Homework Set 8

Solutions to these problems are due at the start of lecture on May 28. Problem 7 is worth 10 points—twice as much as each of the other problems.

1. If Young’s double slit experiment were submerged in water, how would the interference pattern change? (The index of refraction of water is about 1.33.)

2. For diffraction by a single slit, what is the effect of (a) increasing the slit width, and (b) increasing the wavelength? That is, describe, qualitatively, how the resulting interference pattern on a screen would change.

3. White light strikes (a) a diffraction grating, and (b) a prism. In each case, a rainbow pattern appears on a wall above where the incident beam would strike the wall if the grating (or the prism) were not there. What is the color at the top of the rainbow in each case?

4. Page 858, Problem 2. Add: If the screen is 10 meters from the slits, what is the separation (in cm) between two adjacent fringes on the screen?

5. Page 859, Problem 8. (This is listed as a ** problem, but I think it’s easier than this implies.)

6. How far must the adjustable mirror of a Michelson interferometer (see page 840) be moved if 1000 fringes of light from a helium-neon laser are to pass by a reference line? The wavelength of this light is 6328 Å. [Ans: about 0.316 mm.]

7. In lecture we mentioned briefly the phenomenon of a pin-hole camera, in which a small hole, of diameter $D$, is placed between an object and a screen. It is a simple setup: No lenses are involved. If the hole is neither too large nor too small, a remarkably sharp (inverted) image of the object appears on the screen.

For example, I mentioned that on a sunny clear day, when you walk around on the campus under trees, with the sun more-or-less overhead, you will see circles of light on the ground that are images of the sun’s disk. In this case, the “pin-holes” are small openings formed by leaves in the trees high above, while the “screen” is the surface of the path on which you walk. If you look at those circles, you will see that some of them are bright but have fuzzy boundaries, while others are less bright, but have quite sharp boundaries. The fuzzy ones are formed by pin-holes that are too large, while the sharpest ones (which are less bright) are formed by pin-holes of just the right size. Pin-holes that are too small will produce spread-out diffraction patterns from point sources of light as described, for example, in Section 27.6 of the text. A pin-hole of ideal size will have a diameter of the order of $\sqrt{\lambda L}$, where $\lambda$ is a wavelength of visible light (around 0.5 micron), and $L$ is the distance of the pin-hole from the screen.
Here are some relevant questions: (a) What angle (in radians) is subtended by the sun’s disk at the surface of the earth? What is this angle in degrees? [Ans: about 0.53°]. (The relevant data are inside the front cover of our text.) (b) What is the ideal size of a pin-hole if it will be a distance 30 meters from the screen? [Ans: about 4 mm] (c) How far apart will two points on the sun’s disk be in order to be just resolved by a pin-hole of ideal diameter? Express your answer first as an angle in degrees (see Eq. 27.6 on page 847—you will have to convert radians to degrees), and then as a fraction of the total diameter of the sun’s disk.

8. A muon (µ meson) is an elementary particle that has an average lifetime when at rest equal to 2.2 microseconds. (a) If it is traveling at 0.96 of the speed of light, how long does it take to decay? (b) How long would it take to decay if it traveled at 0.999 of the light speed? [Ans: about 49 microseconds.] (c) How far would the muon travel at 0.96c before it decayed?

9. Suppose the average human lifetime (at rest) is 100 years. How fast would he have to travel (moving at constant speed) in order to live for 200 years?