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4. $a = 10{,}1\ cm = 10{,}1 \times 10^{-2}\ m$

$b = 5{,}1\ cm = 5{,}1 \times 10^{-2}\ m$

$TM_{11} \rightarrow m = 1,\ n = 1$

a. $f_c = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$

$= \frac{c}{2\pi} \sqrt{\left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2}$

$= \frac{3 \times 10^8}{2\pi} \sqrt{\left(\frac{\pi}{10{,}1 \times 10^{-2}}\right)^2 + \left(\frac{\pi}{5{,}1 \times 10^{-2}}\right)^2}$

$= 3{,}29\ GHz$

b. $\beta_{11} = \omega\sqrt{\mu\varepsilon} \sqrt{1 - \left(\frac{f_c}{f}\right)^2}$

$f = 6{,}6\ GHz$

$= 6{,}6 \times 10^9\ Hz$

$= \frac{2\pi f}{c} \sqrt{1 - \left(\frac{f_c}{f}\right)^2}$

$= \frac{2\pi \cdot 6{,}6 \times 10^9}{3 \times 10^8} \sqrt{1 - \left(\frac{3{,}29 \times 10^9}{6{,}6 \times 10^9}\right)^2}$

$= 119{,}71$

c. $\lambda_{11} = \frac{2\pi}{\beta_{11}} = \frac{2\pi}{119{,}71} = 0{,}052\ m$

d. $V_{p_{11}} = \frac{\omega}{\beta_{11}} = \frac{2\pi f}{c} \cdot \frac{1}{119{,}71} = \frac{2\pi \cdot 6{,}6 \times 10^9}{3 \times 10^8} \cdot \frac{1}{119{,}71} = 1{,}15\ m/s$

$$\eta_{11} = \eta_0 \sqrt{1 - \left(\frac{f_c}{f}\right)^2}$$

$$= 120\pi \sqrt{1 - \left(\frac{3{,}29 \times 10^9}{6{,}6 \times 10^9}\right)^2}$$

$$= 120\pi \sqrt{1 - 0{,}5^2} = 326{,}5\ \Omega$$