3/6/2005

University of Portland
School of Engineering

EE 301-Electromagnetic Fields-3 cr. hrs.
Spring 2005

SOLUTIONS TO

Midterm Exam # 1

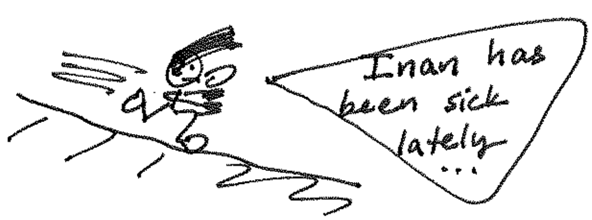
(Prepared by Professor A. S. Inan)

(Wednesday, March 2, 2005)
(Closed Book Exam; 1 Formula Sheet Allowed)
(Total Time: 55 mins.)

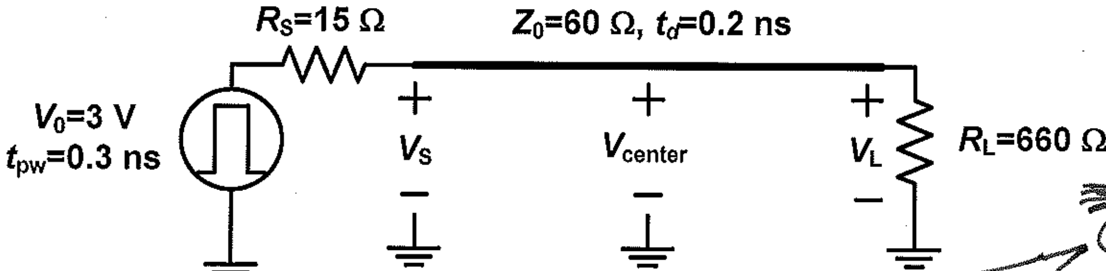
Name: SOLUTIONS ! ☺

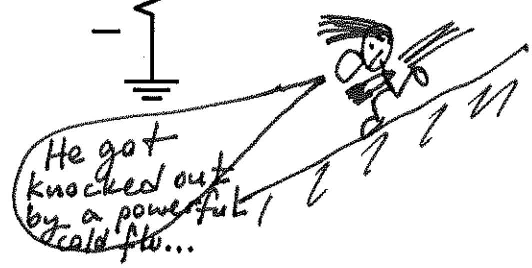
Signature: Solution ☺

> ***"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**



(1) (15 mins., 30 points) **Pulse excitation of a lossless transmission line.** For the transmission line circuit shown, sketch the voltages V_S, V_{center}, and V_L as a function of time between $t = 0$ and $t = 1^+$ ns. Provide all the relevant values on your sketches. Also provide a bounce diagram for your solution.



