67. A teacher stands well back from an outside doorway 0.88 m wide, and blows a whistle of frequency 750 Hz. Ignoring reflections, estimate at what angle(s) it is *not* possible to hear the whistle clearly on the playground outside the doorway.

68. If parallel light falls on a single slit of width D at a 30° angle to the normal, describe the diffraction pattern.

69. The wings of a certain beetle have a series of parallel lines across them. When normally incident 460-nm light is reflected from the wing, the wing appears bright when viewed at an angle of 51°. How far apart are the lines?

70. How many lines per centimeter must a grating have if there is to be no second-order spectrum for any visible wavelength?

71. Show that the second- and third-order spectra of white light produced by a diffraction grating always overlap. What wavelengths overlap exactly?

72. When yellow sodium light, $\lambda = 589$ nm, falls on a diffraction grating, its first-order peak on a screen 60.0 cm away falls 3.32 cm from the central peak. Another source produces a line 3.71 cm from the central peak. What is the wavelength of the new source? How many lines/cm are on the grating?

73. Light is incident on a diffraction grating with 8600 lines/cm, and the pattern is viewed on a screen 2.5 m from the grating. The incident light beam consists of two wavelengths, $\lambda_1 = 4.6 \times 10^{-7}$ m and $\lambda_2 = 6.8 \times 10^{-7}$ m. Calculate the linear distance between the first-order bright fringes of these two wavelengths on the screen.

74. What is the index of refraction of a clear material if a minimum of 150 nm thickness of it, when laid on glass, is needed to reduce reflection to nearly zero when light of 600 nm is incident normally upon it? Do you have a choice for an answer?

75. Monochromatic light of variable wavelength is incident normally on a thin sheet of plastic film in air. The reflected light is a minimum only for $\lambda = 512$ nm and $\lambda = 640$ nm in the visible spectrum. What is the thickness of the film ($n = 1.58$)? [*Hint*: assume successive values of m.]

76. Compare the minimum thickness needed for an antireflective coating ($n = 1.38$) applied to a glass lens in order to eliminate (*a*) blue (450 nm), or (*b*) red (700 nm) reflections for light at normal incidence.

77. What is the minimum (non-zero) thickness for the air layer between two flat glass surfaces if the glass is to appear dark when 640-nm light is incident normally? What if the glass is to appear bright?

78. Suppose you viewed the light *transmitted* through a thin film layered on a flat piece of glass. Draw a diagram, similar to Fig. 24–30 or 24–36, and describe the conditions required for maxima and minima. Consider all possible values of index of refraction. Discuss the relative size of the minima compared to the maxima and to zero.

79. At what angle above the horizon is the Sun when light reflecting off a smooth lake is polarized most strongly?

80. At what angle should the axes of two Polaroids be placed so as to reduce the intensity of the incident unpolarized light by an additional factor (after the first Polaroid cuts it in half) of (*a*) 4, (*b*) 10, (*c*) 100?

81. Unpolarized light falls on two polarizer sheets whose transmission axes are at right angles. A third polarizer is placed between the first two so that its axis makes a 62° angle with the axis of the first polarizer. (*a*) What fraction of the incident light intensity is transmitted? (*b*) What if the third polarizer is in front of the other two?

82. Four polarizers are placed in succession with their axes vertical, at 30° to the vertical, at 60° to the vertical, and at 90° to the vertical. (*a*) Calculate what fraction of the incident unpolarized light is transmitted by the four polarizers. (*b*) Can the transmitted light be *decreased* by removing one of the polarizers? If so, which one? (*c*) Can the transmitted light intensity be extinguished by removing polarizers? If so, which one(s)?

83. A laser beam passes through a slit of width 1.0 cm and is pointed at the Moon, which is approximately 380,000 km from the Earth. Assume the laser emits waves of wavelength 630 nm (the red light of a He-Ne laser). Estimate the width of the beam when it reaches the Moon.

84. A series of polarizers are each placed at a 10° interval from the previous polarizer. Unpolarized light is incident on this series of polarizers. How many polarizers does the light have to go through before it is $\frac{1}{4}$ of its original intensity?

85. A thin film of soap ($n = 1.34$) coats a piece of flat glass ($n = 1.52$). How thick is the film if it reflects 643-nm red light most strongly when illuminated normally by white light?

86. Consider two antennas radiating 6.0-MHz radio waves in phase with each other. They are located at points S_1 and S_2, separated by a distance $d = 175$ m, Fig. 24–61. What are the first three points on the y axis where the signals from the two sources will be out of phase (crests of one meet troughs of the other)?

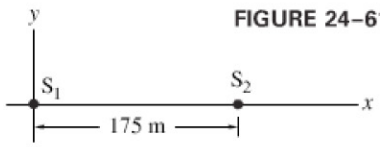

FIGURE 24–61 Problem 86.

87. A parallel beam of light containing two wavelengths, 420 nm and 650 nm, enters a silicate flint glass equilateral prism (Fig. 24–58). (*a*) What is the angle between the two beams leaving the prism? (*b*) Repeat part (*a*) for a diffraction grating with 6200 lines/cm.

* 88. A Lucite planoconvex lens has one flat surface and one with $R = 18.4$ cm. It is used to view an object, located 66.0 cm away from the lens, which is a mixture of red and yellow. The index of refraction of the Lucite is 1.5106 for red light and 1.5226 for yellow light. What are the locations of the red and yellow images formed by the lens? [*Hint*: see Section 23–10.]

Answers to Exercises

A: 2.5 mm.
B: Narrower.
C: 4900 lines/cm.
D: A.
E: Zero for both (*a*) and (*b*), because the two successive polarizers at 90° cancel all light. The 45° Polaroid must be inserted *between* the other two if transmission is to occur.