MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

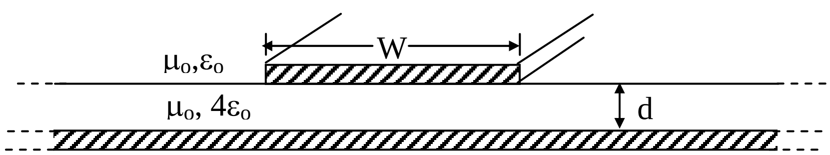
6.013 – Electromagnetics and Applications

Problem Set 6 (five problems)

Suggested Reading: Course notes, Sections 7.1.1-7.1.2, 7.2.1-7.2.2, 8.1, 8.3.1

Problem 6.1

Stripline can be approximated as an ideal parallel-plate TEM line if its width W is much greater than the separation d between top and bottom plates (i.e., if fringing fields can be neglected). Consider the illustrated infinitely long stripline for which d = 1 micron and the medium between the plates has $\mu = \mu_o$ and $\varepsilon = 4\varepsilon_o$.



(a) For what width W is the impedance of this line 50Ω? Is the ideal parallel plate model valid for these dimensions? Discuss briefly.

(b) For a 1-volt DC signal, what is the intensity I (time-average Poynting vector magnitude [W]) of the TEM electromagnetic field propagating between the plates?

(c) Evaluate the time average electric and magnetic energy densities per meter, i.e., W_e and W_m [J/m], on this line for case (b) (neglect fringing fields).

(d) Show that the average power on the line, $c_{line}(W_e + W_m)$, equals the I found in (b).

(e) Show that if two arbitrary signals flowing in opposite directions are superimposed so that $v(z,t) = f_+(t - z/v) + f_-(t + z/v)$, then the total power flowing down this line in the +z direction at any (t,z) equals the power flowing in the +z direction minus the power flowing in the -z direction. Show whether or not such superposition of powers also applies when the two signals flow in the same direction on TEM lines.

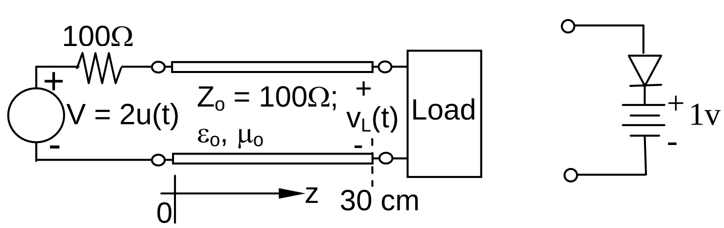
Problem 6.2

A 30-centimeter-long, air-filled 100Ω TEM line is excited at one end by a matched voltage source V(t), where V(t) is a step function 2u(t) volts. Sketch and quantitatively dimension V(z) and I(z) on the line at $t = 15 \times 10^{-10}$ sec for the case where the load is:

(a) a 300 Ω resister

(b) a capacitor $C = 2\times10^{-12}$ F

(c) a diode back-biased with a 1-volt battery, as shown.



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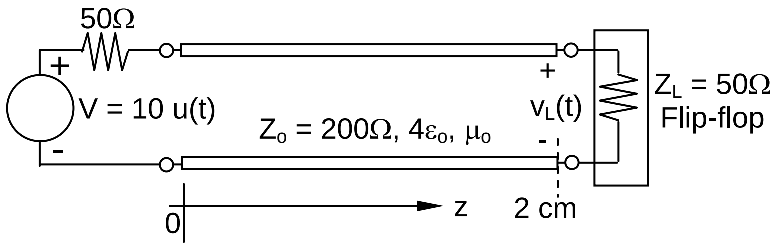
Problem 6.3

A line driver at one end of a 2-cm long 200-ohm TEM transmission line triggers a flip-flop at the other end with a step function, as illustrated. The dielectric in the line has $\varepsilon = 4\varepsilon_o$ and $\mu = \mu_o$.



(a) Sketch and dimension v(t,z) on the line at t = 0.1 ns (10^{-10} sec).

(b) Repeat (a) for t = 0.2 ns.

(c) Sketch quantitatively the load voltage $v_L(t)$ until the flip-flop is triggered; its trigger voltage is 4 volts. Note that triggering is excessively delayed.

(d) What is the asymptotic value of the load voltage $v_L(t)$ as $t \rightarrow \infty$?

(e) If the line impedance were matched at 50 ohms, would there still be excessive delay?

(f) Write a simple equation for v(z,t) valid for 0 < t < 0.1 ns, then extend it to 0.2 ns.

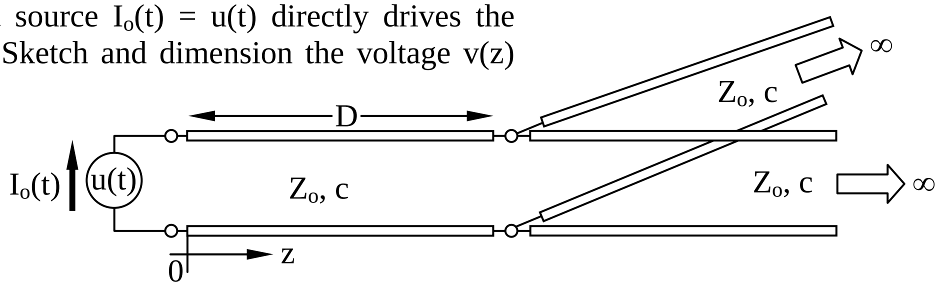
Problem 6.4

A unit-step current source $I_o(t) = u(t)$ directly drives the illustrated circuit. Sketch and dimension the voltage v(z) on all lines at:

(a) t = D/2c

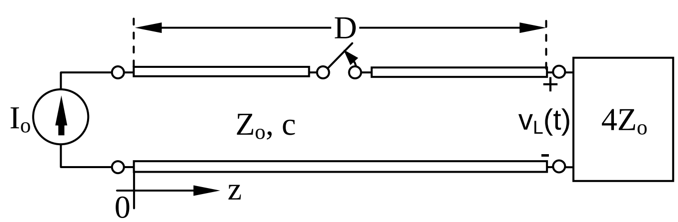
(b) t = 3D/2c

(c) t = 5D/2c.



Problem 6.5

A current source I_o drives a delicate transistor that has an input impedance of $4Z_o$ through a TEM line of impedance Z_o, as illustrated.



(a) At t = 0 the switch at z = D/2 opens for D/10c seconds and then recloses. Sketch the voltage v(z) on the line at t = D/5c.

(b) Will $v_L(t)$ across the transistor load ever exceed its breakdown limit of $7Z_oI_o$ volts? Briefly explain.

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