A 3 GHz plane wave propagates through nylon (610) in the -*z*-direction. a) Find the phase velocity, wavelength, attenuation constant, phase constant, and intrinsic impedance. b) If the electric field has an amplitude of 9 V/m at $z = 0$ and is oriented in the *x*-direction, write the equation for the phasor vector electric field. c) Find the corresponding phasor vector magnetic field. d) Is nylon (610) a good conductor? Why or why not? Regardless, find the skin depth in nylon (610) at 3 GHz.

From App. G & earlier problem, $\varepsilon_r = 2.84$ & $\tan\delta = 0.012$ for nylon (610) at 3 GHz. So, $\varepsilon' = 2.84\,\varepsilon_0 = 2.5146\times10^{-11}$ F/m, $\varepsilon'' = \varepsilon' \tan\delta = 3.0175\times10^{-13}$ F/m, & $\sigma = \varepsilon''\omega = 5.6879\times10^{-3}$ S/m.

a) Use equations from Table 1.1 for general lossy medium

propagation constant $$\gamma = j\omega\sqrt{\mu\varepsilon'}\sqrt{1 - j\frac{\sigma}{\omega\varepsilon'}} = j\omega\sqrt{\mu\varepsilon'}\sqrt{1 - j\tan\delta}$$

$$= j2\pi 3\bullet10^{9}\sqrt{4\pi\bullet10^{-7}(2.5146\bullet10^{-11})'}\sqrt{1 - j0.012}$$

$$\Rightarrow \gamma = 0.635745 + j105.96133 \text{ 1/m} = \alpha + j\beta$$

Phase velocity $v_p = \omega / \beta = 2\pi(3\bullet10^9)/105.96133$ $\Rightarrow$ **$v_p = 1.77891 \times 10^8$ m/s**

Wavelength $\lambda = 2\pi/\beta = 2\pi/105.96133$ $\Rightarrow$ **$\lambda = 0.059297$ m**

attenuation constant $\alpha = \text{Re}(\gamma) = \text{Re}(0.635745 + j105.96133)$ $\Rightarrow$ **$\alpha = 0.635745$ Np/m**

phase constant $\beta = \text{Im}(\gamma) = \text{Im}(0.635745 + j105.96133)$ $\Rightarrow$ **$\beta = 105.96133$ rad/m**

intrinsic impedance $\eta = \dfrac{j\omega\mu}{\gamma} = \dfrac{j(2\pi\, 3\bullet10^9)4\pi\bullet10^{-7}}{0.635745 + j105.96133}$ $\Rightarrow$ **$\eta = 223.5362 + j1.3412\ \Omega$**

b) Per (1.54), $E_x(z) = E^+ e^{-\gamma z} + E^- e^{\gamma z}$. For a wave that propagates in the -*z*-direction, we drop the first term. Given that $E_x(z=0) = 9 \text{ V/m} = E^- e^0$, we get $E^- = 9$ V/m. Adding the unit vector and γ yields-

$$\Rightarrow \bar{E} = \hat{x}\, 9\, e^{0.6357z}\, e^{j105.9613z} \text{ (V/m)}$$

c) Using (1.58) for a wave that propagates in the -*z*-direction and adding the unit vector,

$$\bar{H} = -\hat{y}\frac{1}{\eta}E^- e^{\gamma z} = -\hat{y}\frac{1}{223.5362 + j1.3412} 9\, e^{0.6357z}\, e^{j105.9613z}$$

$$\Rightarrow \bar{H} = -\hat{y}\,(0.0402605 - j0.00024155)\, e^{0.6357z}\, e^{j105.9613z} \text{ (A/m)}$$
$$= -\hat{y}\,(0.00261\angle -0.34376^\circ)\, e^{0.6357z}\, e^{j105.9613z} \text{ (A/m)}$$

d) Check if $\sigma >> \varepsilon\omega$, i.e., $\tan\delta >> 1$? Since $\tan\delta = 0.012$,

$\Rightarrow$ **Nylon (610) is NOT a good conductor.**

Per (1.60), the skin depth is $\delta_s = 1/\alpha = 1/0.635745$ $\Rightarrow$ **$\delta_s = 1.57296$ m**