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, or nearly flat, pieces of glass, are called *Fizeau fringes*. A mercury lamp, which emits predominantly at the wavelength of $\lambda$ =546.1 nm (green), will serve as our primary 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 $2\lambda$ from its design, requiring a major repair in space – by its design 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.

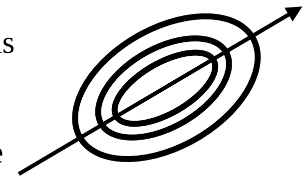
Procedure:

A. Clean surfaces of two microscope slides and stick those slides together. Make observations of interference fringes at the slide interface in white light, tilting the slides around so as to enhance the intensity of reflected light. Next repeat the observations when illuminating those slides with a mercury lamp. **Q1**. Describe qualitatively characteristics of the fringes for the two light sources.

   Next you will be carrying out observations using boxes that allow for both the illumination and the viewing to be directed straight down. Take a pair of flats, preferably more rigid than the slides, and remove any residual dust particles from their surfaces using compressed gas. Press the flats against each other and adjust them so that any fringes are fairly spaced out under the illumination with a mercury lamp. Place a ruler on the bottom plate, next to the upper plate, and photograph the fringe pattern. You may use a tripod to mount the camera, but it may be also sufficient to simply hold the camera above the plates. If possible, set the camera for manual exposure. **Q2**. How flat are your plates? You can answer this question semi-quantitatively by considering the discussion of wedge geometry in the Appendix. Take a picture with a ruler in place to set the length scale and analyze your 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. **Q3.** 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. **Q4.** 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 $\lambda$ 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 Kaleidagraph. **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 $\lambda R$, where $R$ is the larger of the radii of curvature for the surface. Include the best-fit line in your graph. **Q5.** What is the slope and what is the corresponding radius of curvature for the surface? 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.



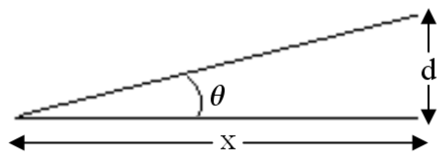
D. Without moving your surfaces relative to each other and with the ruler in the field of view, photograph the pattern of the Newton's rings formed when using first the mercury lamp and then a sodium lamp for illumination. **Q6.** How is the pattern changed for illumination with the sodium light? Comparing the patterns deduce the wavelength for the sodium light.

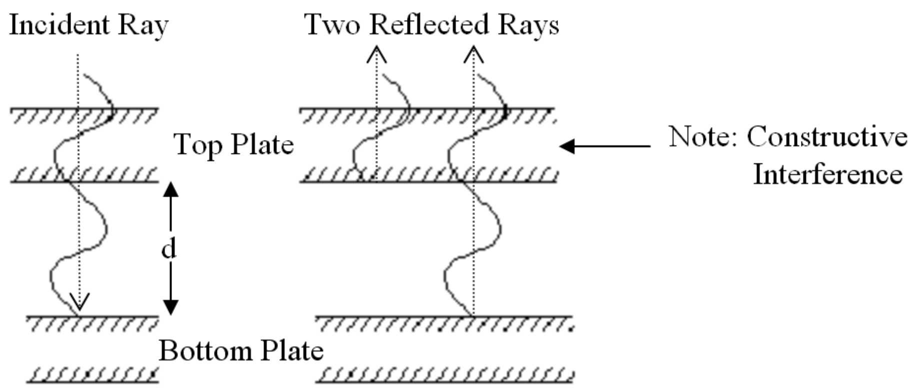
E. Finally, select one of the spherical surfaces with a small radius of curvature. **Q7.** If you are unable to see the Newton's rings, what happened to them?

# 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 $\lambda$, 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 any incomplete contact between the plates at edge. For small angles above, we have

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

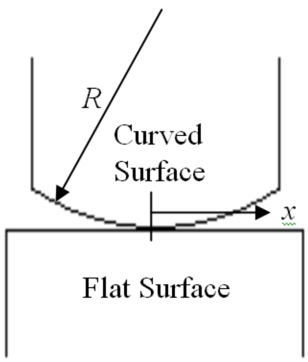
The $m^{th}$ fringe will then occur at a distance $x_m$ from the vertex given by

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

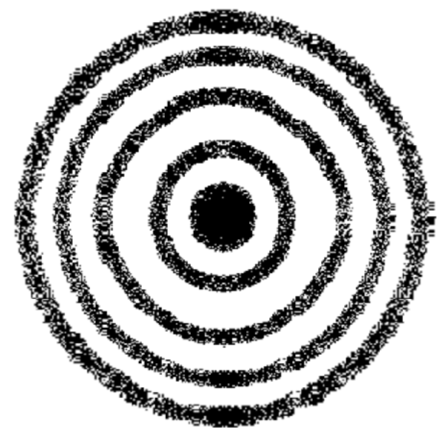
where *C'* is a new constant.

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):




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



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