Group 5

Project Report

Project Title	Newton's Ring		
Team Members:	鄭篤容	蘇彥碩	張哲維

Objectives

Investigate what effects the incidence angle and wavelength of the light, the material and curvature of the lenses, and the distance between the planoconvex lens and the optical flat glass has on the shape and size of the Newton's rings produced.

Background Theories:

Newton's ring is the interference fringes caused by thin air film around an optical flat and a spherical planoconvex lens. Figure 1 shows this very simple configuration of the optical system. The optical flat sits on the planoconvex. When light source coming from the bottom of the optical system, we may see the transmitted light when we look into the optical system from top. We may also see the reflected light when we look into the optical system from bottom. Both of the images the interference fringes of Newton's ring. The principle of Newton's ring resembles that of the thin air film interference. Since the air film is circular around the optical flat, the interference fringes are rings. Interference of thin air film is caused by optical path difference and consequently the phase difference of two light. It then produces Newton's ring on the image. Here's a way of deriving the radius of fringes by the optical path difference. Figure 2 is the diagram for the parameter.

$$d = R - \sqrt{R^2 - r^2}$$

$$2d = (m + \frac{1}{2})\lambda$$

$$(d - R\,)^2 = R^2 - r^2$$

$$2dR - d^2 = r^2$$

$$\sqrt{d(2R - d)} = r$$

$$r \approx \sqrt{2Rd} = \sqrt{R\left(m + \frac{1}{2}\right)\lambda}$$


Figure 1. The basic configuration of the Newton's ring.

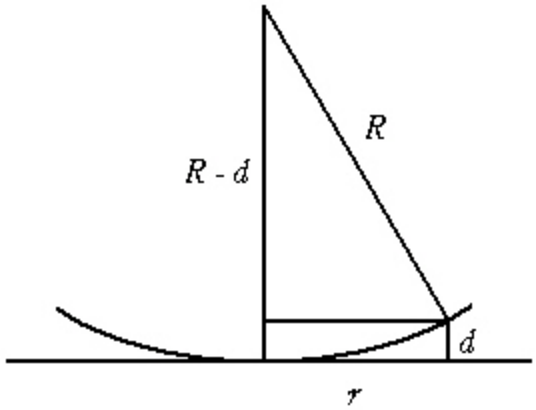


Figure 2. R is the radius of curvature of the planoconvex, and d is the distance of the thin air film between the optical flat and the planoconvex. The small r is the radius of the fringes of the Newton's ring, which is what we are interested in.

There's another way of deriving the radius of the fringes.
First we express t in terms of λ,

$$2t + 2\times\frac{\lambda}{2} = 2(n+1)\times\frac{\lambda}{2}$$

$$\mathrm{t} = \frac{n\lambda}{2}$$

Next as the figure 3. Shows, the angle θ is small thus $\theta \sim \sin\theta \sim \tan\theta$, we have

$$R = \frac{\overline{ab}}{2\theta} = \frac{\sqrt{r_n{}^2 + (\frac{n\lambda}{2})^2}}{2\tan^{-1}(\frac{n\lambda}{2r_n})}$$

where
R = curvature of the plano-convex lens
r_n = distance from the center to middle of the n^{th} bright ring
λ = wavelength of the light used
n = number of bright ring
t = thickness of the air between the plano-complex lens and the optical flat glass

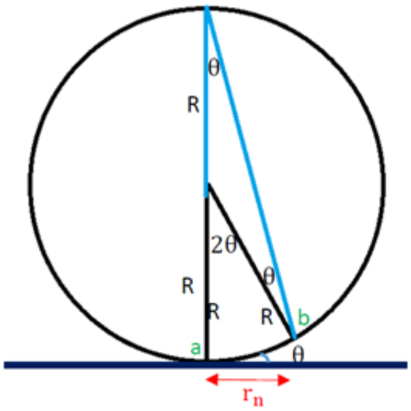


Figure 3. Show the parameters we need to measure.

