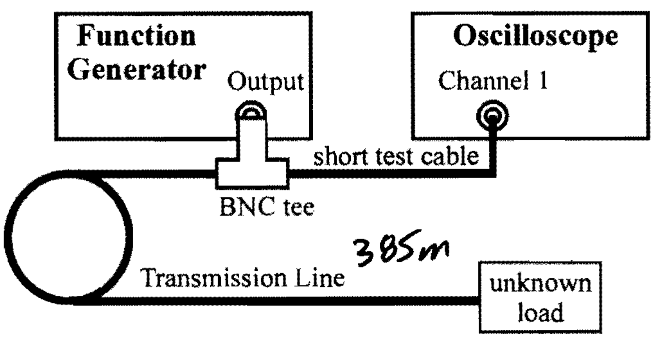
EE 382 Applied Electromagnetics Examination #3 (Spring 2018)

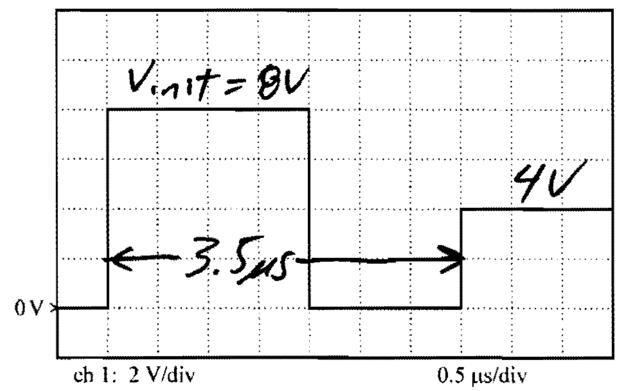
Name *Key A*

Instructions: Place answers in indicated spaces. Use notation as given in class. Show all work for full credit. Turn in equation sheet with exam.

1) A 385 m length of lossless transmission line is driven by a function generator with a measured open circuit voltage of $V_{oc}(t) = 24[u(t) - u(t - 2\,\mu s)]$ V and impedance of 100 Ω. Using an oscilloscope, the voltage at the input of the transmission line is measured. Assume the time delay from the short test cable is negligible and that the oscilloscope has a very large input impedance (i.e., does not distort input voltage). Using this information, determine the one-way transit time, transmission line characteristic impedance, phase velocity, generator & load reflection coefficients, and load impedance.

30 pts



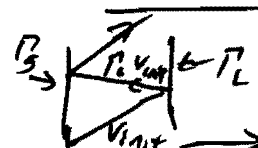


From voltage display, $2T = 3.5\,\mu s \Rightarrow \underline{T = 1.75\,\mu s}$

$$T = \ell/u \Rightarrow u = \ell/T = \frac{385}{1.75\times10^{-6}} = \underline{2.2\times10^{8}\ m/s}$$

$$V_{init} = 8V = V_{oc}\frac{Z_0}{Z_g + Z_0} = 24V\frac{Z_0}{100 + Z_0} \Rightarrow \underline{Z_0 = 50\,\Omega}$$

$$\Gamma_g = \frac{Z_g - Z_0}{Z_g + Z_0} = \frac{100-50}{100+50} = \underline{0.\overline{3}}$$



$$4V = \Gamma_L V_{init} + \Gamma_g \Gamma_L V_{init} = \Gamma_L\left(8 + 0.\overline{3}(8)\right)$$

$$\hookrightarrow \Gamma_L = \frac{4}{8 + 8/3} = \underline{0.375}$$

$$Z_L = Z_0\frac{1+\Gamma_L}{1-\Gamma_L} = 50\,\frac{1+0.375}{1-0.375} = \underline{110\,\Omega}$$

one-way transit time = *1.75 μs* characteristic impedance = *50 Ω*

generator reflection coeff. = *$0.\overline{3}$* load reflection coeff. = *0.375*

phase velocity = *2.2×10^{8} m/s* load impedance = *110 Ω*

2) A phasor electric field of $\bar{E} = \hat{a}_x 60 e^{-\gamma y}$ V/m is propagating through a material where $\varepsilon = 3\varepsilon_0$, $\mu = \mu_0$, and $\sigma = 0.006$ S/m. If the TEM wave oscillates at 220 MHz, find the propagation constant, wavelength, velocity, intrinsic impedance, skin depth, and loss tangent. Then, determine the time-domain electric and magnetic fields (define all constants). Put all complex quantities in rectangular form.

