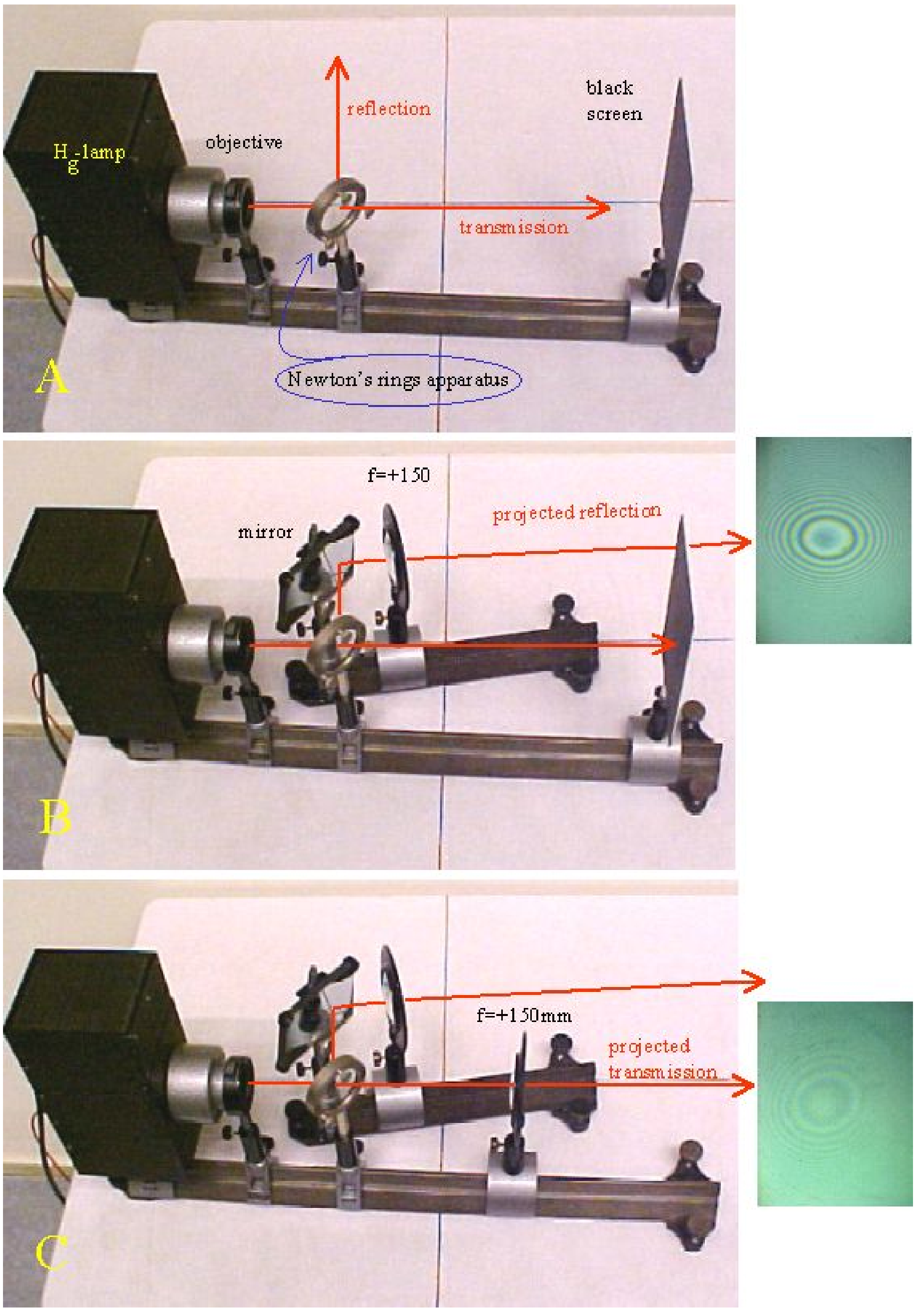
Newton's rings (2)

Aim: To show Newton's rings, and that its colorsequence is not a rainbow.

Subjects: 6D30 (Thin Films)

Diagram:



Equipment:

- Newton's rings apparatus (convex lens pressed against flat glass plate (Duboscq); pressure can be adjusted by screws in the ring-mount).
- Hg-lamp, with power-unit.
- Objective lens.
- Two lenses f=150mm/diam.=70mm.
- Flat surface mirror.
- Black screen.

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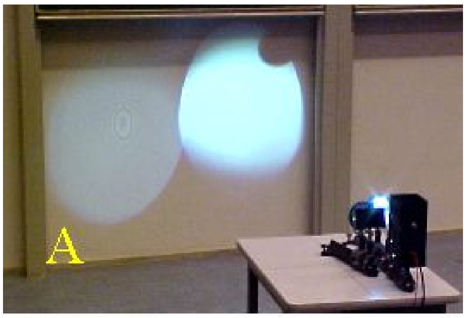
Safety:

- The Hg-lamp needs some time to come to its full light intensity. It also becomes very hot! Do not touch it.

Presentation: Set up the equipment as shown in Diagram. Images are projected on the wall (see Figure 1A).



