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Theory of Newton Ring

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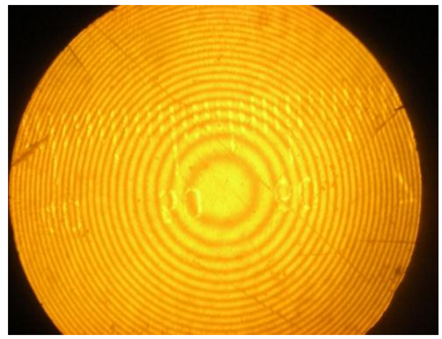
Abstract

This experiment looks to investigate the physical optics of the interference pattern called Newton's rings and calculate the wavelengths of various filters as well as the radius of curvature of a plano-convex lens. Through the consideration of the wavelength dependence of the diameter of the rings, mathematical relationships are derived and applied on the measured data to verify the known wavelength values. The results produced by the data successfully show the relationship between diameters of the rings, their order, the refractive index of the medium causing the interference pattern and the wavelength of the incident light. Graphical analysis confirms that the diameters of the rings are larger at higher orders, and larger still for longer incident wavelengths.

Introduction

Newton's rings is a phenomenon in which an interference pattern is created by the reflection of light between two surfaces—a spherical surface and an adjacent touching flat surface. It is named for Isaac Newton, who first studied the effect in 1717. When viewed with monochromatic light, Newton's

rings appear as a series of concentric, alternating bright and dark rings centered at the point of contact between the two surfaces. When viewed with white light, it forms a concentric ring pattern of rainbow colors, because the different wavelengths of light interfere at different thicknesses of the air between the surfaces



When a Plano convex lens of long focal length is placed in contact on a plane glass plate (*Figure given below*), a thin air film is enclosed between the upper surface of the glass plate and the lower surface of the lens. The thickness of the air film is almost zero at the point of contact **O** and gradually increases as one proceeds towards the periphery of the lens. Thus points where the thickness of air film is constant, will lie on a circle with **O** as center.

By means of a sheet of glass **G**, a parallel beam of monochromatic light is reflected towards the lens **L**. Consider a ray of monochromatic light that strikes the upper surface of the air film nearly along normal. The ray is partly reflected and partly refracted as shown in the figure. The ray refracted in the air film is also reflected partly at the lower surface of the film. The two reflected rays, i.e. produced at the upper and lower surface of the film, are coherent and interfere constructively or destructively. When the light reflected upwards is observed through microscope **M** which is focused on the glass plate, series of dark and bright rings are seen with center as **O**. These concentric rings are known as " Newton's Rings ".

At the point of contact of the lens and the glass plate, the thickness of the film is effectively zero but due to reflection at the lower surface of air film from denser medium, an additional path of **λ/2** is introduced. Consequently, the center of Newton rings is dark due to destructive interference.

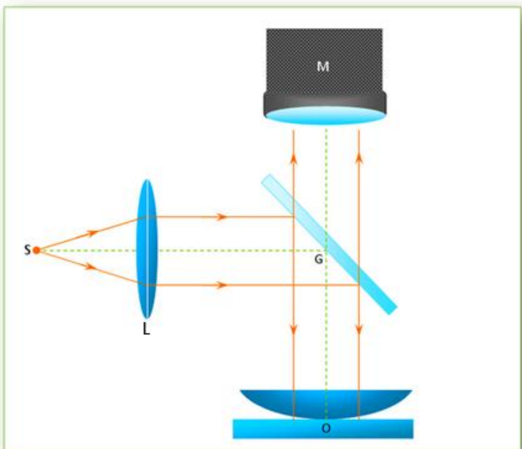
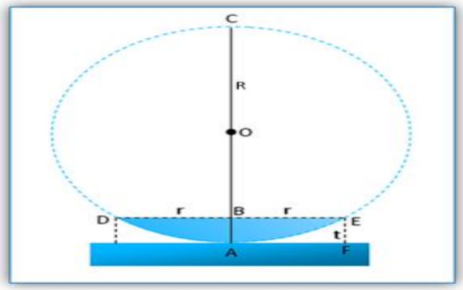


Fig . Experimental arrangement for observing Newton's rings

Let us consider a system of plano-convex lens of radius of curvature **R** placed on flat glass plate it is exposed to monochromatic light of wavelength λnormally.

