ECE 3317

Applied Electromagnetic Waves

Exam 1

Oct. 19, 2021

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 (30 pts)

An electromagnetic surface wave propagates on a grounded dielectric slab as shown below. (The structure is infinite in the y direction.) In the air region above the slab ($z > 0$), the electric field in the phasor domain has the following form:

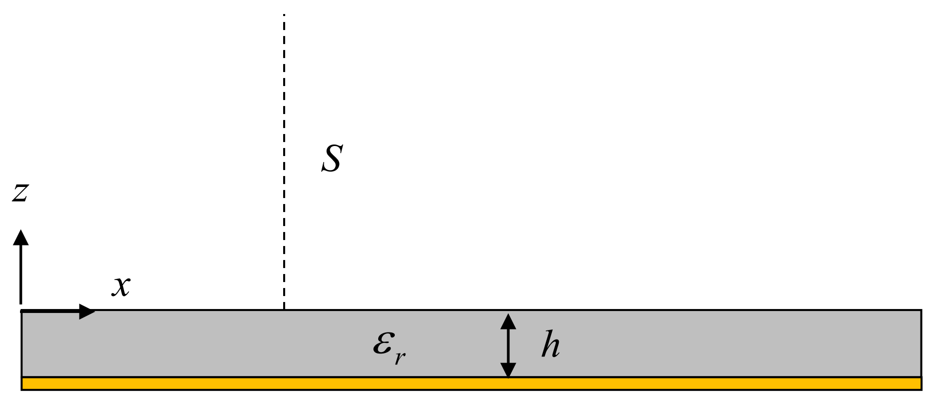
$$\underline{E}(x,z) = \underline{\hat{y}}\, e^{-jk_x x}\, e^{-\alpha_z z} \quad [\text{V/m}],$$

where k_x and α_z are both positive real numbers. Note that there is no y variation of the fields of this surface wave.

a) Find the magnetic field vector $\underline{H}$ in the air region, in the phasor domain.

b) Find the complex Poynting vector in the air region.

c) Find the time average power in watts going (from left to right) through a surface S, which extends from the top of the slab ($z = 0$) to infinity in the vertical z direction, and is one meter wide in the y direction.



SOLUTION

Part (a)

$$\underline{H} = -\frac{1}{j\omega\mu_0}\nabla\times\underline{E}$$

so

$$\underline{H} = -\frac{1}{j\omega\mu_0}\left[\underline{\hat{x}}\left(\alpha_z\right)+\underline{\hat{z}}\left(-jk_x\right)\right]e^{-jk_x x}\, e^{-\alpha_z z} \quad \left[\text{A/m}\right]$$

Part (b)

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

$$\underline{S} = -\frac{1}{2\omega\mu_0}e^{-2\alpha_z z}\left[\underline{\hat{x}}\left(k_x\right)+j\underline{\hat{z}}\left(\alpha_z\right)\right] \quad \left[\text{VA/m}^2\right]$$

Part (c)

$$P = \int_0^\infty \text{Re}\,\underline{S}\cdot\underline{\hat{x}}\,dz$$

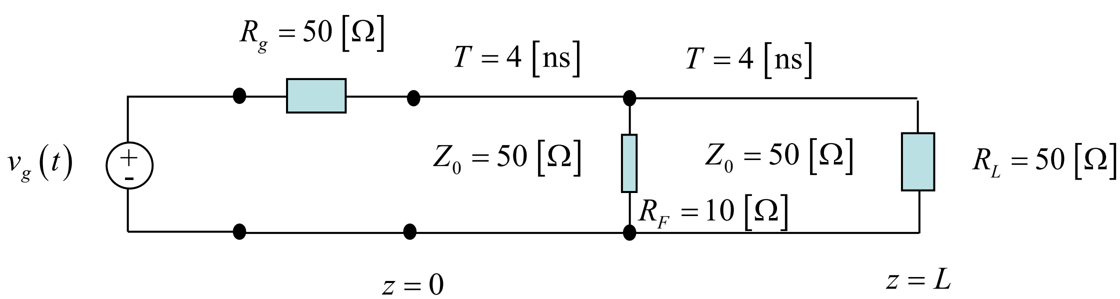
$$P = \frac{k_x}{4\omega\mu_0\alpha_z} \quad \left[\text{W}\right]$$

