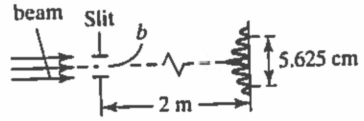

Figure 11-19 Problem 11-3.

11-4 In viewing the far-field diffraction pattern of a single slit illuminated by a discrete-spectrum source with the help of absorption filters, one finds that the fifth minimum of one wavelength component coincides exactly with the fourth minimum of the pattern due to a wavelength of 620 nm. What is the other wavelength?

11-5 Calculate the rectangular slit width that will produce a central maximum in its far-field diffraction pattern having an angular breadth of 30°, 45°, 90°, and 180°. Assume a wavelength of 550 nm.

11-6 Consider the far-field diffraction pattern of a single slit of width 2.125 μm when illuminated normally by a collimated beam of 550-nm light. Determine (a) the angular radius of its central peak and (b) the ratio I/I_0 at points making an angle of $\theta = 5°$, 10°, 15°, and 22.5° with the axis.

11-7 **a.** Find the values of β for which the fourth and fifth secondary maxima of the single-slit diffraction pattern occur. (See the discussion surrounding Figure 11-3.)
b. Find the ratio of the irradiance of the maxima of part (a) to the irradiance at the central maximum of the single-slit diffraction pattern.

11-8 Compare the relative irradiances of the first two secondary maxima of a circular diffraction pattern to those of a single-slit diffraction pattern.

11-9 The Lick Observatory has one of the largest refracting telescopes, with an aperture diameter of 36 in. and a focal length of 56 ft. Determine the radii of the first and second bright rings surrounding the Airy disc in the diffraction pattern formed by a star on the focal plane of the objective. See Figure 11-8b.

11-10 A telescope objective is 12 cm in diameter and has a focal length of 150 cm. Light of mean wavelength 550 nm from a distant star enters the scope as a nearly collimated beam. Compute the radius of the central disk of light forming the image of the star on the focal plane of the lens.

11-11 Suppose that a CO_2 gas laser emits a diffraction-limited beam at wavelength 10.6 μm, power 2 kW, and diameter 1 mm. Assume that, by multimoding, the laser beam has an essentially uniform irradiance over its cross section. Approximately how large a spot would be produced on the surface of the moon, a distance of 376,000 km away from such a device, neglecting any scattering by the earth's atmosphere? What will be the irradiance at the lunar surface?

11-12 Assume that a 2-mm-diameter laser beam (632.8 nm) is diffraction limited and has a constant irradiance over its cross section. On the basis of spreading due to diffraction alone, how far must it travel to double its diameter?

11-13 Two headlights on an automobile are 45 in. apart. How far away will the lights appear to be if they are just resolvable to a person whose nocturnal pupils are just 5 mm in diameter? Assume an average wavelength of 550 nm.

11-14 Assume that the pupil diameter of a normal eye typically can vary from 2 to 7 mm in response to ambient light variations.
a. What is the corresponding range of distances over which such an eye can detect the separation of objects 1 mm apart?
b. Experiment to find the range of distances over which you can detect the separation of lines placed 1 mm. apart. Use the results of your experiment to estimate the diameter range of your own pupils.

11-15 A double-slit diffraction pattern is formed using mercury green light at 546.1 nm. Each slit has a width of 0.100 mm. The pattern reveals that the fourth-order interference maxima are missing from the pattern.
a. What is the slit separation?
b. What is the irradiance of the first three orders of interference fringes, relative to the zeroth-order maximum?

11-16 **a.** Show that the number of bright fringes seen under the central diffraction peak in a Fraunhofer double-slit pattern is given by $2(a/b) - 1$, where a/b is the ratio of slit separation to slit width.
b. If 13 bright fringes are seen in the central diffraction peak when the slit width is 0.30 mm, determine the slit separation.

11-17 **a.** Show that in a double-slit Fraunhofer diffraction pattern, the ratio of widths of the central diffraction peak to the central interference fringe is $2(a/b)$, where a/b is the ratio of slit separation to slit width. Notice that the result is independent of wavelength. peak width — interference
b. Determine the peak-to-fringe ratio, fringe in particular when $a = 10b$.

peak width : interference
fringe width : diffraction

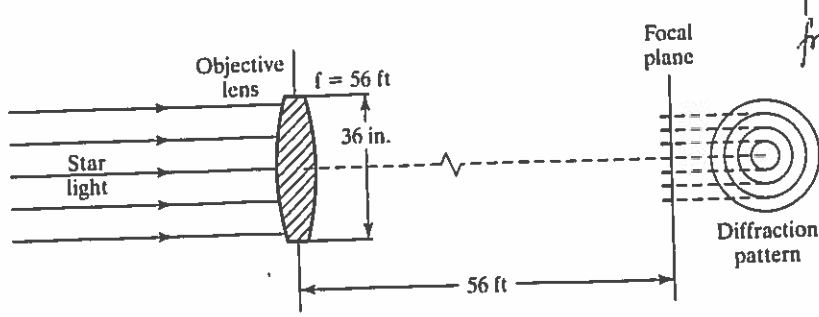

Figure 11-20 Problem 11-9.

