ECT-215 Homework #2 Solution Set

Chapter 16 problems 1-15,17-20,35-39

Scoring: 1 point per problem, 24 points total.

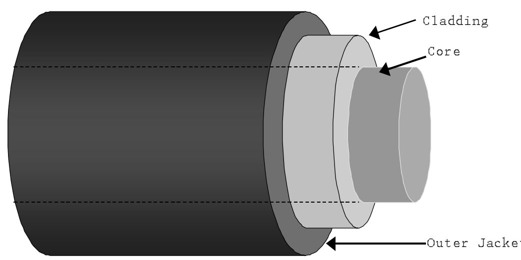
1. *What are fiber optics? What carries the information in a fiber optic cable*?

   Fiber optics are transmission lines designed to convey *light* signals instead of radio signals. Light carries the information in a fiber optic cable.

2. *List several advantages of fiber optic cable over conventional copper transmission line. Are there any disadvantages of fiber*?

   Fiber advantages include low signal attenuation, wide bandwidth, and high security. The disadvantages are minor: Special tools are required to work with fiber optics, and splicing broken cables is difficult.

3. *Draw a diagram showing the parts of a fiber optic cable. Which parts of the cable are responsible for guiding the light*?



[Figure 16-1]

   The *core* and *cladding* are responsible for guiding the light wave in a fiber optic cable.

4. *Calculate the frequency the following light sources:*
   a) Reddish-Orange, λ=680 nm ; b) Blue-Green, λ=500 nm

   a) $\lambda = \frac{v}{f} \Rightarrow f = \frac{v}{\lambda} = \frac{3\times10^8 m/s}{680nm} = \underline{\underline{441.176THz}}$

   b) $f = \frac{v}{\lambda} = \frac{3\times10^8 m/s}{500nm} = \underline{\underline{600.0THz}}$

5. *Define each of the following: a) Reflection ; b) Diffraction ; c) Refraction*

   a) Reflection is the rebounding of light wave from a conductive, reflective surface.
   b) Diffraction is the spreading or diffusion of light at the edge of an opaque surface.
   c) Refraction is the bending of light at the junction of two different media.

6. *In a certain material, light waves travel at 1.5 x 10^8 m/s. What is its index of refraction*?

$$n = \frac{c}{v} = \frac{3\times10^8\, m/s}{1.5\times10^8\, m/s} = \underline{\underline{2.0}}$$

7. *Calculate the velocity of propagation of light through the following substances: a) Water ; b) Glass ; c) Fused Quartz*

a) $n = \frac{c}{v} \Rightarrow v = \frac{c}{n} = \frac{3\times10^8\, m/s}{1.33} = \underline{\underline{2.25\times10^8\, m/s}}$

b) $v = \frac{c}{n} = \frac{3\times10^8\, m/s}{1.5} = \underline{\underline{2.00\times10^8\, m/s}}$

c) $v = \frac{c}{n} = \frac{3\times10^8\, m/s}{1.46} = \underline{\underline{2.05\times10^8\, m/s}}$

8. *Calculate the wavelength of a ray of yellow light if it is passing through a sheet of glass.*

$$\lambda = \frac{\lambda_{fs}}{n} = \frac{580nm}{1.5} = \underline{\underline{386nm}}$$

9. *Calculate the critical angle for the following core-cladding index combinations: a) n_{core} =1.57, $n_{cladding}$ = 1.42 ; b) n_{core} = 2.0, $n_{cladding}$ = 1.8 ; c) n_{core} = 1.33, $n_{cladding}$ = 1.00 ; d) n_{core} = 1.75, $n_{cladding}$ = 1.55*

a) $\Theta_{crit} = \sin^{-1}\frac{n_2}{n_1} = \sin^{-1}\frac{1.42}{1.57} = \underline{\underline{64.75^\circ}}$

b) $\Theta_{crit} = \sin^{-1}\frac{n_2}{n_1} = \sin^{-1}\frac{1.8}{2.0} = \underline{\underline{64.16^\circ}}$

c) $\Theta_{crit} = \sin^{-1}\frac{n_2}{n_1} = \sin^{-1}\frac{1.00}{1.33} = \underline{\underline{48.75^\circ}}$ (The cladding is *air* in this case!)

d) $\Theta_{crit} = \sin^{-1}\frac{n_2}{n_1} = \sin^{-1}\frac{1.55}{1.75} = \underline{\underline{62.34^\circ}}$