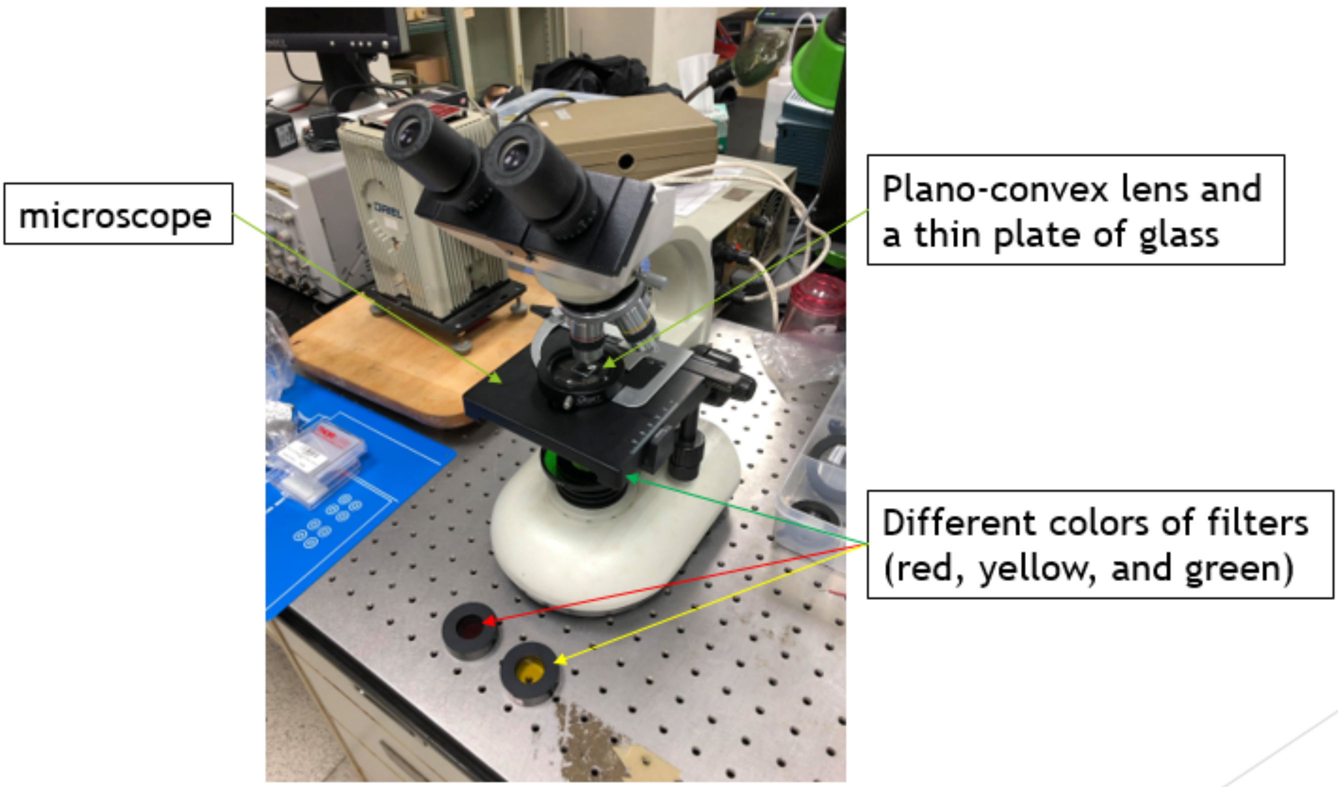
Now, we've obtain the necessary equation for the radius of the fringes.

Experimental Setup:

Components and Instrumentation

Instrument	Quantity	Components	Quantity
Microscope	1	Planoconvex Lens	1
Camera	1	Optical Flat Glass	1
Ruler (on microscope)	1	Lights (on microscope)	1
Compass	1	Filter (of different color)	3

.