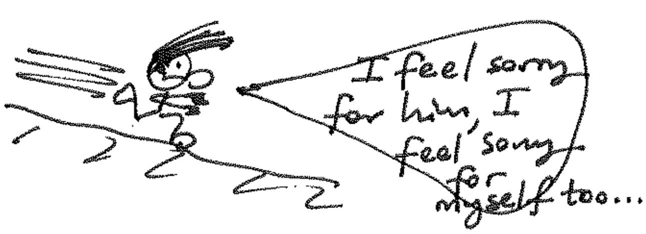


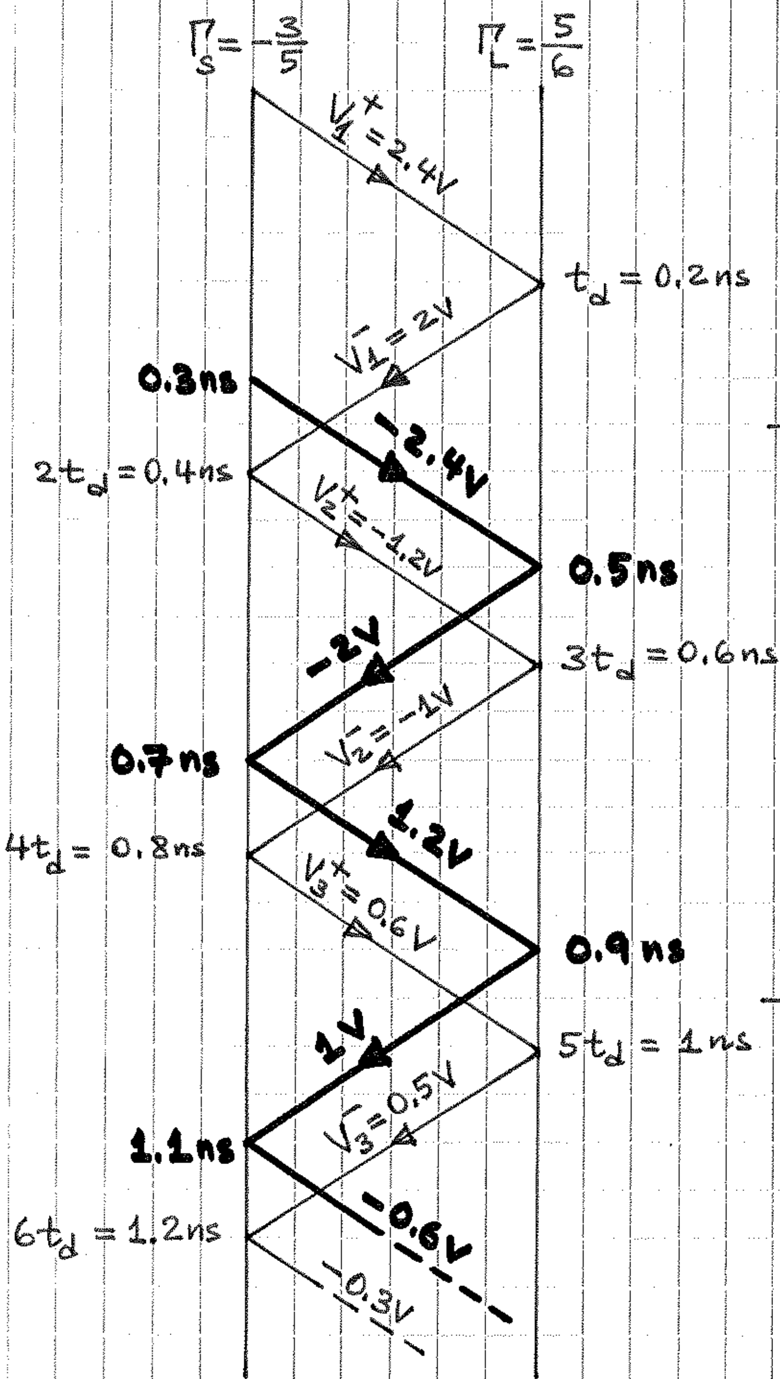
$$V_1^+ = \frac{Z_0}{R_S + Z_0} V_0 = \frac{60}{15 + 60}(3\text{ V}) = 2.4\text{ V}$$

$$\Gamma_L = \frac{R_L - Z_0}{R_L + Z_0} = \frac{660-60}{660+60} = \frac{600}{720} = \frac{5}{6}$$

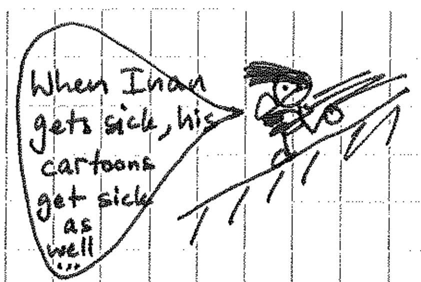
$$\Gamma_S = \frac{R_S - Z_0}{R_S + Z_0} = \frac{15-60}{15+60} = -\frac{45}{75} = -\frac{3}{5} = -0.6$$

Please see the bounce diagram and the voltage sketches on the next page.

