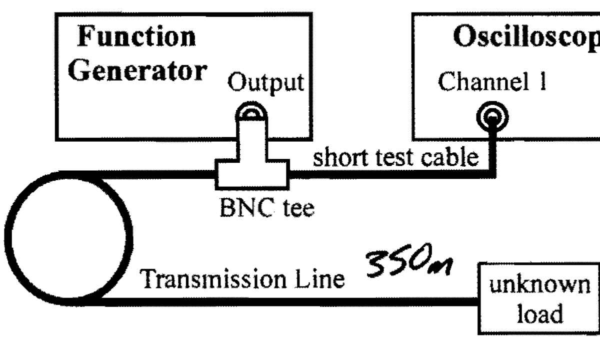
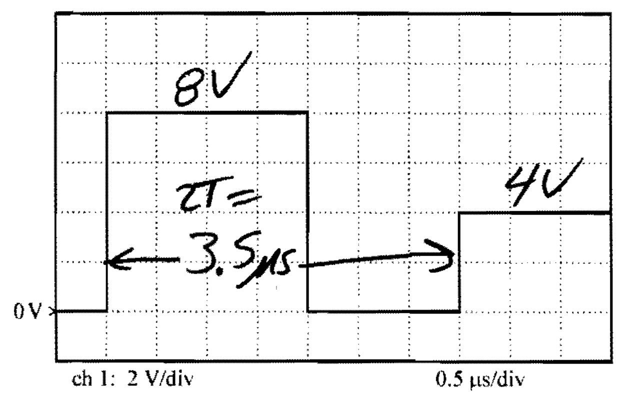
EE 382 Applied Electromagnetics Examination #3 (Spring 2018)

Name *Key B*

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) *30 pts* A 350 m length of lossless transmission line is driven by a function generator with a measured open circuit voltage of $V_{oc}(t) = 12[u(t) - u(t - 2\,\mu s)]$ 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.



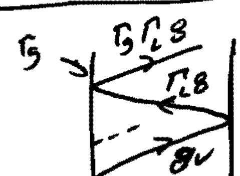


From voltage display, $2T = 3.5\,\mu s \Rightarrow \underline{T = 1.75\,\mu s}$

$\ell = uT \Rightarrow u = \ell/T = \frac{350\,m}{1.75\times10^{-6}} = \underline{2\times10^{8}\ m/s}$

$V_{init} = 8V = V_{oc}\frac{Z_0}{Z_g + Z_0} = 12\frac{Z_0}{100 + Z_0} \Rightarrow \underline{Z_0 = 200\,\Omega}$

$\Gamma_g = \frac{Z_g - Z_0}{Z_g + Z_0} = \frac{100 - 200}{100 + 200} = \underline{-0.\overline{33}}$



$4V = 8\Gamma_L + 8\Gamma_L\Gamma_g = \Gamma_L(8 - 8/3) \Rightarrow \underline{\Gamma_L = 0.75}$

$Z_L = Z_0\frac{1 + \Gamma_L}{1 - \Gamma_L} = 200\frac{1 + 0.75}{1 - 0.75} = \underline{1400\,\Omega}$

one-way transit time = *1.75 μs* characteristic impedance = *200 Ω*

generator reflection coeff. = *$-0.\overline{33}$* load reflection coeff. = *0.75*

phase velocity = *2×10^{8} m/s* load impedance = *1400 Ω*

2) A phasor electric field of $\bar{E} = \hat{a}_y 80 e^{-\gamma x}$ V/m is propagating through a material where $\varepsilon = 4\varepsilon_0$, $\mu = \mu_0$, and $\sigma = 0.005$ S/m. If the TEM wave oscillates at 180 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 pts

$$\gamma = \sqrt{j\omega\mu_0(\sigma + j\omega\varepsilon)} = \sqrt{j2\pi(180\times10^6)4\pi\times10^{-7}(0.005 + j2\pi(180\times10^6)4(8.854\times10^{-12}))}$$

