Interference of Light

APPARATUS

1. Board for mounting glass plates.
2. Two plane parallel plates of glass.
3. Aluminum stand equipped with a lens, a mirror inclined 45, and an index.
4. Mercury arc lamp and a sodium light source.
5. Microscope with a traveling stage and an adjustable "mirror".
6. Cylindrical cartridqe containing a glass plate and a lens.

On the instructor's desk:

7. Paper and metal shims

At the sink:

8. Soap, water and tissues for cleaning glass plates. Do not put the cylindrical cartridges in water.

INTRODUCTION

When light is reflected from the two surfaces of a very thin film of varying thickness, an interference pattern is produced. Wherever the two reflected waves are in phase, bright areas appear. Where the difference in phase is one-half wavelength, dark areas are produced.

Part I: Air Wedge

Let two flat sheets of glass be separated slightly at one edge, Fig. (1a). If H is of the order of a millimeter or less and the wedge is viewed by reflected monochromatic light, bright interference fringes may be observed. Interference occurs between the waves reflected from the top and bottom of the air wedges. Fig. (1b) illustrates the geometry.

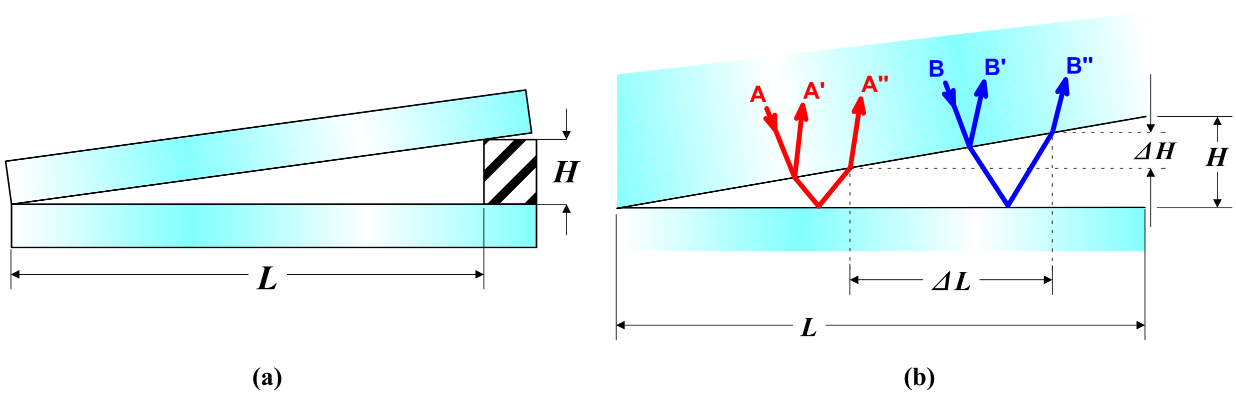

Figure 1: Principle of interference at a thin air wedge.

The ray A produces two reflected rays A' and A". Suppose that A and B correspond to two adjacent dark (or bright) areas. Then

$$2\,\Delta H = \lambda \tag{1}$$

where λ is the wavelength of the light. Consideration of the geometry leads to the conclusion that

$$\frac{H}{L} = \frac{\Delta H}{\Delta L} \tag{2}$$

A little thought also shows that if N bright (or dark) fringes are counted in a length L_1, then

$$\Delta L = \frac{L_1}{N} \tag{3}$$

Substituting (1) and (3) in (2), we obtain

$$\lambda = \frac{2\,H\,L_1}{L\,N} \tag{4}$$

Part II: Spherical Lens and Flat Plate ("Newton's Rings")

If a long focal length lens is placed in contact with a flat plate one may obtain an interference pattern consisting of a series of concentric bright and dark fringes. Fig. 2 illustrates this case.