10. *Calculate the numerical aperture (NA) for each of the four combinations of refractive index given in problem 9.*

a) $NA = \sqrt{n_1^2 - n_2^2} = \sqrt{(1.57)^2 - (1.42)^2} = \underline{\underline{0.67}}$

b) $NA = \sqrt{n_1^2 - n_2^2} = \sqrt{(2.00)^2 - (1.8)^2} = \underline{\underline{0.872}}$

c) $NA = \sqrt{n_1^2 - n_2^2} = \sqrt{(1.33)^2 - (1.00)^2} = \underline{\underline{0.876}}$

d) $NA = \sqrt{n_1^2 - n_2^2} = \sqrt{(1.75)^2 - (1.55)^2} = \underline{\underline{0.812}}$

11. *Examine the four combinations of refractive index given in problem 9. Find the combination with the minimum and maximum acceptance cone angles, and report these two angles.*

The smallest angle is given by the data of part (a):

$$\Theta_{accept} = \sin^{-1} NA = \sin^{-1}(0.67) = \underline{\underline{42^\circ}}$$

The largest angle is given by the data of part (c):

$$\Theta_{accept} = \sin^{-1} NA = \sin^{-1}(0.876) = \underline{\underline{61.2^\circ}}$$

12. *Define the term "propagation mode." What are the two major classifications?*

A *propagation mode* is one particular type of light wave path in a fiber. The two major classifications are *single mode* and *multi mode*.

13. *Explain how can an optical fiber be made to operate in a single mode.*

If the width of the core is kept sufficiently narrow (approximately less than two wavelengths of the light frequency to be propagated), then only one mode can exist within it.

14. *What is the primary disadvantage of single mode fibers?*

It is difficult to couple light efficiently into and out of single mode fibers.

15. *What is modal dispersion? What causes this effect in multi-mode fibers?*

Modal dispersion is the spreading of light wave pulses as they travel down a fiber. Differences in arrival time for different portions of the light wave (due to varying propagation paths) cause the dispersion.

17. *Explain the difference between graded-index and step-index fibers. How is modal dispersion reduced in a graded-index fiber?*

In a step index fiber, the core has a uniform refractive index throughout and there is a sudden jump or "step" in the index at the core-cladding interface. Graded index fiber is designed with a variable index of refraction within the core, higher at the center and lower at the edges. Low-order modes are thus slowed down and arrive at a similar time as the high-order modes.

18. *Explain the mechanism behind chromatic (material) dispersion. Which light source is likely to cause more chromatic dispersion, LEDs or lasers? Why?*

Material dispersion is caused by changes in refractive index with wavelength. LEDs are likely to cause more of this dispersion because they produce a much wider spectral bandwidth than lasers.

19. *What factors control the amount of signal attenuation in a fiber optic cable?*

The amount of signal that will be lost in a fiber optic cable depends on three factors. First is the type of cable and core material used (glass is better than plastic, in general); second, the *wavelength* of the light passing down the cable (most glass fiber has a "sweet spot" around 1300 nm wavelength where attenuation becomes incredibly small), and finally the *length* of the cable.

20. *What type of modulation is almost always used with LED and laser light sources?*

Amplitude modulation or AM is usually employed, as it is the simplest to implement.

35. *What are the two failure modes in fiber optic communication systems? Which one is easier to troubleshoot?*

Fiber optics can experience <u>total failure</u> or <u>decreased quality of transmission</u>. Total failure is much easier to find, because the signal isn't passing at all.

36. *List the two most common causes of total communication failure in a fiber optic system.*

The two most common causes are physical damage to fiber optic cables and power supply outages.

37. *What instrument can be used to find the location of a fault in a long fiber optic line?*

An optical time domain reflectometer (OTDR) can be used to find the fault. The OTDR sends a pulse of light into a fiber and measures the time required for the pulse to reflect back, which gives the location of the fault.

38. *What is the purpose of an optical power meter? Give an example of where it could be connected in a system to evaluate its performance.*

An optical power meter measures the intensity (optical power) of light coming from a fiber, LED, or laser source. It could be connected in place of a receiver to determine whether or not sufficient optical power is being received.

39. *As a communications link degrades, digital systems tend to operate perfectly at first, then slow down. Why is this usually so?*

Digital systems tend to work perfectly until the signal voltages fall below the switching thresholds of the logic family in use. At that point, the system operates quite erratically. The situation is complicated with the use of digital error detection and correction codes, which can mask many marginal failures. The system may still seem to operate perfectly (though a bit slower than normal, due to the retransmission of message packets) until the communication link degrades to the point of marginal operation (at which point, things greatly slow down because many messages are being retransmitted.)