ECE 3317
Applied Electromagnetic Waves

Exam 1
Nov. 4, 2025

Name _____SOLUTION____

General Information:

The exam is open-book and open-notes. You are not allowed to use any device that has communication functionality (laptop, cell phone, ipad, etc.).

Remember, you are bound by the UH Academic Honesty Policy during the exam!

Instructions:

- Show all of your work. No credit will be given if the work required to obtain the solutions is not shown.
- Write neatly. You will not be given credit for work that is not easily legible.
- Leave answers in terms of the parameters given in the problem.
- Show units in all of your final answers.
- Circle your final answers.
- Double-check your answers. For simpler problems, partial credit may not be given.
- If you have any questions, ask the instructor. You will not be given credit for work that is based on a wrong assumption.
- Make sure you sign the academic honesty statement below.

Academic Honesty Statement

By taking this exam, you agree to abide by the UH Academic Honesty Policy during this exam. You understand and agree that the punishment for violating this policy will be most severe, including getting an F in the class and getting expelled from the University.

Signature: ____

Problem 1 (35 pts)

An electric field in free space has the following form in the phasor domain:

$$\underline{E}(x,z) = \underline{\hat{y}}\, E_0 e^{-\alpha_z z} e^{-jk_x x} \quad [\text{V/m}],$$

where α_z and k_x are real numbers and $E_0 = |E_0| e^{j\phi_0}$ is a complex amplitude coefficient.

a) Find the electric field vector in the time domain.

b) Find the magnetic field vector in the phasor domain.

c) Find the complex Poynting vector.

d) Find the complex power flowing (in the positive z direction) through a one square meter area of the $z = 0$ plane.

e) Find the time-average power and the vars flowing (in the positive z direction) through a one square meter area of the $z = 0$ plane.

Solution

Part (a)

$$\underline{\mathscr{E}}(x,z,t)=\underline{\hat{y}}|E_0|e^{-\alpha_z z}\cos(\omega t-k_x x+\phi_0)\quad [\text{V/m}]$$

Part (b)

Use

$$\nabla\times\underline{E}=-j\omega\mu_0\underline{H}$$

so

$$\underline{H}=-\frac{1}{j\omega\mu_0}\left(\underline{\hat{x}}\left(\frac{\partial E_z}{\partial y}-\frac{\partial E_y}{\partial z}\right)-\underline{\hat{y}}\left(\frac{\partial E_z}{\partial x}-\frac{\partial E_x}{\partial z}\right)+\underline{\hat{z}}\left(\frac{\partial E_y}{\partial x}-\frac{\partial E_x}{\partial y}\right)\right)$$

so that

$$\underline{H}=-\frac{1}{j\omega\mu_0}\left(\underline{\hat{x}}\left(-\frac{\partial E_y}{\partial z}\right)+\underline{\hat{z}}\left(\frac{\partial E_y}{\partial x}\right)\right).$$

This gives us

$$\underline{H}=-\frac{E_0}{j\omega\mu}\left(\underline{\hat{x}}(\alpha_z)+\underline{\hat{z}}(-jk_x)\right)e^{-\alpha_z z}e^{-jk_x x}\quad [\text{A/m}].$$

Part (c)

Use

$$\underline{S}=\frac{1}{2}\underline{E}\times\underline{H}^*.$$

This gives us

$$\underline{S}=\frac{1}{2}\left(\underline{\hat{y}}\,E_0e^{-\alpha_z z}e^{-jk_x x}\right)\times\left(-\frac{E_0}{j\omega\mu_0}\left(\underline{\hat{x}}(\alpha_z)+\underline{\hat{z}}(-jk_x)\right)e^{-\alpha_z z}e^{-jk_x x}\right)^*$$

or

$$\underline{S} = \frac{1}{2}\left(\underline{\hat{y}}\,E_0\right)\times\left(-j\frac{E_0^*}{\omega\mu_0}\left(\underline{\hat{x}}\left(\alpha_z\right)+\underline{\hat{z}}\left(jk_x\right)\right)\right)e^{-2\alpha_z z}$$

or

$$\underline{S} = \frac{\left|E_0\right|^2}{2\omega\mu_0}\underline{\hat{y}}\times\left(-j\left(\underline{\hat{x}}\left(\alpha_z\right)+\underline{\hat{z}}\left(jk_x\right)\right)\right)e^{-2\alpha_z z}$$

or

$$\underline{S} = \frac{\left|E_0\right|^2}{2\omega\mu_0}\left(j\left(\underline{\hat{z}}\left(\alpha_z\right)+\underline{\hat{x}}\left(k_x\right)\right)\right)e^{-2\alpha_z z}.$$

