Spring, 1998
D. P. Neikirk, Instructor

EE 363M Introduction to Microwave Engineering

Exam 1: **REWORK FOR HOMEWORK!!**

DUE: Wednesday, March 25, 1998

To gain some extra points, and more importantly, to make sure you understand this material, please rework the exam. To get the extra points, make sure your answers are perfect, and are very clearly written out! No partial credit this time!

I will score the exam in the following way: The test you took in class will count for as many points as you got the first time; this re-worked exam will be worth 50 points. I will sum the two scores, and normalize to 150 points to get your final score.

Things you may or may not find useful:

$\varepsilon_o = 8.854 \times 10^{-14}$ F/cm $\quad \mu = 4\pi \times 10^{-9}$ H/cm $\quad c = 3 \times 10^{10}$ cm/sec

$\sqrt{j} = \frac{1}{\sqrt{2}}(1 + j)$ $\quad (1 \pm x)^{1/2} = 1 \pm \frac{1}{2}x - \frac{1}{8}x^2 \pm \ldots$ for $|x| < 1$ $\quad \frac{1}{1 \pm x} \approx 1 \mp x \quad x<<1$

Transmission line formulas:

$$Z(-l) = \frac{V(-l)}{I(-l)} = Z_o \frac{1 + \rho(0)\, e^{-2\gamma l}}{1 - \rho(0)\, e^{-2\gamma l}} = Z_o \frac{Z_L + Z_o \,\mathbf{tanh}(\gamma l)}{Z_o + Z_L \,\mathbf{tanh}(\gamma l)}$$

For a TEM to z wave: $\quad LC = \varepsilon\mu$

$$\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y} = 0 \qquad \frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = 0 \qquad \mathbf{z} \times \frac{\partial \mathbf{E}}{\partial z} = -j\omega\mu\mathbf{H} \qquad \mathbf{z} \times \frac{\partial \mathbf{H}}{\partial z} = j\omega\mu\mathbf{E}$$

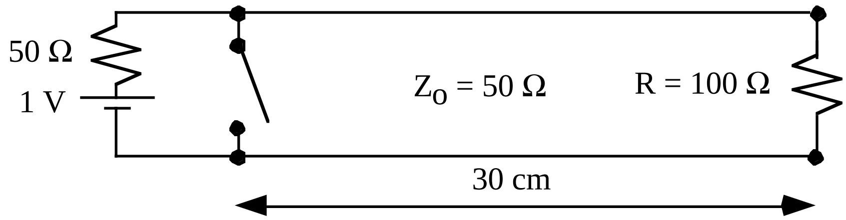
in lossless media:

$$\eta = \sqrt{\frac{\mu}{\varepsilon}} \qquad k = \omega\sqrt{\mu\varepsilon}$$

in general media:

$$\nabla \times \mathbf{E} = -j\omega\mu\mathbf{H} \qquad \nabla \times \mathbf{H} = (\sigma + j\omega\varepsilon)\,\mathbf{E}$$

1. (10 points) A battery and switch are connected to the transmission line circuit shown below. The transmission line is ideal, using a material with relative dielectric constant $\varepsilon_r = 1$ and relative permitivity $\mu_r = 1$. At time t = 0 the switch is closed.

