Reading Assignment: Cheng: Chapters 8 and 10

Homework #4 Due: Friday 10 February 2006

1) Calculate the critical angle for total reflection of a plane wave passing from the following dielectrics into air:

Material	ε_r
Teflon	2.1
Glass	4.0
Alumina (Al_2O_3)	9.8
Titania (TiO_2)	100

2) A circularly polarized wave is obliquely incident from air on the surface of a dielectric ($\varepsilon_r = 4$) at an angle of 45°:
   a. Describe the polarization of the transmitted and reflected waves.
   b. Find the fraction of the incident power density transmitted into the dielectric.

3) A dielectric slab with parallel faces has air on both sides. A linearly polarized plane-wave (electric field in the plane of incidence) is obliquely incident at the Brewster angle on the front surface. Show that 100% of the incident power is transmitted through the slab, regardless of the slab thickness.

4) A dielectric slab ($\varepsilon_r = 3$, and thickness *d*) is surrounded on both sides by air. A circularly polarized plane wave of frequency 10 GHz is obliquely incident on this slab with an angle of incidence θ_1. It is desired to have the *reflected* wave be linearly polarized and have the maximum possible amplitude. Determine the value of θ_1 and *d* which will accomplish this.

5) A 240 degree phase shift is produced by a 4 GHz signal when traveling along a dielectric-filled waveguide which is 3cm long. If the cutoff frequency of the waveguide when air filled is 10 GHz, calculate the dielectric constant of the material inside the waveguide.

6) The transverse electric field in the dominant TE_{10} mode of a rectangular waveguide is given by $E_y = E_0 \sin(\pi x / a)$, where *a* is the guide width and *b* is the guide height, as usual. The wave travels in the *z*-direction. Denoting the wave impedance by Z_{TE}:
   c. Find the transverse magnetic field, H_x, in terms of E_0 and Z_{TE}.
   d. Although there is also a *z*-component of magnetic field, it does not contribute to power flow in the waveguide. Write an expression for the power density (W/m^2) in the waveguide (the *z*-component of the Poynting vector, $\hat{z} \cdot \overline{\mathcal{P}}_{ave}$).
   e. Using your answer for (b), derive an expression for the *total average power* (in Watts) passing through a rectangular waveguide.
   f. Consider a rectangular waveguide with a = 2*b* = 1 cm, filled with a dielectric with $\varepsilon_r = 4$, and operated in the dominant mode at 10 GHz. What is the maximum power that can be transmitted through this waveguide without inducing dielectric breakdown, assuming this occurs at a field strength of 10^6 V/m in this material?