School of Electrical and Computer Engineering, Cornell University

ECE 303: Electromagnetic Fields and Waves

Fall 2007

Homework 10 **Due on Nov. 02, 2007 by 5:00 PM**

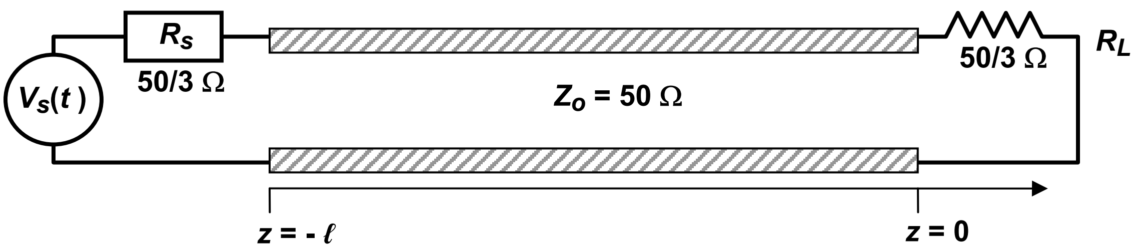
Reading Assignments:

i) Review the lecture notes.
ii) Review sections 6.5, 7.1, 7.2, paperback book *Electromagnetic Waves*.

NOTE: To save time, you can print out as many copies as you like of the empty sketch templates at the end of the problem set and attach these to you answers to problems 10.1 through 10.5.

Problem 10.1: (Warm up exercise: turn-on transient)

Consider the following transmission line circuit:



The source voltage is a step function given by:
$V_S(t) = 4\,u(t)$

a) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t = \ell/2v$.
b) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t = 3\ell/2v$.
c) Plot the currents $I_+(z,t)$, $I_-(z,t)$, and $I(z,t)$ on the transmission line at time $t = 3\ell/2v$.

Hint: the total voltage and current on any transmission line can always be written as:

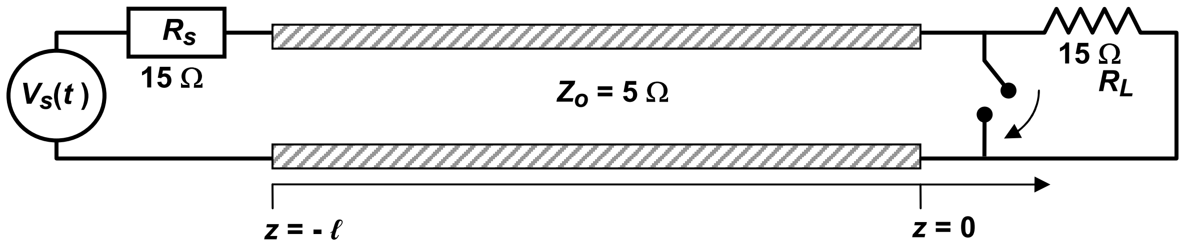
$$V(z,t) = V_+(z,t) + V_-(z,t)$$

$$I(z,t) = I_+(z,t) + I_-(z,t) = \frac{V_+(z,t)}{Z_o} - \frac{V_-(z,t)}{Z_o}$$

d) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t = \infty$.

Problem 10.2: (Switching transient – load end)

Consider the following transmission line circuit:

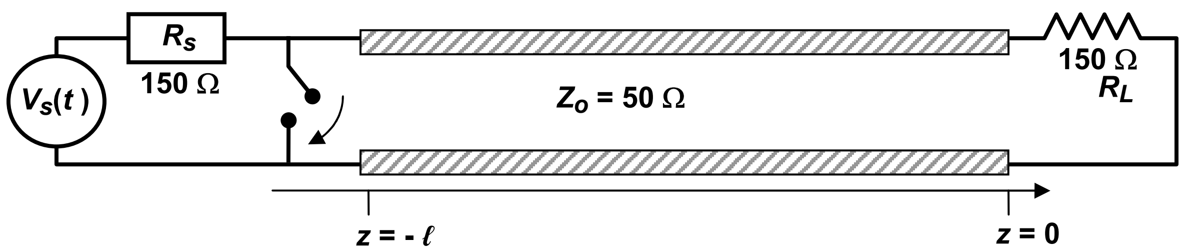


The source voltage equals 2 volts and was switched on at time $t=-\infty$. At time $t=0$, the switch at the load end is closed shorting the resistive load. This situation is a simple model of what happens when switches turn on and off in integrated circuits and the accompanying transients in the power lines.

a) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t=0^-$ (i.e. just before the switch is closed).
b) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t=\ell/2v$.
c) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t=3\ell/2v$.