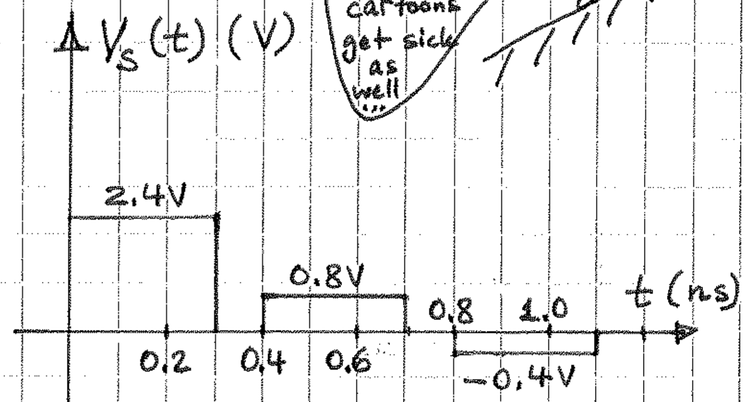




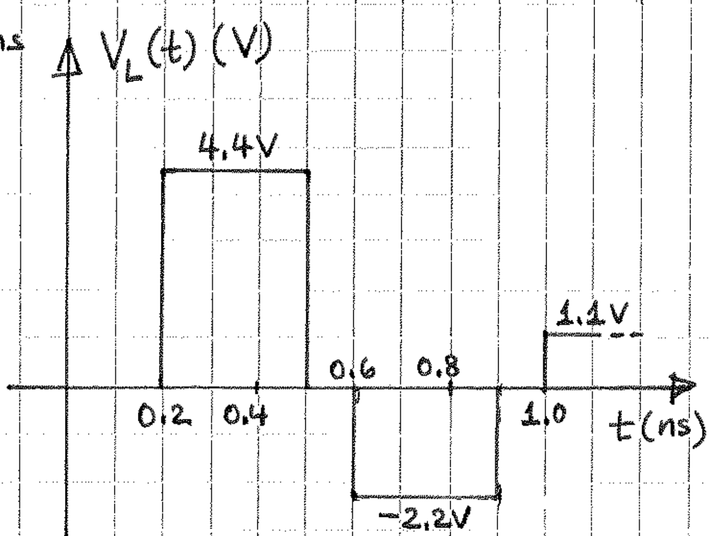
$\Gamma_S = -\frac{3}{5}$
$\Gamma_L = \frac{5}{6}$
$V_1^+ = 2.4V$
$t_d = 0.2ns$
$V_1^- = 2V$
0.3ns
$-2.4V$
$2t_d = 0.4ns$
$V_2^+ = -1.2V$
0.5ns
$-2V$
$3t_d = 0.6ns$
$V_2^- = -1V$
0.7ns
1.2V
$4t_d = 0.8ns$
$V_3^+ = 0.6V$
0.9ns
1V
$5t_d = 1ns$
$V_3^- = 0.5V$
1.1ns
$-0.6V$
$6t_d = 1.2ns$
$-0.3V$



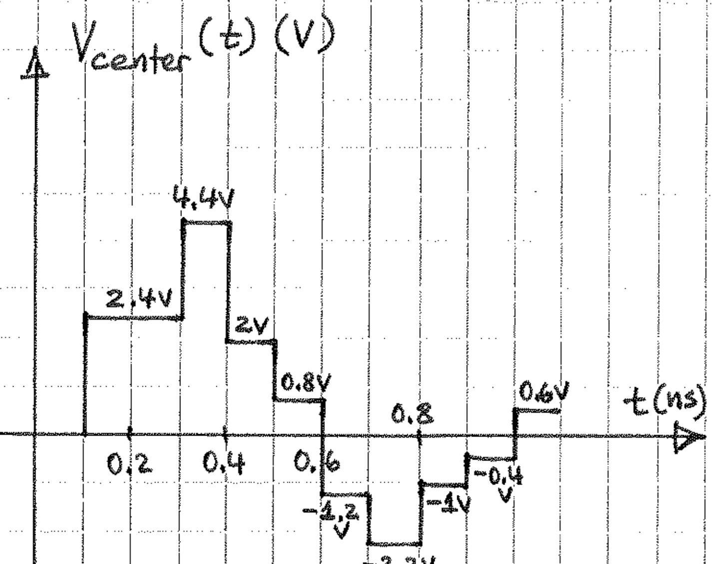
When Inan gets sick, his cartoons get sick as well ...