$$= \underline{0.470002 + j7.55967 \ \tfrac{1}{m}}$$

$$\text{loss tangent} = \frac{\sigma}{\omega\varepsilon} = \frac{0.005}{2\pi(180\times10^6)4(8.854\times10^{-12})} = \underline{0.12483}$$

$$u = \omega/\beta = \frac{2\pi(180\times10^6)}{7.55967} = \underline{1.49606\times10^8 \ m/s}$$

$$\lambda = 2\pi/\beta = \frac{2\pi}{7.5597} = \underline{0.83115 m}$$

$$\delta = \frac{1}{\alpha} = \frac{1}{0.47} = \underline{2.12765 m}$$

$$\eta = \sqrt{\frac{j\omega\mu_0}{\sigma + j\omega\varepsilon}} = \sqrt{\frac{j2\pi(180\times10^6)4\pi\times10^{-7}}{0.005 + j2\pi(180\times10^6)4(8.854\times10^{-12})}} = 187.63845\angle 3.5576^\circ \ \Omega$$

$$= \underline{187.2769 + j11.6434 \ \Omega}$$

$$\bar{\mathcal{E}} = \text{Re}\{\bar{E}e^{j\omega t}\} = \text{Re}\{\hat{a}_y 80 e^{-0.47x} e^{-j7.56x} e^{j2\pi(180\times10^6)t}\}$$

$$= \hat{a}_y 80 e^{-0.47x}\cos(3.6\pi\times10^8 t - 7.56x) \ V/m$$

$$\bar{H} = \frac{\hat{a}_k \times \bar{E}}{\eta} = \frac{\hat{a}_x \times \hat{a}_y 80 e^{-\gamma x}}{187.63845\angle 3.56^\circ} = \hat{a}_z 0.42635 e^{-0.47x} e^{-j7.56x} e^{-j3.56^\circ} \ A/m$$

$$\bar{\mathcal{H}} = \text{Re}\{\bar{H}e^{j\omega t}\} = \hat{a}_z 0.42635 e^{-0.47x}\cos(3.6\pi\times10^8 t - 7.56x - 3.56^\circ) \ A/m$$

propagation constant = $0.470 + j7.5597 \ m^{-1}$

loss tangent = 0.12483

wave velocity = 1.49606×10^8 m/s

wavelength = 0.83115 m

intrinsic impedance = $187.277 + j11.643 \ \Omega$

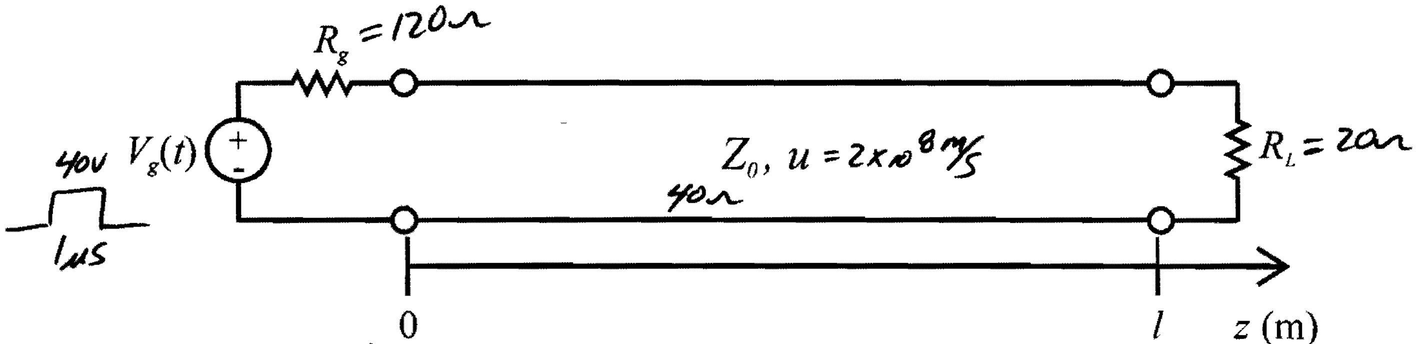
skin depth = 2.12765 m

time-domain electric field = $\hat{a}_y 80 e^{-0.47x}\cos(3.6\pi\times10^8 t - 7.56x)$ V/m