30 pnts

$$\gamma = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)} = \sqrt{j2\pi(220\times10^6)4\pi\times10^{-7}(0.006 + j2\pi(220\times10^6)3(8.854\times10^{-12}))}$$

$$\underline{\gamma = 0.65036 + j8.01268 \ m^{-1}}$$

$$\text{loss tangent} = \frac{\sigma}{\omega\epsilon} = \frac{0.006}{2\pi(220\times10^6)3(8.854\times10^{-12})} = \underline{0.16341}$$

$$u = \frac{\omega}{\beta} = \frac{2\pi(220\times10^6)}{8.01268} = \underline{1.72514\times10^8 \ m/s}$$

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{8.01268} = \underline{0.78416 m}$$

$$\delta = \frac{1}{\alpha} = \frac{1}{0.65} = \underline{1.5376 \ m}$$

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}} = \sqrt{\frac{j2\pi(220\times10^6)4\pi\times10^{-7}}{0.006 + j2\pi(220\times10^6)3(8.854\times10^{-12})}} = 216.0771\angle 4.64034^\circ \ \Omega$$

$$= \underline{215.3688 + j17.4808 \ \Omega}$$

$$\mathscr{E} = \mathrm{Re}\{\bar{E}e^{j\omega t}\} = \mathrm{Re}\{\hat{a}_x 60 e^{-0.6504y} e^{-j8.01268y} e^{j2\pi(220\times10^6)t}\}$$

$$\underline{= \hat{a}_x 60 e^{-0.6504y}\cos(4.4\pi\times10^8 t - 8.01268y) \ V/m}$$

$$\bar{H} = \frac{\hat{a}_k \times \bar{E}}{\eta} = \frac{\hat{a}_y \times \hat{a}_x 60 e^{-\gamma y}}{216.0771\angle 4.64^\circ} = -\hat{a}_z 0.27768 e^{-0.6504y} e^{-j8.0127y} e^{-j4.64^\circ}$$

$$\mathscr{H} = \mathrm{Re}\{\bar{H}e^{j\omega t}\} = -\hat{a}_z 0.27768 e^{-0.6504y}\cos(4.4\pi\times10^8 t - 8.0127y - 4.64^\circ) \ A/m$$

propagation constant = $0.65036 + j8.01268 \ m^{-1}$ loss tangent = 0.16341

wave velocity = $1.72514\times10^8 \ m/s$ wavelength = $0.78416 \ m$

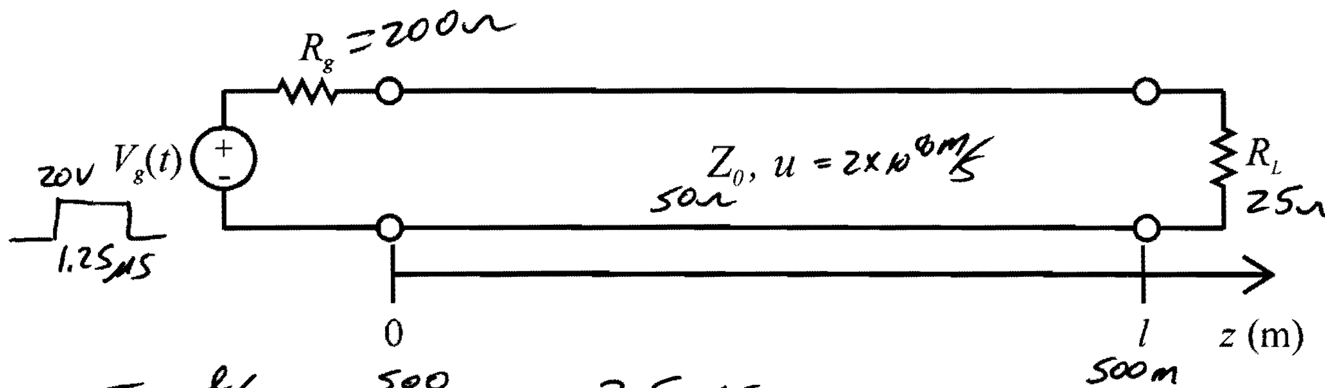
intrinsic impedance = $215.3688 + j17.4808 \ \Omega$ skin depth = $1.5376 \ m$

