ELEC 306
Problem Set 3
Due: September 19, 2014

Homework Problems.
Work the following problems in Sadiku:

H3.1 4.2

H3.2 4.10

H3.3 4.20

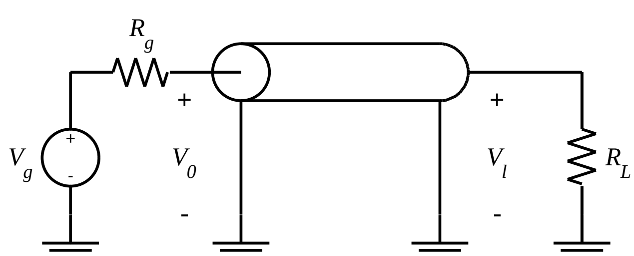
H3.4 Find the magnitude and direction of the electric field produced by two infinite sheets of charge, one of density $+\sigma$ in the xy-plane, the other of density $-\sigma$ in the yz-plane. Sketch the lines of the field $\mathbf{E}$.

Real Problems.

R3.1 Just as a coaxial cable forms a transmission line for electromagnetic waves, a hollow tube forms a transmission line for acoustic waves. Since a hollow tube forms the basis for organ pipes and woodwind instruments, [1] we might try to make an electric musical instrument based on a coaxial cable.

This isn't a new idea; a length of coax driven at one end and terminated in an open or short circuit at the other is known as a *coaxial resonator* and is used in many RF and microwave systems. Resonance is usually studied in the frequency domain, but our frequency domain study of transmission lines is still a few weeks off. However, we can get some insight into resonant behavior in the time domain. In particular, if we excite the line with an impulse it will respond at its resonant frequency(s). To continue the musical analogy, this is equivalent to hitting a chime or piano string with a hammer, causing it to produce a note at its resonant frequency.

Consider the following circuit:



If V_g is an impulse, then V_0 and V_l will be the near-and and far-end impulse responses. If either R_g or R_L are equal to Z_0, the pulse will make at most one round trip through the line before being totally absorbed. However, if both are different from Z_0, there will be a reflection at each end, and the pulse will bounce back and forth forever (although with ever decreasing amplitude). We could take the Fourier

[1] There's a good explanation of the physics behind sound generation in an organ pipe at http://www.pykett.org.uk/how_the_flue_pipe_speaks.htm#Mechanism

transform of this impulse response to get the frequency response, but that would be a lot of work. Let's see how much we can figure out about this resonance without leaving the time domain.

For this problem, assume that the line is 1m long, with $Z_0 = 50\Omega$, and a velocity factor of 2/3. For simplicity, let $R_g = 0$.

(a) Find and sketch the impulse response, $V_l(t)$ for $R_L = 1\Omega$ and for $R_L = 2500\Omega$. If you like, you may use a pulse of nonzero width, as long as that width is significantly less than the delay of the line.

(b) Based on the results of the previous step, what is the fundamental frequency and harmonic content of the output signal, for each value of R_L?

(c) Considering the system consisting of the transmission line and R_L to be a resonator, what is its Q?

(d) How does the system behavior change if the input voltage source is replaced with a current source?