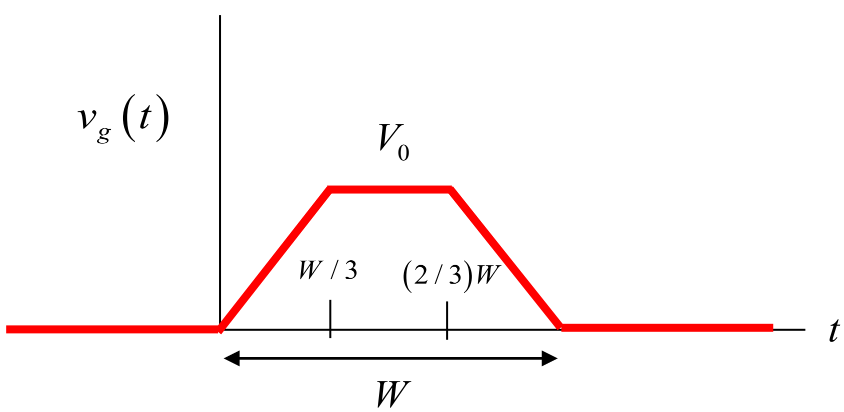
Problem 2 (35 pts)

A voltage source is applied at the left end of a transmission line as shown below. The transmission line meets a second transmission line, which is then terminated by a load. At the junction between the two transmission lines a fault occurs, which is modeled by a parallel (shunt) resistor R_F.

A plot of the generator voltage $v_g(t)$ is shown below. The pulse peak is $V_0 = 8$ [V] and the width of the pulse is $W = 3$ [ns].

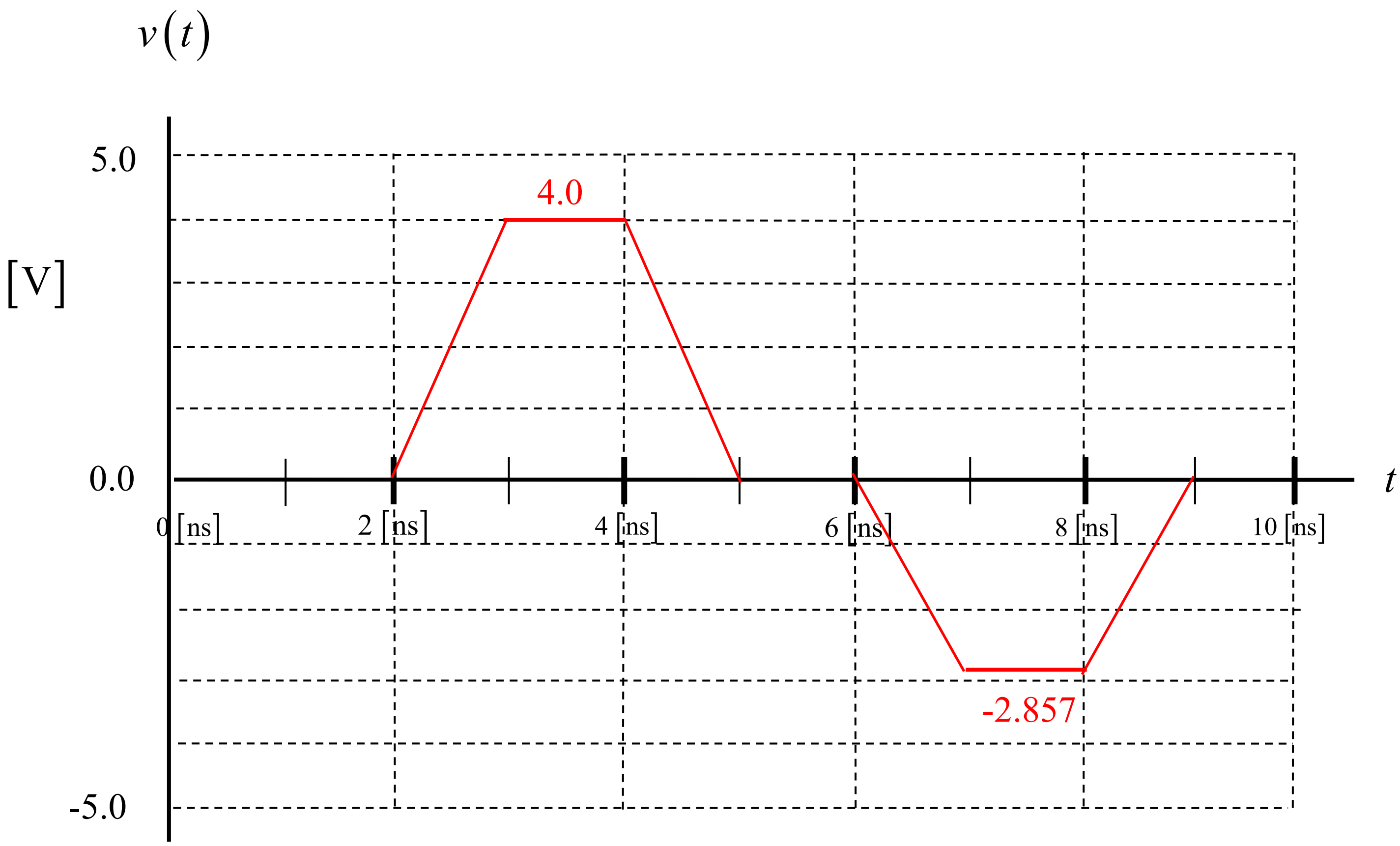
Plot the voltage $v(t)$ measured by an oscilloscope that is connected to the first (left) line at a point halfway down the first line (halfway between the generator and the fault). Plot to a time of 10 [ns]. Use the graph on the next page to make your plot. Label all voltage values on your plot.