time-domain magnetic field = $\hat{a}_z 0.42635 e^{-0.47x}\cos(3.6\pi\times10^8 t - 7.56x - 3.56^\circ)$ A/m

3) For the lossless transmission line ($Z_0 = 40\ \Omega$ and $u = 2 \times 10^8$ m/s) circuit shown, the generator resistance is $120\ \Omega$, the load resistance is $20\ \Omega$, and $V_g(t) = 40\,[u(t) - u(t - 1\ \mu s)]$ V. If $l = 600$ 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 $0 \le t \le 4T$ and **current** along the transmission line (i.e., $0 \le z \le l$) at $t = 2T$.

20 pts

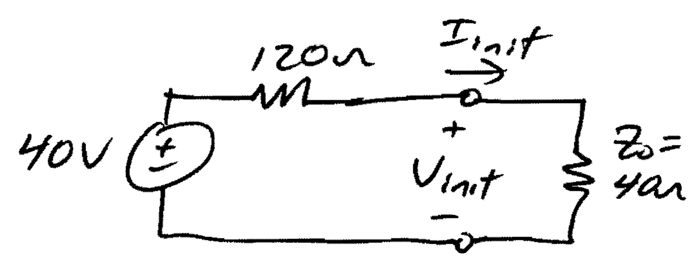


$$T = \frac{l}{u} = \frac{600}{2\times10^8} = 3\,\mu s$$

$$\Gamma_L = \frac{R_L - Z_0}{R_L + Z_0} = \frac{20-40}{20+40} = -\frac{1}{3} = -0.\overline{33}$$

$$\Gamma_g = \frac{R_g - Z_0}{R_g + Z_0} = \frac{120-40}{120+40} = 0.5$$

@ $t = 0^+$



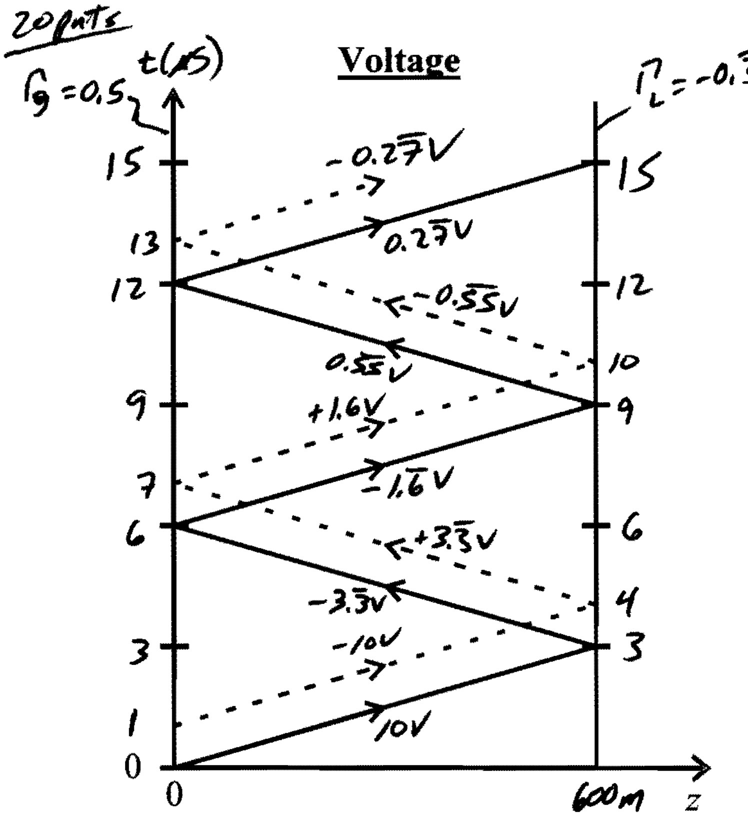
$$I_{init} = \frac{40}{120+40} = 0.25A = 250\,mA$$

