Experiment 6: Interference Fringes and Newton's Rings PHY 431

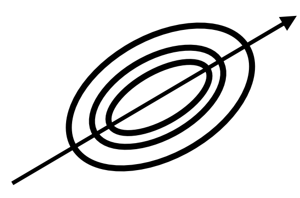
In this lab, we shall examine interference effects in situations where glass surfaces are pressed against each other. The bright and dark patterns that can be observed at the interfaces of two nominally flat pieces of glass are called *Fizeau fringes*. A mercury lamp, which emits predominantly at the wavelength of λ =546.1 nm (green), will serve as our 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 the optical wavelength, typically $\lambda/4$. (Notably, the Hubble Space Telescope had a reflective surface deviation of about 2λ from design, requiring a major repair - it was supposed to be accurate to $< \lambda/50$.) We will explore three geometries: parallel flats, a wedge, and the case of a flat pressed against a spherical surface.

Procedure:

A. First, remove any residual dust particles from a pair of flats using compressed gas. Press the flats against each other and adjust them 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, but it may be also sufficient to simply hold the camera above the plates. Set the camera for manual exposure. **Q1**. How flat are your plates? You can answer this question semi-quantitatively by considering the wedge geometry in the Appendix. Take a picture with a ruler in place to set the length scale and analyze the image on a PC. Find the maximum angle encountered for the surface separation, 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 stretch of hair to form a wedge between the two flats. Photograph the fringes and the ruler as before. **Q3.** From the fringe spacing calculate the wedge angle and the thickness of the hair. As the fringes are not ideally equally spaced, what can you conclude on the deviations of your flats from planarity on the scale of λ or on the scale of the hair thickness?

C. Select next a spherical surface with a large radius of curvature. With this surface and a flat pressed against each other, you should 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 a plotting software such as Kaleidograph. **Note**: If the pattern is not circular, measure values of the semimajor axis of the rings, such as along the indicated axis in the adjacent figure. As derived in the Appendix, this plot should be a straight line of slope λR, where R is the larger of the radii of curvature for the surface. Include the best-fit line in your graph. **Q4.** What is the uncertainty in the slope of the line given by your software? Print a table of residuals from your software for the best-fit line. What is the sum of squared residuals? What is the r.m.s. uncertainty? When you change the slope by its claimed uncertainty, how much does the sum of the squared residuals change and how does this change compare to the r.m.s. value? If your software does not provide an uncertainty for the slope, estimate that uncertainty by adjusting the slope value from best fit until the sum of squared residuals increases by approximately one r.m.s. value.

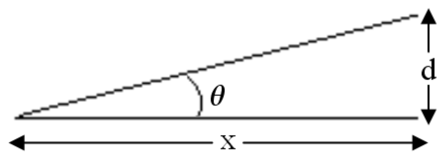


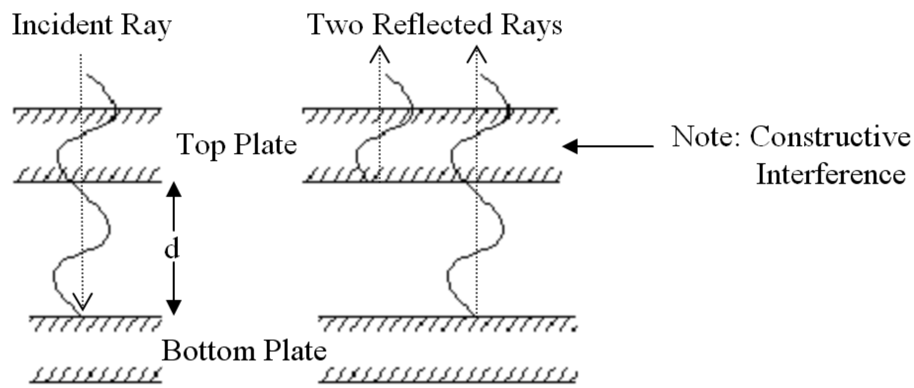
D. Finally, select one of the spherical surfaces with a small radius of curvature. **Q5.** If you are unable to see the Newton's rings, what happened to them?

Appendix

<u>Wedge</u>

Two flat plates forming a wedge gap 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 air gap twice, we see that the m^{th} bright fringe appears when

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

where *C* is a constant that accounts for any phase shifts occurring during the reflection process and that later also absorbs the effect of incomplete contact between the plates at edge. For small angles above, we have

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

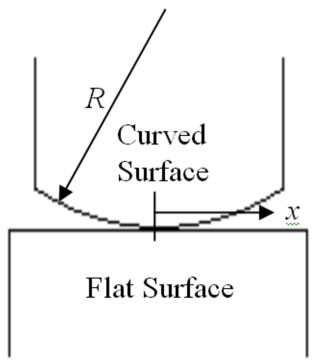
The m^{th} fringe will then occur at a distance x_m from the vertex given by

$$x_m = \frac{m\frac{\lambda}{2} + C}{\theta} = \frac{m\lambda}{2\theta} + C',$$

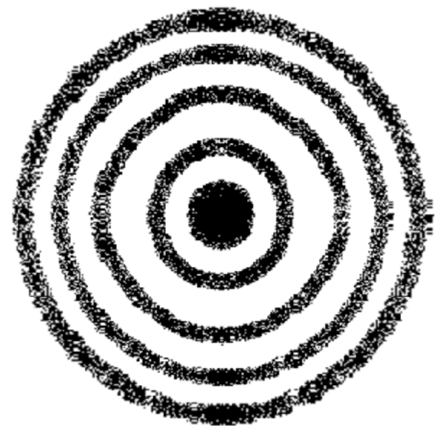
where *C'* is a new constant.

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):



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



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