Interference Fringes and Newton's Rings

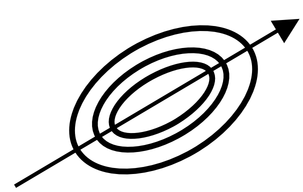
In this lab, we shall examine some interference effects. The bright and dark patterns that appear at the interfaces of two nominally flat pieces of glass are called *Fizeau fringes*. A mercury lamp, which emits predominantly at the wavelength of λ =546.1 nm (green), is the light source. A piece of glass that is smooth and flat on the scale of the optical wavelength is known as an *optical flat*. Optical flats are specified by their flatness across their entire surface, given as a fraction of an optical wavelength, typically $\lambda/4$. (The Hubble Space Telescope had a reflective surface deviation about 2λ, requiring a major repair. It was supposed to be flat to $< \lambda/50$.) We will explore three geometries: parallel flats, a wedge, and the case of a flat and a spherical surface.

Procedure:

A. First, remove residual dust particles using compressed gas. Adjust the flats so that the fringe density is fairly low. Place a ruler on the bottom plate, next to the upper plate, and photograph the pattern. You may use a tripod to mount the camera; however, it may be sufficient to simply hold the camera above the plates. Set for manual exposure. **Q1**. How flat are the plates? You can answer this question quantitatively by considering the wedge geometry. Take a picture with a ruler in place to set the length scale and analyze the image on a PC. Find the maximum angle observed, corresponding to the area with the most closely spaced fringes. Replace the mercury lamp with the white light of your desk lamp. **Q2.** Why is it harder to see fringes with this light source? Why can you see them at all?

B. Use a short length of hair to form a wedge between two flats. Photograph the fringes and ruler as before. **Q3.** From the fringe spacing calculate the wedge angle and the thickness of the hair. If that the fringes are not (approximately) equally spaced, would you conclude that the flats deviate from planarity on the scale of λ or on the scale of the hair thickness?

C. Select a spherical surface with large radius of curvature. With a flat and this surface, you will see circular fringes known as *Newton's rings*. Photograph the pattern with a ruler in place. Find the diameter of each ring, and make a plot of x_n^2 vs n, where x_n is the radius of the n^{th} fringe, using Kgraph. **Note**: If the pattern is not circular, measure along the axis of maximum R as shown below. As derived in the Appendix, this plot should be a straight line of slope λR, where R is the curvature of the surface. Include the best-fit line in your graph. Print a table of the residuals using Kgraph. **Q4.** What is their sum? If you change the slope of the line by the uncertainty given in the least-squares fit, how much do the residuals increase? What is the meaning of the uncertainty given by Kgraph?

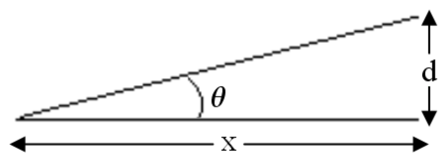


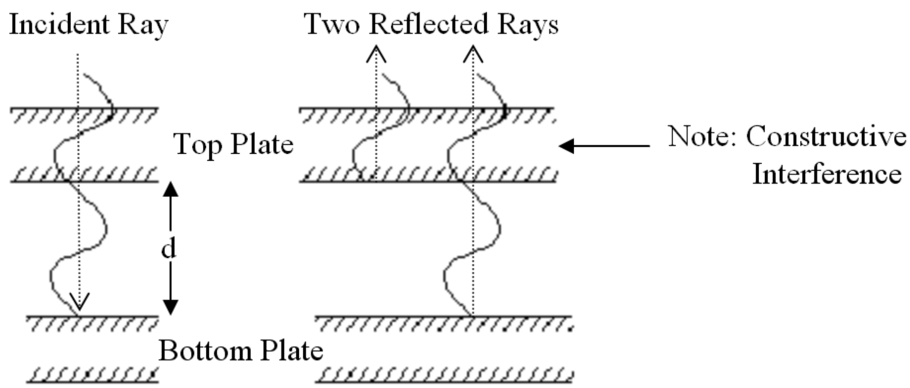
D. Finally, select one of the curved surfaces with small radius of curvature. **Q5.** If you are unable to see Newton's rings, what happened to them?

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 n^{th} bright fringe appears when

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

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 angles, we have

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

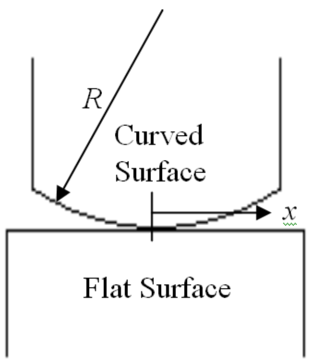
The n^{th} fringe will then occur at a distance x_n from the vertex given by

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

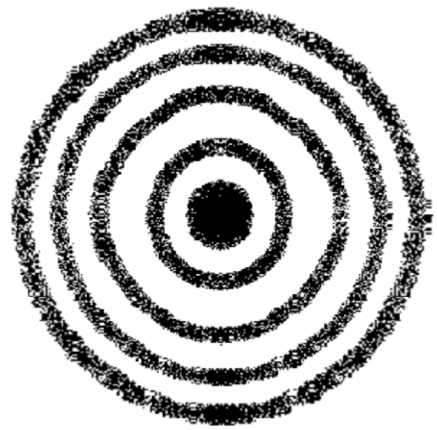
where C' is a new constant.

Newton's Rings

A similar analysis of Newton's rings in the small angle limit yields the following expression (here x_n is the **radius** of the n^{th} fringe):



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



Here, we do not find equally spaced rings since x_n is proportional to $\sqrt{n}$.