Experiment 6:   Interference Fringes & Newton's Rings   Phys 431

This is a significant lab as it is the first one to explore a phenomenon of physical optics (or wave optics). In this experiment, we will examine the interference patterns which arise by simply putting together two pieces of glass. The resulting bright and dark lines and curves are called Fizeau fringes. We will employ mercury lamps which have a well-defined wavelength of λ=5461 Å (green line). A piece of glass that is very smooth and flat on the length scale of λ is known as an "optical flat". Ordinary flats are smooth to about $\lambda/4$. (The Hubble Space Telescope had an error on a reflective surface of about 2λ, which required a major repair. It was supposed to be smooth to better than $\lambda/50$.) We will explore three geometries: parallel flats, the wedge, and Newton's rings, as shown in the appendix. As always, include all of your pictures in the write-up.

Procedure:
A. With careful dusting of a pair of flats, try to get as few fringes as possible. Place a ruler on the bottom plate and photograph the pattern. If you prefer, use a tripod to hold the camera; but it might be easier to focus on the fringes by manually holding the camera very close to the beamsplitter. How flat are your plates? You can answer this question quantitatively by referring to the wedge geometry. Take a picture with a ruler in place to set the length scale precisely, and analyze the image on a PC. Give the maximum angle observed, corresponding to the area that has the most closely spaced fringes. Replace the mercury lamp with the white light of your desk lamp. Is it still possible to see the fringes? **Q1** Why is it harder to see them in this case?

B. Use a short length of hair to form a wedge between two flats. Photograph the fringes and a ruler as above. From the fringe spacing calculate the wedge angle and the thickness of the hair. Suppose that the fringes are not approximately equally spaced. **Q2** Would this allow you to conclude that the flats are rough on the scale of λ, or on the scale of the hair thickness?

C. A spherical surface of very large radii is furnished. With a flat and this surface, you will see the circular fringes known as *Newton's rings*. Once again, photograph the pattern with a ruler in place. Determine the diameter of each ring, and plot x_n^2 versus n, where x_n is the radius of the nth fringe. You are encouraged to use a plotting routine such as Kaleidograph, which is available on our pc's. As shown in the appendix, this plot should be a straight line of slope λR, where R gives the curvature of the surface. Include the line-of-best-fit in your graph. Make a reasonable estimate of the error in the slope by holding a straight edge up to the data. In other words, how much could you vary the slope and still have most of the data points reasonably close to the line. Knowing λ, calculate R and its uncertainty. If the pattern is not perfectly circular, measure along the axis of maximum R as shown below.
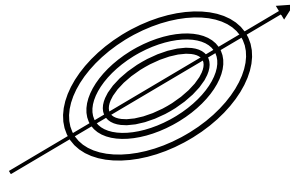

Lastly, take one of the curved surfaces on the back table. **Q3** Can you see Newton's rings? What happened to them?

Appendix

Wedge

Two flat plates forming a wedge of angle θ lead to equally spaced Fizeau fringes. Considering the air trapped between the plates to form a film of increasing thickness, the fringes appear as a result of the interference of light reflected from each side of the film. Constructive interference occurs if the difference in path length is equal to λ, as shown below.
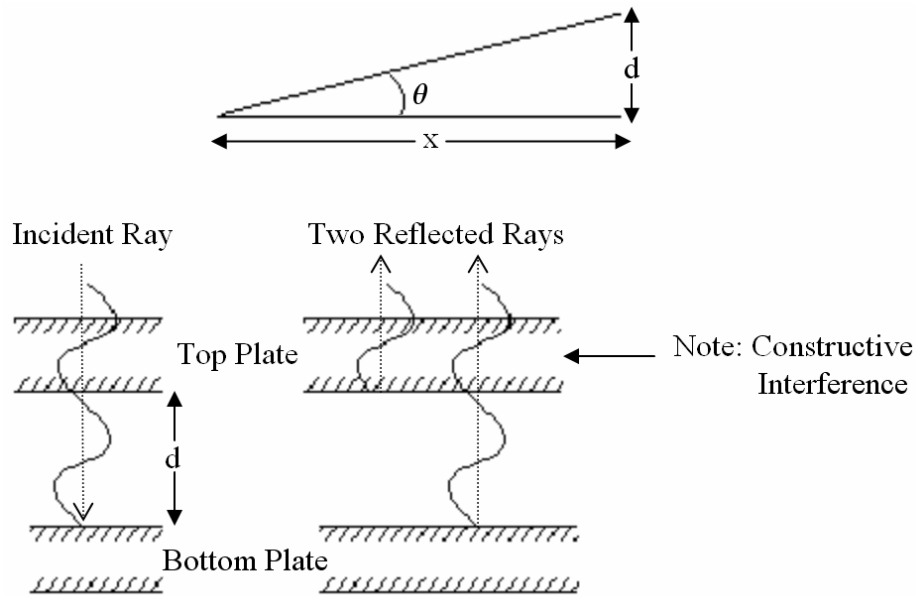
Because the beam reflected from the bottom of the film traverses the film twice, we see that the nth bright fringe appears if

$$d = n\frac{\lambda}{2} + C$$

where C is a constant that can arise due to non-contact (dust) between the two plates, or due to phase shifts occurring during the reflection process. For small angle, we have

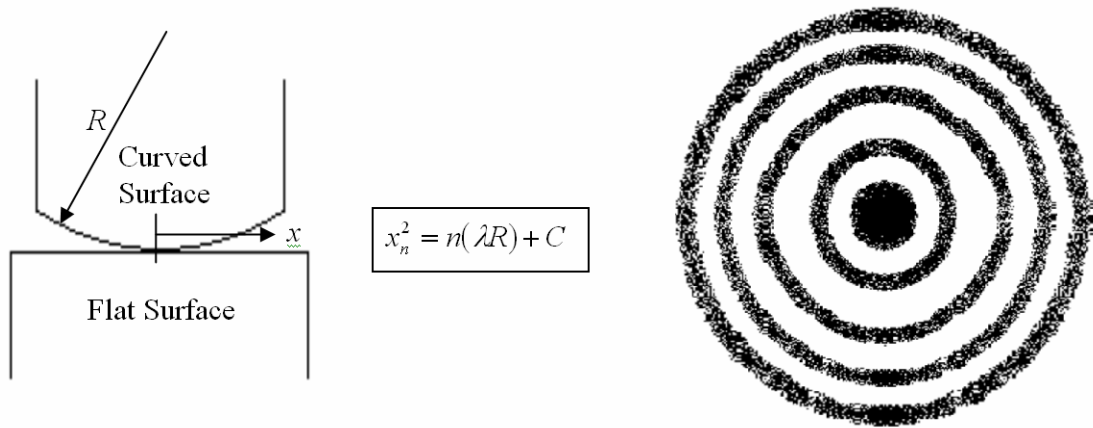$$\theta = \frac{d}{x} \quad \Rightarrow \quad x = \frac{d}{\theta}$$

The nth fringe will then occur at a distance x_n from the vertex given by

$$x_n = \left(n\frac{\lambda}{2} + C\right) \Big/ \theta = \frac{n\lambda}{2\theta} + C',$$

where C' is some new constant.

<u>Newton's Rings</u>

A similar analysis of the Newton's rings geometry in the small angle limit yields the following expression (here x_n is the **radius** of the nth fringe):

$$x_n^2 = n(\lambda R) + C$$

So we do not expect equally spaced rings, instead x_n is proportional to $\sqrt{n}$.