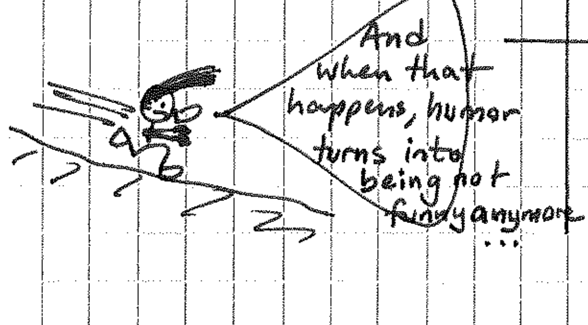
$V_S(t)$ (V)
2.4V
0.8V
0.8
1.0
t (ns)
0.2
0.4
0.6
$-0.4V$



$V_L(t)$ (V)
4.4V
1.1V
0.6
0.8
0.2
0.4
1.0
t (ns)
$-2.2V$

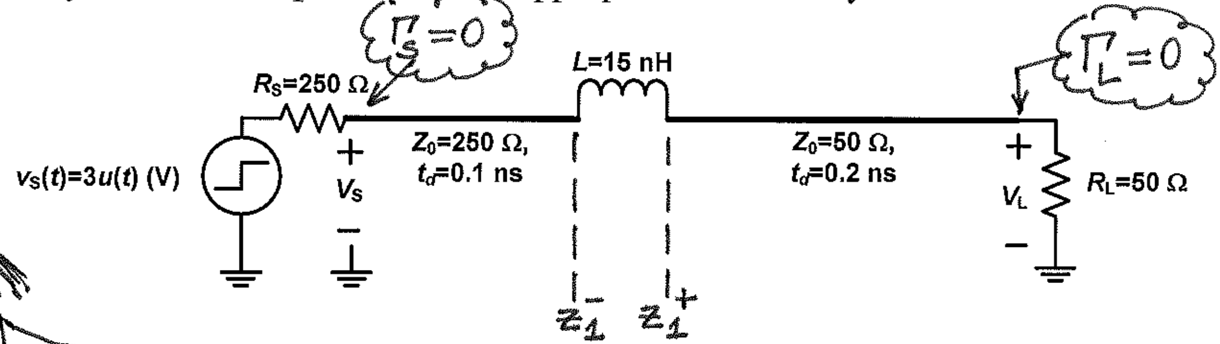


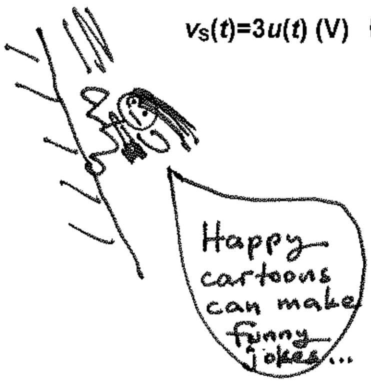
$V_{center}(t)$ (V)
4.4V
2.4V
2V
0.8V
0.6V
t (ns)
0.8
0.2
0.4
0.6
-0.4 V
$-1V$
-1.2 V
$-2.2V$



And when that happens, humor turns into being not funny anymore ...

(2) (20 mins., 40 points) **Lumped inductive element between two lossless transmission lines.** For the transmission line circuit shown, find and sketch the source-end and load-end voltages as a function of time. Show your work and provide all the appropriate values on your sketches.