We simply put the planoconvex lens on the mircroscope and we place the optical flat on top of this spherical planoconvex lens. We turn on the light of the microscope. It then produces the Newton's ring. We can see the Newton's ring of transmitted light when we look into the eyepiece of the microscope

Experimental Procedures:

Part 1 The Effects Wavelength of the Light has on the Size of Newton's Rings

1.Place the planoconvex lens on the optical flat glass, making sure that the convex side is in contact with the optical flat glass.

2.Using a red light as the light source, shine it perpendicularly on the flat surface of the planoconvex lens, observe the Newton's rings produced through a microscope. Measure and record the radius of the smallest five bright and five dark circles.

3.Change the light source to green and blue, and repeat the previous step.

Part 2 The Effects the Incidence Angle has on the Size and Shape of Newton's Rings

1.Using a red light as the light source, shine it perpendicularly on the flat surface of the planoconvex lens, observe the Newton's rings produced through a microscope. Measure and record the radius of the smallest five bright and five dark circles.

2.Change the incidence angle of the red light to 10 degrees, observe the Newton's rings produced through a microscope. Measure and record the minor and major axis of the oval.

3.Change the incidence angle of the red light to 20, 30, 40 degrees and repeat the previous step.

Part 3 The Effects the Material of the Lenses has on the Size of Newton's Rings

1.Using a red light as the light source, shine it perpendicularly on the flat surface of the planoconvex lens of a different material, observe the Newton's rings produced through a microscope. Measure and record the radius of the smallest five bright and five dark circles. 2.Compare with the results obtained in Part 1.

Part 4 The Effects the Curvature of the Lenses has on the Size of Newton's Rings

1.Using a red light as the light source, shine it perpendicularly on the flat surface of the planoconvex lens, observe the Newton's rings produced through a microscope. Measure and record the radius of the smallest five bright and five dark circles.

2.Change to a planoconvex lens with different curvatures and repeat the previous step.

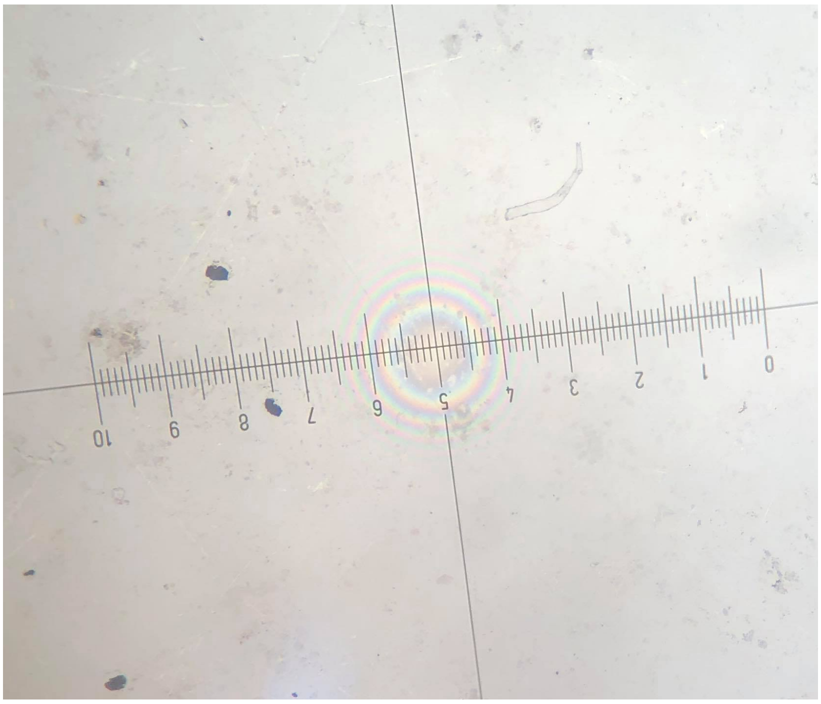
Part 5 The Effects the Distance Between the Planoconvex Lens and the Optical Flat Glass has on the Size of Newton's Rings

1.Using a red light as the light source, shine it perpendicularly on the flat surface of the planoconvex lens, observe the Newton's rings produced through a microscope. Measure and record the radius of the smallest five bright and five dark circles.

