3/4/2007

University of Portland
School of Engineering

EE 301-Electromagnetic Fields-3 cr. hrs.
Spring 2007

You will pay a heavy price for turning the unit-step function into a girly cartoon character Inan! @*$*#&XΘχ@*§ξ!

Best of luck to you EE 301 students and please, demonstrate Inan that unlike what everyone might think, his tests are nothing but simply a piece of cake! (Bring his fame down about giving challenging exams!)

Good job guys, keep up the pressure!

Midterm Exam # 1

(Prepared by Professor A. S. Inan)

(Friday, March 2, 2007)
(Closed Book Exam; 1 Formula Sheet Allowed)
(Total Time: 55 mins.)

Name: SOLUTIONS! ☺

Signature: Solutions ☺

"Honesty is the best policy."
Aesop (~ 620B.C. –?)

"An honest mind possesses a kingdom."
Lucius Annaeus Seneca (4B.C.–65A.D.)

"Honest people are the true winners of the universe."
Anonymous

"Honesty is not for sale."
A. Inan

Thanks Mr. Heaviside and don't worry, we will teach Inan a lesson on this matter!

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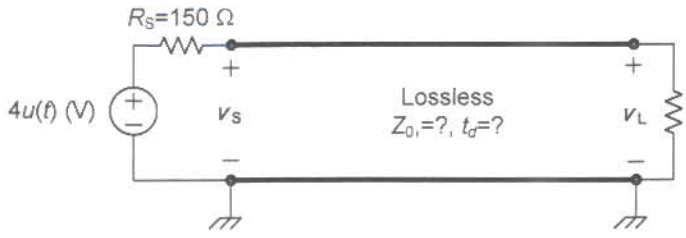
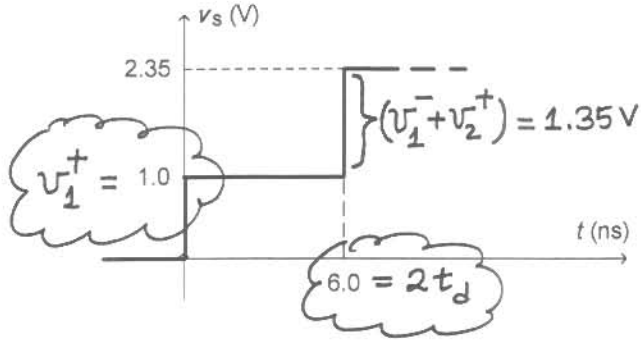
(1) (15 mins., Total: 30 points) **TDR characterization.** A TDR experiment is constructed to determine the unknown parameters of a distributed circuit as shown. Based on the source-end voltage waveform given,

(a) (20 points) Determine the values of Z_0, t_d, and R_L. Show your work clearly.





$$v_1^+ = \frac{Z_0 V_0}{R_S + Z_0} = \frac{Z_0(4)}{150 + Z_0} = 1$$

$$\rightarrow \boxed{Z_0 = 50\,\Omega}$$

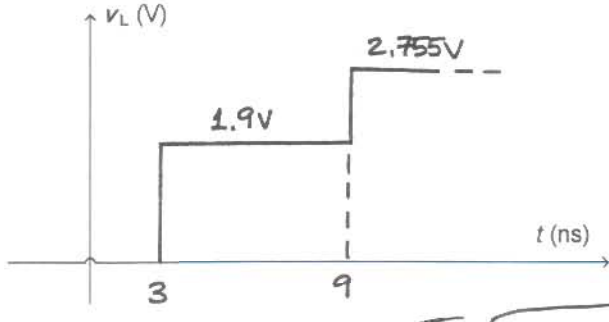
$$\Gamma_S = \frac{R_S - Z_0}{R_S + Z_0} = \frac{150-50}{150+50} = \frac{1}{2}$$

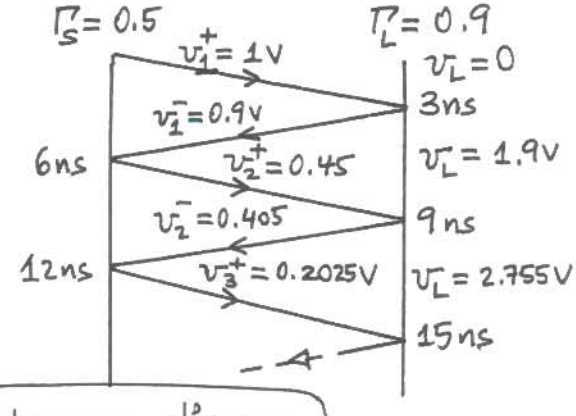
$$v_1^- + v_2^+ = \Gamma_L v_1^+ + \Gamma_S \Gamma_L v_1^+ = \Gamma_L v_1^+ (1 + \Gamma_S) = \Gamma_L (1 + 0.5) = 1.35$$