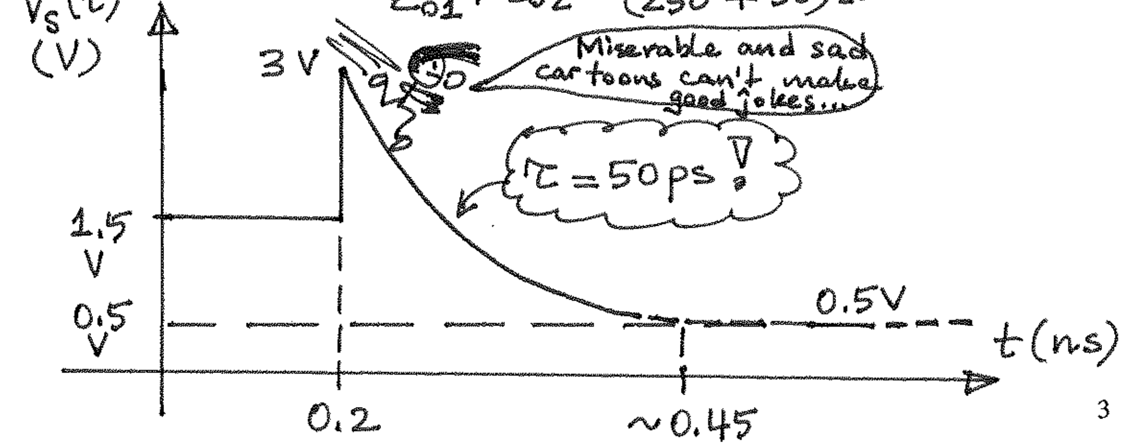


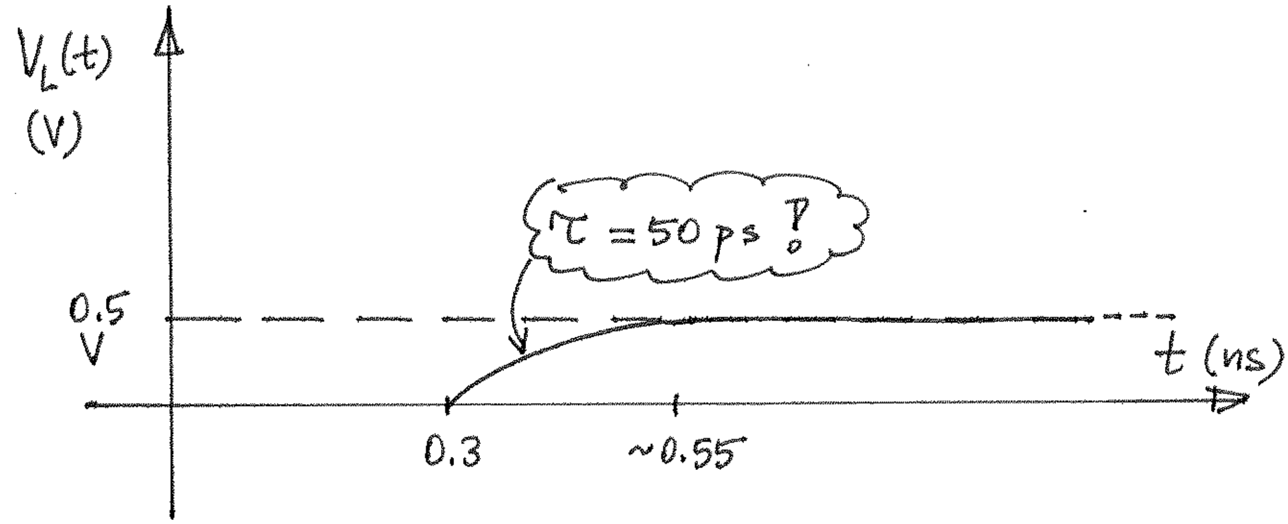


$$V_1^+ = \frac{Z_{01}}{R_S + Z_{01}} V_0 = \frac{250}{250+250}(3\text{V}) = 1.5\text{V}$$

Since the inductor will at first act like an open circuit, we have $V_1^-(z_1^-, t_{d1}) = V_1^+ = 1.5\text{V}$. However, when the inductor reaches steady state, it acts like a short circuit and as a result, we have $V_1^-(z_1^-, \infty) = \frac{Z_{02} - Z_{01}}{Z_{02} + Z_{01}} V_1^+ = \frac{50-250}{50+250}(1.5\text{V}) = -1\text{V}$. The time constant of the circuit can be found as