2.Change the distance between the planoconvex lens and the optical flat glass and repeat the previous step.

Experimental Results:

We look for the Newton's ring with the microscope and we see the rainbow pattern when we use the white light source. As below,



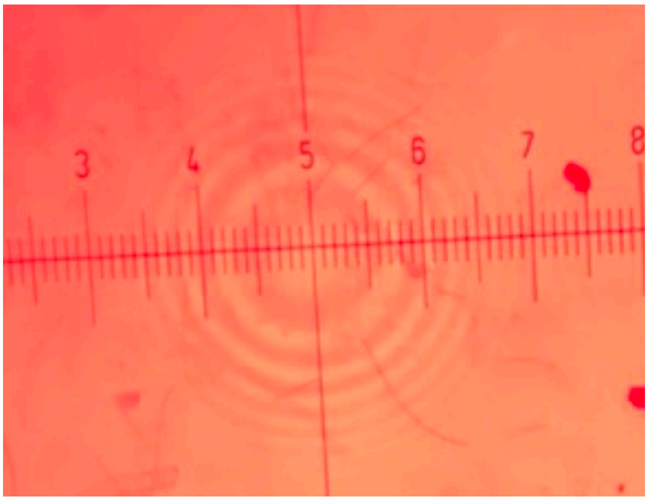
Next we used different filter to produce monochromatic light of different color. These are what we obtain. We count the number of fringes and measure the radius of the fringes. Plug the parameters thus obtain into the equation and we are able to find the radius of curvature of the spherical planoconvex.

$$R = \frac{\overline{ab}}{2\theta} = \frac{\sqrt{{r_n}^2 + (\frac{n\lambda}{2})^2}}{2\tan^{-1}(\frac{n\lambda}{2r_n})}$$

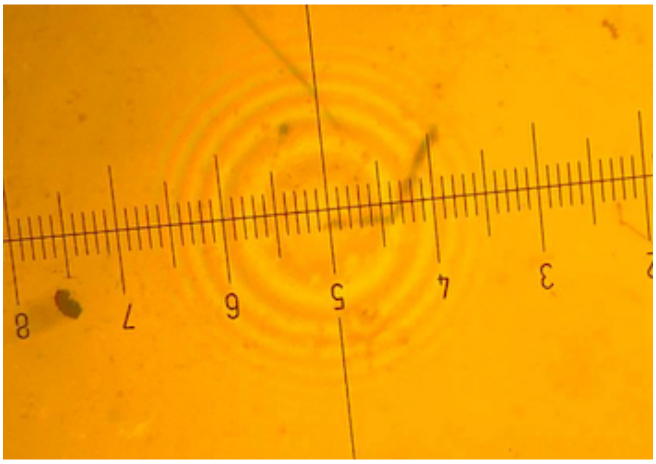
The below equation could be used as a fairly good approximation,

$$R = \frac{{r_n}^2}{n\lambda}$$

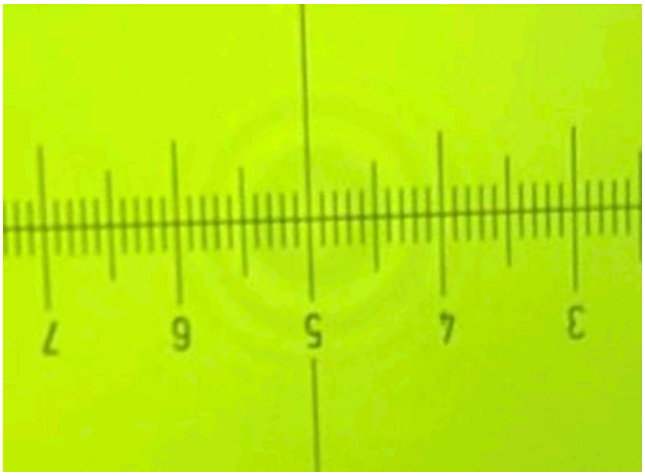
Actual Experiment Result



Actual Experiment



Actual Experiment



Red Light(λ=663nm)							
n	Label number	t(nm)	r_n(m)	$\overline{ab}$(m)	θ	R(m)	R estimate(m)
1	7.5	332	0.000181	0.000181	0.001830	0.04948	0.04948
2	10.9	663	0.000263	0.000263	0.002519	0.05226	0.05226
3	13.1	995	0.000316	0.000316	0.003144	0.05032	0.05032
4	15.1	1328	0.000365	0.000365	0.003636	0.05014	0.05014

