UNIVERSITY OF SASKATCHEWAN

COLLEGE OF ENGINEERING

ELECTRICAL ENGINEERING EE472.3

Midterm Examination

Part B

Instructor: S.O. Kasap March 8, 2005

Time allowed: Part B is nominally 1 hour.
Total time allowed: 2 hours for Parts A and B

Note: Open book examination. Only the textbook is allowed. Calculators are allowed. *Answer any 2 questions from 3 questions.* All questions carry equal marks. Marks for part-questions depend on the difficulty. All answers must be given in conventional units. State clearly all assumptions made in your derivations. Method of solution must be clearly shown. Numerical mistakes, incorrect, unconventional or missing units will be heavily penalized. Mention the source of materials data used.

Note: No laptop or similar computers allowed.

Important Note: You must hand in Part A before you can start Part B. Write your answers in the university answer book.

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[25] **1. Light as a Wave**

A light wave with a wavelength 1500 nm (free space wavelength) that is propagating in GaAs becomes incident on GaInP. The refractive index of GaAs is 3.38 and that of GaInP is 3.15.

a Consider normal incidence. What are the reflection and transmission coefficients and the reflectance and transmittance? (From GaAs into GaInP)

b What is the Brewster angle (the polarization angle θ_p) and the critical angle (θ_c) for total internal reflection for the wave in **a**; the wave that is traveling in GaAs and incident on the GaAs/GaInP interface.

c What is the reflection coefficient and the phase change in the reflected wave when the angle of incidence $\theta_i = 70°$?

d What is the penetration depth of the evanescent wave into medium 2 when $\theta_i = 70°$ and when $\theta_i = 89°$? What is your conclusion?

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2. Fabry-Perot Cavity and Diffraction

Answer both **a** *and* **b**

[10] **a** Consider a Fabry-Perot optical cavity of air of length 200 microns with mirrors that have a reflectance of 0.85 ($R = 0.85$ for each mirror). Calculate the cavity mode nearest to 870 nm. Calculate the separation of the modes and the spectral width of each mode. What is the finesse of this cavity? What happens to the spectral width and the finesse if the cavity losses were higher, for example, the reflectance R were 0.8?

[15] **a** Suppose that a plane wave with a free space wavelength 1550 nm and traveling in a semiconductor medium of refractive index of 3.7 is incident on a circular aperture that has a diameter D of 20 microns. What is the divergence of the beam based on diffraction? What is the diameter of the beam at a distance of 5 m away from aperture? Calculate the divergence if the beam could be described as a Gaussian beam with a waist that has a diameter D. Why is there a difference between the two calculations?

[25] 3. Optical Fibers

Consider a step-index fiber with a core of diameter of 8 μm and refractive index of 1.4530 at 1550 nm and a normalized refractive index difference of 0.20% where the fiber is to be operated using a laser source with a half-maximum width of 3 nm.

- **a** Calculate the V-number for the fiber. Is this a single mode fiber?
- **b** Calculate the wavelength below which the fiber becomes multimode.
- **c** Calculate the numerical aperture.
- **d** Calculate the maximum total acceptance angle.
- **e** Obtain the material, waveguide and chromatic dispersions. (Use Figure 2.21)
- **f** What is the mode field diameter?
- **g** Estimate the bit rate × distance product ($B \times L$) of this fiber.
- **h** What is the maximum allowed diameter that maintains operation in single mode?
- **i** What would be bit the rate × distance product if the original fiber is operated at 1300 nm?
- **j** What is your conclusion from the above calculations?

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