CH 25-2 – Diffraction

Important Ideas

- **Index of Refraction** is a property of a medium that affects the speed of light in the medium. In a vacuum, the speed of light is $c = 3 \times 10^8$ m/s. In a medium of index n, the speed of light is less than c:

$$v = \frac{c}{n}$$

For a vacuum, $n = 1$. For all other materials, $n > 1$. The frequency of light is not changed by the medium. However, the wavelength of light in a medium of index n is shorter than the wavelength of the same light in a vacuum. In a medium of index n, the wavelength of light is

$$\lambda = \frac{\lambda_{vac}}{n}$$

where λ_{vac} is the wavelength of the same light if it is in a vacuum. This means that the color of monochromatic light (like light from a laser) is determined by its frequency, not its wavelength.

- Diffraction refers to the bending of waves as they pass through an opening. Points on the wavefront at the opening act as sources of waves that interfere with one another. When light passes through a single slit of width a, angles at which *total destructive interference* occur are:

$$a\sin(\theta) = m\lambda$$

If the distance to the screen L is much greater than the slit width a, then $\tan(\theta) \approx \sin(\theta)$ and

$$y_m = m\frac{\lambda L}{a}$$

The width w of the central maximum is the distance from the 1st zero on one side to the 1st zero on the other. Thus, $w = 2y_1$ which equals

$$w = 2\frac{\lambda L}{a}$$

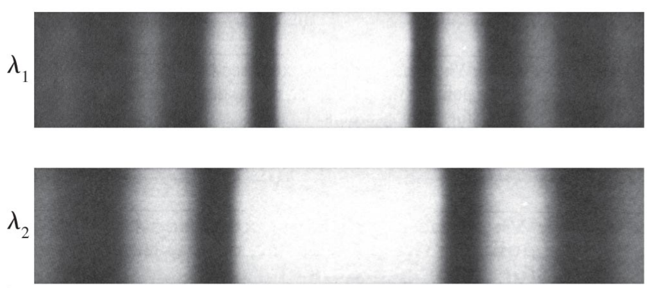
- When light passes through a circular opening of diameter D, it also diffracts. The first "zero" (i.e. location with total destructive interference) occurs at an angle θ in radians:

$$\theta = \frac{1.22\lambda}{D}$$

The Rayleigh criterion refers to one way to define the shortest separation of two point sources so that they can be resolved (i.e. seen as separate objects) when viewed through a circular aperture. The Rayleigh criterion defines this to be when the peak of one source overlaps with the zero of the other. Thus $\theta = \frac{1.22\lambda}{D}$ also represents the angular separation of the sources so that they can be viewed as separate objects.

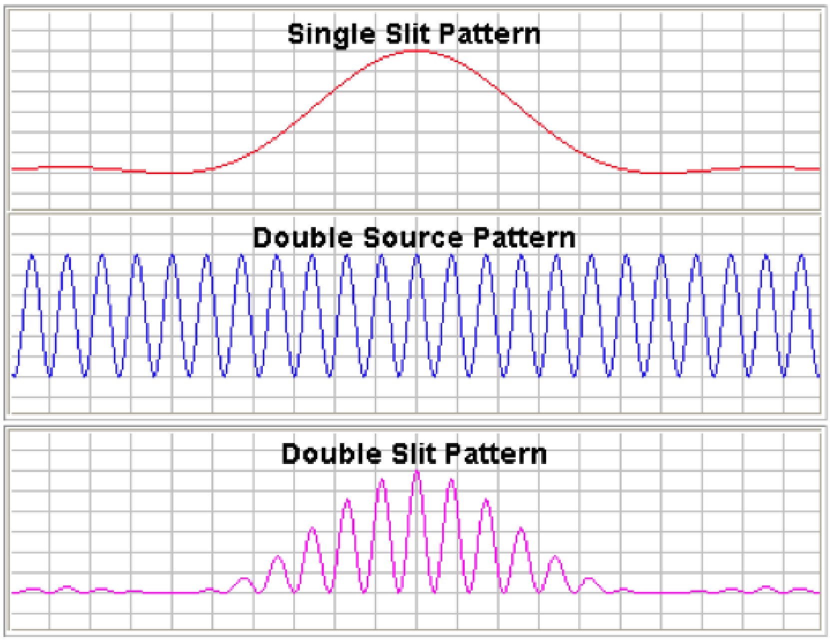
Applications

1. Through which medium will light from a red laser have the longest wavelength?
   (a) Water
   (b) Glass
   (c) Neither, because it has the same wavelength in water and glass.
2. Through which medium will light from a red laser travel the fastest?
   (a) Water
   (b) Glass
   (c) Neither, because its speed is the same in water and glass.
3. Through which medium will light from a red laser have the highest frequency?
   (a) Water
   (b) Glass
   (c) Neither, because its frequency is the same in water and glass.
4. Suppose that light of wavelength 656 nm travels through glass.
   (a) What is its speed in the glass?
   (b) What is its wavelength in the glass?
   (c) What is its frequency in the glass?
5. Two single-slit diffraction patterns are shown below. The diffraction patterns are due to two different color lasers shining on single slits that are the same slit width. Which laser (1 or 2) has a longer wavelength?



   (a) 1
   (b) 2
   (c) Neither; they have the same wavelength.
6. For a demonstration, you cut a thin slit in a piece of aluminum foil. When you shine a laser pointer (λ = 672 nm) through the slit onto a screen 5.8 m away, a diffraction pattern appears. The bright band in the center of the pattern is 6.0 cm wide. What is the width of the slit?

7. The figure below shows the pattern resulting from light with a wavelength of 480 nm passing through only one slit of a double slit. In the middle of the figure is the pattern that would result if both slits were illuminated and the slits sent out light uniformly in all directions. At the bottom of the figure is the actual pattern observed when the light illuminates both slits. What is the ratio of the distance between the slits to the width of one of the slits?



8. At night, the pupil of a typical person's eye opens up to as wide as 8 mm. What would be the smallest possible angular separation between two stars in the sky that the human eye might be able to resolve? Use a wavelength in the middle of the visible spectrum.