UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, MAY 1 1995

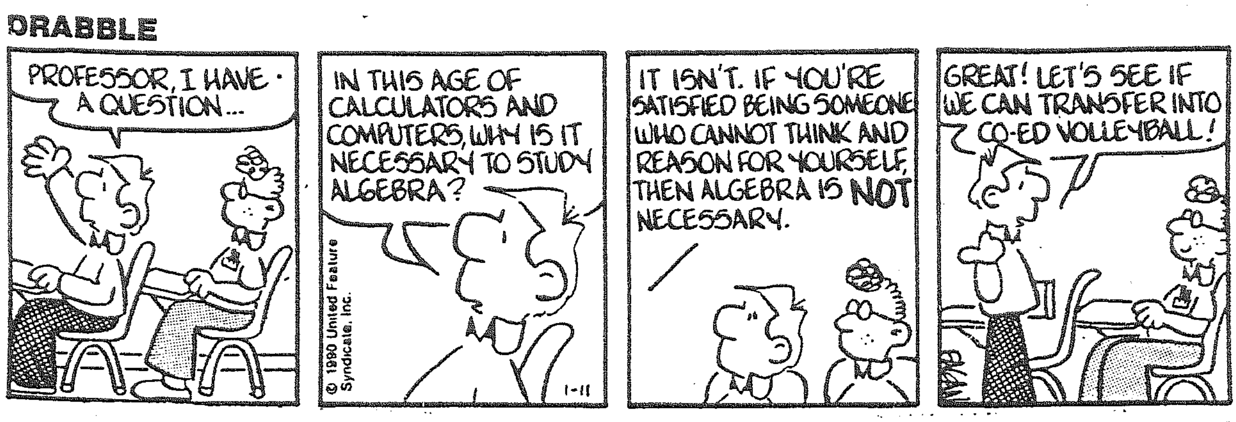
Third Year

ECE357S - ELECTROMAGNETIC FIELDS

Professor E. van Deventer

<u>AIDS PERMITTED:</u>

Double-sided aid sheet and non-programmable calculator



Electromagnetic Waves

Problem 1 (10 points)

A microwave engineer designed a $\lambda/2$ dipole antenna to operate in free space at 600 MHz.

(i) Calculate the length of this antenna.
(ii) If he still wants to use a $\lambda/2$ dipole antenna at the same frequency for underwater communication ($\sigma = 4$ S/m, $\varepsilon = 81\ \varepsilon_o$), calculate the necessary change in the dimensions of the antenna.

Problem 2 (12 points)

Match the following descriptions with the figures shown in Figure 1. Fields are near the interface but on opposite sides of the boundary. Explain your choice (*else no points will be given!*)

(a) medium 1 and medium 2 are dielectrics with $\varepsilon_1 > \varepsilon_2$
(b) medium 1 and medium 2 are dielectrics with $\varepsilon_1 < \varepsilon_2$
(c) impossible
(d) impossible
(e) there is a positive surface charge on the boundary between the two dielectrics
(f) medium 2 is a perfect conductor

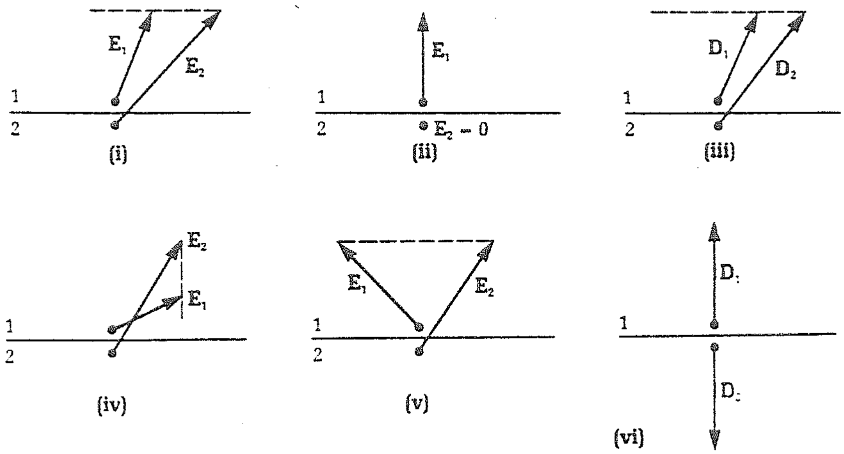


Figure 1

Transmission Lines

Problem 3 (15 points)

In the system shown in Figure 2(a), the switch is closed at $t=0$. The line voltage variation with time at a certain location $z = z_0$ for the first 3 μs is observed to be as shown in Fig. 2(b). Find the values of V_0, R_g, R_L, T, and z_0/l.

