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1. A parallel-plate waveguide is known to have a cutoff wavelength for the $m = 1$ TE and TM modes of $\lambda_{c1} = 4.1\,\text{mm}$. The guide is operated at wavelength $\lambda = 1.0\,\text{mm}$. How many modes propagate?

2. The cutoff frequency of the $m = 1$ TE and TM modes in an air-filled parallel-plate waveguide is known to be $f_{c1} = 7.5\,\text{GHz}$. The guide is used at wavelength $\lambda = 1.5\,\text{cm}$. Find the group velocity of the $m = 2$ TE and TM modes.

3. A rectangular waveguide has dimensions $a = 6\,\text{cm}$ and $b = 4\,\text{cm}$.
   a) Over what range of frequencies will the guide operate in single mode? b) Over what frequency range will the guide support both TE_{10} and TE_{01} modes and no others?

4. A parallel-plate guide has plate spacing $d = 5\,\text{mm}$ and is filled with glass (refractive index $n = 1.45$). What is the maximum frequency at which the guide will operate in the TEM mode only?

5. An air-filled rectangular waveguide has dimensions $a = 2\,\text{cm}$ and $b = 1\,\text{cm}$. Determine the range of frequencies over which the guide will operate in single mode (TE_{10}).

6. Consider a rectangular waveguide with dimensions 2.28 cm × 1.01 cm.
   (a) What TE modes will propagate in this waveguide if the driving frequency is 1.70×10^{10} Hz?
   (b) Suppose you wanted to excite only one TE mode; what range of frequencies could you use?
   (c) What are the corresponding wavelengths (in open space)?

7. Show that the mode TE_{00} cannot occur in a rectangular waveguide.
   Hint: Show that B_z is a constant, and hence-applying Faraday's law in integral form to a cross section-that $B_z = 0$, so this would be a TEM mode.

8. Specify the minimum width, a, and the maximum height, b, of an air-filled rectangular waveguide so that it will operate in a single mode over the frequency range
$$15\ \text{GHz} < f < 20\ \text{GHz}.$$

9. A parallel-plate waveguide with plate separation $d = 1$ cm is filled with glass having refractive index $n = 1.45$. If the operating frequency is 32 GHz, determine which modes will propagate.

10. An air-filled rectangular waveguide is to be constructed for single-mode operation at 15 GHz. Specify the guide dimensions, a and b, such that the design frequency is 10% higher than the cutoff frequency for the TE_{10} mode, while being 10% lower than the cutoff frequency for the next-higher-order mode.