time-domain electric field = $\hat{a}_x 60 e^{-0.6504y}\cos(4.4\pi\times10^8 t - 8.01268y) \ V/m$

time-domain magnetic field = $-\hat{a}_z 0.2777 e^{-0.6504y}\cos(4.4\pi\times10^8 t - 8.01268y - 4.64^\circ) \ A/m$

20 pnts

3) For the lossless transmission line ($Z_0 = 50\ \Omega$ and $u = 2 \times 10^8$ m/s) circuit shown, the generator resistance is 200 Ω, the load resistance is 25 Ω, and $V_g(t) = 20\,[u(t) - u(t - 1.25\ \mu s)]$ V. If $l = 500$ m, compute the one-way transit time T, load & generator voltage reflection coefficients, and the magnitude of the initial current & voltage waves at the input ($z = 0$). Then, draw the current & voltage bounce diagrams (properly labeled with values) for $0 \le t \le 5T$. Using bounce diagrams, make **fully-labeled** sketches of the **load** voltage for $0 \le t \le \mathbf{4T}$ and **current** along the transmission line (i.e., $0 \le z \le l$) at $t = 2T$.

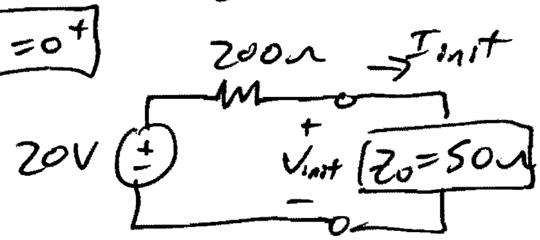


$$T = \frac{l}{u} = \frac{500}{2\times10^8} = \underline{2.5\,\mu s}$$

$$\Gamma_L = \frac{R_L - Z_0}{R_L + Z_0} = \frac{25-50}{25+50} = -\frac{1}{3} = \underline{-0.\overline{33}}$$

$$\Gamma_g = \frac{R_g - Z_0}{R_g + Z_0} = \frac{200-50}{200+50} = \underline{0.6}$$