Make your plot here:

The plot is shown below. The calculation is done on the next page.



SOLUTION

The load seen by the first transmission line is 50 [Ω] in parallel with 10 [Ω], or 8.3333 [Ω]. The load reflection coefficient is then

$$\Gamma_J^{+} = -0.71429 \, .$$

We also have

$$\Gamma_g = 0$$

and

$$A = \frac{1}{2} \, .$$

We then use

$$\begin{aligned} v(z,t) = {} & 0.5 v_g\left(t - z / c_d\right) \\ & + \Gamma_J^{+} A v_g\left(t - L / c_d - (L - z)/ c_d\right) \\ & + \cancel{\Gamma}_g \Gamma_J^{+} A v_g\left(t - 2L / c_d - z / c_d\right) \\ & + \cancel{\Gamma}_g \Gamma_J^{+2} A v_g\left(t - 3L / c_d - (L - z)/ c_d\right) \\ & + \dots \end{aligned}$$

This gives us

$$\begin{aligned} v(z,t) = {} & 0.5 v_g\left(t - 2.0[\text{nS}]\right) \\ & + (-0.71429)(0.5) v_g\left(t - 4.0[\text{nS}] - 2.0[\text{nS}]\right) \end{aligned}$$

or

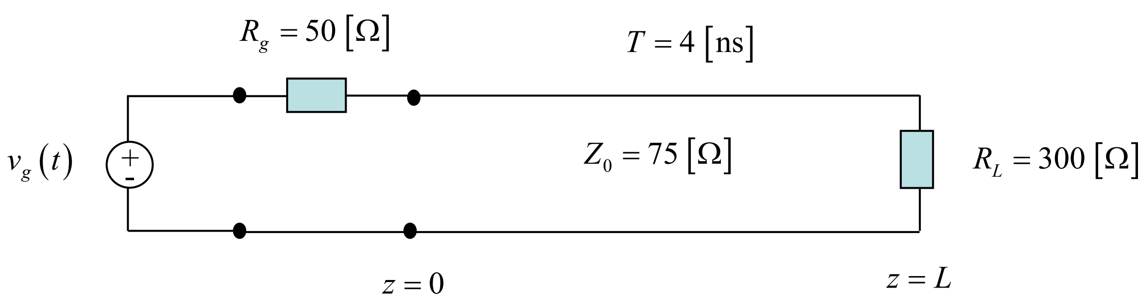
$$v(z,t) = 0.5 v_g\left(t - 2.0[\text{nS}]\right) - 0.35714 v_g\left(t - 6.0[\text{nS}]\right)$$