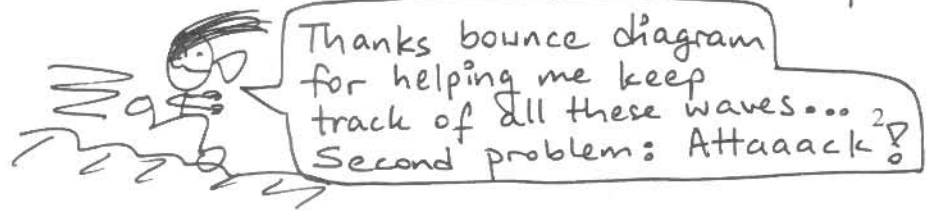
$$\rightarrow \Gamma_L = \frac{1.35}{1.5} = 0.9 = \frac{R_L - Z_0}{R_L + Z_0} = \frac{R_L - 50}{R_L + 50} \rightarrow \boxed{R_L = 950\,\Omega}$$

$$2t_d = 6\text{ ns} \rightarrow \boxed{t_d = 3\text{ ns}}$$

(b) (10 points) Sketch the load-end voltage v_L as a function of time t for the time interval $0 \le t \le 10$ ns.







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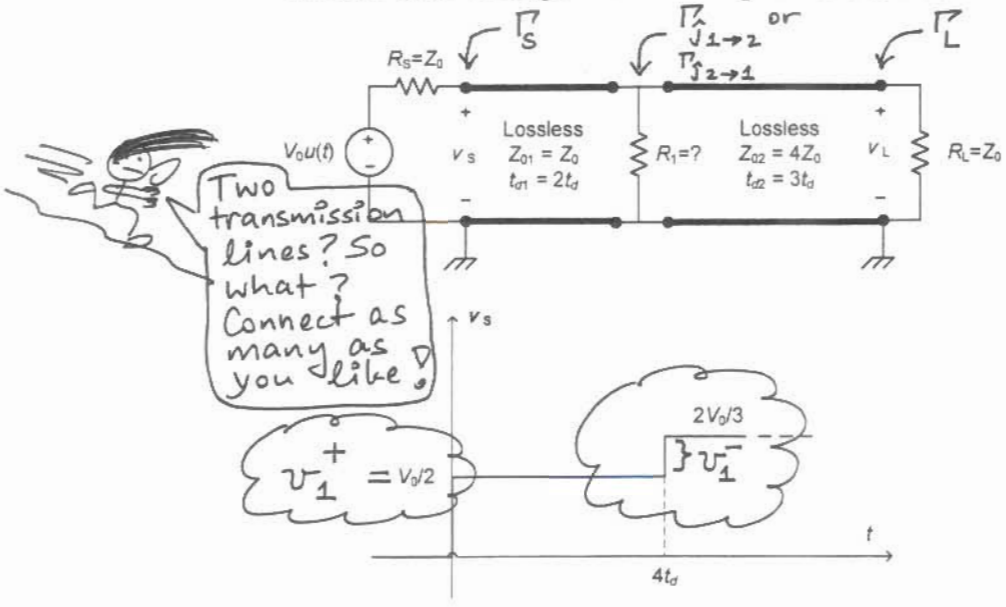
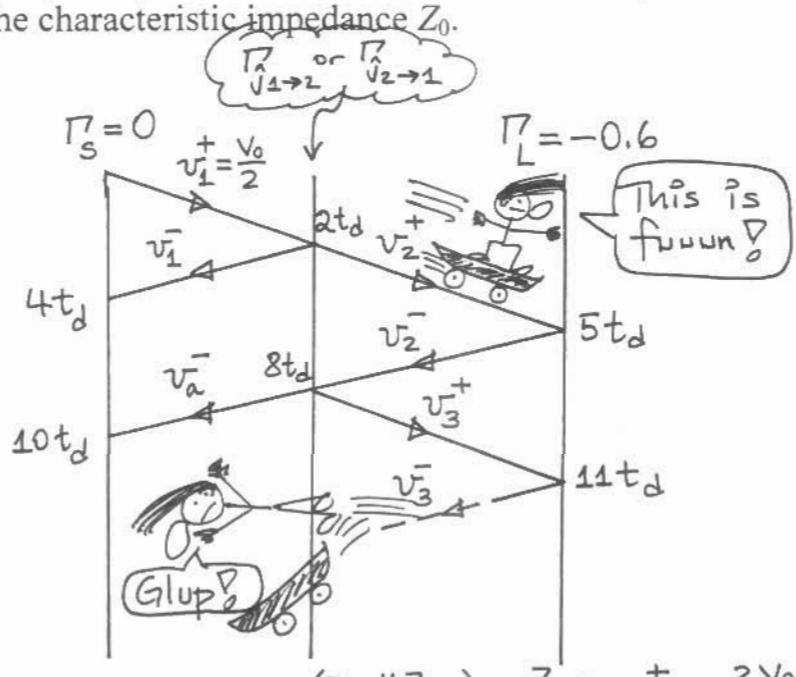
(2) (15 mins., Total: 35 points) **A distributed circuit involving two transmission lines.** For the transmission line circuit shown, based on the source-end voltage waveform provided, do the following:



$$\Gamma_S = \frac{R_S - Z_{01}}{R_S + Z_{01}} = \frac{Z_0 - Z_0}{Z_0 + Z_0} = 0$$

$$\Gamma_L = \frac{R_L - Z_{02}}{R_L + Z_{02}} = \frac{Z_0 - 4Z_0}{Z_0 + 4Z_0} = -0.6$$

(a) (15 points) Determine the value of the lumped resistor R_1 in terms of the characteristic impedance Z_0.



$$v_1^- = \Gamma_{\hat{J}1\to2}\, v_1^+ = \frac{(R_1 // Z_{02}) - Z_{01}}{(R_1 // Z_{02}) + Z_{01}}\, v_1^+ = \underbrace{\frac{2V_0}{3} - \frac{V_0}{2}}_{\text{from graph!}} = \frac{V_0}{6}$$

$$\Gamma_{\hat{J}1\to2} = v_1^-/v_1^+ = (V_0/6)/(V_0/2) = 1/3$$

$$\frac{(R_1 // 4Z_0) - Z_0}{(R_1 // 4Z_0) + Z_0} = \frac{1}{3} \rightarrow (R_1 // 4Z_0) = 2Z_0 \rightarrow \boxed{R_1 = 4Z_0}$$

(b) (10 points) Determine the value of the load-end voltage $\mathbf{v}_L$ in terms of V_0 at $t = 6t_d$.

See the bounce diagram on the previous page!

$$v_2^+ = v_1^+ + v_1^- = \frac{V_0}{2} + \frac{V_0}{6} = \frac{2V_0}{3}$$

$$v_2^- = \Gamma_L v_2^+ = (-0.6)\left(\frac{2V_0}{3}\right) = -0.4V_0 = -\frac{2V_0}{5}$$

$$\therefore v_L(t=6t_d) = v_2^+ + v_2^- = \frac{2V_0}{3} - \frac{2V_0}{5} = \boxed{\frac{4V_0}{15} \cong 0.2\overline{6}\,V_0}$$

Give me a break, piece of cake!

Inan's tests are not diffucult after all!

(c) (10 points) Determine the value of the source-end voltage $\mathbf{v}_S$ in terms of V_0 at $t = 11t_d$.

$$\Gamma_{\hat{J}_{2\to1}} = \frac{(R_1 // Z_{01}) - Z_{02}}{(R_1 // Z_{01}) + Z_{02}} = \frac{(4Z_0 // Z_0) - 4Z_0}{(4Z_0 // Z_0) + 4Z_0}$$

$$= \frac{4Z_0/5 - 4Z_0}{4Z_0/5 + 4Z_0} = -\frac{16}{24} = -\frac{2}{3}$$

$$\therefore v_3^+ = \Gamma_{\hat{J}_{2\to1}} v_2^- = \left(-\frac{2}{3}\right)\left(-\frac{2V_0}{5}\right) = \frac{4V_0}{15}$$

$$v_a^- = v_2^- + v_3^+ = -\frac{2V_0}{5} + \frac{4V_0}{15} = -\frac{2V_0}{15}$$

$$\therefore v_S(t=11t_d) = v_1^+ + v_1^- + v_a^- = \frac{V_0}{2} + \frac{V_0}{6} - \frac{2V_0}{15} = \boxed{\frac{8V_0}{15} \cong 0.5\overline{3}\,V_0}$$

Any more problems? Come out, cowards!

