EECS 412 - FALL 2003

FINAL EXAM – 12/12/03

NAME: ________________ CWRUnet e-mail address:____________

IMPORTANT INFORMATION:

1. All questions are worth the same.
2. Exam is due December 12th at 12 noon in Glennan 518.

		Possible	
1.		10	Multi-layer dielectric coatings
2.		10	Optical fiber waveguides
3.		10	Dielectric slab waveguides
4.		10	Rectangular waveguides – dominant mode
5.		10	Rectangular waveguides - losses
6.		10	Rectangular waveguides - modes
7.		10	Waveguides - general
SCORE		70	

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1. MULTI-LAYER DIELECTRIC COATINGS

You have been given the task of designing a phodetector for an optical local area network which uses a GaAs laser diode light source (freespace wavelength λ_o=850nm) . You decide to use a silicon photodiode which responds well at this wavelength. To improve the photoresponse, you decide to add an anti-reflection coating to the diode . You have equipment which can deposit either SiO_2 (refractive index n=1.45) or TiO_2 (n=2.25) coatings. Silicon has a relative permittivity ε_r=11.9.

Determine which of the two available materials gives the best antireflection coating, and determine the optimum thickness for the coating.

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2. OPTICAL FIBER WAVEGUIDES

What is the angular (from the normal) range for rays to enter the core of an optical fiber waveguide with core index n=1.70 and cladding index 1.65 and be trapped to propagate. Assume that the rays are entering from air.

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3. DIELECTRIC SLAB WAVEGUIDES

A dielectric slab waveguide is d=9mm thick and is parallel to the y-z plane, centered at x=0. The electric and magnetic fields are:

$$\left.\begin{aligned}\overline{H} &= \left[\hat{x}B\sin(1000x) - \hat{z}jC\cos(1000x)\right]e^{-j1000z}\\ \overline{E} &= \hat{y}A\sin(1000x)e^{-j1000z}\end{aligned}\right\}|x| \le \frac{d}{2}$$

$$\left.\begin{aligned}\overline{H} &= \hat{y}De^{-750x}e^{-j1000z}\\ \overline{E} &= \left[\hat{x}Fe^{-750x} - \hat{z}jGe^{-750x}\right]e^{-j1000z}\end{aligned}\right\}|x| > \frac{d}{2}$$

where A, B, C, D, E, and F are real positive constants.

(a) What are the propagation constants α and β as well as ω outside the slab in the free-space region?

(b) What are the propagation constants α and β inside the slab where $\varepsilon \neq \varepsilon_o$. What is ε?

(c) What mode is propagating?

(d) What is the cutoff frequency for this mode?

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4. RECTANGULAR WAVEGUIDES – DOMINANT MODE

Consider a 1.016x2.286 cm rectangular waveguide . Assume that it is air filled ($\varepsilon=\varepsilon_o$) for z<0 and filled with a dielectric with $\varepsilon=2\varepsilon_o$ for z>0. Is it possible for only a dominant mode to propagate through this waveguide structure? If so, over what frequency range?

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5. RECTANGULAR WAVEGUIDES – LOSSES

One way to construct a microwave attenuator is to insert a poorly conducting sheet $\sigma << \omega\varepsilon_o$ (S/m) parallel to the electric field in a waveguide at a distance d from the sidewall ($0<d<a$). The conducting sheet thickness is $\delta << a$ and the waveguide has dimensions $a \times b$ where $a \geq b$.

(a) Using a perturbation approach calculate the power dissipated per meter for the propagating TE_{10} mode.

(b) What is the approximate attenuation coefficient (α) for this waveguide as a function of frequency? What happens near the cut-off frequency?

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6. RECTANGULAR WAVEGUIDES – MODES

An AM 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. Model the tunnel as a rectangular metallic waveguide of dimensions 6.55×4.19 meters.

(a) Give the range of frequencies for which only the dominant mode, TE_{10}, will propagate.

(b) Explain why AM broadcast band signals (540-1600 kHz) cannot be received in the tunnel. How far into the tunnel will a 1 MHz signal travel before its signal intensity drops by 20 dB?

(c) Can FM broadcast frequencies (88-108 MHz) be received in the tunnel? Why?

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7. WAVEGUIDES – GENERAL

A 10-m long waveguide needs to be built for a 25 GHz radar system. You have a 6.3cm x 10 meter piece of 3mm thick copper sheet from which you are to build the waveguide. Neglecting dielectric losses and fringing fields (for the parallel plate), what type of waveguide would you build to transmit the maximum power , i.e., lowest losses. Justify (in as much detail as you can) the type of waveguide (parallel-plate, rectangular, or circular which is best suited for this application. Provide the final dimensions and the expected losses for a 10-m length of the waveguide you design.