(1)

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HOMEWORK-4

(1) Parallel-plate air waveguide has a plate seperation of 6mm.

(a) $f_{cm} = \frac{mc}{2a} = \frac{m.3.10^8}{2.6.10^{-3}} = m.25.10^9 = \boxed{25.m\ GHz}$

$f_{c0} = 0$, $f_{c1} = 25\,GHz$, $f_{c2} = 50\,GHz$, $f_{c3} = 75\,GHz$

→ Possible seven lowest order modes are TM_0 (TEM), TM_1, TE_1, TM_2, TE_2, TM_3 and TE_3

→ for this guide: TM_0, TM_1 & TE_1, TM_2 & TE_2, TM_3 & TE_3

(b) 40GHz ⇒ $f_{c0} = 0$ and $f_{c1} = 25GHz$ are the propogation modes at 40GHz.
And those are $\boxed{TM_0}$ (TEM) and $\boxed{TM_1\ \&\ TE_1}$

(c) 60GHz → $f_{c0} = 0$, $f_{c1} = 25GHz$ and $f_{c2} = 50GHz$ are the propagation modes at 60GHz. And those are TM_0, TM_1 & TE_1 and TM_2 & TE_2

(d) $\varepsilon_r = 2{,}25$, $\mu_r = 1$ ⇒ $f_c = \frac{m.c}{2a.\sqrt{\varepsilon_r.\mu_r}} = \frac{m.3.10^8}{2.6.10^{-3}.\sqrt{2{,}25}} \cong 16{,}62.m\ GHz$

$f_{c0} = 0$, $f_{c1} = 16{,}62\,GHz$, $f_{c2} = 33{,}34\,GHz$, $f_{c3} = 50.01\,GHz$ and $f_{c4} = 66.68\,GHz$.

So in 60 GHz, propogating modes are TM_0, TM_1 & TE_1, TM_2 & TE_2 and TM_3 & TE_3

(2) $a = 1\,cm$, $b = 0{,}6\,cm$, $25\,GHz$.

* Dommant mode: $\boxed{m = 1, n = 0}$

$$f_c = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \cancel{\left(\frac{n\pi}{b}\right)^2}} = \frac{c\,m\pi}{2\pi a} = \frac{c}{2a} = \frac{3.10^8}{2.10^{-2}} = 15\,GHz$$

(a)
$$Z = \frac{\eta_0}{\sqrt{1-\left(\frac{f_c}{f_0}\right)^2}} = \frac{120\pi}{\sqrt{1-\left(\frac{15}{25}\right)^2}} = \frac{120\pi}{\sqrt{\frac{16}{25}}} = \frac{120\pi}{0{,}8} = 471{,}23\,\Omega$$

(b)
$$Z_0\sqrt{\frac{\mu}{\varepsilon}} = 471{,}23\sqrt{\frac{1}{2{,}25}} = 314{,}153\,\Omega$$

(3) $f_c = 25\,GHz$, $\quad f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$, $\quad \lambda_c = \frac{c}{f_c} = \frac{3.10^8}{25.10^9} = 0{,}012\,m$

$$\lambda_{operates} = \frac{c}{f_c} = \frac{3.10^8}{40.10^9} \cong 7{,}5.10^{-3}\,m$$

$$\lambda_{guide} = \frac{\lambda_0}{\sqrt{1-\left(\frac{\lambda_0}{\lambda_c}\right)^2}} = \frac{7{,}5.10^{-3}}{\sqrt{1-\left(\frac{7{,}5.10^{-3}}{12.10^{-3}}\right)^2}} \cong 9{,}607.10^{-3} \text{ meters.}$$

$$v_p = \frac{c}{\sqrt{1-\left(\frac{f_c}{f_0}\right)^2}} = \frac{3.10^8}{\sqrt{1-\left(\frac{25.10^9}{40.10^9}\right)^2}} \cong 3{,}84.10^8\,m/sn$$

$$\beta = \frac{w}{v_p} = \frac{2.\pi.40.10^9}{3{,}84.10^8} = 654{,}498$$

$$Z_{TE} = \frac{\eta_0}{\sqrt{1-\left(\frac{25.10^9}{40.10^9}\right)^2}} = \frac{120\pi\,\Omega}{\sqrt{1-\left(\frac{25}{64}\right)}} \cong 488\,\Omega$$

④ Rectangular waveguide

$a = 2{,}4\,cm$
$b = 1{,}2\,cm$ $\rightarrow TE_{10}$

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

$$f_c = \frac{3.10^8}{2}\sqrt{\left(\frac{1}{2{,}4.10^{-2}}\right)^2} = \frac{3.10^9}{4{,}8} = \underline{6{,}25\,GHz} \} f_{cut\text{-}off}$$

$\rightarrow$ operating frequency is $= 6{,}25 \cdot \frac{5}{4} = \underline{7{,}8125\,GHz} \} f_{operating}$

$$h = \sqrt{\underbrace{\left(\frac{m\pi}{a}\right)^2}_{k_x} + \cancel{\underbrace{\left(\frac{n\pi}{b}\right)^2}_{k_y}}} \quad 0 = n$$

$$\Rightarrow \quad h = \frac{\pi.10^2}{2{,}4} \cong 130{,}899$$