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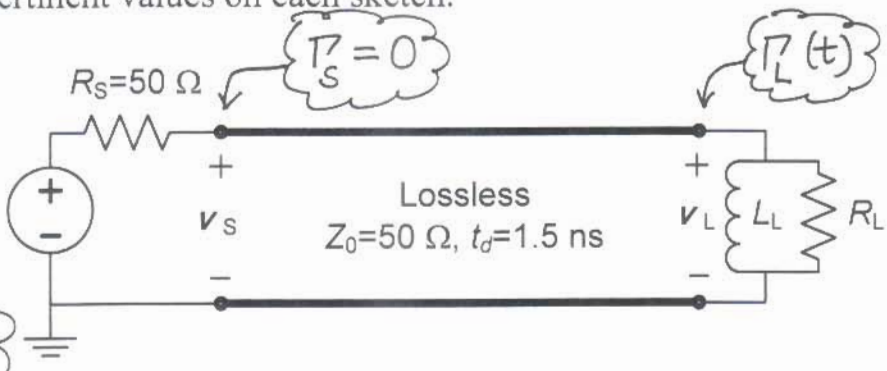
(3) (15 mins., 35 points) **Reactive termination.** In the transmission-line circuit shown, find the complete mathematical expression and sketch both the source-end voltage v_S and the load-end voltage v_L as a function of time. Sketch the two waveforms separately. Provide all the pertinent values on each sketch.



Time constant!

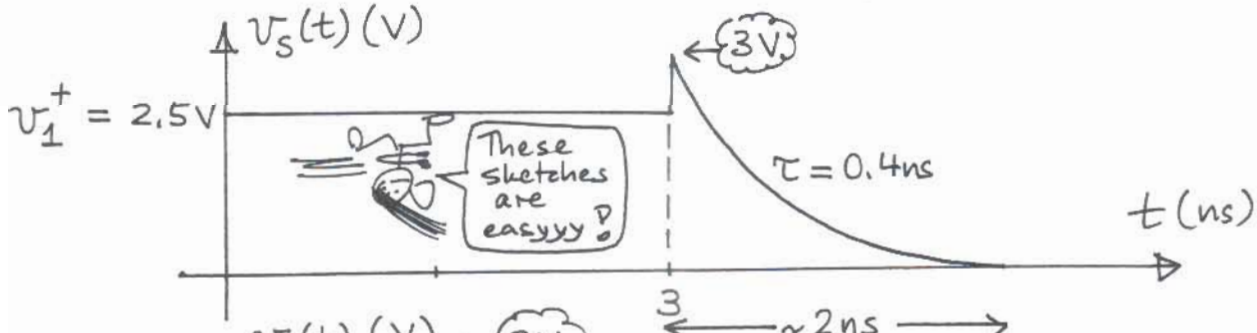
R_L=75 Ω
L_L=12 nH

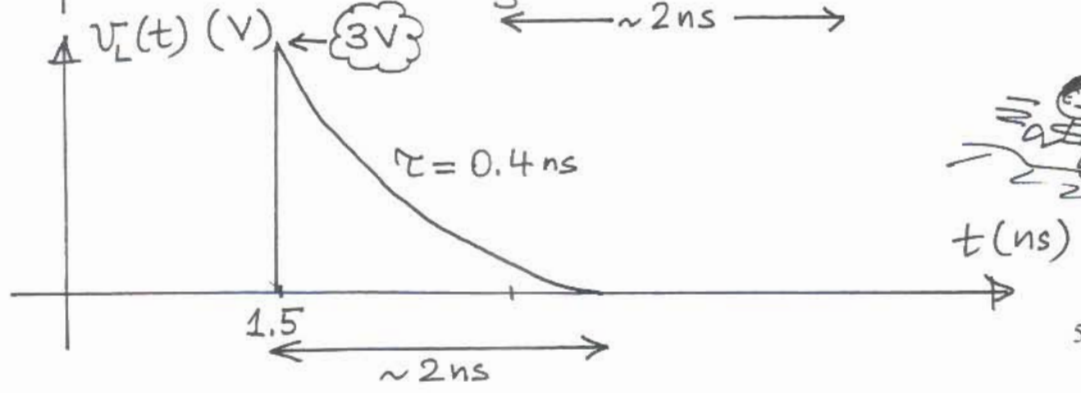
$$\tau = \frac{L}{R_T} = \frac{L}{(Z_0 // R_L)} = \frac{12\text{ nH}}{(50//75)\Omega} = \frac{12\text{ nH}}{30\,\Omega} = 0.4\text{ ns}$$