$\boxed{t = 0^+}$

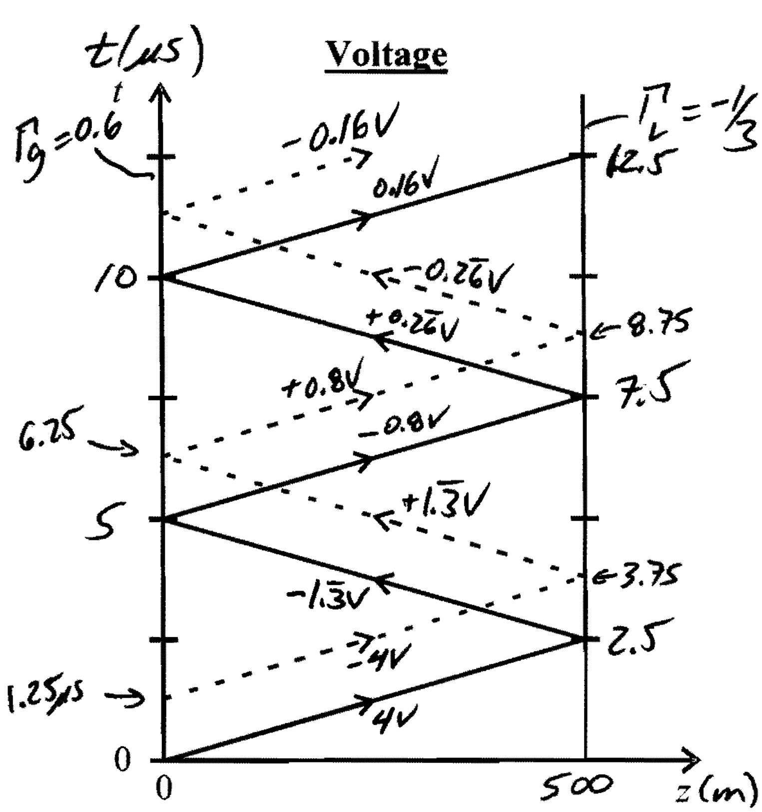


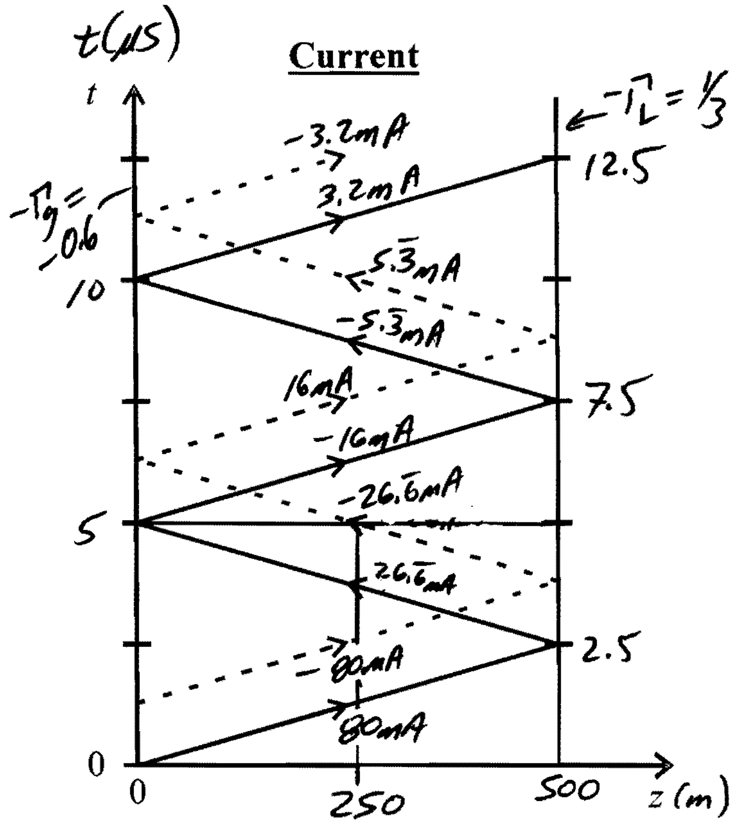
$$I_{init} = \frac{20}{200+50} = 0.08\ A = \underline{80\ mA}$$

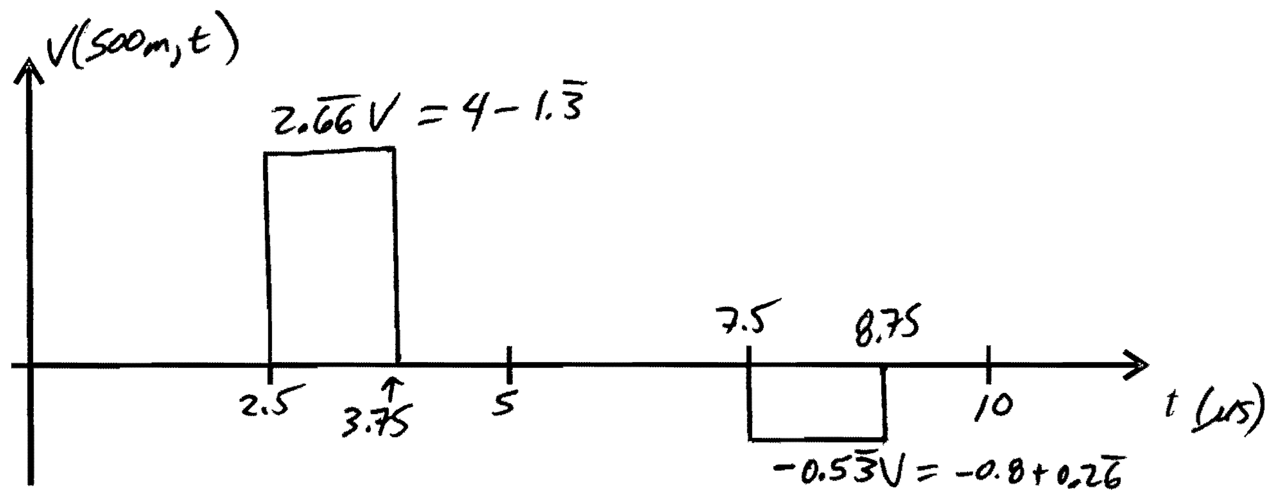
$$V_{init} = 20\,\frac{50}{200+50} = \underline{4V}$$