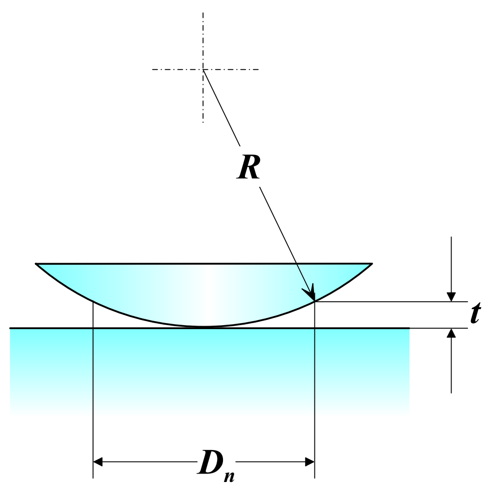

Figure 2: Principle setup for the observation of Newton's rings.

R is the radius of curvature of the lens, t is the thickness of the air wedge at the n$^{\text{th}}$ fringe and D_n is the diameter of the n$^{\text{th}}$ dark ring. The center null is counted as zero. From equation (1) above follows that

$$t = \frac{n\,\lambda}{2} \tag{5}$$

You should be able to prove that

$$D_n^2 = 4\,n\,\lambda\,R - n^2\,\lambda^2$$

Since λ is a very small quantity, we may neglect $n^2\lambda^2$ in comparison with $4n\lambda R$. Therefore, to a high order of precision

$$\lambda = \frac{D_n^2}{4\,R\,n}$$

PROCEDURE

Part I: Air Wedge

Examine the two large glass plates. Note the frosted surfaces and the lines which are ruled 1 cm apart. Arrange the plates and the black stand on the board to produce the situation illustrated in Fig. (3). Place the frosted surfaces down with the ruled lines on the inside. Use a thin strip of paper as a separator. Place the sodium lamp nearby and arrange the geometry so that the light of the lamp is reflected to the eye of the observer (Fig.(3)).

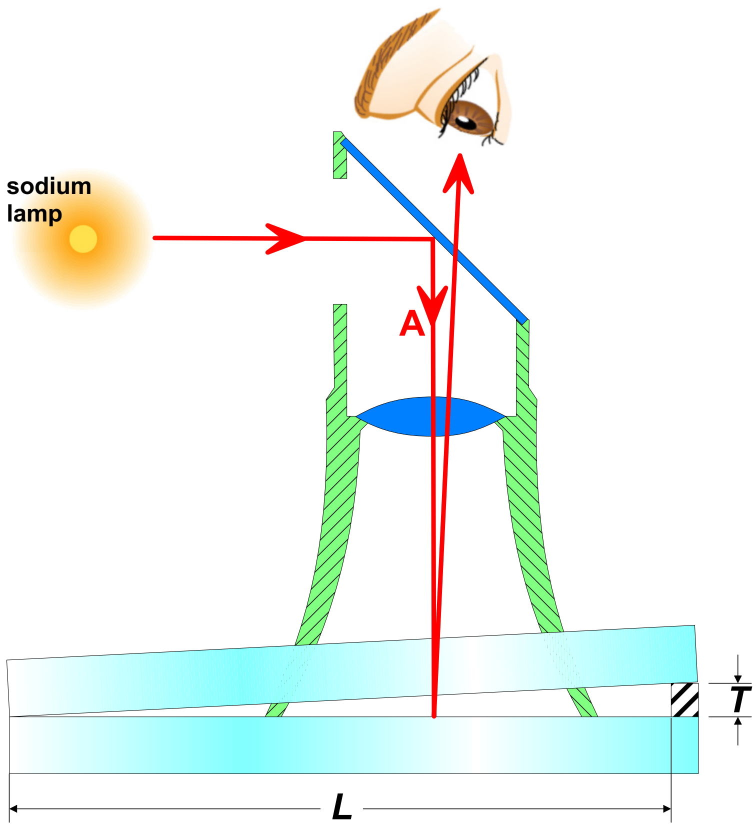

Figure 3: Setup for observation of interference fringes at two glass plates.

The image of the lamp should be crossed by parallel closely spaced bright and dark fringes. Ideally these will be straight, parallel, and evenly spaced. If lines do not appear, make sure the frosted sides are facing the correct way. If they still cannot be seen, remove the plates and wash them thoroughly with soap and water. Free them of all finger prints and lint and reassemble the system. If the pattern is diagonal, press firmly on one corner and release. Do not expect perfection, but arrange the system in a way that you are able to reasonably count the fringes.

