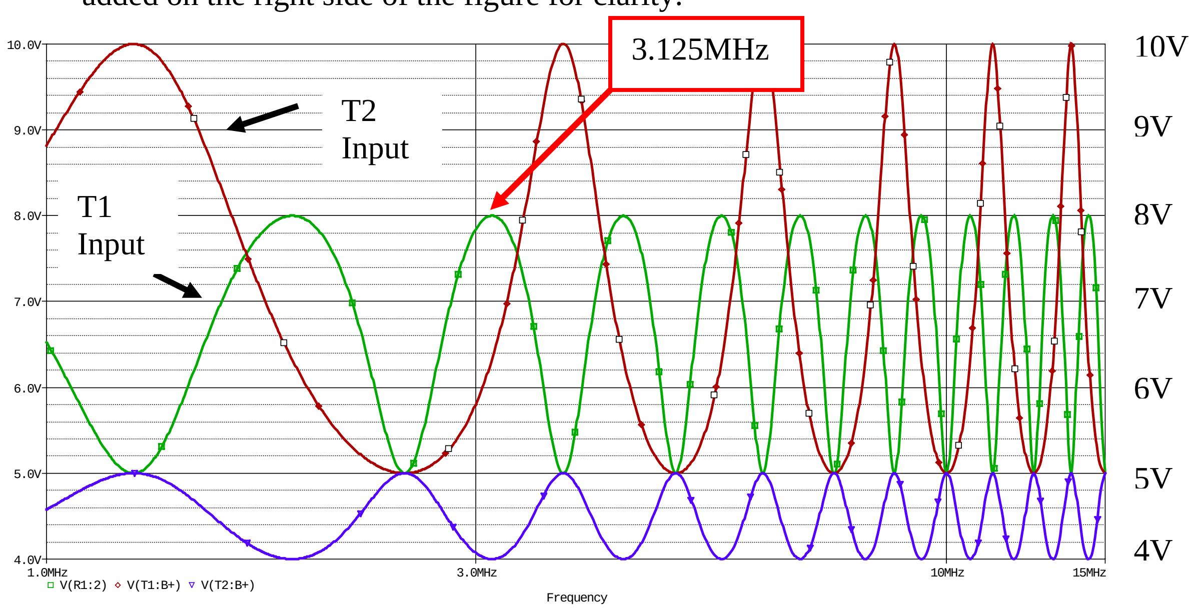
REGULAR QUESTIONS

5. Sinusoidal Voltages on a Lossless Transmission Line (30 points)

Two identical, unidentified lossless transmission lines are connected in series, as shown below. A series of experiments is performed to determine their properties. For these experiments, both *R1* and *R2* are *50 Ohms*.



a. The time delay observed for each of the lines is observed to be *200ns*. The voltage at the input and output of each of the two lines is measured at frequencies from *1MHz* to *15MHz*. In the plot below, the top curve is measured at the input to T2, the middle curve at the input to T1 and the bottom curve at the load. Six peaks (maxima) are observed in the voltage at the input to T2 at the following frequencies: *1.25MHz, 3.75MHz, 6.25MHz, 8.75MHz, 11.25MHz, and 13.75MHz.* Six valleys (minima) are also observed at *2.5MHz, 5MHz, 7.5MHz, 10MHz, 12.5MHz, and 15MHz.* These frequencies and an enlarged voltage scale have been added on the right side of the figure for clarity.



From the measurements above, determine the characteristic impedance of the two identical lines and the reflection coefficient at the load Γ_L. (5 pts)

When the length of the combination of both lines is equal to an odd multiple of quarter wavelengths, we have $Z_{IN} = \frac{Z_o^{\,2}}{Z_L} = \frac{Z_o^{\,2}}{50}$

From the voltage divider action at the input, $10\frac{Z_{IN}}{Z_{IN}+50}8$ *where the latter voltage is read from the plot at 3.125MHz. Combining these expressions gives us* $Z_o = 100\Omega$ *The frequencies where this happens are between those listed.*

The reflection coefficient is then $\Gamma_L = \frac{50-100}{50+100} = -\frac{1}{3}$

b. Now determine the total capacitance and total inductance for *each* of the two identical lines. (5 pts)