The incident light is partially reflected from the upper surface of air film between lens and glass and light is partially refracted into the film which again reflects from lower surface with phase change of 180 degree due to higher index of glass plate. Therefore the two parts of light interfere constructively and destructively forming alternate dark and bright rings.

Now consider a ring of radius **r** due to thickness **t** of air film as shown in the figure given below:



According to geometrical theorem, the product of intercepts of intersecting chord is equal to the product of sections of diameter then,

$$\overline{DB} \times \overline{BE} = \overline{AB} \times \overline{BC}$$
$$r \times r = t(2R - t)$$
$$r^2 = 2Rt - t^2$$

As **t** is very small then t^2 will be so small which may be neglected, then,

$$r^2 = 2Rt$$

$$t = \frac{r^2}{2R} \qquad \Rightarrow (1)$$

Radius for bright ring

The condition for constructive interference in thin film is,

$$2tn = \left(m + \frac{1}{2}\right)\lambda \qquad m = 0,1,2,....$$

From equation (1) putting the value of **t** in the above equation we get,

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

since **n = 1** for air film

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

or

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

$\Rightarrow (2)$

For first bright ring, *m* = 0

$$r_1 = \sqrt{\frac{1}{2}\lambda R}$$

For second bright ring, *m* = 1

$$r_2 = \sqrt{\frac{3}{2}\lambda R}$$

For third bright ring, *m* = 2

$$r_2 = \sqrt{\frac{5}{2}\lambda R}$$

Similarly, for *Nth* bright ring,

m = N - 1

$\Rightarrow (3)$

Radius for dark ring

The condition for destructive interference in thin film is,

2tn = mλ *m* = 0,1,2,....

By putting the value of **t**, we get,

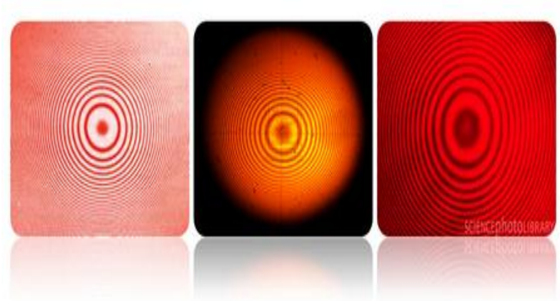
$$2\left(\frac{r^2}{2R}\right)(1) = m\lambda$$

For air **n = 1**

$$r = \sqrt{m\lambda R} \quad \Rightarrow (4)$$

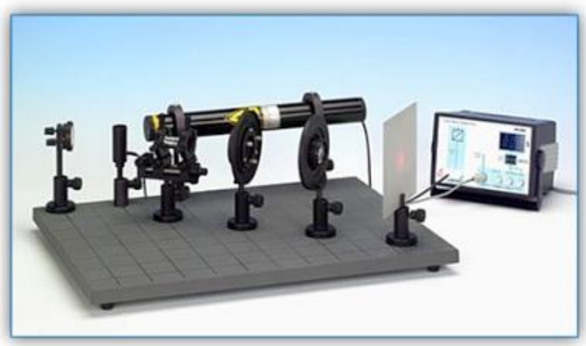
For $m = 0 \Rightarrow r = 0$ i.e. point of contact.