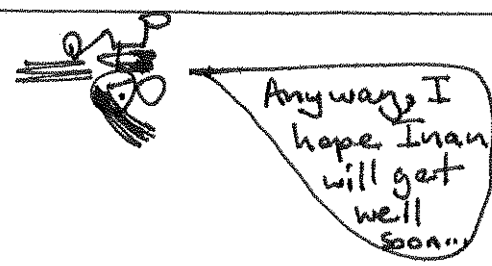
$$\tau = \frac{L}{Z_{01} + Z_{02}} = \frac{15\,\text{nH}}{(250+50)\,\Omega} = 50\,\text{ps}$$



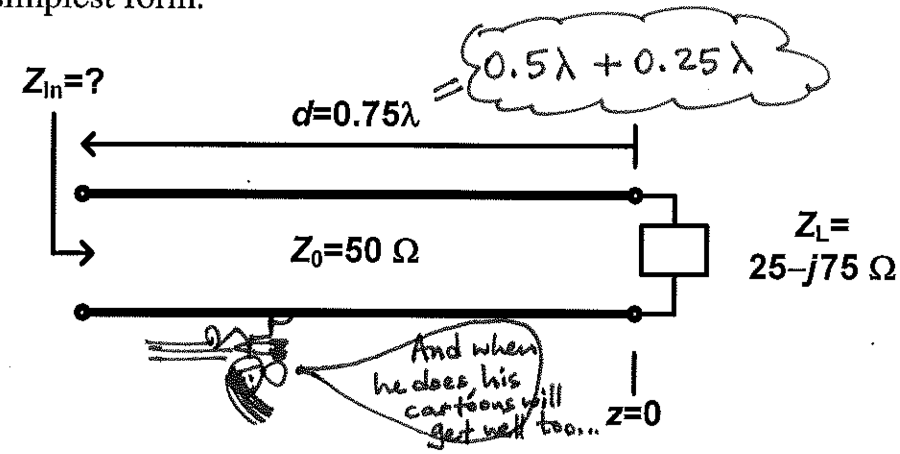


The mathematical expressions for the source-end and load-end voltages can be written as follows:

$$\boxed{\begin{aligned} V_S(t) &= 1.5\left[u(t) - u(t-0.2n)\right] \\ &\quad + \left[3e^{-2\times 10^{10}(t-0.2n)} + 0.5\left(1-e^{-2\times 10^{10}(t-0.2n)}\right)\right]u(t-0.2n) \quad (V) \\ V_L(t) &= 0.5\left(1-e^{-2\times 10^{10}(t-0.3n)}\right)u(t-0.3n) \quad (V) \end{aligned}}$$



(3) (15 mins., 30 points) **Load reflection coefficient, standing wave ratio and input impedance.** Consider the transmission line circuit shown. Assuming sinusoidal steady-state condition, find (a) the load reflection coefficient; (b) the standing wave ratio on the line; and (c) the input impedance of the line. Show your work and provide all your results in their simplest form.



(a)
$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{25 - \hat{j}75 - 50}{25 - \hat{j}75 + 50} = \frac{-25 - \hat{j}75}{75 - \hat{j}75}$$

$$= \frac{-1 - \hat{j}3}{3 - \hat{j}3} \cdot \frac{(3 + \hat{j}3)}{(3 + \hat{j}3)} = \frac{6 - \hat{j}12}{18} = \frac{1}{3} - \hat{j}\frac{2}{3}$$

$$= \frac{\sqrt{5}}{3} e^{\hat{j}\tan^{-1}(-2)} \cong \boxed{0.745 e^{-\hat{j}63.4^\circ}}$$

(b)
$$S = \frac{1 + |\Gamma_L|}{1 - |\Gamma_L|} = \frac{1 + \frac{\sqrt{5}}{3}}{1 - \frac{\sqrt{5}}{3}} = \frac{3 + \sqrt{5}}{3 - \sqrt{5}} \cong \boxed{6.85}$$

And be humorous and funny again...

(c)
$$Z_{in} = \frac{Z_0^2}{Z_L} = \frac{50^2}{25 - \hat{j}75} = \frac{100}{1 - \hat{j}3} \cdot \frac{(1 + \hat{j}3)}{(1 + \hat{j}3)} = 10(1 + \hat{j}3)$$

$$= \boxed{(10 + \hat{j}30)\ \Omega}$$