A Victorian brass and beeswax coaxial transmission line operates at 2.5 GHz has the distributed parameters $R = 4\ \Omega/\text{m}$, $L = 264$ nH/m, $G = 4.1$ mS/m, and $C = 105$ pF/m. Calculate the a) propagation constant, b) attenuation constant (both Np/m and dB/m), c) phase constant, d) characteristic impedance (both polar & rectangular forms), e) wavelength, and f) phase velocity (m/s and fraction of c).

a) (2.5) $\gamma = \sqrt{(R+j\omega L)(G+j\omega C)} = \alpha + j\beta$

$$= \sqrt{(4+j2\pi(2.5\times10^{9})264\times10^{-9})(4.1\times10^{-3}+j2\pi 2.5\times10^{9}\,105\times10^{-12})}$$

$$\underline{\underline{\gamma = 0.1427 + j82.7021\ \tfrac{1}{m}}}$$

b) $\underline{\underline{\alpha = 0.1427\ \tfrac{Np}{m}}}$ or $\alpha = 0.1427(20\log e) = \underline{\underline{1.239\ \tfrac{dB}{m}}}$

c) $\underline{\underline{\beta = \mathrm{Im}(\gamma) = 82.7021\ \tfrac{rad}{m}}}$

d) (2.7) $Z_0 = \sqrt{\dfrac{R+j\omega L}{G+j\omega C}} = \sqrt{\dfrac{4+j2\pi(2.5\times10^{9})(264\times10^{-9})}{4.1\times10^{-3}+j2\pi(2.5\times10^{9})105\times10^{-12}}}$

$$\underline{\underline{Z_0 = 50.1426 + j0.0381\ \Omega = 50.1426\angle 0.0436^\circ\ \Omega}}$$

e) (2.10) $\lambda = \dfrac{2\pi}{\beta} = \dfrac{2\pi}{82.702} \Rightarrow \lambda = 0.075974\ m$

$$\underline{\underline{\lambda = 7.597\ cm}}$$

f) (2.11) $v_p = \dfrac{\omega}{\beta} = f\lambda = 2.5\times10^{9}(7.5974\times10^{-2})$

$$\underline{\underline{v_p = 1.89934\times10^{8}\ \tfrac{m}{s}}}$$

$$\frac{v_p}{c}\times100\% = \frac{1.89934\times10^{8}}{2.9979\times10^{8}}\times100\% = \underline{\underline{63.355\%}}$$

OR $\underline{\underline{v_p = 0.634c}}$