The time delay is $t_d = \dfrac{d}{u}$ *and the total capacitance divided by the time delay is* $\dfrac{C}{t_d} = \dfrac{t_d d}{d} u = cu = \dfrac{1}{Z_o}$ *The total capacitance is then* $C = \dfrac{t_d}{Z_o} = 2nF$ *The total inductance is* $L = Z_o{}^2 C = 20\mu H$

c. Assume that the one fact that is known about the lines is their insulating material – polyethylene. (See Ref below from Picwire) Using the velocity factor for polyethylene, determine the velocity of propagation and the length of each identical cable. (5 pts)

The velocity of propagation is $u = \dfrac{2}{3} 3x10^8 = 2x10^8 m/s$ *and the length of each cable is* $d = ut_d = 40m$

MATERIAL	∊ @ 1.0 GHz	VOP	Delay
Typical Insulation Materials			
Cellular TFE	1.38	85%	1.2
FEP	2.1	69%	1.47
Silicone Rubber	3.6—2.1	53—69%	1.92—1.47
TFE	2.1	69%	1.47
Polyethylene	2.3	66%	1.55
PVC	8.2—3.0	35—58%	2.9—1.75
Nylon	4.5—3.6	47—53%	2.16—1.92
*Non-Typical Insulation Materials**			
Snow (Fresh)	1.2	91%	1.1
Vaseline	2.2	68%	1.49
Beeswax	2.8	60%	1.69
Ice	3.2	56%	1.8
Glass	8.2—3.8	35—51%	2.9—2.0
Water (Distilled)	82	11%	9.2

*Theoretical values, if cables were constructed of these materials

Table 1. Electrical parameters of various materials.

d. Write the general expression for the input impedance seen by the source at the input to T1, simplifying it as much as possible. Then evaluate it at both *f=3.75MHz* and *f=5MHz.* (5 pts)

$$Z_{IN} = \frac{50 + j100\tan\omega t_d}{100 + j50\tan\omega t_d} = 50\Omega$$ *for both frequencies, because the lines are either* $\dfrac{\lambda}{2}$ *or* $\dfrac{\lambda}{4}$ *long and thus their combination will always be a multiple of* $\dfrac{\lambda}{2}$.

e. What is the voltage at the input to T1 and the output to T2 at these two frequencies? Using this information, determine the average power delivered to the input of T1 and to the load. (5 pts)

At both frequencies, the lines are matched, so the input voltage is 5V. The average power is therefore $P = \frac{5^2}{2(50)} = 250mW$

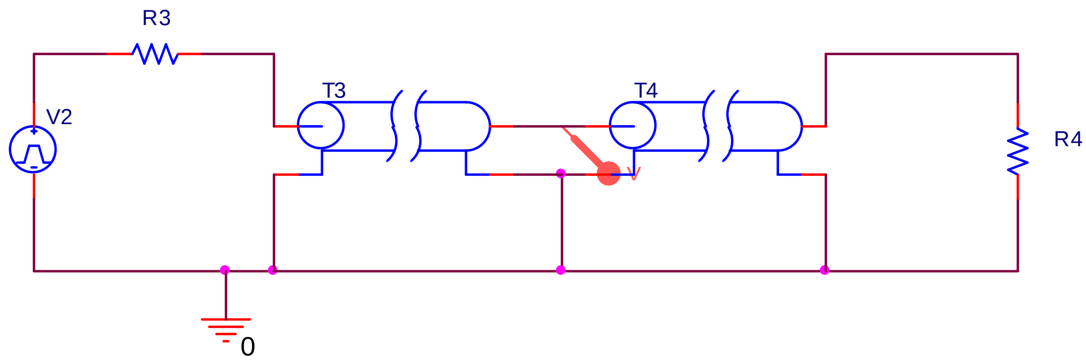
f. Find the propagation constant β and wavelength λ for the two frequencies. (5 pts)

$$\beta = \frac{2\pi f}{u} \;\; or \;\; \beta = \frac{2\pi 3.75x10^6}{2x10^8} = .0375\pi \;\; and \;\; \beta = \frac{2\pi 5x10^6}{2x10^8} = .05\pi$$