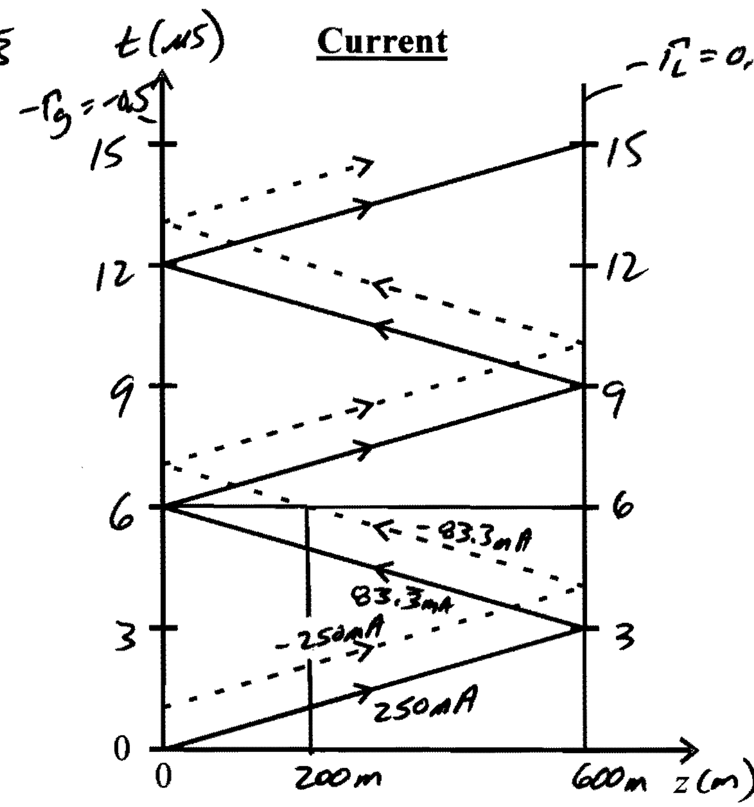
$$V_{init} = I_{init} Z_0 = 0.25(40) = 10V$$

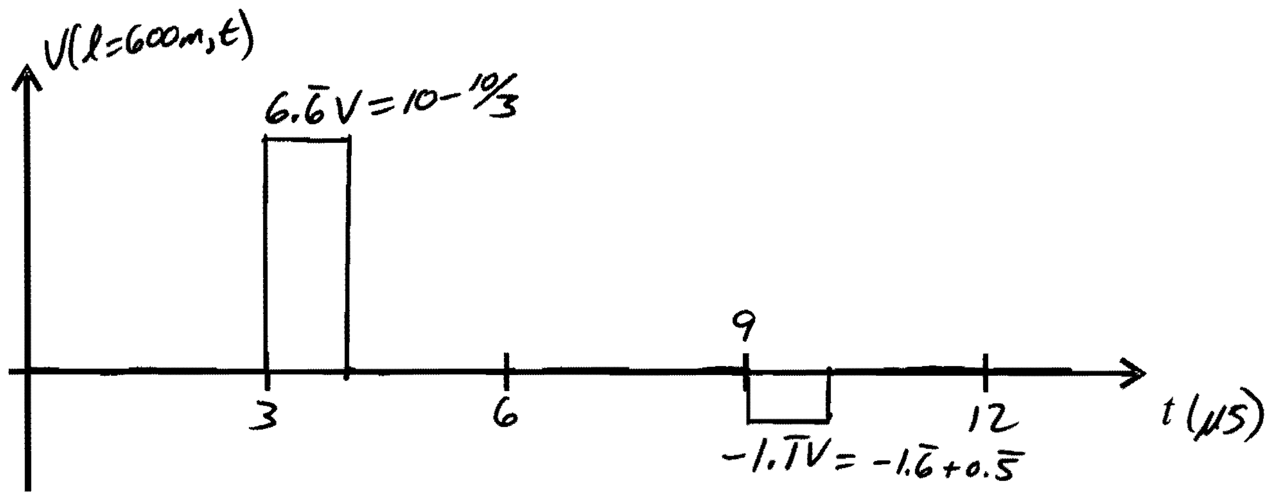
$T =$ 3 µs $\Gamma_L =$ $-0.\overline{33}$ $\Gamma_g =$ 0.5

