MINOR WRITTEN PRELIM EXAM

Spring 2008

February 13, 2008
8:30 a.m. to 12:00 p.m.

Please answer all questions.

Start each answer on a new page.

In the upper right hand corner of each sheet you hand in, put your name and the problem number. Staple together all sheets for a given problem.

Insert your answers and this exam into the manila envelope supplied. The exam questions will be returned to you along with your answers after they have been graded.

The following are some helpful items:

$h = 6.625 \times 10^{-34}\ \mathrm{J \cdot s} = 4.134 \times 10^{-15}\ \mathrm{eV \cdot s}$

$e = 1.6 \times 10^{-19}\ \mathrm{C}$

$c = 3.0 \times 10^{8}\ \mathrm{m/s}$

$k_B = 1.38 \times 10^{-23}\ \mathrm{J/K}$

$\sigma = 5.67 \times 10^{-8}\ \mathrm{W/K^4 \cdot m^2}$

$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F/m}$

$\mu_0 = 1.26 \times 10^{-6}\ \mathrm{H/m}$

$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$

$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$

$2 \cos A \cos B = \cos(A - B) + \cos(A + B)$

$2 \sin A \sin B = \cos(A - B) - \cos(A + B)$

$2 \sin A \cos B = \sin(A + B) + \sin(A - B)$

$2 \cos A \sin B = \sin(A + B) - \sin(A - B)$

$\sin 2A = 2 \sin A \cos A$

$\cos 2A = 2 \cos^2 A - 1$

$\cos 2A = 1 - 2 \sin^2 A$

$\sinh x = \frac{1}{2}\left(e^x - e^{-x}\right)$

$\cosh x = \frac{1}{2}\left(e^x + e^{-x}\right)$

$\nabla(\phi + \psi) = \nabla\phi + \nabla\psi$

$\nabla\phi\psi = \phi\nabla\psi + \psi\nabla\phi$

$\nabla \cdot (\mathbf{F} + \mathbf{G}) = \nabla \cdot \mathbf{F} + \nabla \cdot \mathbf{G}$

$\nabla \times (\mathbf{F} + \mathbf{G}) = \nabla \times \mathbf{F} + \nabla \times \mathbf{G}$

$\nabla(\mathbf{F} \cdot \mathbf{G}) = (\mathbf{F} \cdot \nabla)\mathbf{G} + (\mathbf{G} \cdot \nabla)\mathbf{F} + \mathbf{F} \times (\nabla \times \mathbf{G}) + \mathbf{G} \times (\nabla \times \mathbf{F})$

$\nabla \cdot (\phi\mathbf{F}) = \phi(\nabla \cdot \mathbf{F}) + \mathbf{F} \cdot \nabla\phi$

$\nabla \cdot (\mathbf{F} \times \mathbf{G}) = \mathbf{G} \cdot \nabla \times \mathbf{F} - \mathbf{F} \cdot \nabla \times \mathbf{G}$

$\nabla \cdot (\nabla \times \mathbf{F}) = 0$

$\nabla \times (\phi\mathbf{F}) = \phi(\nabla \times \mathbf{F}) + \nabla\phi \times \mathbf{F}$

$\nabla \times (\mathbf{F} \times \mathbf{G}) = \mathbf{F}(\nabla \cdot \mathbf{G}) - \mathbf{G}(\nabla \cdot \mathbf{F}) + (\mathbf{G} \cdot \nabla)\mathbf{F} - (\mathbf{F} \cdot \nabla)\mathbf{G}$

$\nabla \times (\nabla \times \mathbf{F}) = \nabla(\nabla \cdot \mathbf{F}) - \nabla^2\mathbf{F}$

$\nabla \times \nabla\phi = 0$

$\oint_S (\mathbf{F} \cdot \mathbf{n})\, da = \int_V (\nabla \cdot \mathbf{F})\, d^3x$

$\oint_C \mathbf{F} \cdot d\boldsymbol{\ell} = \int_S (\nabla \times \mathbf{F}) \cdot \mathbf{n}\, da$

$\oint_S \phi\mathbf{n}\, da = \int_V \nabla\phi\, d^3x$

$\oint_S \mathbf{F}(\mathbf{G} \cdot \mathbf{n})\, da = \int_V [\mathbf{F}(\nabla \cdot \mathbf{G}) + (\mathbf{G} \cdot \nabla)\mathbf{F}]\, d^3x$

$\oint_S (\mathbf{n} \times \mathbf{F})\, da = \int_V (\nabla \times \mathbf{F})\, d^3x$

(a) (3 points) schematically plot the absorption and reflection spectra of NaCl, an insulator, as a function of frequency near the phonon resonance.

(b) (2 points) Write down the expressions for conservations of energy and momentum for Stokes and anti-Stokes scattering processes, with ω_i and ω_s being the frequencies of the incident and scattered photons, $\mathbf{q}_i$ and $\mathbf{q}_s$ being the wavevectors of incident and scattered photon; and Ω and $\mathbf{K}$ being the phonon frequency and wavevector, respectively.