1. Make a sketch showing the appearance of the fringes
2. Count the number of dark fringes in 2 cm. It will be helpful if you move the viewing frame as you count, so as to make use of the pointer to keep your place.
3. Measure the length of the air wedge L. The thickness of the paper will be given to you by the lab instructor.
4. Then apply equation (4) to calculate the wavelength.

Part II: Spherical Lens and Flat Plate ("Newton's Rings")

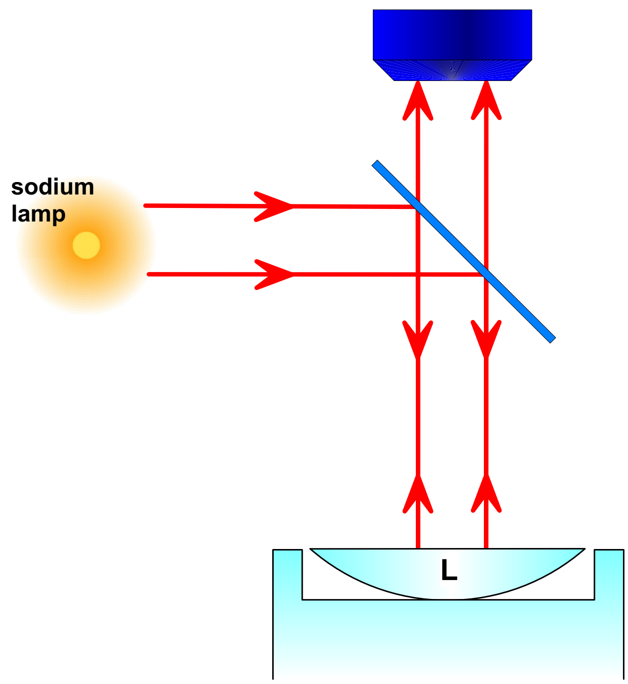

Figure 4: Setup for observation of Newton's rings.

1. Position the Sodium lamp to the left, with the micrometer aligned to the edge of the table to the right. Turn the lamp ON and allow it to warm up for several minutes. Use this time to answer the question: Why is equation (5) true ?

2. Position the telescope at the **top** of its travel, and orient the glass disk so that light from the lamp illuminates the lens capsule as seen through the telescope. You may have to rotate the base slightly to compensate for a drooping disk.

3. Focus the telescope by lowering it slowly. Stop when you see the interference pattern. Align one of the cross hairs so that it is parallel to the micrometer barrel, if possible.

4. Rotate the lens cell until the pattern is aligned with the cross hairs. You may have to move the stage by turning the barrel of the micrometer. If possible, center the pattern. Question: Is the center of the pattern as bright as the ring surrounding the center? Why? (It is rarely completely dark due to contamination at the glass surfaces.)

5. Translate the stage to the first dark ring by turning the micrometer to **smaller** values. Record the position. (Use the light and the magnifier to examine the micrometer scales, refer to notes on the micrometer caliper in the introduction.)

6. Proceed to the second dark ring by rotating the micrometer barrel in the **same** direction. Record the position. Continue to rings 3, 5, 7, and 10. If time permits, continue by 3s.

ANALYSIS

1. Plot the positions of the rings against the square root of the ring number.

2. Draw the best fit straight line through your data points.

3. Determine the slope of the straight line you drew. Question: What is the algebraic relation between the slope and the radius of curvature? ($D_n = 2(X_{center} - X_n)$, where X_n is the micrometer value for the nth dark ring.

4. Determine the radius of curvature of the lens from your value for the slope.
(Na: $\lambda = 589$ nm)

Part III

If a filter for the green line of the mercury spectrum is available, arrange the mercury lamp and filter so as to observe the interference pattern. Measure a number of positions of the dark rings in order to calculate the wavelength, using the value for R that you found with the sodium lamp.