Portland State University
General Physics Workshop
Problem Set 7

Interference and Diffraction

Equations and Relations:

Double Slit interference:
Bright fringes
$d \sin\theta = m\lambda \qquad m = 0, \pm 1, \pm 2, \pm 3, ...$
Dark fringes
$d \sin\theta = \left(m - \frac{1}{2}\right)\lambda \qquad m = \pm 1, \pm 2, \pm 3, ...$

Air Wedge
Bright fringes
$\frac{1}{2} + \frac{2d}{\lambda} = m \qquad m = 1, 2, 3, ...$
Dark fringes
$\frac{1}{2} + \frac{2d}{\lambda} = m + \frac{1}{2} \qquad m = 0, 1, 2, 3, ...$

Single-Slit Diffraction, condition for dark fringes
$W \sin\theta = m\lambda \qquad m = \pm 1, \pm 2, \pm 3, ...$

First dark fringe for a circular aperture:
$\sin\theta = 1.22\frac{\lambda}{D}$

Rayleigh's Criterion:
$\theta_{\min} = 1.22\frac{\lambda}{D}$

Diffraction grating, principle maxima
$d \sin\theta = m\lambda \qquad m = \pm 0, \pm 1, \pm 2, ...$

1. The interference pattern shown in the figure below is produced by light with a wavelength of 450 nm passing through two slits with a separation of 50 μm After passing through the slits, the light forms a pattern of bright and dark spots on a screen located 1.25 m from the slits. What is the distance between the two vertical, dashed lines in the figure below?

- *Does the spacing between fringes in a two-slit interference pattern increase, decrease, or stay the same if*
  - *(a) the slit separation is increased*
  - *(b) the light intensity is increased*
  - *(c) the color of the light is switched from red to blue*
  - *(d) the whole apparatus is submerged in cooking sherry?*

- *If the slits are illuminated with white light, then at any side maximum, does the blue component or the red component peak closer to the central maximum?*

2. In a single-slit diffraction experiment, the width of the slit is 1.90 μm. If a beam of light of wavelength 632 nm forms a diffraction pattern.

   (a) What is the angle associated with the first minimum above the central bright fringe?

   (b) What is the angle associated with the third minimum above the central bright fringe?

   (c) At what distance above the central bright fringe are those minima if the pattern is view on a screen 2 m from the slit.

   (d) How many dark fringes will be produced on either side of the central bright fringe?

   - *Why can you easily hear sound around a corner, while you cannot see around the same corner?*

3. If diffraction were the only limitation, what would be the maximum distance at which the headlights of a car could be resolved (seen as two separate sources) by the naked human eye? – The diameter of the pupil of the eye is about 7mm when dark-adapted. Make reasonable estimates for the distance between the headlights and for the wavelength.

4. The Hubble space telescope has an aperture with a diameter of 2.4 m. How close together can two asteroids at 5×10^{10} m distance be if they are still seen as two objects (assume λ=500 nm)?

   - *The resolving power of some microscopes is increased by illuminating the object with ultraviolet light. Explain.*

   - *Telescopes used in astronomy have large lenses (or mirrors). One reason is to let a lot of light in – important for seeing faint astronomical bodies. Can you think of another reason why it is an advantage to make these telescopes so large?*

   - *At night, many people see rings (called entoptic halos) surrounding bright outdoor lamps in otherwise dark surroundings. The rings are the first of the side maxima in diffraction patterns produced by structures that are thought to be within the cornea (or possibly the lens) of the observer's eye. (The central patterns of such maxima overlap the lamp.)*
     (a) Would a particular ring become smaller or larger if the lamp were switched from blue to red light?
     (b) If a lamp emits white light, is blue or red on the outside edge of the ring?

5. A film of soapy water in air is held vertically and viewed in reflected light. The film has index of refraction n = 1.36.

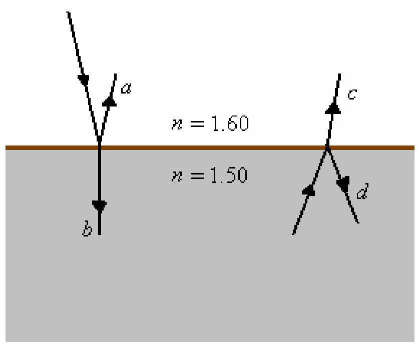
   (a) Explain why the film appears black at the top.

(b) The light reflected perpendicular to the film at a certain point is missing the wavelengths 504 nm and 630.0 nm. No wavelengths between these two are missing. What is the thickness of the film at that point?
(c) What other visible wavelengths are missing, if any?

6. A sodium light (λ = 589.3 nm) is used to view a soap film to make it look black when directed perpendicular to the film. What is the minimum thickness of the soap film if the index of refraction of soap solution is 1.36?

7. A nonreflective coating of magnesium fluoride (n=1.38) is applied to a camera lens (n=1.5). If one wants to prevent light at a wavelength of 560 nm to reflect from the lens, what minimum thickness does the coating need to be?

- *The figure shows two rays of light encountering interfaces, where they reflect and refract. Which of the resulting waves are shifted in phase at the interface?*



8. A diffraction grading produces a bright fringe at an angle of 14° for 400 nm. For another wavelength the same order (m) fringe is at an angle of 27°.
(a) What is the unknown wavelength?
(b) If m=8, what is the separation between the slits on the grating?
(c) At what angle would the bright fringes occur if the slit separation is doubled?

- *In a diffraction grating, how does the spacing of the lines affect the separation of the fringes in the interference pattern?*

- *If white light were incident upon a diffraction grating, instead of monochromatic light, what would the resulting interference pattern look like?*

- *When white light falls on a prism, it is dispersed, forming a spectrum of colors, with the red component receiving the least deviation. Compare this spectrum with that produced by a diffraction grating.*

Additional Questions

1. AM radio waves have wavelengths hundreds of meters long. Can AM radio waves be used as radar to detect aircraft? Explain.

2. Visible light has wavelengths from about 4.0×10^{-7} m to about 7.5×10^{-7} m. Can visible light be used to detect individual atoms? Explain.

3. Photography using what type of light (i.e. infrared, ultraviolet, visible, gamma rays, etc.) is needed to image individual atoms?

4. Radio waves and light waves are both electromagnetic waves, yet radio waves can be received behind tall buildings. Explain why this is possible when light cannot reach these areas.

5. What effect places a lower limit on the size of an object that can be clearly seen with the best optical microscope?