Advanced Higher Physics: Assignment Support

Astronomy & Physics Education Group

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Measurement of wavelength by Newton's Rings

Introduction

When a long focus convex lens is placed on an optically flat glass plate and illuminated from above with monochromatic light, an interference pattern of circular rings is produced, known as "Newton's Rings". The interference pattern is caused by two beams of light: the first is internally reflected off the lower surface of the convex lens; the second is transmitted through that lower surface, then reflects off the flat glass plate beneath. Figure 1 shows the typical arrangement of the equipment for a Newton's Ring set up. The glass reflecting plate, aligned at 45°, allows light to illuminate the set up whilst simultaneously allowing the resulting interference pattern to be viewed with a travelling microscope.

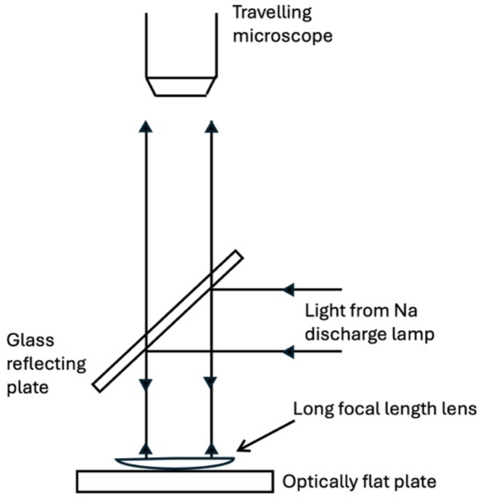

Figure 1: Newton's Rings set-up

The pattern only occurs where the space between the lens surface and the plate is very small, i.e. in the region close to the point of contact of the lens with the plate. The greater the focal length of the lens, the smaller its curvature and consequently the greater the extent of the resulting ring pattern and the more widely spaced the rings.

Figure 2 shows a more detailed illustration of the rays involved: the incident ray (black), the internally reflected ray (green) and the ray which emerges from the lens and is reflected from the glass plate (red).

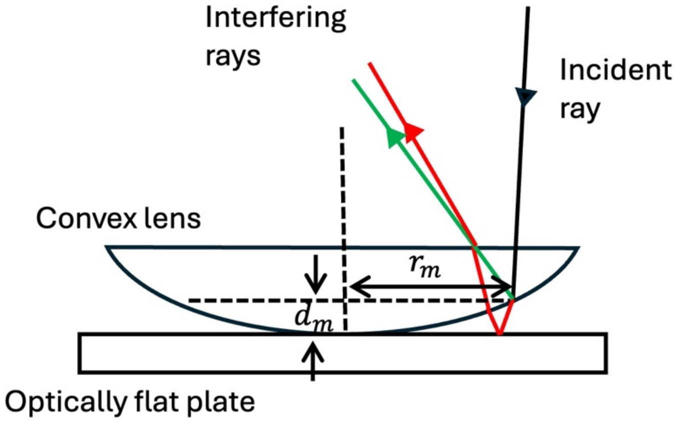

Figure 2: Main rays of interest

For light incident normally on the lens the displacement of light emerging from the lower lens surface due to refraction can be ignored and the effective path difference between the interfering rays is given by $\delta = 2d$.

In the Newton's Ring set up we have two boundaries – lens to air, then air to lens. When light moves from a less dense medium to a denser medium, the reflected ray undergoes a π radians phase shift, relative to the original ray. So, in our set up one of the beams – the red one – will undergo such a shift. This means that dark interference fringes occur at distances d_m as given by

$$2d_m = m\lambda$$

$$\Rightarrow d_m = \frac{m\lambda}{2}$$

[1]

The shape in Figure 3 represents a circle of radius R, of which the convex lens is a section. The figure illustrates the connection between R, d_m and r_m, the radius of the interference rings.