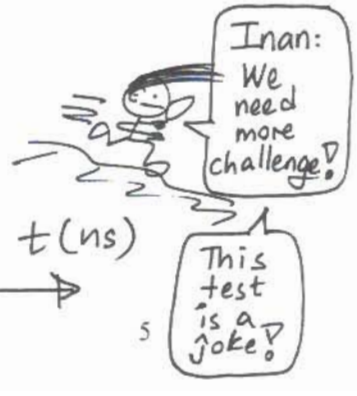
$$\Gamma_L(t=t_d) = \frac{R_L - Z_0}{R_L + Z_0} = \frac{75-50}{75+50} = 0.2$$

since the inductor acts like an open circuit at $t = t_d$!

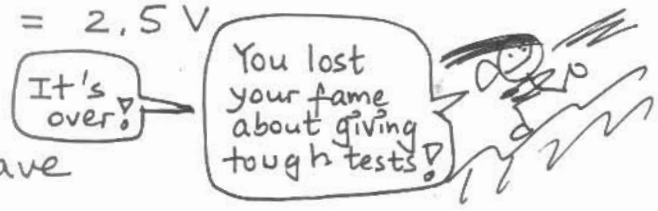
$\Gamma_L(t \to \infty) = -1$ since the inductor acts like a short circuit at steady state!







$$v_1^+ = \frac{Z_0 V_0}{R_s + Z_0} = \frac{(50)(5)}{50+50} = 2.5\ \text{V}$$



At the load end, we have

$$v_1^-(t=t_d) = \Gamma_L(t=t_d)\, v_1^+ = (0.2)(2.5) = 0.5\ \text{V}$$

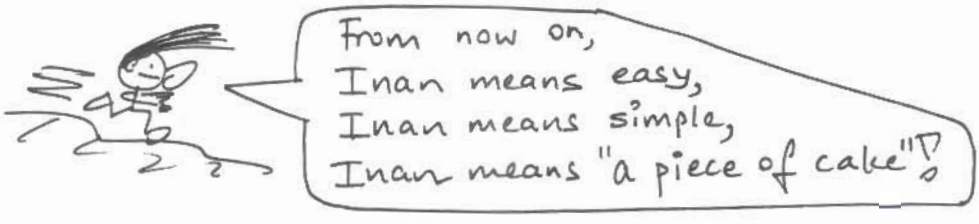
$$v_1^-(t\to\infty) = \Gamma_L(t\to\infty)\, v_1^+ = (-1)(2.5) = -2.5\ \text{V}$$

$$v_L(t=t_d) = v_1^+ + \Gamma_L(t=t_d)\, v_1^+ = 2.5 + 0.5 = 3\ \text{V}$$

$$v_L(t\to\infty) = v_1^+ + \Gamma_L(t\to\infty)\, v_1^+ = 2.5 - 2.5 = 0$$

At the source end, we have

$$v_s(t=2t_d) = v_1^+ + \Gamma_L(t=t_d)\, v_1^+ = 2.5 + 0.5 = 3\ \text{V}$$

$$v_s(t\to\infty) = v_1^+ + \Gamma_L(t\to\infty)\, v_1^+ = 2.5 - 2.5 = 0$$

$$\boxed{\begin{aligned} v_s(t) &= 2.5\left[u(t) - u(t-3\text{ns})\right] + 3e^{-(t-3\text{ns})/0.4\text{ns}} \cdot u(t-3\text{ns}) \quad (\text{V}) \\ v_L(t) &= 3e^{-(t-1.5\text{ns})/0.4\text{ns}} \cdot u(t-1.5\text{ns}) \quad (\text{V}) \end{aligned}}$$