Part (d)

Use

$$P_z = \int_S \underline{S}\cdot\underline{\hat{z}}\;dS = \int_S\left(\frac{\left|E_0\right|^2}{2\omega\mu_0}\left(j\left(\underline{\hat{z}}\left(\alpha_z\right)+\underline{\hat{x}}\left(k_x\right)\right)\right)e^{-2\alpha_z z}\right)\cdot\underline{\hat{z}}\;dS = \int_S\left(\frac{\left|E_0\right|^2}{2\omega\mu_0}\left(j\alpha_z\right)e^{-2\alpha_z z}\right)dS\,.$$

This gives us

$$P_z = \frac{\left|E_0\right|^2}{2\omega\mu_0}\left(j\alpha_z\right)\;\left[\text{VA}\right].$$

Part (e)

$$\operatorname{Re}P_z = 0\;\left[\text{watts}\right]$$

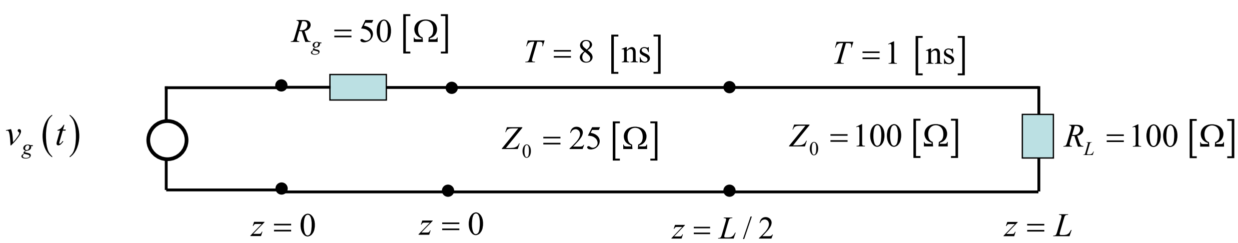
$$\operatorname{Im}P_z = \frac{\left|E_0\right|^2}{2\omega\mu_0}\left(\alpha_z\right)\;\left[\text{vars}\right].$$

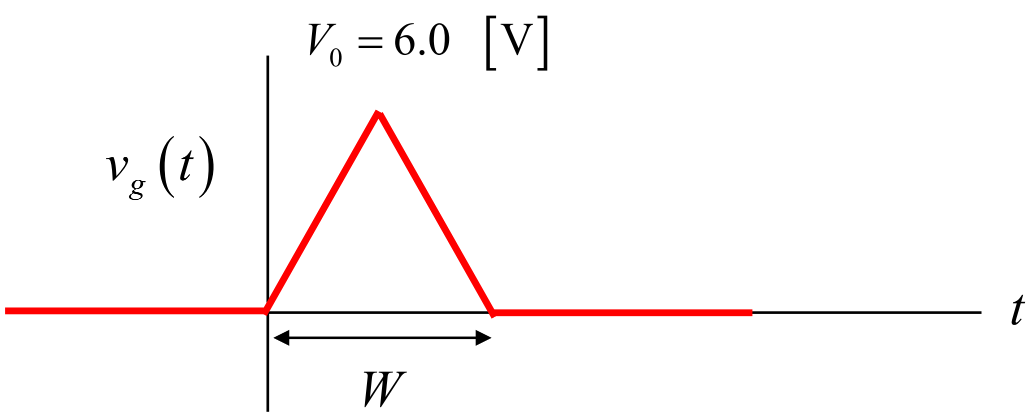
Problem 2 (30 pts)

A voltage source is applied at the left end of a two-section transmission line as shown below. A plot of the triangular-shaped generator voltage $v_g(t)$ is shown below. The pulse peak is $V_0 = 6.0$ [V] and the width of the pulse is $W = 2.0$ [ns].

