Optics Final Exam
TTVN Optics, Spring 2011

D. Craig

April 29, 2011

The following problems all have equal weight. Please submit this to `dcraig@wtamu.edu` (or by hand) by May 10.

1. A point light source S in figure 1 emits light of wavelength 500 nm in air. A and B are two points 1 cm apart on a screen 100 cm from S. (a) How many more waves are there in path SB than in path SA? (b) A plate of glass of index 1.50 is inserted in the path SA, with its faces normal to SA. What thickness of glass is required, if the number of waves in the path SA is equal to the number in SB?

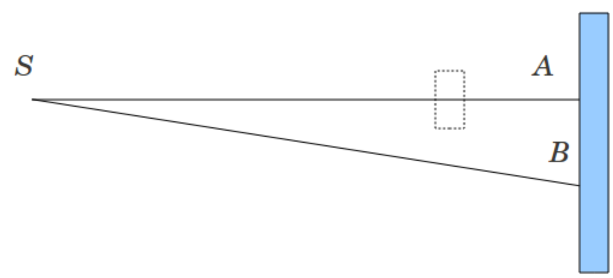

Figure 1: Figure for problem 1.

2. A ray of light is incident on the left vertical face of a glass cube of index 1.5, as shown in fig. 2. The plane of incidence is in the plane of the paper, and the cube is surrounded by water. At what maximum angle must the ray be incident on the left vertical surface of the cube if total internal reflection is to occur at the top surface?

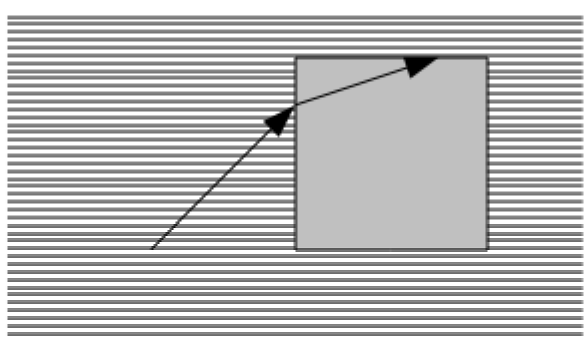

Figure 2: A glass cube immersed in water.

3. A small tropical fish is at the center of a spherical fish bowl 30 cm in diameter. The bowl is full of water. Find (a) the position and (b) the lateral magnification of the image of the fish, seen by an observer outside the bowl. The effect of the thin glass walls of the bowl may be neglected.

4. Before it was common to make multi-element lenses, astronomers would limit chromatic aberration by using long-focus systems. Suppose you are a 17th-century astronomer, and your coppersmith can make you a tube for a refractor that will accommodate a focal length of 4.0 m. You have a crown glass blank ($n = 1.52$) to grind to a single-element lens of diameter 150 mm.
   (a) If you make a biconvex lens with the same radius of curvature on both sides, what is that radius of curvature? Remember to follow the sign conventions!
   (b) If you make a plano-convex lens (typically used with the curved side out) what will be the radius of curvature of the curved side?
   (c) What is the $f/\#$ for the system? If you use an eyepiece of focal length 50 mm to look at Mars, what is the angular magnification?
5. Your text makes the statement that "had the pressure of sunlight exerted on the the Viking spacecraft during its journey been neglected, it would have missed Mars by about 15 000 km." Roughly confirm this as follows:
   The mass of the spacecraft was approximately 2000 kg. Its solar panels had an area of about $16\,\text{m}^2$, and the spacecraft "bus" probably contributed about another $4\,\text{m}^2$. The transit time to Mars was about 260 days.
   At the Earth's orbit, the irradiance of light from the Sun is $1400\,\text{W/m}^2$. Mars is about 1.52 Earth's distance from the Sun.
   Estimate
   (a) The light pressure on the spacecraft, and the total force on the spacecraft. It was not totally reflective, so use some average of the pressure for a perfect reflector and a perfect absorber.
   (b) The acceleration due to sunlight, the total velocity change this could impart in 260 days, and the displacement this would produce, ignoring gravity and the orbital mechanics.[1] Use an average solar flux for the trip, or even just try the Earth-orbit value. Remember this is a back-of-the-envelope estimate.
6. A giant squid has an eye of diameter as much as 25 cm. I am not sure of the size of the pupil, but let's suppose a squid eye has pupil that makes a round aperture of diameter 5 cm. For blue light of wavelength 480 nm, what will be the theoretical resolution of the squid eye? (In reality, it is probably lower, since the squid lives at great depths and its retinal neurons are probably large to respond quickly to dim light.)
7. Suppose that the light used in a Young's double slit experiment consists of a mixture of two wavelengths λ_1 and λ_2, almost equal to each other. Derive an expression for the difference of these wavelengths such that one of the maxima for one wavelength is located is located at the position of a neighboring intensity minimum of the other.
8. Find the thickness of a plane soap film of refractive index 1.33 for a strong first-order reflection of red light at 656 nm for normal incidence. What is the wavelength of the light inside the film?
9. Two pieces of plane plate glass are placed together with a piece of paper between the two at one edge. When viewed at normal incidence with light of wavelength 589.3 nm, eight interference fringes per centimeter are observed. Find the angle of the wedge-shaped air film between the plates.

[1] The actual shift would depend on the details of the orbit, and probably be almost orthogonal to the direction of light pressure. But just calculating the displacement ignoring other factors gives us a plausible value for comparison