Learning Objective 3.2: 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.

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

1. **Characteristic impedance.** A lossless line has $L' = 300$ nH/m and $C' = 120$ pF/m.

   (a) Starting from $-d\widetilde{V}/dz = (R' + j\omega L')\widetilde{I}$ and $\widetilde{V}(z) = V_0^+ e^{-\gamma z} + V_0^- e^{+\gamma z}$, derive $Z_0 = \sqrt{\dfrac{R' + j\omega L'}{G' + j\omega C'}}$.

   (b) Find Z_0 and v_p for this line.

   Z_0 =

   v_p =

   (c) The voltage on the line has $V_0^+ = 10$ V and $V_0^- = 2$ V. Find I_0^+ and I_0^-.

   I_0^+ =

   I_0^- =

   (d) A classmate measures a 1 m length of this line with an ohmmeter and expects to read $50\,\Omega$. Explain what Z_0 is, and why the ohmmeter does not read it.

2. **Phase velocity and wavelength.** A 120 MHz signal on a lossless coaxial line has a phase constant $\beta = 4$ rad/m.

   (a) Starting from the phase of the incident wave, derive $v_p = \omega/\beta$.

   (b) Find v_p and the wavelength.

   v_p =

   λ =

   (c) For a coaxial line, $v_p = c/\sqrt{\epsilon_r}$. Find the relative permittivity of the dielectric.

   ϵ_r =

3. **Low-loss attenuation.** A $50\,\Omega$ cable at 200 MHz has $R' = 2\,\Omega/\text{m}$, $L' = 250$ nH/m, $G' = 1 \times 10^{-5}$ S/m, and $C' = 100$ pF/m.

   (a) Check that the low-loss approximation applies.

   (b) Find α in Np/m and in dB/m.

   α =

   α =

   (c) A 25 m run of this cable feeds an antenna. Find the loss in dB and the fraction of the input power that reaches the antenna.

   loss =

   fraction =

   (d) We use the same cable at 800 MHz. Conductor loss scales as the square root of frequency, and dielectric loss in proportion to it. Estimate the new α in dB/m, and state which mechanism dominates.

Documentation: _____