Pre-Lab 7

Diffraction and Interference

Objectives

- Study single slit diffraction.
- Study double slit interference and observe other interference patterns.
- Learn how to use the optical path difference to analyze thin film interference.
- Observe and analyze the interference patterns produced by thin air gaps between flat glass plates.

Text Reference

Physics 123:
Tipler & Mosca, *Physics for Scientists and Engineers, 6th edition,* Vol. 1 (Yellow book). Chapter 33, sections 33-1 through 33-4, especially Examples 33-2, 33-3.

Physics 119:
Walker, *Physics, 4th edition,* Vol. 3 (Orange book). Chapter 28, sections 28-1 through 28-4.

1. Interference and Diffraction as Superposition of Light Waves

If two light waves are present at the same place at the same time, their electric and magnetic fields add according to the superposition principle. If the two waves are in phase, they add *constructively* to produce a new wave with greater amplitude. If the two waves are 180° out of phase and have the same amplitude, they add *destructively* and the combined amplitude is zero. The result of adding two light wave amplitudes is called *interference* and can be observed in a variety of situations.

Single Slit Diffraction

Diffraction is the name we give to interference phenomena that occur when a light wave passes the edge of an obstruction. The diffraction of light is usually not noticeable because its effects are often too small or too faint to be seen with the naked eye. We will study diffraction by passing light from a laser through an opening with a size on the order of 100 times the wavelength of the light.

Recall from lecture and tutorial that the equation describing the location of single slit diffraction *minima* is

$$a\sin\theta = n\lambda \quad \text{where} \quad n = \pm 1,\ \pm 2,\ \pm 3,\ \dots$$

where *a* is the slit width, θ is the angle from the central maximum to the *n*th minimum, and λ is the wavelength of the light. In this experiment, we will be using He-Ne gas lasers that emit red light of wavelength 633nm, (1 nm = 10^{-9} m).

Two-Slit Interference

If the single slit is replaced with two slits separated by a small distance *d*, the equation describing the location of the interference ***maxima*** is:

$$d\sin\theta = m\lambda \quad \text{where} \quad m = 0,\ \pm 1,\ \pm 2,\ \pm 3,\ \dots$$

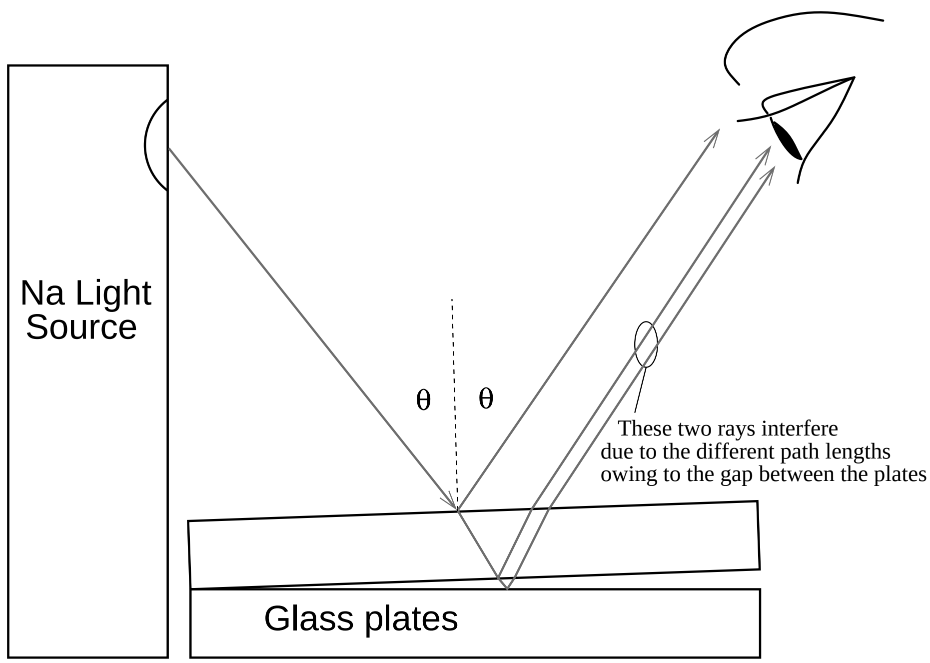
In this equation, *d* is the distance between the centers of the slits, θ is the angle from the center of the slits to the *m*th maximum, and λ is the wavelength of the light.

The pattern for the double slit will contain features of both two-slit interference and single-slit diffraction. You must learn to recognize which features in the pattern result from two-slit interference and which result from single-slit diffraction.

2. Air Wedge: Thin Film Interference

“Thin film interference” is the type of interference responsible for the colors seen in oil films on puddles on a wet day.

The figure shows the situation that we will study in the lab. In this case, the “film” is the layer of air between the plates. We will look at the image of the sodium lamp reflected by the glass plates. Three rays are shown, reflecting from the top surface, and bottom surfaces of the upper plate, and the top surface of the bottom plate. The latter two interfere, causing a pattern of bright and dark bands depending on the distance between the plates.



Interference between rays taking different paths.

As you may recall from your text, for *normal* incidence, the condition for an interference minimum is that the separation between the plates, *t,* is a multiple of $\lambda/2$. At zero thickness is a minimum due to the phase change of one ray with respect to the other. In this case, there is no phase change for the reflection from the upper glass-air boundary, since the index of refraction is less in air than glass, but 180^o for the lower air-glass boundary. As *t* increases, due to the wedge, you should see a series of parallel bands.

Consider perfectly smooth glass plates shaped and oriented in the following ways (note that the plate spacings and fringe separations are greatly exaggerated). For each case, sketch the interference pattern you would observe if the plates were illuminated from above with a sodium lamp. Draw your sketches directly on the top plates, and make sure your patterns are consistent with each other. The top right one is an example.