1.A: Diffraction (Answers)

Check Your Understanding

4.1. $17.8^\circ, 37.7^\circ, 66.4^\circ$; no

4.2. $74.3^\circ, 0.0083 I_0$

4.3. From $dsin\theta = m\lambda$, the interference maximum occurs at 2.87° for $m = 20$. From Equation 4.1, this is also the angle for the second diffraction minimum. (Note: Both equations use the index m but they refer to separate phenomena.)

4.4. $3.332 \times 10^{-6} m$ or 300 lines per millimeter

4.5. $8.4 \times 10^{-4} rad$, 3000 times broader than the Hubble Telescope

4.6. 38.4° and 68.8°; Between $\theta = 0^\circ \rightarrow 90^\circ$, orders 1, 2, and 3, are all that exist.

Conceptual Questions

1. The diffraction pattern becomes wider.

3. Walkie-talkies use radio waves whose wavelengths are comparable to the size of the hill and are thus able to diffract around the hill. Visible wavelengths of the flashlight travel as rays at this size scale.

5. The diffraction pattern becomes two-dimensional, with main fringes, which are now spots, running in perpendicular directions and fainter spots in intermediate directions.

7. The parameter $\beta = \phi/2$ is the arc angle shown in the phasor diagram in Figure 4.7. The phase difference between the first and last Huygens wavelet across the single slit is 2β and is related to the curvature of the arc that forms the resultant phasor that determines the light intensity.

9. blue; The shorter wavelength of blue light results in a smaller angle for diffraction limit.

11. No, these distances are three orders of magnitude smaller than the wavelength of visible light, so visible light makes a poor probe for atoms.

13. UV wavelengths are much larger than lattice spacing in crystals such that there is no diffraction. The Bragg equation implies a value for sinθ greater than unity, which has no solution.

15. Image will appear at slightly different location and/or size when viewed using 10 shorter wavelength but at exactly half the wavelength, a higher-order interference reconstructs the original image, different color.

Problems

17. a. 33.4°;

b. no

19. a. $1.35 \times 10^{-6} m$;

b. 69.9°

21. 750 nm

23. 2.4 mm, 4.7 mm

25. a. 1.00λ;

b. 50.0λ;

c. 1000λ

27. 1.92 m

29. 45.1°

31. $I/I_0 = 2.2 \times 10^{-5}$

33. $0.63 I_0, 0.11 I_0, 0.0067 I_0, 0.0062 I_0, 0.00088 I_0$

35. 0.200

37. 3

39. 9

41. 5.97°

43. 8.99×10^3

45. 707 nm

47. a. $11.8^\circ, 12.5^\circ, 14.1^\circ, 19.2^\circ$;

b. $24.2^\circ, 25.7^\circ, 29.1^\circ, 41.0^\circ$; c. Decreasing the number of lines per centimeter by a factor of x means that the angle for the x-order maximum is the same as the original angle for the first-order maximum.

49. a. using $\lambda = 700nm, \theta = 5.0^\circ$;

b. using $\lambda = 460nm, \theta = 3.3^\circ$

51. a. 26,300 lines/cm;

b. yes;

c. no

53. $1.13 \times 10^{-2} m$

55. 107 m

57. a. $7.72 \times 10^{-4} rad$;

b. 23.2 m;

c. 590 km

59. a. $2.24 \times 10^{-4} rad$;

b. 5.81 km;

c. 0.179 mm;

d. can resolve details 0.2 mm apart at arm's length

61. $2.9 \mu m$

63. 6.0 cm

65. 7.71 km

67. 1.0 m

69. 1.2 cm or closer

71. no

73. 0.120 nm

75. 4.51°

77. 13.2°

Additional Problems

79. a. 2.2 mm;

b. 0.172°, second-order yellow and third-order violet coincide

81. 2.2 km

83. 1.3 cm

85. a. 0.28 mm;

b. 0.28 m;

c. 280 m;

d. 113 km

87. 33 m

89. a. vertically;

b. $\pm 20^{\circ}, \pm 44^{\circ}$;

c. $0, \pm 31^{\circ}, \pm 60^{\circ}$;

d. 89 cm;

e. 71 cm

91. 0.98 cm

93. $I/I_0 = 0.041$

95. 340 nm

97. a. 0.082 rad and 0.087 rad;

b. 480 nm and 660 nm

99. two orders

101. yes and N/A

103. 600 nm

105. a. $3.4 \times 10^{-5^{\circ}}$;

b. 51°

107. 0.63 m

109. 1

111. $0.17 mW/cm^2$ for $m = 1$ only, no higher orders

113. 28.7°

115. a. 42.3 nm;

b. This wavelength is not in the visible spectrum.

c. The number of slits in this diffraction grating is too large. Etching in integrated circuits can be done to a resolution of 50 nm, so slit separations of 400 nm are at the limit of what we can do today. This line spacing is too small to produce diffraction of light.

117. a. 549 km;

b. This is an unreasonably large telescope.

c. Unreasonable to assume diffraction limit for optical telescopes unless in space due to atmospheric effects.

Challenge Problems

119. a. $I = 0.00500 I_0, 0.00335 I_0$

b. $I = 0.00500 I_0, 0.00335 I_0$

121. 12,800

123. $1.58 \times 10^{-6} m$