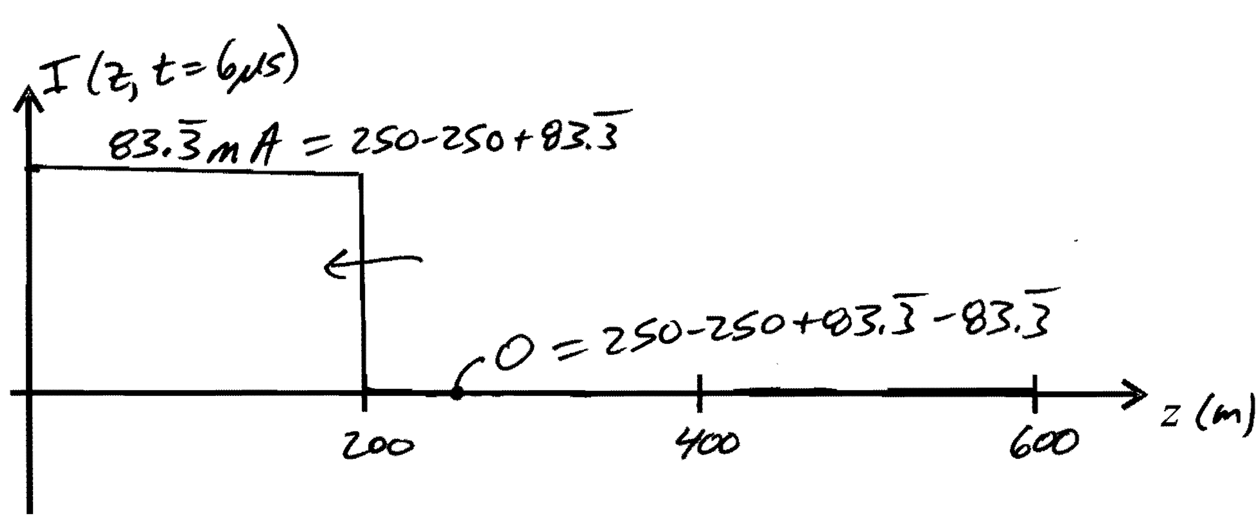
$I_{init} =$ 250 mA $V_{init} =$ 10 V

20 pnts


Voltage
t (μs)
$\Gamma_g = 0.5$
$\Gamma_L = -0.\bar{3}$
10V
-10V
-3.3̄V
+3.3̄V
1.6̄V
+1.6V
0.5̄5̄V
-0.5̄5̄V
0.27̄V
-0.27̄V
600m
z


Current
t (μs)
$-\Gamma_g = -0.5$
$-\Gamma_L = 0.\bar{3}$
250mA
-250mA
83.3̄mA
-83.3mA
200m
600m
z (m)


V(l=600m, t)
6.6̄V = 10 - 10/3
-1.1̄V = -1.6̄ + 0.5̄
t (μs)


I (z, t = 6μs)
83.3̄mA = 250-250+83.3̄
0 = 250-250+83.3̄-83.3̄
z (m)