Plot the voltage $v(t)$ measured by an oscilloscope that is connected to the left line at $z = L/4$ [m] (halfway down the first line). Plot to a time of 24 [ns].

Use the graph on the next page to make your plot. Label all important values of voltage and time on your plot, so that the voltage amplitude and the start and end times of the waveforms can be clearly seen.





ROOM FOR WORK

(Please make your voltage plot on the next page.)

Use

$$v^+(z,t) = Av_g\left(t - z/c_d\right) + \Gamma_J^+ Av_g\left(t - L/c_d - (L-z)/c_d\right) + \Gamma_g \Gamma_J^+ Av_g\left(t - 2L/c_d - z/c_d\right) + \dots .$$

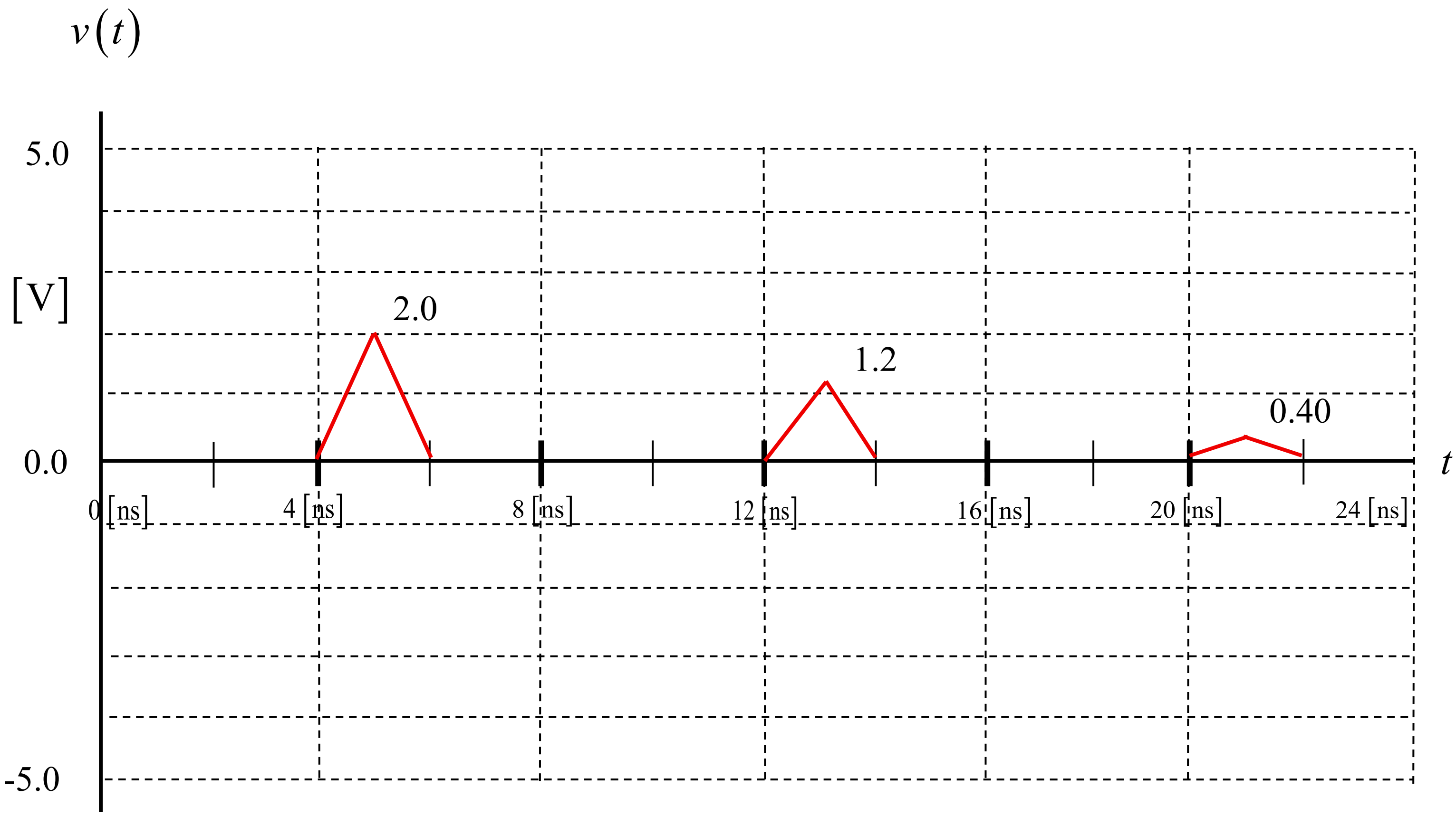
This gives us

$$v^+(z,t) = \frac{1}{3}v_g\left(t - 4.0\ [\text{ns}]\right) + \left(\frac{3}{5}\right)\frac{1}{3}v_g\left(t - 12.0\ [\text{ns}]\right) + \left(\frac{1}{3}\right)\left(\frac{3}{5}\right)\frac{1}{3}v_g\left(t - 20.0\ [\text{ns}]\right) + \dots .$$

or

$$v^+(z,t) = \frac{1}{3}v_g\left(t - 4.0\ [\text{ns}]\right) + \left(\frac{1}{5}\right)v_g\left(t - 12.0\ [\text{ns}]\right) + \frac{1}{15}v_g\left(t - 20.0\ [\text{ns}]\right) + \dots .$$