The lines AB and CD are chords that meet at S; the theory of intersecting chords states that

$$AS \times SB = CS \times SD$$
$$\Rightarrow (2R - d_m) \times d_m = r_m \times r_m$$
$$\Rightarrow r_m^2 = 2Rd_m - d_m^2$$
$$\Rightarrow r_m^2 \approx 2Rd_m$$

since $d_m \ll R$. Combining this with [1] we then get

$$r_m^2 = \frac{2Rm\lambda}{2}$$

In practice it is more common to measure the diameter of the rings in a Newton's Ring pattern:

$$\boxed{D_m^2 = 4Rm\lambda}$$

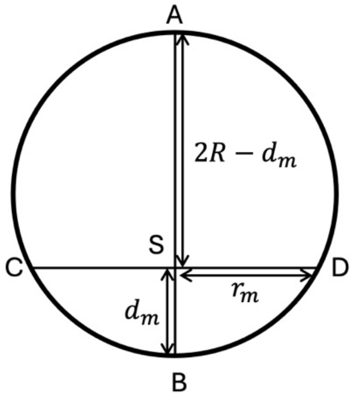

Figure 3: Circle of radius equal to that of convex lens

[2]

If graph of D_m^2 against m is plotted then λ can be determined provided the radius of curvature of the lens, R, is known.

Notes on equipment

Equipment list

- Travelling microscope
- Convex lens
- Flat glass plate
- 45° angle reflecting plate
- Sodium discharge lamp

Equipment guidance

Travelling microscope

- Make sure the crosswires are in focus by adjusting the eyepiece. Then focus the microscope on the ring pattern.

- To measure the diameters of the rings, first find the centre of the ring pattern. Move the microscope to the left (or right), counting out to the 10th ring. Note the position of the microscope, then move in ring by ring recording the positions of each. Continue back to the centre, then outwards to the 10th ring again. These values will give you the diameters of the first 10 rings.

Lens set up

- To get the clearest interference pattern, place the convex lens, plate and reflecting glass assembly on the tray of the travelling microscope and then adjust the reflecting plate and lamp to get as much light on to the convex lens as possible.

Determining the radius of curvature of the lens

There are a range of ways to do this; the method described below is known as the method of self-conjugate points. This method follows from the fact that the light reaching a convex lens from its focal plane is rendered parallel to the optic axis of the lens. It uses the arrangement shown in Figure 4.

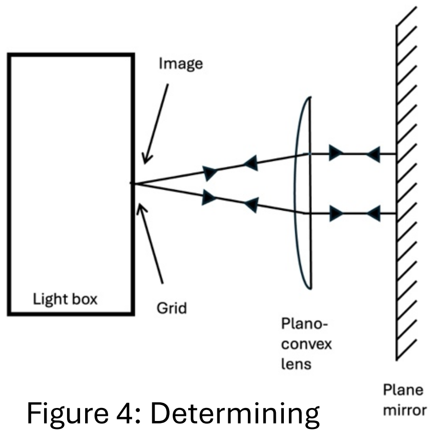

Figure 4: Determining focal length of lens

When the distance between the grid and the lens equals the focal length of the lens, the beams reaching the lens will emerge parallel. As a result when they then reflect from the plane mirror they will return along the same path, creating an image superimposed on the original source. The arrows in Figure 4 show this.

The following procedure should be carried out:

1. Create the set up shown in Figure 4, adjusting the plane mirror until the reflected light forms an image of the grid on the light box.
2. Adjust the positions of the lens and plane mirror until the image is as sharply focussed as possible, then clamp the lens holder in place.

3. Measure the distance between the light box and the lens. You can use a metre rule for this, or a vertex pointer. The latter method uses a horizontal pointer mounted on a post. Place one end of the pointer against the light box then note the position of the post. Move the post until the other end of the pointer is in contact with the lens; note the position of the post. The distance between box and lens is then the difference in these positions PLUS the length of the vertex pointer itself.
4. Measure the thickness of the lens with vernier callipers and hence determine the distance from the surface of the lens to its centre along its optic axis, and therefore the total distance from grid to centre of lens. This is the focal length.
5. The lens is plano-convex and made of crown glass of refractive index 1.52. Together with the value now calculated for the focal length, the lens maker's formula allows the radius of curvature of the convex surface of the lens to be determined.

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

[3]

Original script: Peter Law

Updated script: Peter H Sneddon