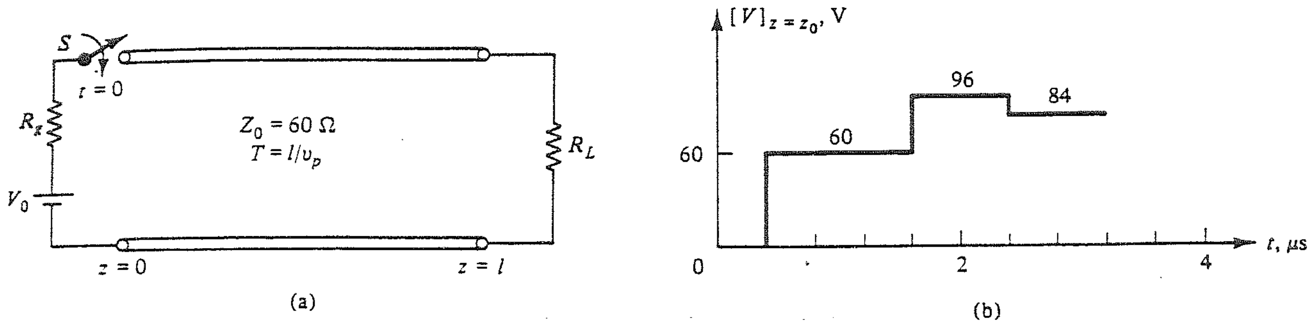


Figure 2

Problem 4 (20 points)

Figure 3 shows an arrangement, known as the alternated-line transformer, for achieving a matched interconnection between two lines of different characteristic impedances Z_{01} and Z_{02}. It consists of two sections of the same characteristic impedances as those of the lines to be matched, but alternated, as shown in the figure. The electrical lengths of the two sections are equal.

(i) Show that to achieve a match, the required electrical length of each section is

$$\frac{l}{\lambda} = \frac{1}{2\pi}\tan^{-1}\sqrt{\frac{n}{n^2+n+1}}$$

where $n = Z_{02} / Z_{01}$

(ii) For $Z_{02} = 200\ \Omega$ and $Z_{01} = 50\ \Omega$, what would be the length l needed to achieve matching?

(iii) Rather than solving the problem analytically, how would you do it graphically using a Smith Chart?

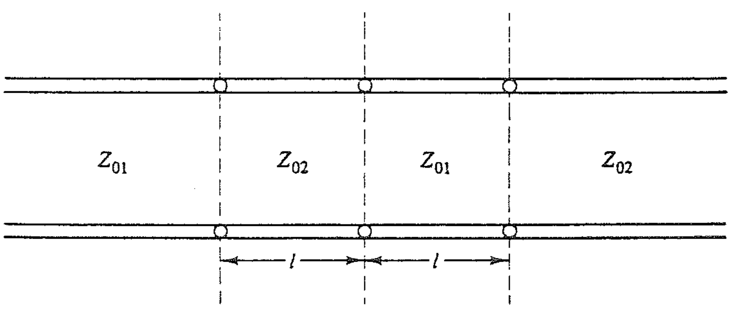


Figure 3

Waveguides and Antennas

Problem 5 (20 points)

An attenuator can be made using a section of waveguide operating below cutoff, as shown in Figure 4. If $a = 2.286\ cm$ and the operating frequency is 12 GHz, determine the required length of the below-cutoff section of waveguide to achieve an attenuation of 100 dB between the input and output guides. Ignore reflections at the step discontinuities.

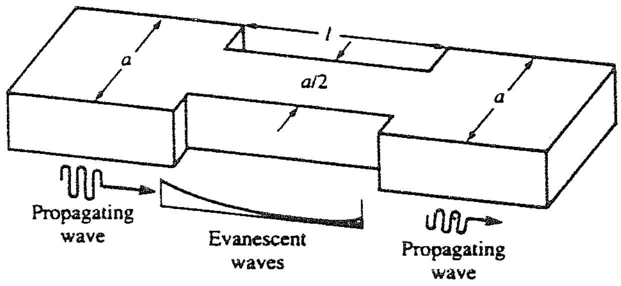


Figure 4

Problem 6 (8 points)

The pattern multiplication technique can be used in reverse to synthesize an array for a specified radiation pattern. Find an arrangement of isotropic elements for the group pattern

$$\cos\left(\frac{\Pi}{2}\cos\psi\right)\left|\sin\left(\frac{\Pi}{2}\cos\psi\right)\right|$$

Problem 7 (15 points)

Consider the antenna system consisting of two short dipoles arranged perpendicularly to each other in space, as shown in Figure 5. These dipoles are driven by the same amount of power from a common source. However, the current on the x-oriented dipole has a -90° phase with respect to that on the y-oriented dipole because of a phase shifter inserted in the transmission line that leads to the former.

(i) Find the total radiated electric field on the x axis. (*Hint*: Think before writing)
(ii) What is the polarization of the wave on the x-axis?

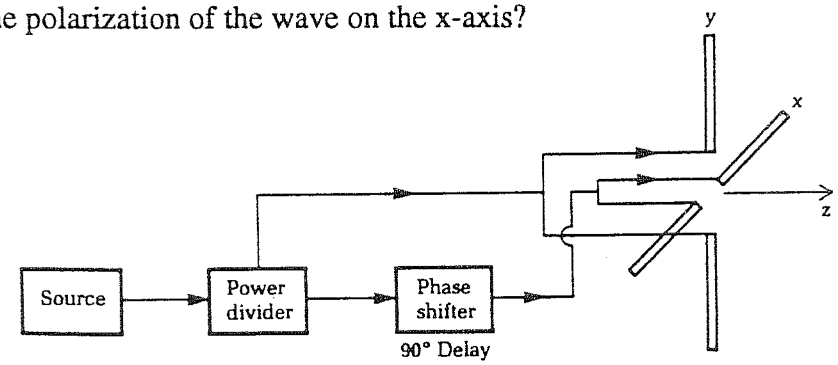


Figure 5