Make your voltage plot here:



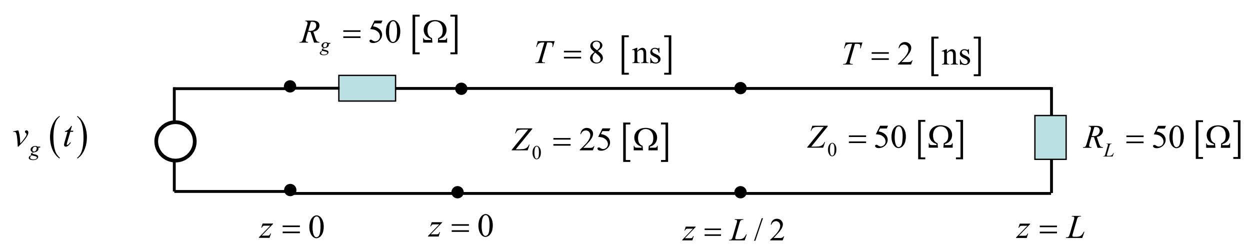
Problem 3 (35 pts)

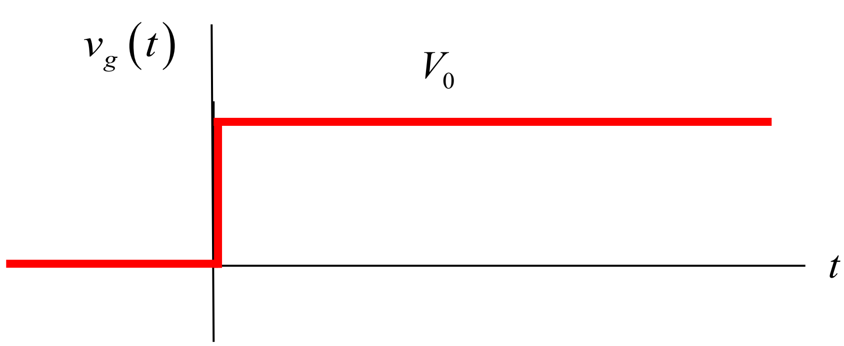
A voltage source is applied at the left end of a two-section transmission line as shown below. (Note that this is the same two-section line as in Prob. 2, except that the transit time T for the second line is different, so you can take advantage of anything that you calculated in Prob. 2 if you wish.) A plot of the generator voltage $v_g(t)$ is shown below. The amplitude of the step function from the generator is $V_0 = 9.0\,[\mathrm{V}]$.

a) Make a bounce diagram for this problem. Plot up to 24 [ns].

b) Plot a snapshot of the voltage on the system at 12.0 [nS]. Label the direction that each wavefront is moving on your plot.

Use the next pages to make your bounce diagram and snapshot plot. Label all important values of voltage and distance on your snapshot plot, so that the voltage amplitude and places where the waveform suddenly changes can be clearly identified.





ROOM FOR WORK

(Please make your bounce diagram and voltage plot on the next pages.)