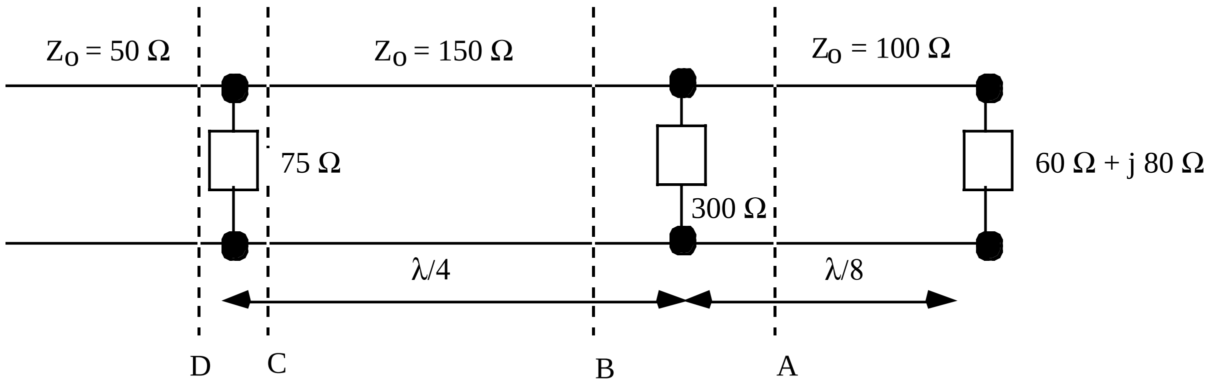


a) What is the time of flight for this transmission line?

b) At t = 0.5 nsec, what is V(z)? (i.e., draw V as a function of position along the T-line circuit from the switch to the load.) What is V_+ ?

c) At t = 1.5 nsec, what is V(z)?

2. (10 points) Consider the transmission line circuit shown below. All lines have Z_o as indicated on the diagram. **SHOW YOUR WORK ON THE ATTACHED SMITH CHART!**



a) What is the impedance at plane A?

Answer:____________________

b) What is the impedance at plane B?

Answer: ____________________

c) What is the impedance at plane C?

Answer: ____________________

d) What is the impedance at plane D?

