The formula $\sin\theta = m\lambda/d$ for constructive interference also holds for a **diffraction grating**, which consists of many parallel slits or lines, separated from each other by a distance d. The peaks of constructive interference are much brighter and sharper for a diffraction grating than for the simple two-slit apparatus.

A diffraction grating (or a prism) is used in a **spectroscope** to separate different colors or to observe **line spectra**; for a given order m, θ depends on λ. Precise determination of wavelength can be done with a spectroscope by careful measurement of θ.

Diffraction refers to the fact that light, like other waves, bends around objects it passes, and spreads out after passing through narrow slits. This bending gives rise to a **diffraction pattern** due to interference between rays of light that travel different distances.

Light passing through a very narrow slit of width D (on the order of the wavelength λ) will produce a pattern with a bright central maximum of half-width θ given by

$$\sin\theta = \frac{\lambda}{D}, \tag{24–3a}$$

flanked by fainter lines to either side.

Light reflected from the front and rear surfaces of a thin film of transparent material can interfere. A phase change of $180°$ $\left(\frac{1}{2}\lambda\right)$ occurs when the light reflects at a surface where the index of refraction increases. Such **thin-film interference** has many practical applications, such as lens coatings and Newton's rings.

In **unpolarized light**, the electric field vectors oscillate in all transverse directions. If the electric vector oscillates only in one plane, the light is said to be **plane-polarized**. Light can also be partially polarized.

When an unpolarized light beam passes through a **Polaroid** sheet, the emerging beam is plane-polarized. When a light beam is polarized and passes through a Polaroid, the intensity varies as the Polaroid is rotated. Thus a Polaroid can act as a **polarizer** or as an **analyzer**.

The intensity of a plane-polarized light beam incident on a Polaroid is reduced by the factor

$$I = I_0\cos^2\theta, \tag{24–5}$$

where θ is the angle between the axis of the Polaroid and the initial plane of polarization.

Light can also be partially or fully **polarized by reflection**. If light traveling in air is reflected from a medium of index of refraction n, the reflected beam will be *completely* plane-polarized if the incident angle θ_p is given by

$$\tan\theta_p = n. \tag{24–6b}$$

The fact that light can be polarized shows that it must be a transverse wave.

Questions

1. Does Huygens' principle apply to sound waves? To water waves? Explain.
2. What is the evidence that light is energy?
3. Why is light sometimes described as rays and sometimes as waves?
4. We can hear sounds around corners, but we cannot see around corners; yet both sound and light are waves. Explain the difference.
5. If Young's double-slit experiment were submerged in water, how would the fringe pattern be changed?
6. Monochromatic red light is incident on a double slit, and the interference pattern is viewed on a screen some distance away. Explain how the fringe pattern would change if the red light source is replaced by a blue light source.
7. Two rays of light from the same source destructively interfere if their path lengths differ by how much?
8. Why was the observation of the double-slit interference pattern more convincing evidence for the wave theory of light than the observation of diffraction?
9. Compare a double-slit experiment for sound waves to that for light waves. Discuss the similarities and differences.
10. Why doesn't the light from the two headlights of a distant car produce an interference pattern?
11. Suppose white light falls on the two slits of Fig. 24–7, but one slit is covered by a red filter (700 nm) and the other by a blue filter (450 nm). Describe the pattern on the screen.
12. When white light passes through a flat piece of window glass, it is not broken down into colors as it is by a prism. Explain.
13. For both converging and diverging lenses, discuss how the focal length for red light differs from that for violet light.
14. A ray of light is refracted through three different materials (Fig. 24–55). Rank the materials according to their index of refraction, least to greatest.

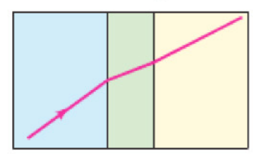

FIGURE 24–55 Question 14.

15. Hold one hand close to your eye and focus on a distant light source through a narrow slit between two fingers. (Adjust your fingers to obtain the best pattern.) Describe the pattern that you see.
16. What happens to the diffraction pattern of a single slit if the whole apparatus is immersed in (*a*) water, (*b*) a vacuum, instead of in air.
17. For diffraction by a single slit, what is the effect of increasing (*a*) the slit width, and (*b*) the wavelength?
18. What is the difference in the interference patterns formed (*a*) by two slits 10^{-4} cm apart, (*b*) by a diffraction grating containing 10^4 lines/cm?
19. For a diffraction grating, what is the advantage of (*a*) many slits, (*b*) closely spaced slits?
20. White light strikes (*a*) a diffraction grating, and (*b*) a prism. A rainbow appears on a wall just below the direction of the horizontal incident beam in each case. What is the color of the top of the rainbow in each case? Explain.
21. For light consisting of wavelengths between 400 nm and 700 nm, incident normally on a diffraction grating, for what orders (if any) would there be overlap in the observed spectrum? Does your answer depend on the slit spacing?
22. Why are interference fringes noticeable only for a *thin* film like a soap bubble and not for a thick piece of glass, say?