Homework #1

1. Calculate the frequency of the following optical wavelengths λ=800nm, 1300nm, 1550nm.
2. If two optical signals have a frequency separation of Δf=100GHz, what is the wavelength separation if one of the wavelengths is λ=1550nm?
3. Assume that a digital communication system can be operated at a bit rate up to 1% of the carrier frequency. How many audio channels at 64 kb/s can be transmitted over a microwave carrier at f=5GHz and at λ=1.55μm?
4. A 1 hour lecture script is stored on a computer hard disk in the ASCII format. Estimate the total number of bits assuming a delivery rate of 200 words per minute and an average 5 letters per word. How long will it take to transmit the script at a bit rate of 10 Gb/s?

For problems 5-7

A symmetric slab waveguide has a slab index of refraction of n_2=1.5 and surrounding refractive indices of n_1=1.49.

5. What is the range of the propagation constant, β, for this waveguide?
6. What is the range of effective indices of the waveguide?
7. What is the numerical aperture of this waveguide?

HW 1

(1) $f = \frac{c}{\lambda}$

(a) $\lambda = 800\,nm$ $f = 3.75 \times 10^{14}$ Hz

(b) $\lambda = 1300\,nm$ $f = 2.31 \times 10^{14}$ Hz

(c) $\lambda = 1550\,nm$ $f = 1.93 \times 10^{14}$ Hz

(2) $\Delta f = 100\,GHz$

$$\lambda_1 = 1550\,nm$$
$$f_1 = 1.93 \times 10^{14}$$
$$f_2 = 1.93 \times 10^{14} + 100 \times 10^{9}$$
$$\lambda_2 = \frac{c}{f_2} = \frac{3 \times 10^8}{1.93 \times 10^{14} + 100 \times 10^9}$$

$$\Delta\lambda = 1550 \times 10^{-9} - \frac{3 \times 10^8}{\frac{3 \times 10^8}{1550 \times 10^{-9}} + 100 \times 10^9}$$

$$\boxed{\Delta\lambda = 0.8\,nm}$$

Another method $f = \frac{c}{\lambda}$

$$\frac{df}{d\lambda} = -\frac{c}{\lambda^2}$$

$$\Delta\lambda = \frac{\lambda^2}{c}\Delta f$$
$$= \frac{(1550 \times 10^{-9})^2 \; (100 \times 10^9)}{3 \times 10^8}$$

$$\boxed{\Delta\lambda = 0.8\,nm}$$

(3) $BR = (0.01)\, f_c$

$$\#\text{ Channels} = \frac{(0.01) f}{64\times10^3}$$

$f = 5\text{GHz}$ $\qquad$ **# channels = 781**

$\lambda = 1550\text{nm}$ $\quad f = \frac{3\times10^8}{1550\times10^{-9}}$ $\quad \#\text{ Channels} = \frac{(0.01)(3\times10^8)}{(1550\times10^{-9})(64\times10^3)}$

3.02×10^7 channels

(4) Assume 8 bits / letter

$$\text{Bits} = (1\text{ hour})\left(\frac{60\text{ minutes}}{\text{hour}}\right)\left(\frac{200\text{ words}}{\text{minute}}\right)\left(\frac{5\text{ letters}}{\text{word}}\right)\left(\frac{8\text{ bits}}{\text{letter}}\right)$$

$$= 4.8\times10^5\text{ bits}$$

$$T = \frac{4.8\times10^5\text{ bits}}{10\times10^9\text{ b/s}}$$

$T = 48\,\mu s$

$n_1 = 1.49 \quad n_2 = 1.5$

(5) $n_1 k_0 < \beta < n_2 k_0$

$$\boxed{1.49\, k_0 < \beta < 1.5\, k_0}$$

(6) $n_{eff} = \dfrac{\beta}{k_0}$

$$\boxed{1.49 < \beta < 1.5}$$

(7) $NA = \sqrt{n_2^2 - n_1^2}$

$= \sqrt{1.5^2 - 1.49^2}$

$$\boxed{NA = 0.173}$$