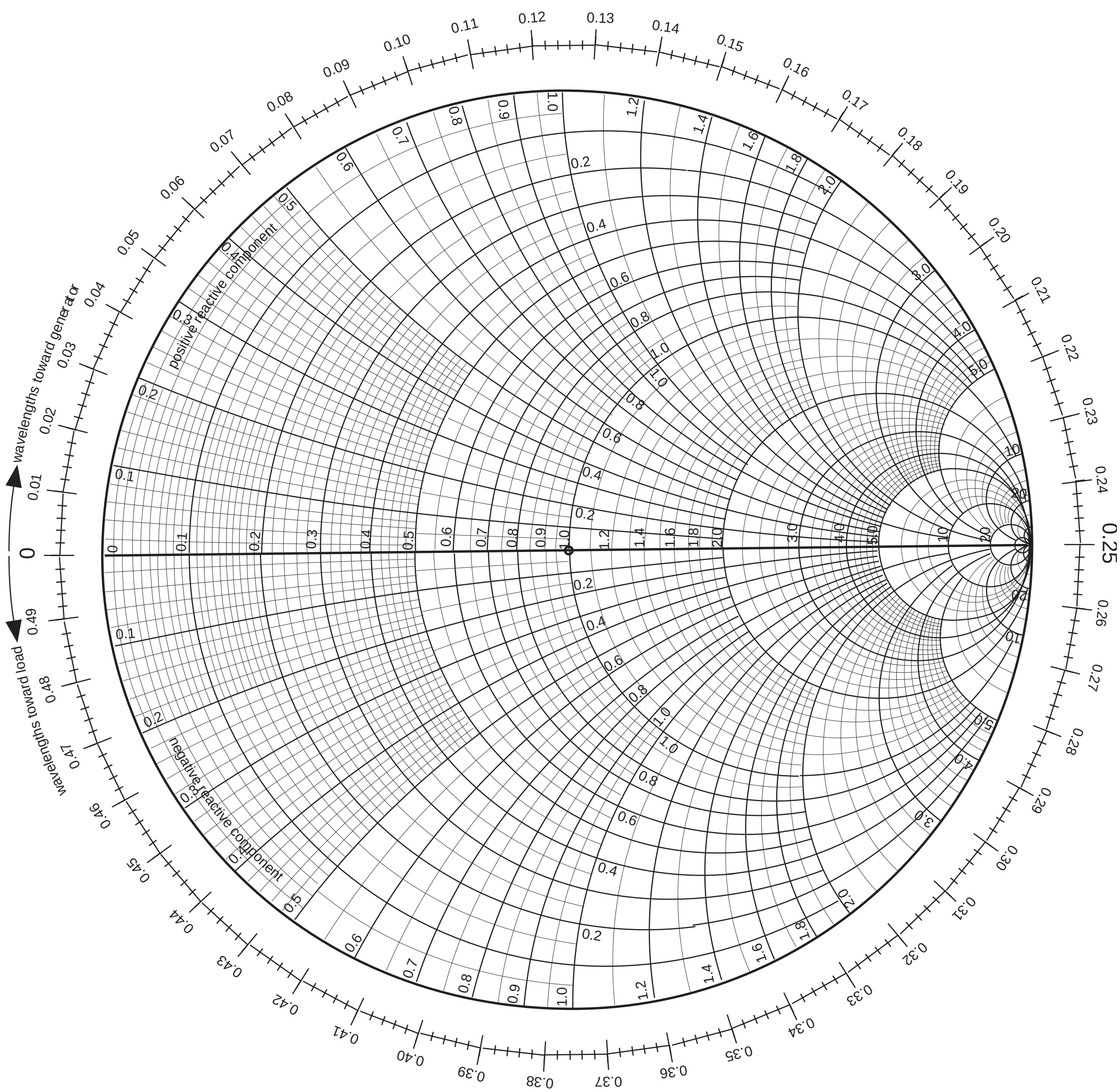
Answer: ____________________

e) What is the reflection coefficient ρ at plane D?

Answer: ____________________

Exam 1 **REWORK**, Spring '98

Smith chart for problem 2:

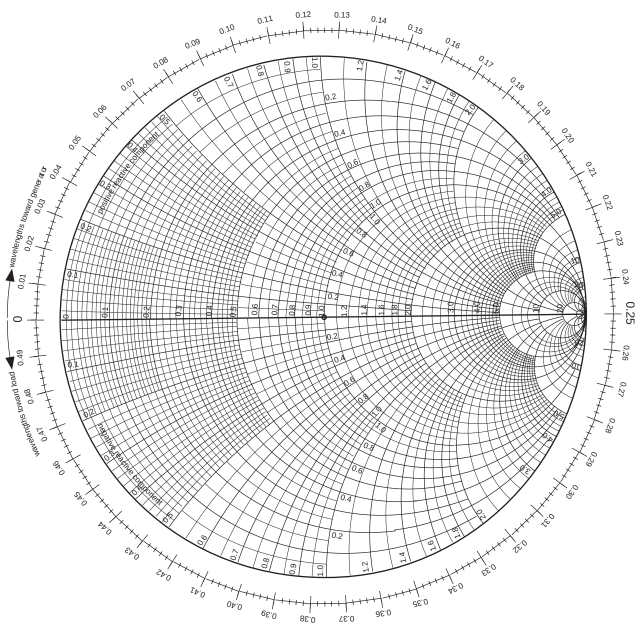


3. (10 points) A signal generator with internal impedance Z_o is connected to an ideal transmission line of length *l* and characteristic impedance Z_o. The transmission line is terminated with a load that has impedance $Z_l = jX$.

a) Show that $|\rho| = 1$.

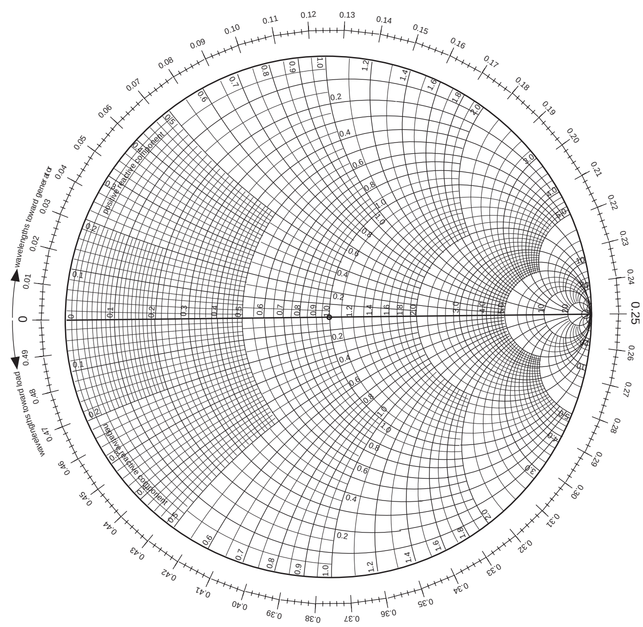
b) How much power is deposited in the load?

c) If a Smith Chart was used to display the impedance due to the load, and the frequency was swept from "dc" to "high frequency," sketch a Smith chart to show what the display would look like, assuming that the load is a capacitor (i.e., $X = \frac{-1}{\omega C}$); repeat, assuming the load is an inductor (i.e., $X = \omega L$).