11-18 Calculate by integration the irradiance of the diffraction pattern produced by a three-slit aperture, where the slit separation a is three times the slit width b. Make a careful sketch of I versus $\sin\theta$ and describe properties of the pattern. Also show that your results are consistent with the general result for N slits, given by Eq. (11-32).

11-19 Make a rough sketch for the irradiance pattern from seven equally spaced slits having a separation-to-width ratio of 4. Label points on the x-axis with corresponding values of α and β.

11-20 A 10-slit aperture, with slit spacing five times the slit width of 1×10^{-4} cm, is used to produce a Fraunhofer diffraction pattern with light of 435.8 nm. Determine the irradiance of the principal interference maxima of orders 1, 2, 3, 4, and 5 relative to the central fringe of zeroth order.

11-21 Show that one can arrive at Eq. (11-32) by taking the origin of coordinates at the midpoint of the central slit in an array where N is odd.

11-22 A rectangular aperture of dimensions 0.100 mm along the x-axis and 0.200 mm along the y-axis is illuminated by coherent light of wavelength 546 nm. A 1-m focal length lens intercepts the light diffracted by the aperture and projects the diffraction pattern on a screen in its focal plane. See Figure 11-21.

a. What is the distribution of irradiance on the screen near the pattern center as a function of x and y (in mm) and I_0, the irradiance at the pattern center?
b. How far from the pattern center are the first minima along the x and y directions?
c. What fraction of the I_0 irradiance occurs at 1 mm from the pattern center along the x- and y-directions?
d. What is the irradiance at the point ($x = 2$, $y = 3$) mm?

11-23 What is the angular half-width (from central maximum to first minimum) of a diffracted beam for a slit width of (a) λ; (b) 5λ; (c) 10λ?

11-24 A property of the Bessel function $J_1(x)$ is that, for large x, a closed form exists, given by

$$J_1(x) = \frac{\sin x - \cos x}{\sqrt{\pi x}}$$

Find the angular separation of diffraction minima far from the axis of a circular aperture.

11-25 We have shown that the secondary maxima in a single-slit diffraction pattern do not fall exactly halfway between minima, but are quite close. Assuming they are halfway:

a. Show that the irradiance of the mth secondary peak is given approximately by

$$I_m \cong I_0 \frac{1}{\left[\left(m + \frac{1}{2}\right)\pi\right]^2}$$

b. Calculate the percent error involved in this approximation for the first three secondary maxima.

11-26 Three antennas broadcast in phase at a wavelength of 1 km. The antennas are separated by a distance of $\frac{2}{3}$ km and each antenna radiates equally in all horizontal directions. Because of interference, a broadcast "beam" is limited by interference minima. How many well-defined beams are broadcast and what are their angular half-widths?

11-27 A collimated light beam is incident normally on three very narrow, identical slits. At the center of the pattern projected on a screen, the irradiance is I_{max}.

a. If the irradiance I_P at some point P on the screen is zero, what is the phase difference between light arriving at P from neighboring slits?
b. If the phase difference between light waves arriving at P from neighboring slits is π, determine the ratio I_P/I_{max}.
c. What is I_P/I_{max} at the first principal maximum?
d. If the average irradiance on the entire screen is I_{av}, what is the ratio I_P/I_{av} at the central maximum?

11-28 Draw phasor diagrams illustrating the principal maxima and zero irradiance points for a four-slit aperture.

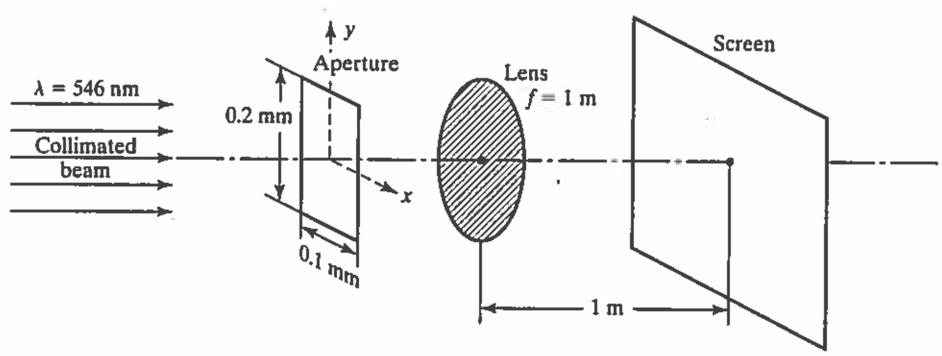

Figure 11-21 Problem 11-22.