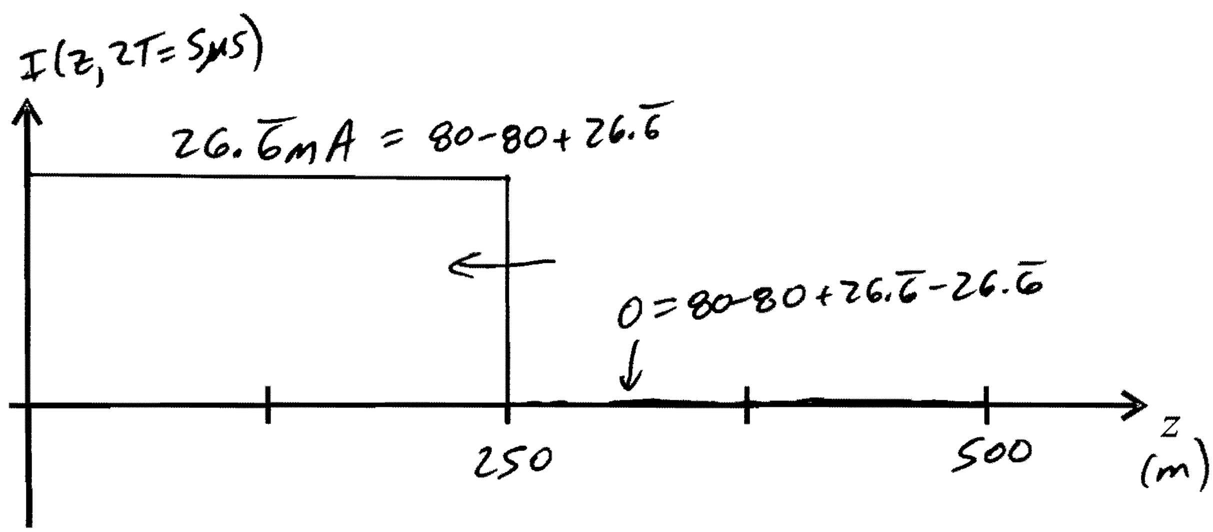
$T =$ 2.5μs $\Gamma_L =$ $-0.\overline{33}$ $\Gamma_g =$ 0.6

$I_{init} =$ 80 mA $V_{init} =$ 4 V


Voltage
t(μs)
t
$\Gamma_g = 0.6$
$\Gamma_L = -1/3$
-0.16V
0.16V
-0.26̄V
+0.26̄V
+0.8V
-0.8V
+1.3̄V
-1.3̄V
4V
4V
12.5
10
8.75
7.5
6.25
5
3.75
2.5
1.25μs
0
0
500
z (m)


Current
t(μs)
t
$-\Gamma_L = 1/3$
$-\Gamma_g = -0.6$
-3.2mA
3.2mA
5.3̄mA
-5.3̄mA
16mA
-16mA
-26.6̄mA
26.6̄mA
-80mA
80mA
12.5
10
7.5
5
2.5
0
0
250
500
z (m)


V(500m, t)
2.66̄ V = 4 − 1.3̄
7.5
8.75
2.5
3.75
5
10
t (μs)
−0.53̄V = −0.8 + 0.26̄


I(z, 2T = 5μs)
26.6̄mA = 80 − 80 + 26.6̄
0 = 80 − 80 + 26.6̄ − 26.6̄
250
500
z (m)