Chapter 28 Solutions - 3, 5, 7, 9, 11, 12, 14, 17, 20, 21, 26, 28

3. This problem refers to Sec 28.1, interference between waves. The waves of the two identical speakers, on at $x_1 = 0$ and the other at $x_2 > 0$, can add constructively (waves are in phase with each other) or destructively (waves are out of phase with each other). The person at $x_p = 20$m $>> x_2$ hears loudest sounds when $x_2 - x_1 = \lambda, 2\lambda, 3\lambda$ …… Thus, with $\lambda = 70$ cm = 0.7 m and $x_2 < 5$m, the second speaker positions can be 0.0m, 0.7m; 1.4m; 2.1m; 2.8m, 3.5m, 4.2m; 4.9m .

5. Again, this problem refers to Sec 28.1, recognizing now that the distance between the two speakers $x_2 - x_1 = 1.4$ m should be such that an odd number of half-wave lengths should fit between the two speakers:

$$x_2 - x_1 = \frac{\lambda_1}{2}, \frac{3\lambda_2}{2}, \frac{5\lambda_3}{2}, \frac{7\lambda_4}{2}, etc..$$

Thus, $\lambda_1 = 2.8$m; $\lambda_2 = 0.93$m; $\lambda_3 = 0.56$ m, $\lambda_4 = 0.4$m

7. This problem refers to Sec. 28.3, (see Fig 28.3 and 28.4). The slits are a distance d = 0.070mm = 7 x 10^{-5}m apart. The screen is at h = 2m.
   a. The zeroth order fringe is the center of the pattern of fringes: by definition it is at x =0, and it is directly below the middle of the two slits. Therefore, the distances from the zeroth order fringe to the slits are the same: the difference is 0.
   b. Difference for the first bright fringe x is such that

   $$\frac{x}{h} = \frac{\Delta S}{d} = \frac{\lambda}{d} \rightarrow x_1 = \frac{\lambda h}{d} = 1.56\,cm$$

   c. $x_2 = 2x_1 = 3.12$ cm
   d. $x_3 = 3x_1 = 4.68$ cm

9. Again, as above, reference to Sec. 28.3. Slit separation d = 0.100 mm = 10^{-4}m. Slit-to-screen distance h=1.5m . Yellow light wavelength λ = 589 mm = 5.89 x 10^{-7}m.
   a. Distance x from zeroth order bright fringe to third **bright** fringe is such that path length difference ΔS = 3 λ, thus, with

   $$\frac{\Delta S}{d} = \frac{x}{h} \rightarrow x = \frac{(3\lambda)(h)}{d} = 2.65\,cm$$

   b. To third **dark** fringe, ΔS = λ/2, thus

   $$x = \frac{\Delta S}{d} h = 2.21\,cm$$

11. Once more, see Sec. 28.3. With 8000 lines, d = 1/8000 cm = 1.25 x 10^{-6} m.
   a. The angle $\theta_2 = 72^o$ for second order maximum, for which $\Delta S = 2\lambda$. Thus, with

   $$\sin\theta_2 = \frac{\Delta S}{d} = \frac{2\lambda}{d}$$
   $$\rightarrow \lambda = \frac{d}{2}\sin\theta_2 = 5.94\times10^{-7}\,m = 594\,nm$$

   b. For third order maximum we will have

   $$\sin\theta_3 = \frac{3\lambda}{d} = \frac{(3)(5.94\times10^{-7}\,m)}{1.25\times10^{-6}\,m} = 1.43 > 1 : impossible$$ *[Third order maximum is invisible.]*

12. See Sec 28.4. A helium-neon laser has λ = 633nm = 6.33 x 10^{-7} m. First order maximum occurs at $\theta_1 = 52^o$, on each side of central maximum.
   a. Using Eq. (28.2) we can express the distance d between centers of grating lines:

   $$\lambda = d\sin\theta, \rightarrow d = \frac{\lambda}{\sin\theta_1} = 8.0\times10^{-7}\,m$$

   b. The number of grating lines per centimeter is simply

$$\frac{1}{d} = 1.24 \times 10^4 \, / cm$$

14. Diffraction grating has 9000 lines/cm, thus

$$d = \frac{1}{9000 \text{ lines/cm}} \quad \text{or} \quad d = 1.11 \times 10^{-6} \, m$$

Light's wavelength λ = 582 mm = 5.82 x 10^{-7} m.

a. Angle θ_1, for first order maximum occurs when, $\lambda = d \sin \theta_1$

$$\rightarrow \sin \theta_1 = \frac{\lambda}{d} \rightarrow \theta_1 = 31.6°$$

b. Second order maximum at θ_2 such that,

$$\sin \theta_2 = \frac{2x}{d} \rightarrow \theta_2 = impossible!$$

[$\sin\theta_2 = 1.049 > 1$]

17. For a single slit case, see Fig 28.9. Wavelength of the light is λ = 5.79 x 10^{-7}m, and the slit width w = 0.020 mm = 2 x 10^{-5} m. Thus, the half-width angle of the bright spot is $\sin \theta_c = \lambda / w$, thus

$$\theta_c = \sin^{-1}\left(\frac{\lambda}{w}\right) = 1.66°$$

20. This problem refers to Sec. 28.6. The angular resolution θ_c, with which the Yerkes telescope can see spots on the Moon is given by

$$\sin \theta_c = 1.22 \lambda / D = 1.22 \, \frac{5.5 \times 10^{-7} m}{1.02 m}$$

The linear resolution is now

$$d = R_{EM} \sin \theta_c = R_{EM}\left(1.22 \frac{\lambda}{D}\right) = (3.84 \times 10^8 \, m)\left(1.22 \frac{5.5 \times 10^{-7} \, m}{1.02 m}\right)$$

$$d = 252.6 m$$

21. Again, Sec 28.6 is involved. Now lens diameter D = 0.25 cm = 2.5 x 10^{-3}m, and the light's wavelength is λ =500 mm = 5 x 10^{-7}m. If we want millimeter lines to still be clearly discernible, then d = 1mm = 10^{-3}m. Now, what should be distance h? It is obvious that,

$$\sin \theta_c = 1.22 \frac{\lambda}{D} = \frac{d}{h}$$

$$\text{or:} \quad h = \frac{dD}{1.22\lambda} = \frac{(10^{-3} m)(2.5 \times 10^{-3} m)}{(1.22)(5 \times 10^{-7} m)}$$

$$h = 4.10 m$$

26. Refer to Fig 28.11. The separation x, given the strongest reflections, should be such that $x = n \lambda / 2$ (n = 1, 2, 3, 4, …) with λ the light's wavelength, λ = 4.4 x 10^{-7}m.

For the first four strongest reflections, x = (2.2, 4.4, 6.6, 8.8) x 10^{-7} m.

28. Again, Fig 28.11. Now, for near zero reflection ("near" became reflection not transmission perfect from second glass plate!) $x = (n + 1/2) \lambda / 2$ gap widths, λ = 5.46 x 10^{-7}m.

For the first four zero reflection distances, x = (1.1, 3.3, 5.5, 7.7) x 10^{-7} m