Experiment no(4)
Celestial telescope or Keplerian beam expander

Object:

Construction keplerian beam expander or keplerian telescope.

Apparatuses:
Two convex lenses , optical bench , HeNe laser , screen .

Theory :

Some uses for the single lens have been mentioned already. Complex optical tasks generally require the use of two or more lenses in an optical system. One such well-known lens system is the telescope, shown in Figures 1 and 2. The Galilean telescope, shown in Figure 16, gives an upright image of a distant object. .

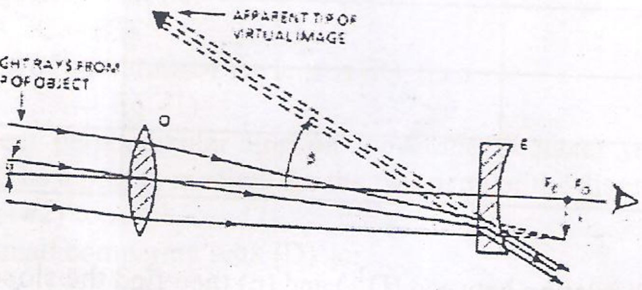


Fig. 1
Galilean telescope

The Galilean telescope consists of a positive objective O and a negative lens eyepiece E. Their focal points F_E and F_O are in coincidence, as shown. If no eyepiece lens were present, rays from a distant object would, after refraction through the objective lens, meet to form a real, inverted image "i" in the focal plane. However, because these rays are intercepted at the eyepiece, in front of the focal plane, the rays are diverged and seem to the eye to be coming from an object of much larger dimensions. The dotted lines at angle β indicate the direction along which the tip of the virtual image is seen with the Galilean telescope the image is erect and magnified. The amount of magnification is the ratio of angle β to angle a. This type of telescope is preferred for use as field or opera glasses because it is very short and compact and gives a bright, erect image. The telescope in Figure 2 is called a celestial or astronomical telescope. is telescope uses two lens systems, the objective lens system and the eyepiece lens system. Rays from a distant object are shown entering a long-focal-length objective lens as a parallel beam. These rays are brought to a focus and form a real, reduced image in the focal plane of the objective, F_O'.

If we assume the distant object to bé an arrow with the arrowhead upward, the image is real and inverted, as shown. The real image, viewed by the eye through the eyepiece lens system, is seen as a magnified, virtual image as shown by the dotted lines. The image, compared with the original object, is inverted. But this is not important when we look at stars, for example.

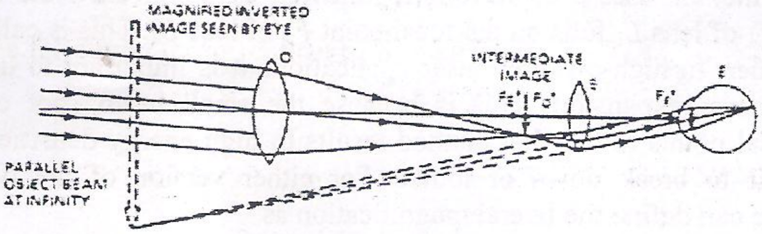


Fig. 2 Astronomical or celestial telescope

The celestial telescope is the basis for many instruments used in optics. The transit, sight level, alignment telescope, and the collimator all use a telescope in one form or another. One use of a telescope of this type in laser work is for the function of beam expansion. As shown in Figure 3, if a beam of light from the laser is used to illuminate the eyepiece and therefore is sent through the telescope "backward," it will emerge from the objective lens larger in diameter than when it entered and the rays will be somewhat more collimated or parallel..

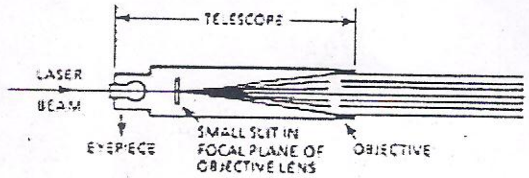
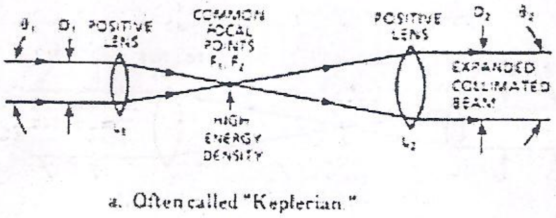
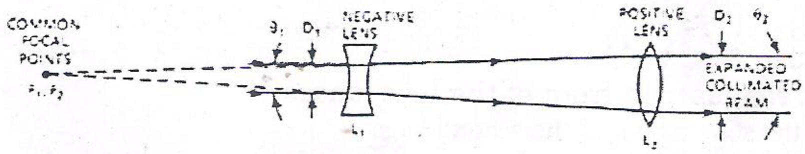


Fig. 3
Principle of beam collimation and expansion

As shown in Figure 4 there are two different ways to produce beam expansion or beam reduction. The first method (Figure 4a) uses a convex lens followed by another convex lens. Note that the focal point F_1 of lens L_1 falls on the focal point F_2 of lens L_2. This beam expander/collimator often is called the Keplerian beam expander. It and the one shown in Figure 4b have names derived from alleged inventors of refracting telescopes that closely resemble the beam expanders.



a. Often called "Keplerian."



b. Often called "Galilean."