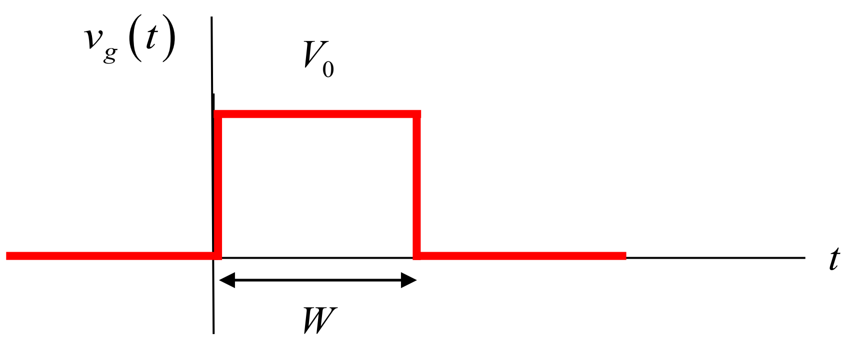
Problem 3 (35 pts)

A voltage source is applied at the left end of a transmission line as shown below. A plot of the generator voltage is shown below. The pulse width is $W = 6\,[\text{ns}]$ and the pulse voltage is $V_0 = 5\,[\text{V}]$.

a) Construct a bounce diagram for this problem that extends to a time of 16 [ns]. (Make your bounce diagram on the next page.)

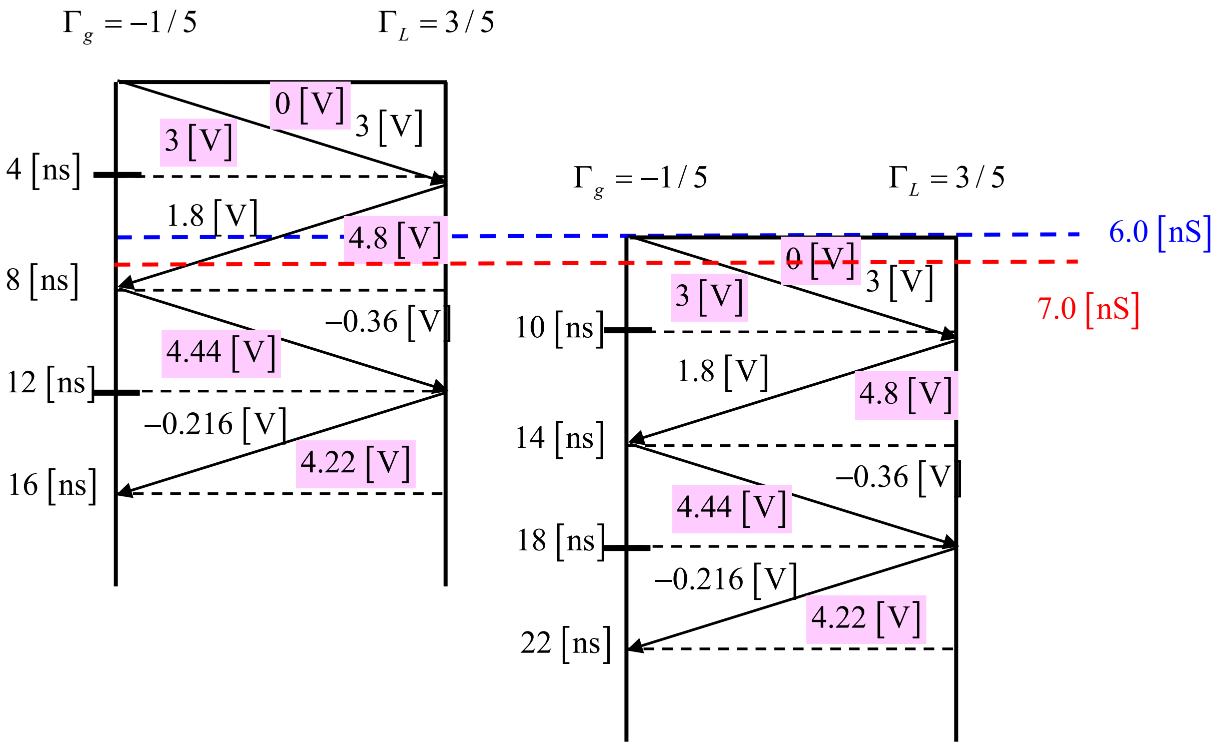
b) Make an accurate "snapshot" plot of the voltage $v(z)$ on the line at $t = 7.0\,[\text{ns}]$. Make your plot on the graph that is given below on the next page. Label all voltage values on your plot.





SOLUTION

The original bounce diagram and the shifted one are shown below.



The snapshot due to the original bounce diagram (black solid line) and the shifted bounce diagram (black dashed line) are shown below. The final plot (coming from the black solid plot minus the black dashed plot) is shown in red.