We have:

$$A = \frac{1}{3}$$

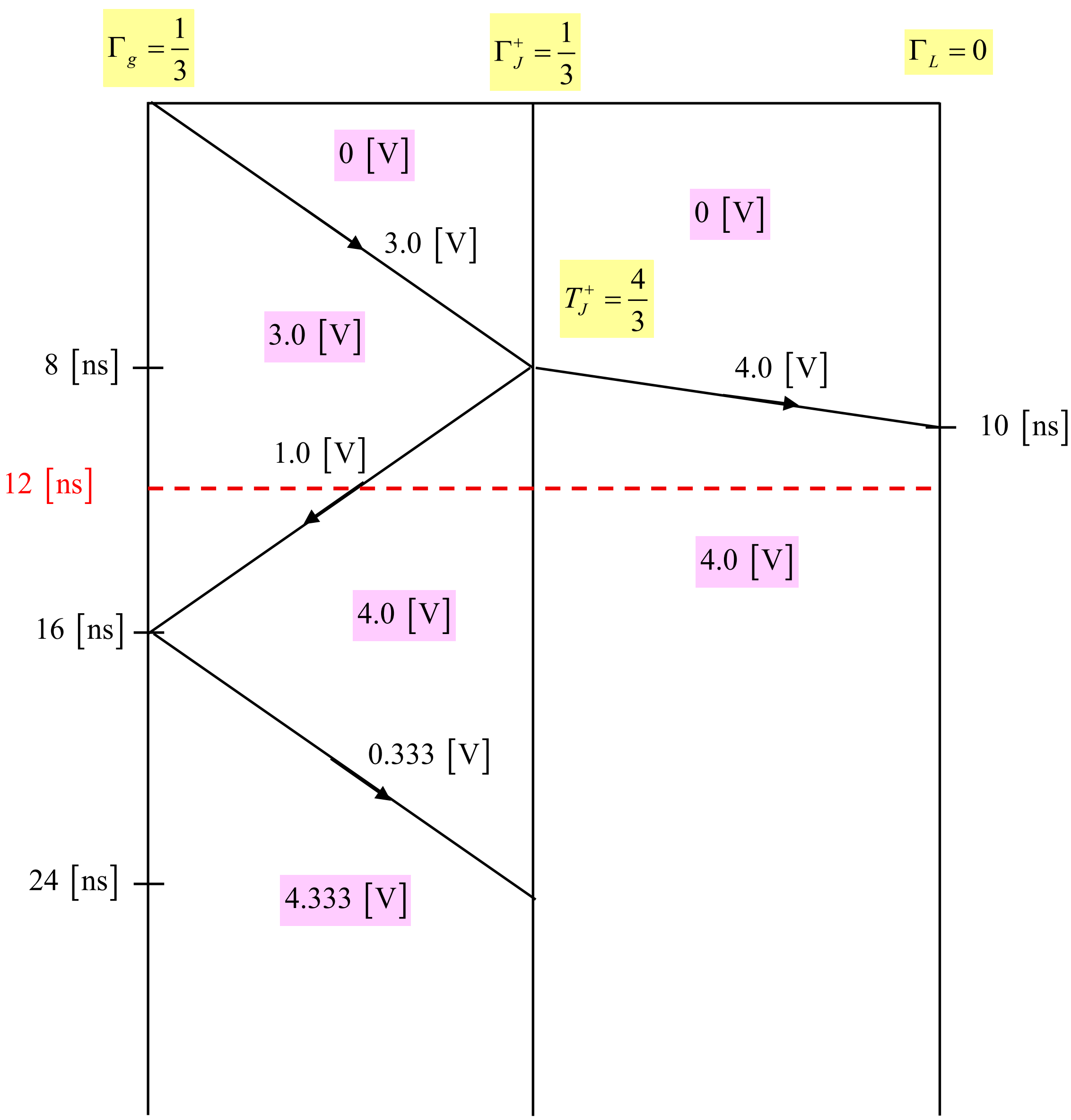
$$\Gamma_J^+ = \frac{1}{3}$$

$$\Gamma_g = \frac{1}{3}$$

$$T_J^+ = 1 + \Gamma_J^+ = \frac{4}{3}.$$

$$\Gamma_L = 0$$

Make your bounce diagram here (part (a)):



Make your voltage plot here:

Part (b)