

Chapter 24

Wave Optics

Quick Quizzes

1. (c). The fringes on the screen are equally spaced only at small angles where $\tan \theta \approx \sin \theta$ is a valid approximation.
2. (b). The space between successive bright fringes is proportional to the wavelength of the light. Since the wavelength in water is less than that in air, the bright fringes are closer together in the second experiment.
3. (b). The outer edges of the central maximum occur where $\sin \theta = \pm \lambda/a$. Thus, as a , the width of the slit, becomes smaller, the width of the central maximum will increase.
4. The compact disc. The tracks of information on a compact disc are much closer together than on a phonograph record. As a result, the diffraction maxima from the compact disc will be farther apart than those from the record.

Answers to Even Numbered Conceptual Questions

2. The wavelength of light is extremely small in comparison to the dimensions of your hand, so the diffraction of light around obstacles the size of your hand is totally negligible. However, sound waves have wavelengths that are comparable to the dimensions of the hand or even larger. Therefore, significant diffraction of sound waves occurs around hand sized obstacles.
4. The wavelength of light traveling in water would decrease, since the wavelength of light in a medium is given by $\lambda_n = \lambda/n$, where λ is the wavelength in vacuum and n is the index of refraction of the medium. Since the positions of the bright and dark fringes are proportional to the wavelength, the fringe separations would decrease.
6. Every color produces its own interference pattern, and we see them superimposed. The central maximum is white. The first maximum is a full spectrum with violet on the inside and red on the outside. The second maximum is also a full spectrum, with red in it overlapping with violet in the third maximum. At larger angles, the light soon starts mixing to white again.
8. (a) Two waves interfere constructively if their path difference is either zero or some integral multiple of the wavelength; that is, if the path difference is $m\lambda$, where m is an integer. (b) Two waves interfere destructively if their path difference is an odd multiple of one-half of a wavelength; that is, if the path difference equals $\left(m + \frac{1}{2}\right)\lambda = (2m + 1)\frac{\lambda}{2}$.
10. The skin on the tip of a finger has a series of closely spaced ridges and swirls on it. When the finger touches a smooth surface, the oils from the skin will be deposited on the surface in the pattern of the closely spaced ridges. The clear spaces between the lines of deposited oil can serve as the slits in a crude diffraction grating and produce a colored spectrum of the light passing through or reflecting from the glass surface.
12. Suppose the index of refraction of the coating is intermediate between vacuum and the glass. When the coating is very thin, light reflected from its top and bottom surfaces will interfere constructively, so you see the surface white and brighter. Once the thickness reaches one-quarter of the wavelength of violet light in the coating, destructive interference for violet light will make the surface look red. Then other colors in spectral order (blue, green, yellow, orange, and red) will interfere destructively, making the surface look red, violet, and then blue. As the coating gets thicker, constructive interference is observed for violet light and then for other colors in spectral order. Even thicker coatings give constructive and destructive interference for several visible wavelengths, so the reflected light starts looking white again.
14. The reflected light is partially polarized, with the component parallel to the reflecting surface being the most intense. Therefore, the polarizing material should have its transmission axis oriented in the vertical direction in order to minimize the intensity of the reflected light from horizontal surfaces.

16. One way to produce interference patterns is to allow light to pass through very small openings. The opening between threads in a tautly stretched cloth like that in an umbrella is small enough for the effects to be observed.
18. Sound waves are longitudinal waves and cannot be polarized.
20. The first experiment. The separation between maxima is inversely proportional to the slit separation (see Eq. 24.5), so increasing the slit separation causes the distance between the two maxima to decrease.
22. The separations are greater in the second experiment when using red light having the longer wavelength.