Physics 2220 (Schroeder) Name ______________________________
fall 2005

Problem Set 10

(due Monday, November 7)

1. Suppose that a double-slit experiment is performed with blue-green light of wavelength 500 nm. The slits are 1.2 mm apart, and the viewing screen is 5.4 m from the slits. How far apart are the points of maximum brightness?

2. Two small antennas separated by 2.0 m are emitting radio waves in phase with a wavelength of 0.50 m. A detector moves in a large circular path around the sources in a plane containing them. Without written calculation, find how many points of maximum intensity it detects.

3. If the distance between the first and tenth dark spots of a double-slit pattern is 18 mm and the slits are separated by 10.15 mm with the screen 50 cm from the slits, what is the wavelength of the light used?

4. Does the spacing between fringes in a two-slit interference pattern increase, decrease, or remain the same if (a) the slit separation is increased, (b) the color of the light is switched from red to blue, and (c) the whole apparatus is submerged in cooking sherry? (d) Describe some features of the pattern that would result from illuminating the slits with white light.

5. Consider the interference pattern produced by monochromatic light incident on *three* evenly spaced slits in a screen. Let d be the distance between any two adjacent slits, so the distance between the ones on the ends is $2d$. In this problem you will derive some properties of the interference pattern produced in this situation. This will give you a chance to think carefully about the derivation of the interference conditions, examining how each step must be modified when there are three slits instead of two. You may make all the same assumptions and approximations as in the two-slit case, but be sure to state these clearly in your solution.

   (a) Using a sketch similar to the one used in class for two slits, show that the condition for constructive interference from all three slits is the same as for two slits: $d\sin\theta = m\lambda$. Argue that where this condition is met, the pattern on the viewing screen is brighter than anywhere else.

   (b) In the case of two-slit interference, the condition for *destructive* interference is $d\sin\theta = (m+\frac{1}{2})\lambda$. Argue that when there are three sources, this same condition does *not* give total destructive interference. This implies that points halfway between the brightest places are not completely dark.

6. Light entering a diffraction grating contains both red and green components, so that part of the pattern produced by the grating consists of a red line and a green line, near each other but separated by a gap. Suppose, now, that we increase the number of grooves in the grating, perhaps by removing some tape that covered part of it. (a) Would the widths of the lines increase, decrease, or remain the same? (b) Would the

separation between the lines increase, decrease, or remain the same? (c) Would the lines shift toward the red, shift toward the green, or remain in place?

7. For the same situation as in the previous question, suppose now that we instead increase the spacing between the grooves in the grating (i.e., substitute a different grating with grooves farther apart). Answer parts (a) through (c) for this change.

8. Estimate the spacing between grooves on a compact disk, as follows: Shine a light down vertically on the CD, and observe the angle at which you see the first-order spectrum as you look at the disk. Have a friend help you measure this angle with a protractor. The angle will, of course, depend on the color of light you observe. Pick any color, and look up its wavelength in your text. For greater accuracy, you may wish to repeat the exercise for several different colors. (Note: The CD acts as a diffraction grating for reflected light, not transmitted light. However, you may consider each ridge on the disk to be a light source, analogous to a slit in a conventional grating. Thus, the same formulas apply to both.)

9. Bright light of wavelength 585 nm (in air) is incident perpendicularly on a soap film ($n = 1.33$) of thickness 1.21 μm, suspended in air. Is the light reflected by the two surfaces of the film closer to interfering fully destructively or fully constructively?

10. A lens with index of refraction greater than 1.30 is coated with a thin transparent film of index 1.30 to eliminate the reflection of red light (680 nm) incident perpendicularly on the lens. What minimum film thickness is needed?

11. A plane wave of monochromatic light is incident normally on a uniformly thin film of oil that covers a glass plate. The wavelength of the source can be varied continuously. Fully destructive interference of the reflected light is observed for wavelengths of 500 nm and 700 nm and for no wavelengths in between. If the index of refraction of the oil is 1.30 and that of the glass is 1.50, find the thickness of the film of oil.

12. Draw a careful sketch of the diffraction pattern produced when monochromatic light passes through a single slit and then hits a viewing screen some distance away. If the slit is 0.022 mm wide and the first diffraction minimum is at an angle of 1.8° from the direction of the incident light, what is the wavelength?

Study Guide

In a two-slit interference pattern, the positions of the bright spots ("constructive interference") are given by

$$d \sin \theta = p\lambda,$$

where d is the distance between the slits, θ is the angle measured relative to straight-ahead, λ is the wavelength, and p is any integer. You should understand why this formula is correct and be able to derive it using an appropriate diagram. The points of destructive interference (dark spots) lie half-way between the bright spots.

You should be able to determine which wavelengths of light will interfere constructively and destructively at a thin film. This entails understanding both the difference in path lengths for rays reflecting off the front and back surfaces and also any possible phase changes upon reflection (which depend on whether the material surrounding the film has a higher or lower index of refraction).

You should understand and be able to draw the diffraction pattern produced by a single slit. The formula for the angles of *de*structive interference is

$$a \sin \theta = m\lambda,$$

where a is the slit width and m is any integer other than zero. You should be able to derive this formula using an appropriate diagram.