(c) (2 points) Use these conservation expressions and obtain an equation relating the magnitude of the phonon wavevector K as a function of q_i and the angle θ between $\mathbf{q}_i$ and $\mathbf{q}_s$.

(d) (2 points) If the phonon is acoustic, use the result in part (c) and obtain a relation for the acoustic phonon frequency as a function of speed of light c, speed of sound υ_s, and ω_i.

(e) (1 point) What is the typical value of the acoustic phonon energy? You may use the relation in part (d) to get this typical; value.

Opti 512

You are given an ideal telecentric, "4F", imaging system. It consists of two lenses of focal-length *f* separated by a distance *2f*. The input plane to the system is *f* upstream of the first lens and the output plane is *f* downstream of the second lens. Midway between the lenses is an aperture with complex-amplitude transmittance $a(x, y)$. There is a transparency, with complex amplitude transmittance $t(x, y)$ in the input plane.

Case 1:

The transparency is illuminated by coherent light in the form of a normally-incident plane wave.

- What is the coherent transfer function of the system? Show the conversion to reduced coordinates for the spatial frequencies.
- What is the coherent point spread function of the system?

Case 2:

The same transparency is illuminated with quasi-monchromatic incoherent light.

- What is the incoherent transfer function of the system? How is it related to the coherent transfer function?
- What is the modulation transfer function (MTF) of the system?
- What is the incoherent point spread function of the system?
- A cosine grating, $a(x, y) = \frac{1}{2}\left[1 + \cos(2\pi\xi_0 x)\right]$, replaces the aperture. What is the resulting incoherent point spread function?
- What is the output of the system with the grating in place?

Minor prelim question - Macleod day 2

OPTI577 (575) Minor Prelim Question - Day 2

The question refers to normal incidence. The incident medium is air of characteristic admittance unity.

(a) State the quarterwave rule.

(b) Quarterwave antireflection coatings are to be provided for the following materials:

(i) BK 7 glass. $y = 1.52$

(ii) SF 5 glass. $y = 1.68$

(iii) Fused silica. $y = 1.46$

Calculate the required admittances for perfect quarterwave antireflection coatings for each of the above.

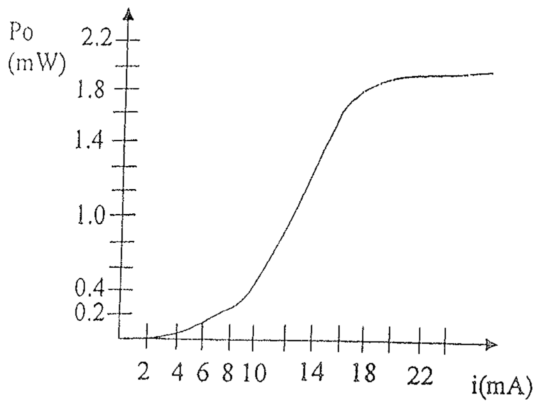
(c) The only available material is magnesium fluoride with characteristic admittance 1.38. Calculate the minimumum reflectance for each of the above materials if a quarterwave of magnesium fluoride is used as the antireflection coating.

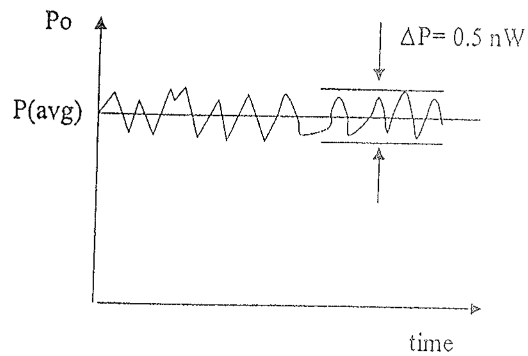
Minor Exam

Opti587

a. What is the V# number for a fiber with a radius of 4 μm, a wavelength of 1.55 μm, n_1 = 1.51, and n_2 = 1.50. Will this fiber support multiple modes? Why? What diameter of a Gaussian beam will best couple to this fiber?

b. Consider the laser characteristics shown below for use in an analog communications system. The system operates at a wavelength of 850 nm with a high impedance mode receiver with a resistance of 50 Ω, a detector junction capacitance of 1 pF, temperature of 300°K, and a detector quantum efficiency of 0.7. The figure on the right shows the laser power fluctuation when biased at useful operating currents.





i. Using the above characteristics determine the threshold current and differential efficiency for the laser.

ii. At what current should the laser be biased to provide the maximum analog index modulation parameter (m)? What is the value for m?

iii. Draw a diagram for the high impedance receiver with the simplified circuit model for the detector. Compute the detector responsivity.

iv. Compute the system carrier-to-noise ratio when the laser is biased at a current that gives the maximum m parameter as found in part (b)? (If you could not do part (b) use a bias current of 14 mA and m = 0.05.)