Problem P5.1

Consider an asymmetric slab waveguide shown in Figure 1. It is known that $\epsilon_1 > \epsilon_2 > \epsilon_0$. Derive the guidance condition for TM modes. What is the cutoff spatial frequency for TM_m mode?

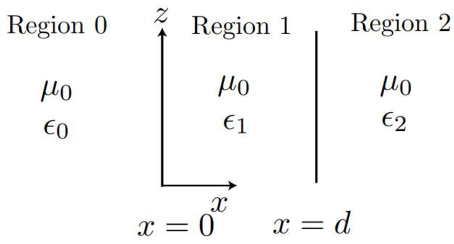


Fig. 1

Problem P9.1

What is the lowest frequency of an electromagnetic wave that can be propagating in the TE mode in the earth-ionosphere waveguide? Model the latter as two perfectly conducting parallel plates separated by 80 km.

Problem P9.2

Consider a perfectly conducting parallel-plate waveguide filled with a dielectric medium for $z > 0$ as shown in the figure. The dielectric medium has permittivity ϵ_1 . The operating frequency is 30 GHz. The guided wave propagates in the $\hat{z}$ direction.

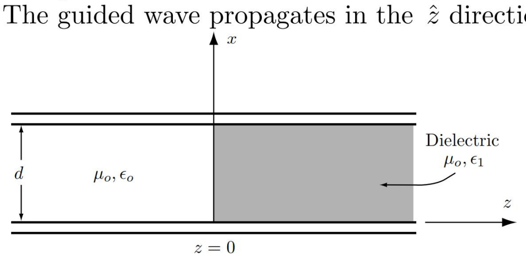


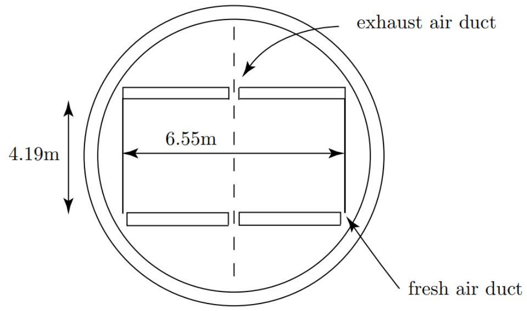
Fig. 1.

(a) Let $d = \sqrt{3}$ cm and consider the empty waveguide with $\epsilon_1 = \epsilon_o$ (in the absence of the dielectric). Which TE_m and TM_m modes can propagate in this waveguide?
(b) Find expressions for the $\overline{E}$ and $\overline{H}$ fields for the TM_2 mode in the absence of the dielectric.
(c) What are the phase and group velocities for the TM_2 mode at this operating frequency in the absence of the dielectric?
(d) Let $\epsilon_1 = 3\epsilon_o$ and $d = \sqrt{3}$ cm. For waves propagating in the $+\hat{z}$ direction, for which values of m will the TM_m modes be totally reflected at the dielectric boundary? Why?
(e) Let $\epsilon_1 = 3\epsilon_o$ and $d = \sqrt{3}$ cm. Calculate k_x and k_z for the TM_m mode. Will the TM_m mode be totally transmitted (no reflection) and why?

Problem P9.3

Practical rectangular-geometry optical waveguides are most easily understood as variants of the simple dielectric slab waveguide. Consider a plane slab of polystyrene ($\epsilon = 2.56\epsilon_o$) with 1 cm thickness whose operation frequency is 30 GHz. How many propogating modes are available using this dielectric waveguide? Determine the operation frequency range within which only the fundamental mode(s) is(are) available.

Problem P10.1



Tunnel modeled as rectangular waveguide.

An AM(535-1605 kHz) radio in an automobile cannot receive any signal when the car is inside a tunnel. Consider, for example, the Lincoln Tunnel under the Hudson River, which was built in 1939. A cross-section of the tunnel as shown in the figure. Ignore the air ducts; assume they are closed. Model the tunnel as a rectangular waveguide of dimension $6.55m \times 4.19m$.

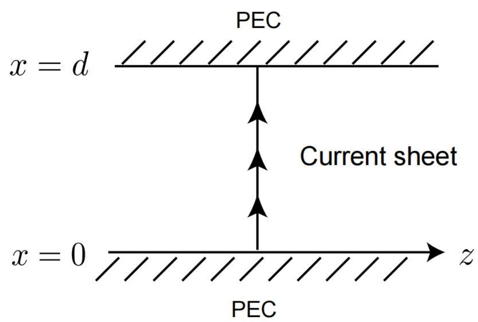
(a) Give the range of frequencies for which only the dominant mode, TE_{10}, may propagate.
(b) Explain why AM signals cannot received.
(c) Can FM(88-108 MHz) signals be received? Above what frequencies?

Problem P10.2

Consider the excitation of a parallel-plate waveguide by a current sheet with

$$\overline{J}_s = \hat{x} J_s \cos \frac{3\pi x}{d}$$

The plates are at $x = 0$ and $x = d$ and the propagation direction is $\hat{z}$. Find the amplitudes of the excited modes. (Hint: Only TM modes are excited in this case.)



Problem P10.3

A waveguide is often designed such that only the fundamental mode is able to propagate. The reason is that two different propagating modes travel with different velocities, which leads to the difficulty of receiving the clear signals at the other end of the waveguide. Consider a rectangular waveguide as shown in the figure, where $a = 2b = 3$ cm and the length $\ell = 300$ m. It is known that signals travel with their group velocity.

(a) If a signal is modulated at 6 GHz and travels from one end of this waveguide to the other end, how much time will it take?

(b) If a signal is modulated at 10.5 GHz, how many propagating modes can carry this signal? How much time will it take for each of these modes to reach the other end of the waveguide?