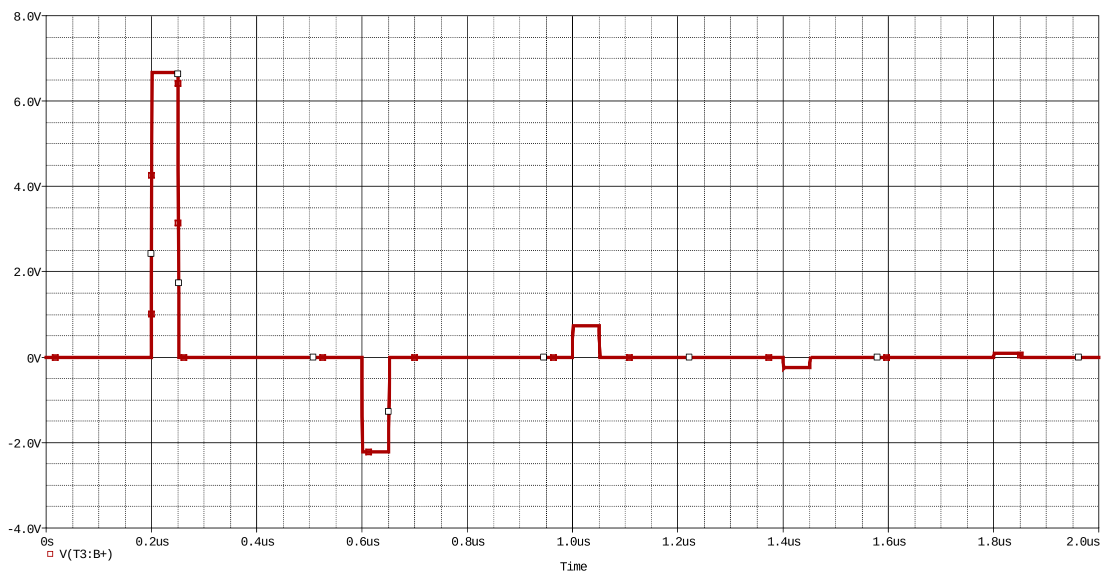
$$\lambda = \frac{2\pi}{\beta} \;\; or \;\; \lambda = \frac{2\pi}{.0375\pi} = 53.33 \;\; and \;\; \lambda = \frac{2\pi}{.05\pi} = 40$$

Checking for each line, does $\beta d = \omega t_d$? *For the latter case* $\beta d = .05\pi 40 = 2\pi(5x10^6)(200ns) = \omega t_d$ *which checks.*

6. Pulses on Transmission Lines (20 pts)



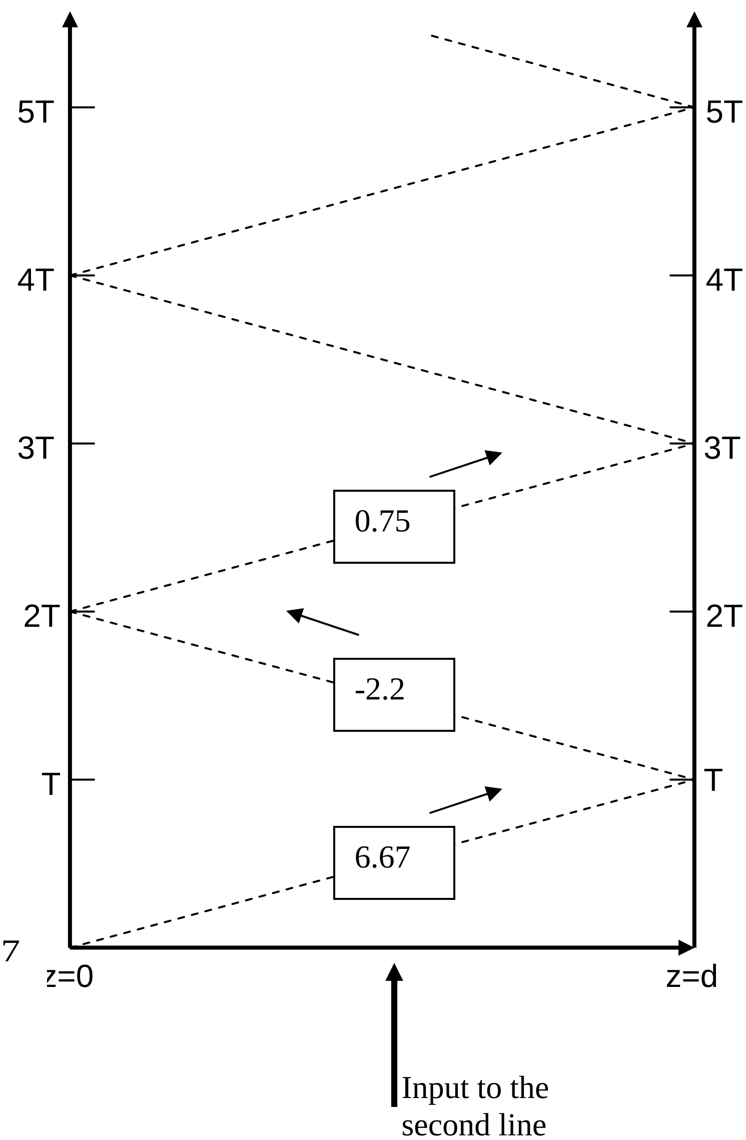
Using the same configuration as in the previous problem, a *10V, 50ns* pulse was input to line *T3* and measured at the input to *T4*, with the result shown below. (These are the same lines as in the previous problem, but have different names to keep PSpice happy.) Also, *R3* and *R4* are the same.