Problem 10.3: (Switching transient – source end)

Consider the following transmission line circuit:

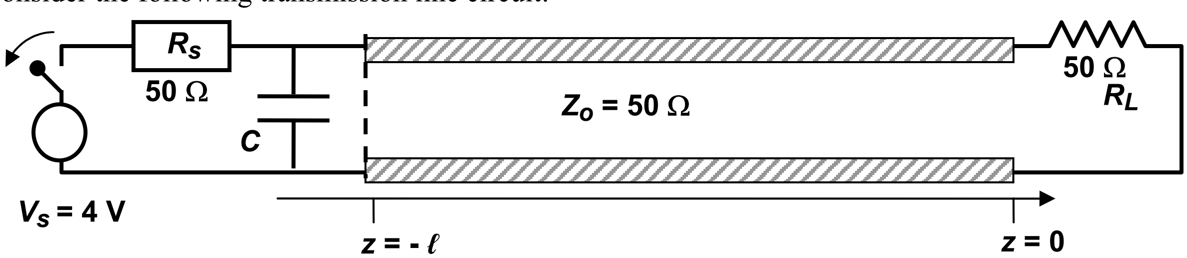


The source voltage equals 2 volts and was switched on at time $t=-\infty$. At time $t=0$, the switch at the source end is closed shorting out the source.

a) Plot the voltage $V(z=0,t)$ across the load resistor for times $0\le t\le 9\ell/2v$.

Problem 10.4: (Source capacitor - I)

Consider the following transmission line circuit:



The source voltage is a constant and equals 4 volts. The switch at the source end was in closed position at time $t = -\infty$ allowing the capacitor to charge and voltages to get established in the transmission line. At time $t = 0$, the switch at the source end is opened. Assume that $\ell = 3$ cm, $v = 3 \times 10^8$ m/s, and $C = 0.4$ pF.

a) Make the Thevenin equivalent circuit that represents the circuit to the right of the dashed line for times $0 \le t \le 3\ell/v$.

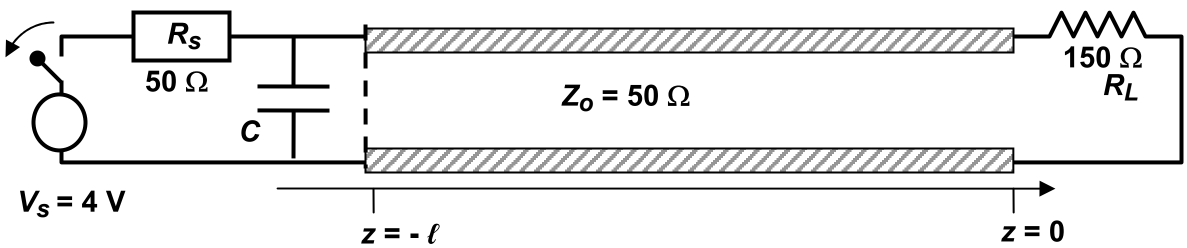
b) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t = 0^-$ (i.e. just before the switch at the source end was opened).

c) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t = \ell/2v$.

d) Plot the currents $I_+(z,t)$, $I_-(z,t)$, and $I(z,t)$ on the transmission line at time $t = \ell/2v$.

e) Plot the voltages $V_+(z,t)$, $V_-(z,t)$, and $V(z,t)$ on the transmission line at time $t = \infty$.

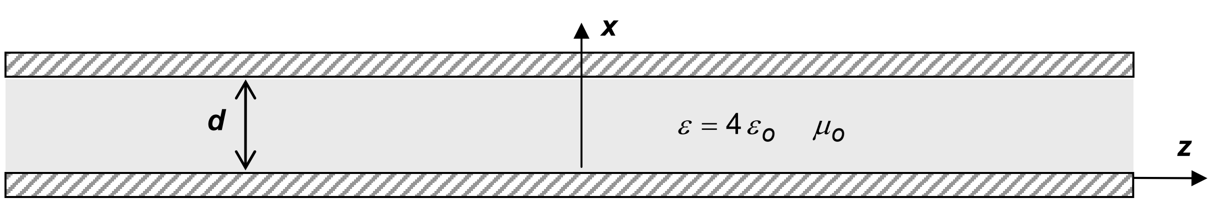
Problem 10.5: (Source capacitor - II)



This is the same as problem 10.4. The only difference is that the load resistor R_L is not 50 Ohms but 150 Ohms. Repeat parts (a) through (e) of problem 10.4 assuming that the load resistor is 150 Ohms.

Problem 10.6: (Parallel-plate waveguide)

Consider the parallel plate waveguide shown below:



The plate separation is $d = 5$ mm.

a) Find the cut-off frequencies (in Hz) of the TE_2 and TM_2 modes.

b) Sketch the electric and magnetic field lines for the TE_2 mode.

c) Sketch the electric and magnetic field lines for the TM_2 mode.

(**Hint**: for parts (b) and (c) it will help if you figure out the analytical expressions for the fields)

Problem and Part Number:

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$V_+(z,t)$

$V_-(z,t)$

$V(z,t)$

$z = -\ell$ $z = 0$ $z = -\ell$ $z = 0$

$t =$ $t =$

Problem and Part Number:

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$V_+(z,t)$

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$t =$ $t =$