Yellow Light (λ=580nm)							
n	Label number	t(nm)	r_n(m)	$\overline{ab}$(m)	θ	R(m)	R estimate(m)
1	7	290	0.000169	0.000169	0.001715	0.04927	0.04927
2	10.1	580	0.000244	0.000244	0.002378	0.05129	0.05129
3	12.4	870	0.000299	0.000299	0.002905	0.05154	0.05154
4	14.2	1160	0.000343	0.000343	0.003383	0.05069	0.05069

Green Light(λ=530nm)							
n	Label number	t(nm)	r_n(m)	$\overline{ab}$(m)	θ	R(m)	R estimate(m)
1	6.5	265	0.000157	0.000157	0.001688	0.04649	0.04649
2	9.4	530	0.000227	0.000227	0.002335	0.04862	0.04862
3	11.7	795	0.000283	0.000283	0.002814	0.05021	0.05021

Matlab simulation:

Using the program and get the simulation value of r_n as the following tables.

red light (λ=663nm)

n	r_n(m)
1	0.0001275
2	0.0001825
3	0.0002225
4	0.0002575

yellow light (λ=580nm)

n	r_n(m)
1	0.0001175
2	0.0001675
3	0.0002075
4	0.0002375

green light (λ=530nm)

n	r_n(m)
1	0.0001125
2	0.0001625
3	0.0001975
4	0.0002275

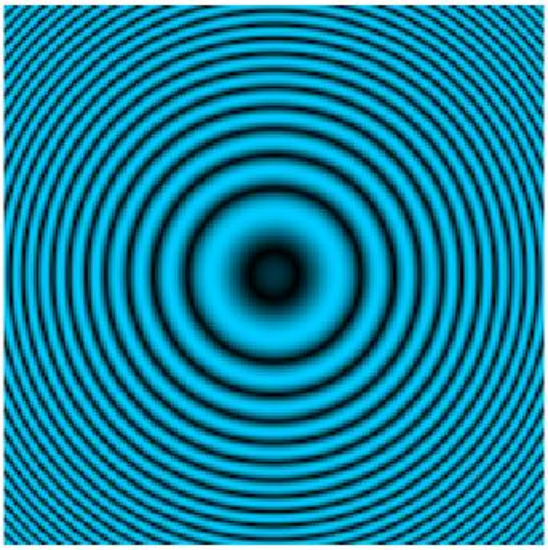
We can type in the value of the parameters(wave length, curvature radius and air thickness) in the program and get the correspond pictures.