$X = \frac{-1}{\omega C}$

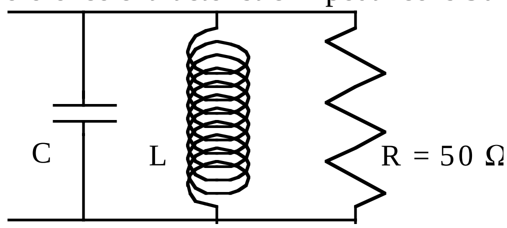
smith



$X = \omega L$

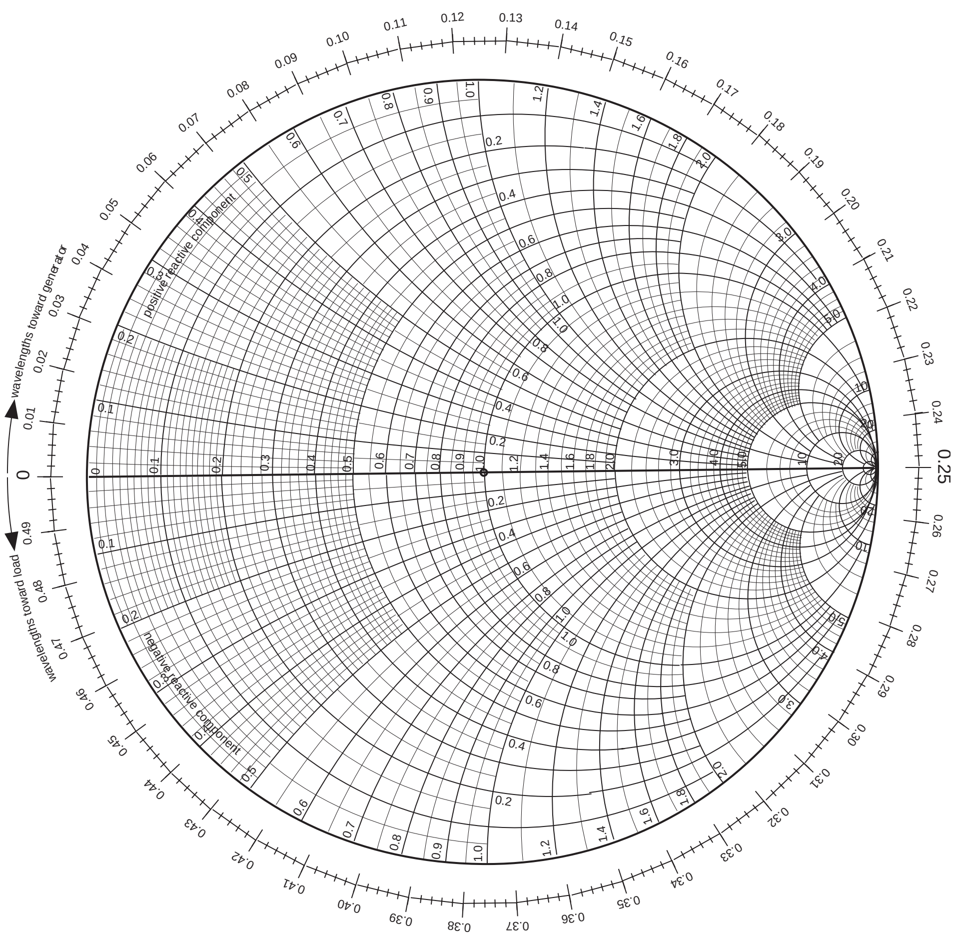
smith

d) If the load were a parallel R-L-C circuit as shown below, **sketch** on the Smith chart the impedance as a function of frequency from dc to “high frequency” (i.e., to a frequency $\omega >> 1/\sqrt{LC}$). Make sure to clearly label where on the Smith chart you would be at $\omega = 1/\sqrt{LC}$, and at low and high frequency. HINT: first write out what the admittance for the circuit is, then think about what the admittance would be for ω = 0, $\omega = 1/\sqrt{LC}$, and $\omega >> 1/\sqrt{LC}$. Assume the reference characteristic impedance is 50 Ω.

