Learning Objective 3.7: I can plot the transient response of a load connected to a source through a transmission line.

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate). All lines are lossless, and every source switches on at $t = 0$.

1. **Turn-on.** A 12 V step source with internal resistance $\mathrm{Z_s} = 75\ \Omega$ drives a 300 m line with $\mathrm{Z_0} = 50\ \Omega$ and $v_p = 2 \times 10^8$ m/s. The line ends in $\mathrm{Z_L} = 25\ \Omega$.

   (a) Find the one-way delay T.

   T =

   (b) Find the voltage V_1^+ launched onto the line at turn-on, and explain why the load does not affect it.

   V_1^+ =

   (c) Find Γ_L and Γ_s.

   Γ_L =

   Γ_s =

   (d) Find the final, steady-state voltage at the load.

   $V_L(\infty)$ =

2. **The bounce diagram.** Continue with the line in Question 1.

   (a) Draw the bounce diagram through $t = 5T$, labeling each wave with its amplitude.

   (b) Find the load voltage on each interval: $T < t < 3T$, $3T < t < 5T$, and $5T < t < 7T$.

   $V_L(2T)$ = [ ]

   $V_L(4T)$ = [ ]

   $V_L(6T)$ = [ ]

   (c) Find the voltage at the source end of the line on $0 < t < 2T$ and $2T < t < 4T$.

   $V(T)$ = [ ]

   $V(3T)$ = [ ]

3. **The steady state.** The load voltage after many round trips is

$$V_L(\infty) = V_1^+ (1 + \Gamma_L) \sum_{n=0}^{\infty} (\Gamma_L \Gamma_s)^n$$

(a) Explain why the series converges for any pair of passive resistive terminations other than both ends being shorts or opens.

(b) Sum the series and show that $V_L(\infty) = V_s \dfrac{Z_L}{Z_L + Z_s}$.

(c) Check the result numerically with the values from Question 1.

$V_L(\infty)$ =

4. **A pulse.** The worked example from the lesson ($V_s = 10$ V, $\mathrm{Z_s} = 25\ \Omega$, $\mathrm{Z_0} = 50\ \Omega$, $\mathrm{Z_L} = 150\ \Omega$, $T = 2\ \mu$s) is driven by a 10 V pulse that lasts from $t = 0$ to $t = T$ instead of a step.

   (a) Write the pulse as the sum of two steps, and explain why the load voltage is the step response minus a delayed copy of itself.

   (b) The step response at the load is 0, then 10.00, 8.33, and 8.61 V on successive intervals of $2T$ starting at T. Find the pulse response at the load on $T < t < 2T$, $2T < t < 3T$, and $3T < t < 4T$.

   $V_L(1.5T)$ = ____

   $V_L(2.5T)$ = ____

   $V_L(3.5T)$ = ____

   (c) The load is a digital receiver. The pulse should produce one clean pulse at the load, but a second, inverted pulse arrives at $3T$. What single change to the circuit would remove it, and why?

Documentation: _____