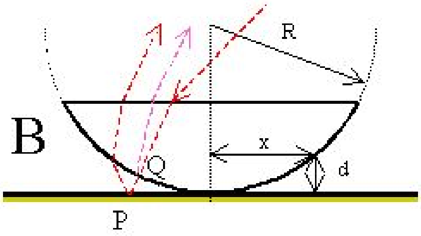


Figure 1

After the lamp is heated up, situation of Diagram A is presented to the students, to indicate that there will be a reflected and a transmitted beam of light. Then the transmitted beam is blocked (black screen) and using the mirror and a +150mm-lens the reflection image is projected (Diagram B). Clearly Newton's rings are observed. Observe the central dark spot (see also: Remarks) observe the colored rings, the color-sequence and observe the diminishing distance between the rings when moving away from the centre. Changing the pressure on the Newton's rings apparatus will change/move the reflected image. Then the black screen is removed and using the second +150mm-lens the transmitted image is projected next to the reflected image (see Diagram C and Figure 1). It is clearly visible that both images are complementary.
At first glance, the observed colors look rainbowlike, but careful observation shows that it differs from a rainbow (see Figure 2; *reality is much better than this photograph*).

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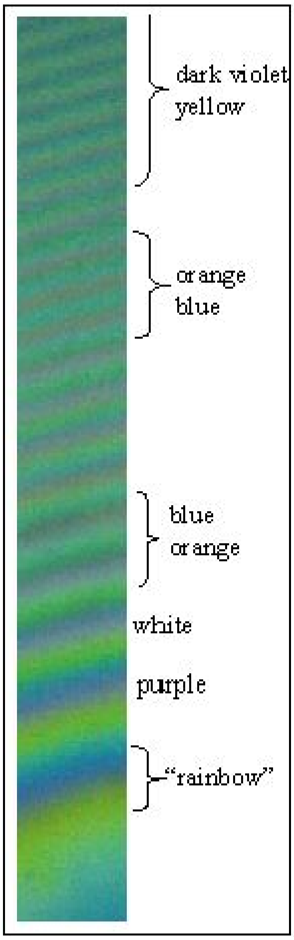

Figure 2

Observing the reflected image shows, when moving away from the central dark spot, at first a rainbow, but already in the next ring the color purple appears; in the next rings white and orange are dominating; around ring 10 there is a repeating sequence of blue and orange and around ring 16 repeating bands of dark violet and yellowish rings are visible giving form a distance the impression of a continuity of black and white fringes.

Explanation: See Figure1 B. Looking at the two red rays drawn in this figure, we see that it is the height d that introduces the phasedifference. $d=R-(R^2-x^2)^{1/2}$.

The two rays, one reflecting from the hemisphere and the other reflecting from the plane, will have a phasedifference of $\Delta\phi=k(2d)-\pi$ (π at reflection off the plane).

Maximum, constructive interference will occur at $\Delta\varphi=\frac{4\pi d}{\lambda}-\pi=m2\pi$, so when

$d=1/2\lambda(m+1/2)$.

This result translated to the distance x (because x lies in the plane we are watching/projecting) yields $1/2\lambda(m+1/2)=R-(R^2-x^2)^{1/2}$, giving $x=\{\lambda R(m+1/2)-1/4\lambda^2(m+1/2)^2\}^{1/2}$. And R being much larger than λ will give $x=\{\lambda R(m+1/2)\}^{1/2}$.

First conclusion is that x is proportional to the squareroot of wavelength. So a higher wavelength yields a higher x: blue is on the inside, red on the outside. Second, the proportionality in $(m+1/2)^{1/2}$ shows that the sequence of the bright fringes follows a square root: moving away from the centre the fringes come closer and closer together.

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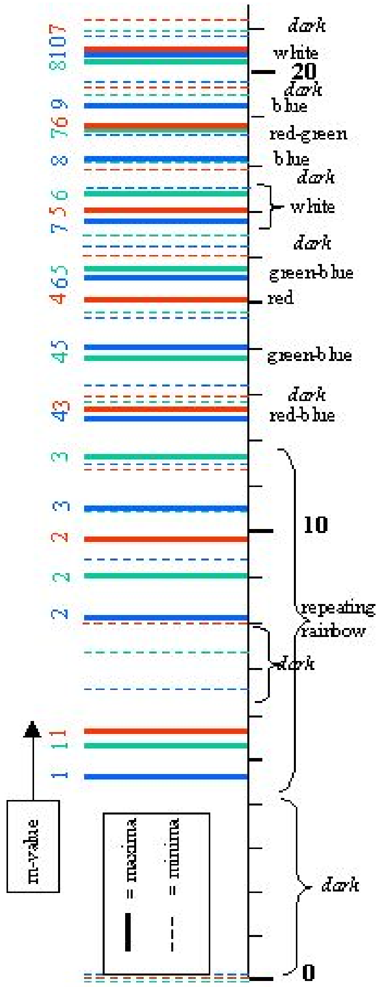

Figure 3

Finally, we calculated for a number of m-values *x*. Figure 3 shows the calculated results (10^{-5}; R=1m) for the red, green and blue line of H_g-light. In this way it is clear that the colours observed are the result of different combinations. Only near the centre a rainbow pattern appears.

It is not difficult now to show that for destructive interference we get $x=(\lambda Rm)^{1/2}$. This yields that the centre of the reflected Newton's rings must be a dark spot. Figure3 shows the minima as dashed lines for red, green and blue.

Remarks:

- Using filters, it is possible to show a monochromatic interference pattern. Especially in the yellow line of Hg the pattern is bright.
- In the projected reflection image the central area should be dark. But usually there is a coloured spot instead. This is probably due to trapped dirt in the contact area between the two surfaces.

Sources:

- Giancoli, D.G., Physics for scientists and engineers with modern physics, pag. 878-879
- Hecht, Eugene, Optics, pag. 398-399
- Young, H.D. and Freeman, R.A., University Physics, pag. 1152-1153