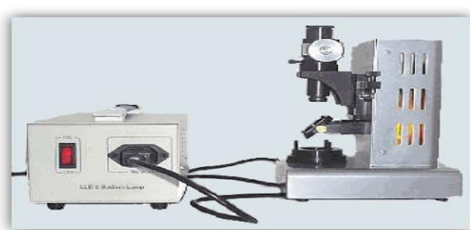
Now, if the radius of curvature of plano-convex lens is known and radius of particular dark and bright ring is experimentally measured then the wavelength of light used can be calculated from equation (3) and (4).



Images of Newton's Rings s

Newton's Ring Apparatus

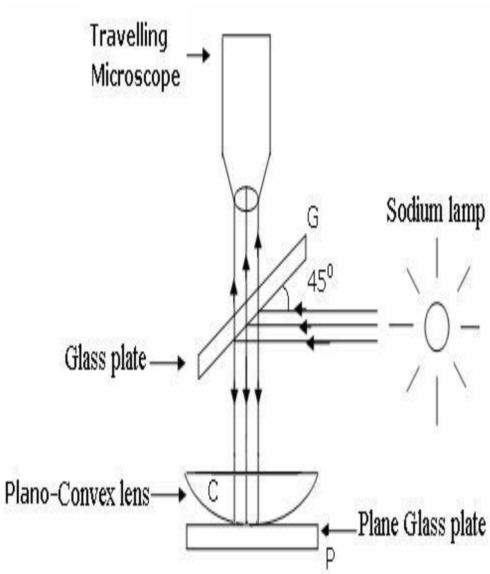




Application of Newton Ring

Determination of Wavelength of Light

In order to determine the wavelength of monochromatic source an experimental arrangement is set up as shown in figure.



The monochromatic light is made incident on the plano-convex lens and the reflected light is viewed in travelling microscope. Microscope is adjusted till the circular rings came in focus. Now the microscope crosswire is focused on the central dark spot and is moved slowly at one side, say right side. As the cross – wire moves in the field of view, dark rings are counted. The movement is stopped when it reaches at the 22nd dark ring. The cross wire is moved in opposite side and stopped at 20th dark ring such that the vertical cross-wire is made tangential to the ring. Thus starting from 20th the microscope position is noted down for 18th, 16th, 14th, …..6th ring. The microscope is quickly moved to the left side of the ring pattern and the positions of microscope is again noted down for 6th, 8th, 10th,……..20th ring. The diameter of the nth order ring is calculated by subtracting the left and right side position of the microscope. As we know that the square of diameter of nthdark ring is

$$D_n^2 = 4n\lambda R$$

Therefore the square of diameter of (n+p)th ring is

$$D_{n+p}^2 = 4(n+p)\lambda R$$

Subtracting both the above equation

$$D_{n+p}^2 - D_n^2 = 4(n+p)\lambda R - 4n\lambda R \quad ....(5)$$

Therefore

$$\boldsymbol{\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR}} \quad .(6)$$

B. Determination of Refractive Index of liquid

In order to determine the refractive index of liquid the Newton's ring experiment is first performed for the air medium and the difference in the square of the diameter of (n+p)th and nth dark ring is found as discussed above.

$$(D_{n+p}^2 - D_n^2)_{air} = 4p\lambda R \quad ...(.6)$$

After this few drops of liquid of μ refractive index is placed on the glass plate. The plano-convex lens is then placed on the glass plate, as a result a film of liquid is formed between the lens and the plate.

The difference in the square of the diameter of (n+p)th and nth dark ring is again calculated in the same manner for the liquid medium.

$$(D_{n+p}^2 - D_n^2)_{liquid} = \frac{4p\lambda R}{\mu} \quad ....(7)$$

Dividing equation 2.29 by 2.30, we get

$$\mu = \frac{(D_{n+p}^2 - D_n^2)_{air}}{(D_{n+p}^2 - D_n^2)_{liquid}} \quad ....8)$$

Conclusion:

Newton's rings can be produced by using a plano-convex lens adjacent to a optically flat glass surface in order to exploit the thin-film phenomena. & Find the radius of newton rings varies with order of rings

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