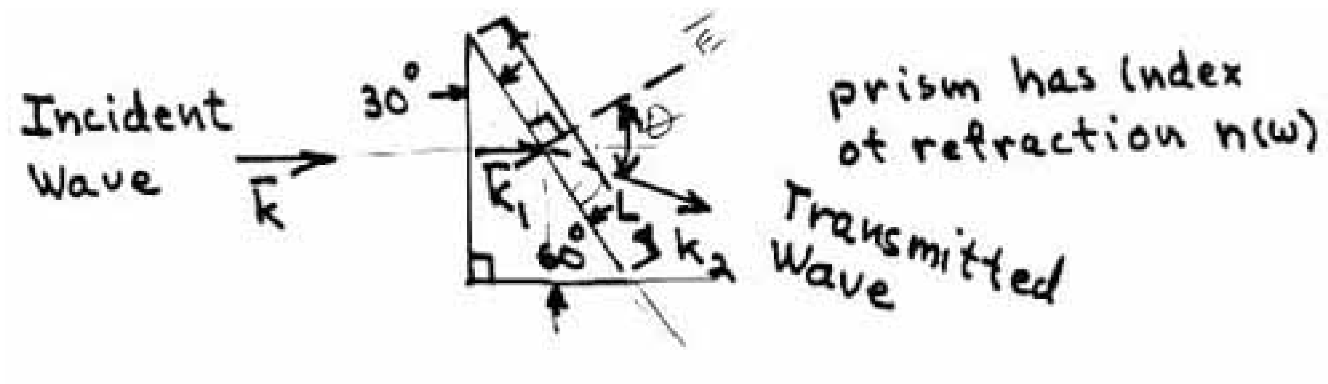
Electrical Engineering 118
Spring 2001 Midterm 1
Professor Gustafson

Problem #1 (30 points)

A plane wave travels through a right-angle glass prism as shown. The prism materials has an index of refraction which depends upon frequency (w = 2*pi*f)



The incident wave has an electric field equal to E = Eo*cos(wt - k_x*x) = Eo*cos(wt - k . r) with k = k_x*i_x, and i_x a unit vector in the x direction. k is known as the k-vector!

a) What is the magnitude of k in terms of the frequency w and the speed of light c?

b) What is the magnitude of k_1 for the wave inside the prism?

c) What is the magnitude of k_2, the k-vector of the wave emerging from the prism (as shown in the figure)

d) The field E is incident perpendicularly on the prism as shown. Use "Snell's law" to obtain the emergence angle theta (or its cosine, sine, or tangent) in terms of the index of refraction n(w); that is, the value of n at the frequency w.

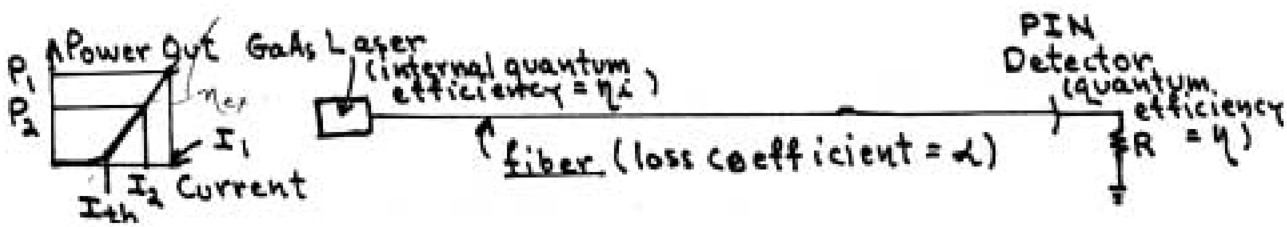
e) For a small increase, delta w in omega determine the change delta theta in angle theta due to the change in n with frequency w, as given by (dn/dw)*(delta w). Thus obtain an expression for (delta theta)/(delta w), the prism dispersion coefficient, in terms of dn/dw and n(w).

f) What is the "resolution" in this case (the minimum value of delta w that can be discerned)? Hint -- this is a diffraction problem! Express your answer in terms of (w*dn/dw), c, the speed of light, and L (the hypotenuse of the prism).

g) A typical value of w*dn/dw is 0.875 (flint glass at red wavelengths). What length must the prism hypotenuse be to resolve 100GHz?

Problem #2 (30 points)

An optical communication system has the components with corresponding characteristics shown.



a) Express the detector current Id_1 and Id_2 obtained if the laser transmitter is driven respectively with currents I1 and I2. Express these in terms of P1 (the optical power obtained by exciting the laser with current I1) and P2, a, L, where a is the loss coefficient of the optical fiber and L is its length; n, the quantum efficiency of the dtector; the frequency f; and the electronic charge e.

b) Express Id_1 and Id_2 in terms of I1 and I2 as well as n_i, the internal quantum efficiency of the laser diode, a_i, the internal loss of the laser diode, and a_m, the mirror loss (cm^-1) coefficient of the laser diode.

c) Assuming that the detection is thermal noise limited with resistance, R, what is the signal to noise ratio defined as K^2 = (delta Id)^2/(i_NT)^2, where delta Id = Id_1 - Id_2. In terms of T, the temperature, R, the resistance, delta f, the bandwidth and I1 and I2 and the parameters which define them.

d) If an APD is used rather than a PIN diode, and M is the current amplification and F the noise enhancement factor, what is the minimum value of M required to guarantee that the detection is shot-noise limited? Assume that F is approximately constant.

Problem #3 (10 points)

The system in problem 2 is used as a digital transmission system with I2 corresponding to a 1 and I1 corresponding to a 0. The signal to be sent digitally is sampled at a 100Mhz rate and the laser can be switched so that 10 bits per sample period can be obtained. How many levels can be used the quantize the signal before the noise makes it impossible to discern one level from another? What is the corresponding signalt o noise ratio for this encoding process?

Solutions!
