11.23 A coaxial line 5.6 m long has distributed parameters $R = 6.5\ \Omega/\text{m}$, $L = 3.4\ \mu\text{H/m}$, $G = 8.4\ \text{mS/m}$, and $C = 21.5\ \text{pF/m}$. If the line operates at 2 MHz, calculate the characteristic impedance and the end-to-end propagation time delay.

Per (11.19), $Z_0 = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}} = \sqrt{\dfrac{6.5 + j(2\pi\, 2{\bullet}10^6)3.4{\bullet}10^{-6}}{0.0084 + j(2\pi\, 2{\bullet}10^6)21.5{\bullet}10^{-12}}}$

$\Rightarrow$ **$Z_0 = 55.1303 + j\ 45.8575\ \Omega$**

Per (11.11), the propagation constant is

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \alpha + j\beta$$
$$= \sqrt{[6.5 + j(2\pi 2{\bullet}10^6)3.4{\bullet}10^{-6}][0.0084 + j(2\pi 2{\bullet}10^6)21.5{\bullet}10^{-12}]}$$

$\Rightarrow$ **$\gamma = 0.4507 + j\ 0.4001$ 1/m**

Per (11.14), the phase velocity is $u = \omega/\beta = 2\pi(2*10^6)/0.4001$ $\Rightarrow$ **$u = 3.14083*10^7$ m/s**

From physics, $d = u\,t$. Therefore, the time delay is

$t_d = l/u = 5.6/3.14083*10^7$ $\Rightarrow$ **$t_d = 1.78297*10^{-7}$ s = 178.3 ns**