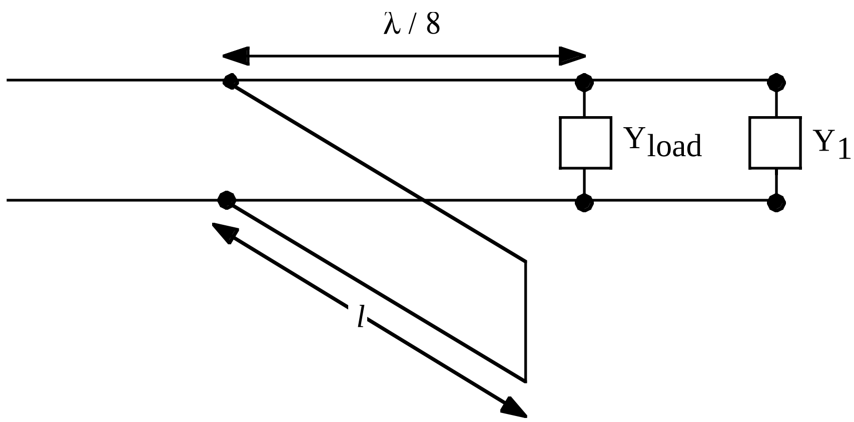


MAKE SURE TO TELL ME WHETHER YOU ARE PLOTTING ADMITTANCES OR IMPEDANCES ON THE CHART BELOW!!

smith chart:

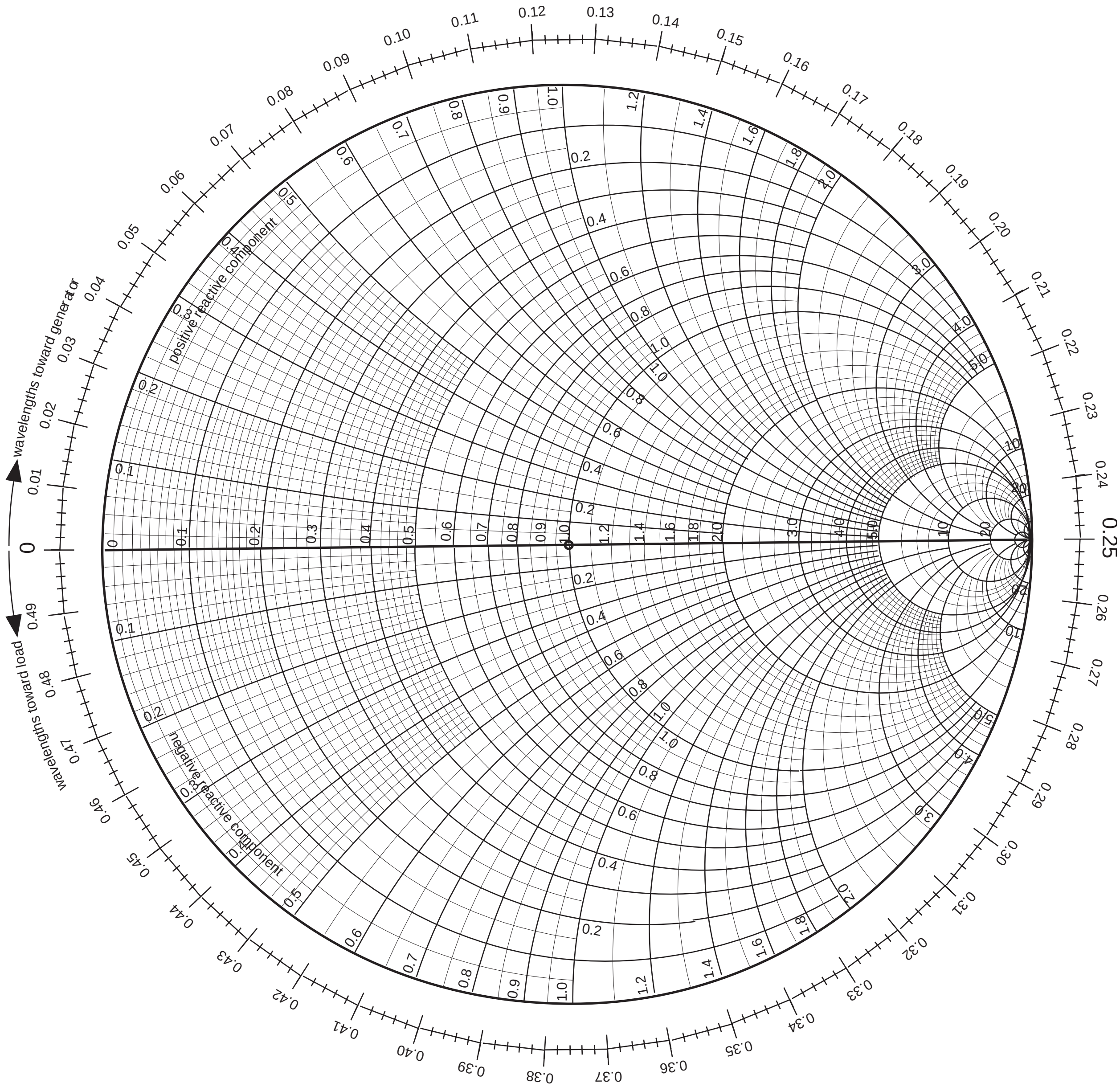


4. (10 points) For the circuit shown below, find the length *l* (in wavelengths) of the tuning stub and value of the (normalized) matching admittance Y_1, so that there are no reflections and all the power is deposited in the load. Assume Z_o for all the lines is the same, and that the normalized load admittance is $Y_{load} = 0.4 - j\,1.0$.

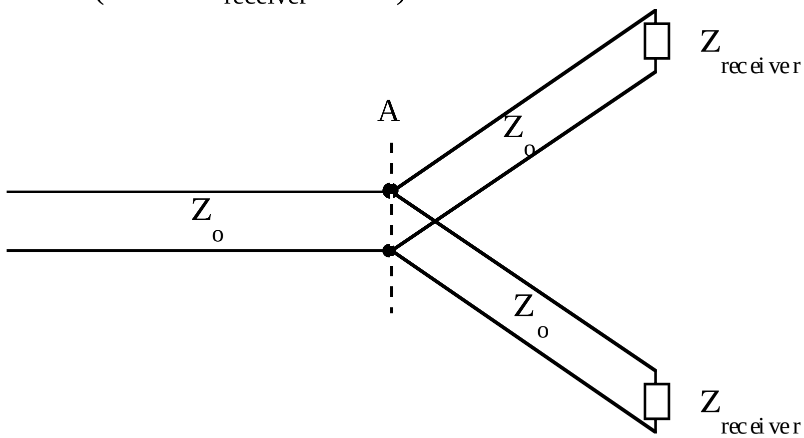


Exam 1 **REWORK**, Spring '98

Smith chart for problem 4:



5. (10 points) We want to split an incoming TV cable signal and distribute it to two receivers. The characteristic impedance of the cable is 75 Ω. Assume the receivers are impedance-matched to the cable (i.e. that $Z_{receiver} = 75\Omega$).



a) If we split the signal as shown above, what is the reflection coefficient ρ at plane A?

b) For this signal splitter, what percentage of the incident **power** is reflected? What percentage is transmitted to **each** receiver?

c) If we want to eliminate the reflection, what kind of **series** matching element (i.e., resistance, inductance, capacitance) do we have to add at plane A? What is Z_{match}?

d) For this signal splitter, what percentage of the incident power is lost in the matching element? What percentage is transmitted to **each** receiver? (HINT: it is easiest to get this just doing "dc-like" circuit analysis!!)