a. Using the information in this plot, determine the characteristic impedance of the two identical lines and then fill in the bounce diagram for the complete configuration. Use the information on the velocity of propagation from the previous problem. (10 pts)

T=400ns for the combo of the two lines

$$\Gamma_g = \frac{Z_g - Z_o}{Z_g + Z_o} = -\frac{1}{3}$$

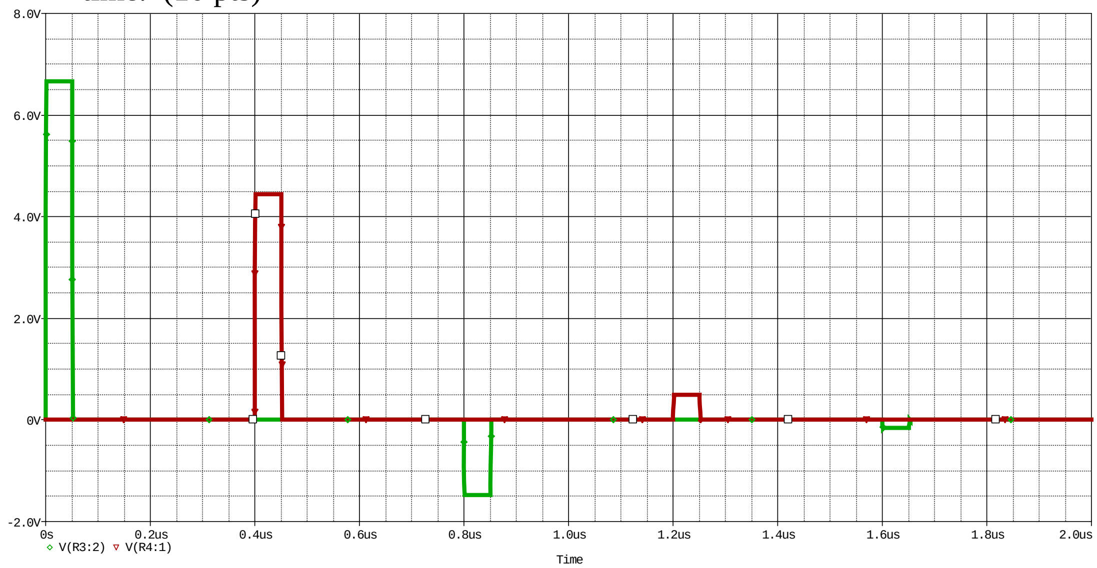


$$V_{IN} = 10\frac{Z_o}{50 + Z_o} = 6.67$$

$$\Gamma_L = \frac{Z_L - Z_o}{Z_L + Z_o} = -\frac{1}{3}$$

$$Z_o = 100\Omega$$

a. Determine and plot the voltages at the input to *T3* and at the load, as functions of time. (10 pts)



The green pulses are at the input and the red at the output. The first green pulse is from the voltage divider and thus is 6.67V. The second green pulse is equal to the incident pulse (the first one) times ($\Gamma_L(1+\Gamma_g)$) and thus is equal to -1.5V. The first red pulse (at the load) is equal to the incident pulse times $(1+\Gamma_L)$ and thus is equal to 4.44V. The second red pulse is equal to the incident pulse times $\Gamma_L\Gamma_g(1+\Gamma_L)$ and so on ….