Chapter 24: Questions

(4) 8 points  We can hear sounds around corners, but we cannot see around corners; yet both sound and light are waves. Explain the difference.

The main reason that we can hear sounds around corners, but not see around corners, is diffraction. Sound waves have very long wavelengths when compared to light waves, which makes diffraction effects much more obvious. Diffraction effects are very noticeable once the size of the object that the wave is diffracting around is about the same size as the wavelength of the wave. The wavelength of sound is on the order of 1 m, while the wavelength of light is on the order of 0.1 µm.

(A secondary reason is reflection. Sound waves reflect off of walls very well in a specular manner, and so can bounce around corners, but light deflects off of the walls in a very diffuse manner.)

(5) 8 points  If Young’s double-slit experiment were submerged in water, how would the fringe pattern be changed?

The wavelength of light in a medium such as water is decreased when compared to the wavelength in air. Thus, \( d \sin \theta = m \lambda \) says that \( \theta \) is decreased for a particular \( m \) and \( d \). This means that the bright spots on the screen are more closely packed together in water than in air.

(10) 8 points  Why doesn’t the light from the two headlights of a distant car produce an interference pattern?

The reason you do not get an interference pattern from the two headlights of a distant car is that they are not coherent light sources (they have random phases). Thus you cannot produce zones of destructive and constructive interference where the crests and troughs match up or the crests and crests match up. Also, the headlights are far enough apart that even if they were coherent, the interference pattern would be so tightly packed that it would not be observable with the unaided eye.

(17) 8 points  For diffraction by a single slit, what is the effect of increasing (a) the slit width, and (b) the wavelength?

For a singlet slit, the location of the minima (dark fringes) is \( \sin \theta = m \lambda / D \)

(a) From the above equation, we find that \( \theta \) is decreased for a particular \( m \) and \( \lambda \) when the width \( D \) is increased. This means that the dark fringes are more closely packed together for a wider slit.

(b) From the above equation, we find that \( \theta \) is increased for a particular \( m \) and \( D \) when the wavelength \( \lambda \) is increased. This means that the dark fringes are spread further apart for a longer wavelength.

(22) 8 points  Why are interference fringes noticeable only for a thin film like a soap bubble and not for a thick piece of glass, say?

Once the thickness of the film becomes more than a few wavelengths thick, several interference patterns become mixed together, and it is hard to see any individual effects. As a result, this effect is most noticeable when the thickness of the film is on the order of one wavelength.

(30) 8 points  Two polarized sheets rotated at an angle of 90° with respect to each other will not let any light through. Three polarized sheets, each rotated at an angle of 45° with respect to each other, will let some light through. What will happen to unpolarized light if you align four polarized sheets, each rotated at an angle of 30° with respect to the one in front of it?

The first sheet of polarizer will diminish the intensity of the incoming non-polarized light by 50%: \( I_1 = \frac{1}{2} I_0 \). The next polarizer will diminish the light again, but this time only by a factor of \( \cos^2 \theta \): \( I_2 = I_1 \cos^2 30° = \frac{3}{4} I_1 = \frac{3}{8} I_0 \). The next polarizer will diminish the light by the same factor: \( I_3 = \frac{3}{4} I_2 = \frac{9}{32} I_0 \). The last polarizer will again diminish the light by the same factor: \( I_4 = \frac{3}{4} I_3 = \frac{27}{128} I_0 = 0.211 I_0 \). Thus, about 21% of the light gets through these four polarizers.
(4) 8 points  
(II) A parallel beam of light from a He-Ne laser, with a wavelength 656 nm, falls on two very narrow slits 0.060 mm apart. How far apart are the fringes in the center of the pattern on a screen 3.6 m away?

For constructive interference, \( d \sin \theta = m\lambda \) where \( m = 0, 1, 2, 3, \ldots \). The center fringe \((m = 0)\) occurs at \( \theta = 0 \). The closest fringe one either side \((m = 1)\) occurs at

\[
\theta - \sin^{-1} \left( \frac{m\lambda}{d} \right) = \sin^{-1} \left( \frac{(1)(656 \times 10^{-9} m)}{0.060 \times 10^{-3} m} \right) = 0.626^\circ.
\]

The location \( y \) of a fringe on the screen is \( y = L \tan \theta \) where \( L \) is the distance to the screen. Therefore, the distance between adjacent fringes is

\[
y = L \tan \theta = (3.6 \text{ m}) \tan(0.626^\circ) = 3.93 \times 10^{-2} \text{ m}.
\]

(20) 10 points  
(II) A single slit 1.0 mm wide is illuminated by 450-nm light. What is the width of the central maximum (in cm) in the diffraction pattern on a screen 5.0 m away?

We can find the angle to the first minimum by

\[
\sin^{-1} \left( \frac{m\lambda}{D} \right) = \sin^{-1} \left( \frac{(1)(450 \times 10^{-9} m)}{1.0 \times 10^{-3} m} \right) = 0.0258^\circ.
\]

The location \( y \) of this minimum is

\[
y = L \tan \theta = (5.0 \text{ m}) \tan(0.0258) = 0.00225 \text{ m}.
\]

Thus, the width of the central maximum is

\[
2y = 0.0045 \text{ m} = 0.45 \text{ cm}.
\]

(30) 8 points  
(II) A grating has 8300 lines/cm. How many complete spectral orders can be seen (400 nm to 700 nm) when it is illuminated by white light?

Because the angle increases with wavelength, to have a complete order we use the largest wavelength. The maximum angle is 90\(^\circ\), so, using \( d \sin \theta = m\lambda \) and solving for \( m \) we find that

\[
m = \frac{d \sin \theta}{\lambda} = \frac{(1.20 \times 10^{-6} \text{ m}) \sin(90^\circ)}{700 \times 10^{-9} \text{ m}} = 1.7.
\]

Thus, only one full order can be seen on each side of the central white line.

(58) 10 points  
(II) Two polarizers are oriented at 40\(^\circ\) to each other and plane-polarized light is incident on them. If only 15% of the light gets through both of them, what was the initial polarization direction of the incident light?

If the initial intensity is \( I_0 \), then the intensity of the light through the two sheets is \( I = I_0 \cos^2 \theta_1 \cos^2 40^\circ \) where \( \theta_1 \) is the angle between the first polarizer’s transmission axis and the plane of polarization of the incoming wave. Using \( I = 0.15I_0 \), we can solve for \( \theta_1 \)

\[
\theta_1 = \cos^{-1} \left( \frac{I}{I_0 \cos^2 40^\circ} \right)^{1/2} = \cos^{-1} \left( \frac{0.15}{\cos^2 40^\circ} \right)^{1/2} = 59.6^\circ.
\]
Two sources of light waves of equal frequency and amplitude are shown. The magnitude of the electric field is represented by the light and dark areas. The lighter the spot, the greater is the magnitude of the electric field at that spot (position is given in arbitrary units). At the points indicated (A, B, C, D), is the interference of the waves from the two sources maximally constructive, completely destructive, or somewhere in between?

Examining each area, we conclude that:
A: completely destructive
B: somewhere in between
C: maximally constructive
D: maximally constructive

This animation models light hitting a single slit. You can change the width of the slit and use the protractor to measure angles (position is given in centimeters and angle is given in degrees). What is the wavelength of the light?

We have made the higher-order diffraction patterns easier to see by brightening them (since the higher-order terms are very dim).

Through trial and error, I calculated that the wavelength is approximately 660-710 nm. (Individual results may vary.)