Learning Objectives 3.2 and 3.3: I can explain the physical meaning of and calculate the following quantities: propagation constant, phase constant, attenuation constant, characteristic impedance, VSWR, reflection coefficient, and transmission coefficient. I can use the transmission line equation to calculate the voltage/current at an arbitrary point on a specified transmission line.

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate). All lines are lossless.

1. **Coaxial line.** For a coaxial line with inner radius a, outer radius b, and a nonmagnetic dielectric of relative permittivity ϵ_r, $Z_0 \approx \dfrac{60}{\sqrt{\epsilon_r}} \ln \dfrac{b}{a}\ \Omega$.

   (a) A cable has $a = 0.29$ mm, $b = 1.85$ mm, and a polyethylene dielectric, $\epsilon_r = 2.25$. Find Z_0.

   $Z_0 =$ ____

   (b) Find the phase velocity in this cable.

   $v_p =$ ____

   (c) Design an air-filled coaxial line, $\epsilon_r = 1$, with $Z_0 = 50\ \Omega$ and an inner conductor of radius $a = 1$ mm. Find the radius b of the outer conductor.

   $b =$ ____

   (d) We fill the line in part (c) with polyethylene, $\epsilon_r = 2.25$, without changing a or b. Find the new Z_0, and explain in one sentence why it went down.

   $Z_0 =$ ____

2. **Reflection coefficient.** Each load below terminates a $50\ \Omega$ line.

   (a) $Z_L = 25\ \Omega$. Find Γ and the VSWR.

   Γ = ____

   VSWR = ____

   (b) $Z_L = 30 - j40\ \Omega$. Find Γ in polar form and the VSWR.

   Γ = ____

   VSWR = ____

   (c) What fraction of the incident power does the load in part (b) reflect, and what fraction does it absorb?

   reflected = ____

   absorbed = ____

   (d) A load consists of a capacitor alone. Without computing, state $|\Gamma|$ and the VSWR, and explain why.

3. **Reading a standing wave.** A probe slid along a $50\ \Omega$ RG-58 line at 300 MHz measures a largest voltage of 12 V and a VSWR of 3.

   (a) Find $|\Gamma|$.

   $|\Gamma|$ =

   (b) Find the smallest voltage on the line and the amplitude of the incident wave, $|V_0^+|$.

   V_{min} =

   $|V_0^+|$ =

   (c) Find the distance between adjacent voltage minima. Signals travel along RG-58 at 2×10^8 m/s.

   spacing =

   (d) One voltage minimum falls exactly at the load, and the load is a pure resistance. Is Z_L larger or smaller than Z_0? Find Z_L.

   Z_L =

4. **A complex load.** A load $Z_L = 100 + j100\,\Omega$ terminates a $50\,\Omega$ line.

   (a) Find Γ in rectangular and polar form.

   $\Gamma =$

   (b) Find the VSWR.

   VSWR =

   (c) Find the distance from the load to the first voltage maximum, in wavelengths.

   $d_{max} =$

   (d) Find the transmission coefficient τ in polar form.

   $\tau =$

5. **Is it worth matching?** A handheld radio feeds a $75\ \Omega$ antenna through $50\ \Omega$ coaxial cable.

   (a) Find Γ, the VSWR, and the fraction of the incident power the antenna absorbs.

   Γ = ____

   VSWR = ____

   absorbed = ____

   (b) A matching network would raise the absorbed power to 100%, but it adds parts, cost, and a little loss of its own. Using the VSWR rule of thumb from the lesson, would you add one? Justify your answer in one or two sentences.

Documentation: _____