1. The following standing wave pattern is measured on a transmission line of impedance $Z_0 = 100 \, \Omega$ terminated with a load of unknown impedance. The frequency of the signal is 25 MHz. (30 points)

![Standing Wave Diagram]

a. What is the wavelength of the signal on the transmission line?
b. What is the speed of propagation on the line?
c. What is the voltage standing wave ratio?
d. What is the complex reflection coefficient?
e. What is the unknown load impedance?

[Hint: d. & e. may be answered using a Smith Chart. At the voltage minima (maxima), the normalized equivalent impedance is real and less (greater) than unity.]

a) $\lambda = 6 \, \text{m}$
b) $v = \lambda f = 1.5 \times 10^8 \, \text{m/s}$
c) $\text{VSWR} = 1.21.8 = 1.5$
d) $Z_{\text{max}} = -2.4 \, \text{m} = -0.4 \lambda$
   $|p| = (\text{VSWR}-1)/(\text{VSWR}+1) = \angle p = -72^\circ$ (see Smith chart) $=0.2$
e) $Z_L/Z_0 = 1.08 - j0.4 \, (\, \| \, )$
2. An electromagnetic wave is obliquely incident on a surface \((z=0)\) as shown. (30 points)

The electric field is polarized perpendicular to the plane of incidence. The angle of incidence is 10 degrees.

a) Calculate the transmitted angle.

b) What is the wave impedance in each region?

c) What is the reflection coefficient?

d) For what angles of incidence is all the incident power reflected?

Note impedance of free space = 377 \(\Omega\).

a) \(\theta_i = 10^\circ\) \(\sin\theta_i = 0.174\) \(\sin\theta_t = \sin\theta_i/\sqrt{3} = 0.521\)

\[\theta_t = 31.4^\circ\]

b) Region I \(Z_{te} = \frac{n_{\text{e}}}{\cos\theta_i} = \frac{\sqrt{\mu_{\text{e}}/\varepsilon_{\text{e}}}}{\cos\theta_i} = \frac{1}{3} \times \frac{377}{0.985} = 128 \Omega\)

Region II \(Z_{te} = \frac{\sqrt{\mu_{\text{e}}/\varepsilon_{\text{e}}}}{\cos\theta_t} = \frac{377}{0.854} = 442 \Omega\)

c) \(\rho = \frac{442-128}{442+128} = 0.554\)

c1) \(\sqrt{\rho} \sin \theta_{te} = 1\) \(\theta_{te} = 19.3^\circ\)
3. A signal generator launches, at t=0, a single 12 volt square wave pulse of duration 0.1 μsec., on a lossless transmission line of length 300 meters. The impedance of the line is 300 ohms, the source impedance of the generator is 100 ohms, and the impedance of the load is 900 ohms. The speed of propagation on the line is $3 \times 10^8$ meters/sec. (40 points)

\[
R_G = 100 \ \Omega \\
Z_0 = 300 \ \Omega \\
R_L = 900 \ \Omega \\
V_0 = 12 \ V
\]

(a) Make plots of the voltage and current, as a function of z on the transmission line, at t=.5 μsec. 10 points

(b) Make a plot of the voltage at the load as a function of time for 4 μsec. > t > 0. Label the voltage levels in terms of the applied voltage and the reflection coefficients $\rho_g$ and $\rho_l$ that apply at the generator and load. 10 points

c) How much energy has been supplied by the ideal generator? Discuss in words where this energy goes? 5 points

d) Now suppose that the line has both series resistance $R'$ and shunt conductance $G'$, but these are such that the line is distortionless. \( R' / L' = G' / C' \). Show that $\alpha = R' \sqrt{C'/L'}$. Calculate the amplitude of the voltage pulse that arrives at the load if R’=1 Ohm/m. Assume the characteristic impedance remains 100 Ohms. (Hints: in general $\gamma = \alpha + j\beta = \sqrt{(R' + j\omega L')(G' + j\omega C')}$, $Z_0 = \sqrt{(R' + j\omega L')/(G' + j\omega C')}$. )
a) \[ V = 3 \times 10^8 \text{ m/s} \quad \alpha + t = 0.5 \times 10^{-4} \text{s} \]

\[ V = 12 \cdot \frac{300}{400} = 9 \text{ V} \]

\[ I = \frac{9}{300 \Omega} = 0.03 \text{ A} \]

\[ p_L = \frac{9 \cdot 0 - 300}{9 \cdot 0 + 300} = 0.5 \]

\[ V = (1 + p_L) \cdot 9 \text{ V} = 13.5 \text{ V} \quad P_g = -0.5 \]

\[ E = (1 + p_L) \cdot p_g \cdot 9 \text{ V} = -3.375 \text{ V} \]

b) \[ U = P \cdot \tau \quad \tau = 1 \mu \text{sec} \]

\[ P = IV \quad V = 12 \text{ V} \quad I = \frac{12}{400} = 0.03 \text{ A} \]

\[ U = 3.6 \times 10^3 \text{ J} \quad \text{ENERGY IS DISIPATED IN RESISTORS } R_y R_u \]

d) \[ L' \text{ is} \ G' \text{ is} \]

\[ G' + jwL' = (R' + jwL') \frac{1}{jwL'} \]

\[ \alpha + j \beta = \frac{(R' + jwL')}{jwL'} = \frac{1}{jwL'} \]

\[ \beta = \frac{1}{(L')/100 \Omega} = 0.001 \text{ m}^{-1} \]

\[ V = \exp(-\alpha \ell) (1 + p_L) \cdot 9 \text{ V} = \exp(-3) \cdot 13.5 \text{ V} = 0.67 \text{ V} \]