Wavelengh:480.0 nm

Curvature radius:10.0 m

Air thickness:50.0 nm

Simulate Newtons Ring

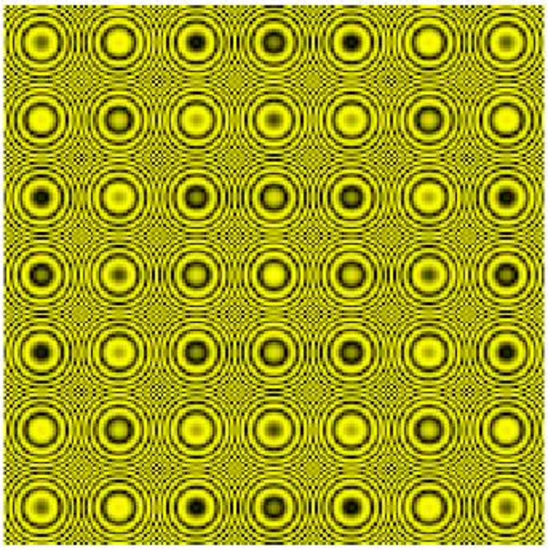


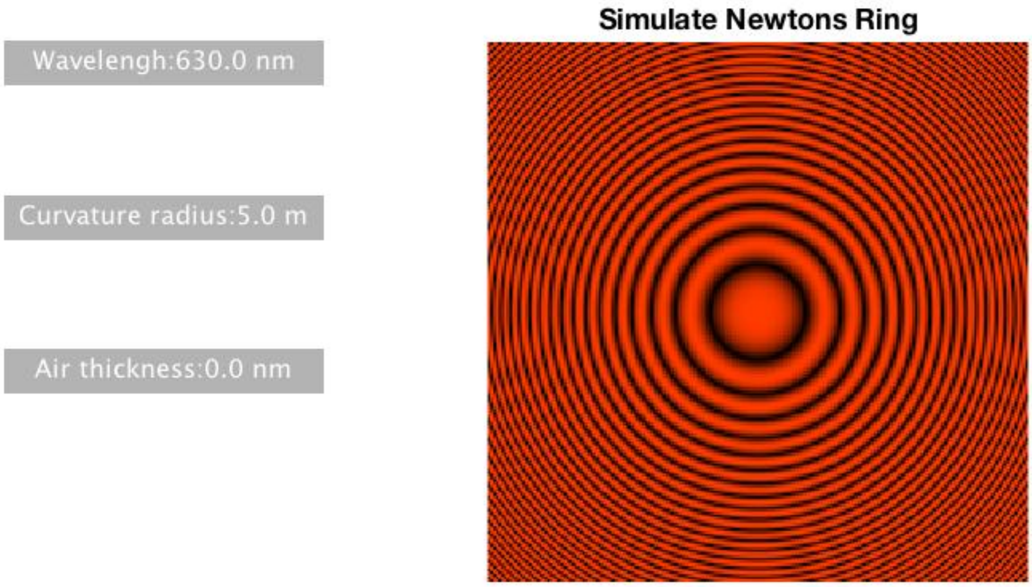
Wavelengh:580.0 nm

Curvature radius:0.5 m

Air thickness:0.0 nm

Simulate Newtons Ring





Discussion:

From the lensmaker's equation for thin lens in air:

$$\frac{1}{f} = (n-1)(\frac{1}{R_1} - \frac{1}{R_2})$$

The focal length of the plano-convex lens is measured to be 10cm.

Applying $n = 1.50$ and $R_2 = \infty$, the equation yields $R_1 = 5.0(\mathrm{cm})$

The focus of a planoconvex could be easily obtain when we apply a light source on the lens and look for the focus of the lens on a wall. So, the only problem is that we often do not know the refractive index n of the material we use. By finding the Newton's ring of the optical system, we can obtain the measurement value of the planoconvex and thus compute the value of the refractive index by lensmaker's equation.

Summary:

1. Newton's ring is the interference pattern caused by the thin air film between an optical flat and a planoconvex due to the optical path difference.
2. We can find the radius of curvature by measuring the parameters $\mathrm{r}, \lambda, \mathrm{r_n}, \mathrm{n}, \mathrm{t}$. Next use the equation below:

$$R = \frac{\overline{ab}}{2\theta} = \frac{\sqrt{{r_n}^2 + (\frac{n\lambda}{2})^2}}{2\tan^{-1}(\frac{n\lambda}{2r_n})}$$

$$\frac{1}{f} = (n-1)(\frac{1}{R_1} - \frac{1}{R_2})$$

We could obtain the approximate radius of curvature of the spherical planoconvex R and the refractive index n of the glass we use.

References:

- https://www.scipress.com/ILCPA.48.27.pdf
- http://en.pudn.com/Download/item/id/1885640.html
- http://www.animations.physics.unsw.edu.au/jw/light/Newton%27s-rings.html
- http://materias.df.uba.ar/f2aa2016c1/files/2016/06/anillos_de_newton2.pdf