

1. A parallel-plate waveguide is filled with a dielectric  $\epsilon = 9\epsilon_0$  and  $\mu = \mu_0$ . The separation between the plates is 2.5 cm. Determine the propagating modes for a wave of frequency 5 GHz. For each propagating mode, fill in the following table. Waves are incident on the plates with an angle  $\theta$  with respect to the normal to the plates.  $v_{pz}$  and  $v_g$  are the phase and group velocities respectively.

Mode	$f_c$ (GHz)	$\theta$ (deg)	$v_{pz}$ (m/s)	$v_g$ (m/s)
TEM				
TE <sub>1</sub>				
TM <sub>1</sub>				
TE <sub>2</sub>				
TM <sub>2</sub>				

2. An air-filled rectangular waveguide has largest side  $a = 1$  cm. Find the length of the side  $b$ , necessary to have identical cutoff frequency for the TE<sub>20</sub> and TM<sub>11</sub> modes.

3. An air-filled, X-band (8-12GHz), WC-94 circular waveguide has an inner diameter of 2.383 cm.

- Determine the cutoff frequencies of the TE<sub>11</sub>, TM<sub>01</sub>, and TE<sub>21</sub> modes.
- Find the modes that will propagate through this guide at 10 GHz.
- Find the frequency range within which only the TE<sub>11</sub> mode propagates.