P214/Homework #2 Professor Lynn Cominsky Due 2/11/04

Problems are from Tipler Chapter 31:

(1) 4 A ray of light passes from air into water, striking the surface of the water with an angle of incidence of 45°. Which of the following four quantities change as the light enters the water? (1) wavelength, (2) frequency, (3) speed of propagation, (4) direction of propagation?

(a) 1 and 2 only; (b) 2,3, and 4 only; (c) 1,3 and 4 only; (d) 3 and 4 only; or (e) 1,2,3 and 4.

(2) 15 The human eye perceives color using a structure called a cone, located on the retina. The molecules of the cones come in three types that respond in a process similar to resonance absorption to red, green and blue light, respectively. Use this fact to explain why the color of a blue object (450 nm in air) does not appear to change when immersed in clear, colorless water, in site of the fact that the wavelength of the light is shortened in accordance with $\lambda' = \lambda/n$.

(3) 17 Ole Romer's method for measuring the speed of light requires the precise prediction of the time of occurrence for the eclipse of Jupiter's moon Io. Assuming an eclipse took place on June 1 at midnight when the earth was in location A, as shown in Figure 31-11, predict the expected time of the eclipse one quarter year later at location B, assuming (a) the speed of the light is infinite and (b) the speed of light is the presently defined value of 2.998×10^8 m s^{-1}.

(4) 22 A gas is irradiated with monochromatic ultraviolet light of 368 nm wavelength. Scattered light of the same wavelength and of 658 nm wavelength is observed. Assuming that the gas atoms were in their ground state prior to irradiation, find the energy difference between the ground state and the atomic state excited by the irradiation.

(5) 29 In Galileo's attempt to determine the speed of light, he and his assistant were located on hilltops about 3 km apart. Galileo flashed a light and received a return flash from his assistant. (a) If his assistant had an instant reaction, what time difference would Galileo need to be able to measure for this method to be successful? (b) How does this time compare to the human reaction time, which is 0.2 s?

(6) 32 (a) A beam of light in air is incident on an air-water interface. Using a spreadsheet or graphing program, plot the angle of refraction as a function of the angle of incidence from 0° to 90°. (b) Repeat for a beam of light initially in water, incident on a water-air interface. For (b), what is the meaning of your graph for angles of incidence that are greater than the critical angle? *Note: It is recommended that you use Excel to do this problem.*

(7) 39 Light is initially in a medium (e.g. air) of refraction of index n_1. It is incident at angle θ_1 on the surface of a liquid (e.g. water) of index of refraction n_2. The light passes through the layer of water and enters glass of index of refraction n_3. If θ_3 is the angle of refraction in the glass, show that $n_1 \sin\theta_1 = n_3 \sin\theta_3$. That is, show that the second medium can be neglected when finding the angle of refraction in the third medium.

(8) 46 An optical fiber allows rays of light to propagate long distances through total internal reflection. As shown in Figure 31-57, the fiber consists of a core material with index of refraction n_2 and radius b, surrounded by a cladding material of index $n_3 < n_2$. The numerical aperture of the fiber is defined as $\sin\theta_1$, where θ_1 is the angle of incidence of a ray of light impinging the end of the fiber that reflects off the core-cladding interface at the critical angle. Using the figure as a guide, show that the numerical aperture is given by $\sqrt{n_2^2 - n_3^2}$ assuming the ray is incident from air. *(Hint: use the Pythagorean theorem)*

(9) 52 Different colors (frequencies) of light travel at different speeds (a phenomena referred to as dispersion). This can cause problems in fiber-optic communications systems where pulses of light must

travel very long distances in glass. Assuming a fiber is made of silicate crown glass, calculate the difference in time needed for two short pulses of light to travel 15 km of fiber if the first pulse has a wavelength of 700 nm and the second pulse has a wavelength of 500 nm. See Figure 31-29.

(10) 80 Light is incident from air on a transparent substance at an angle of 58° with the normal. The reflected and refracted rays are observed to be mutually perpendicular. (a) What is the index of refraction of the transparent substance? (b) What is the critical angle for total internal reflection in this substance?