Fig. 4

Two common types of beam expanders/collimators

The second method uses a concave lens followed by a convex. Note again that the focal point F_1 of lens L_1 falls on the focal point F_2 of lens L_2. This is called a Galilean beam expander. In high-powered laser applications it is important to use the second method of beam expansion. This is because the small beam spot created at the common focal points in the first method results in high energy densities, which may cause the air to break down or ionize. For either version of the two-lens beam expander, we can define the lateral magnification as

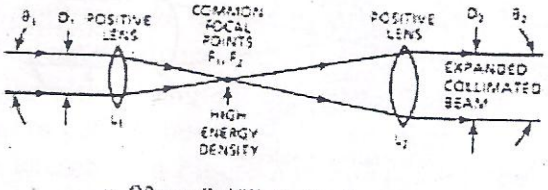
$$M = \frac{D_2}{D_1}$$

Optics texts show that the lateral magnification of the beam expander is given simply by the ratio of the focal lengths,

$$M = \frac{f_2}{f_1}$$

Procedure:

1- Put lenses on the optical bench as shown in the following set up.



a. Often called "Keplerian."

2- Put the laser in front of the first lenses.
3- Put the screen behind the second lens.
4- Change the position of the two lenses until obtain a collimated and magnified spot .
5- Measure D_1 and D_2 calculate the magnification factor.

Discussion :

1- Explain the following terms, concepts, or instruments.

e. Lens systems

f. Collimation.

2-When working with high-power lasers, why is it necessary to use a beam expander made of a negative and a positive lens rather than one made from two positive lenses? Use accurately drawn ray diagrams to help explain your answer.

3- explain what is the difference between telescope and beam expander ?.

Experiment No.(12)
Diffraction Grating

Object:

To measure the wavelength of light using a diffraction grating.

Apparatus:

- Spectrometer
- diffraction grating
- Na lamp and power supply

Theory

When parallel light is normally incident on a diffraction grating, one can derive the familiar "grating equation":

$n\lambda = d \sin \theta_n$, [1]

Where λ is the wavelength of the diffracted light, θ_n is the angle of diffraction relative to the grating normal, d is the grating constant (i.e., the spacing between lines on the grating) and n is the diffraction order. This equation is derived in the far-field, or Fraunhofer approximation which assumes that all diffracted rays for a given λ are parallel. Since the light rays from the source are normally incident on the grating surface the angular deviations corresponding to +n and −n are equal. A more general approach, in which normal incidence is not assumed, leads to

$$n\lambda = d\ \sin\left(\frac{\theta_n + \theta_n^{`}}{2}\right)\ \cos\left(\frac{i}{\cos\theta_n}\right) \qquad (2)$$

The angles θ_n and $\theta_n^{`}$ and i are shown in Fig 1, where SO is an incident ray from the source (S), OC is an undeviated ray corresponding to n = 0, and ON is the normal to the grating (GG`). OD and OD` are diffracted rays corresponding to order |n| and wavelength $\lambda$, whose angular deviations ($\theta_n$ and$\theta_n^{`}$) are no longer equal.

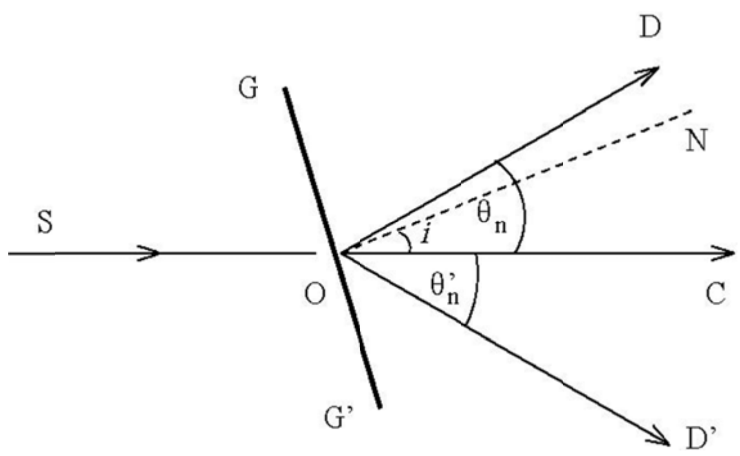
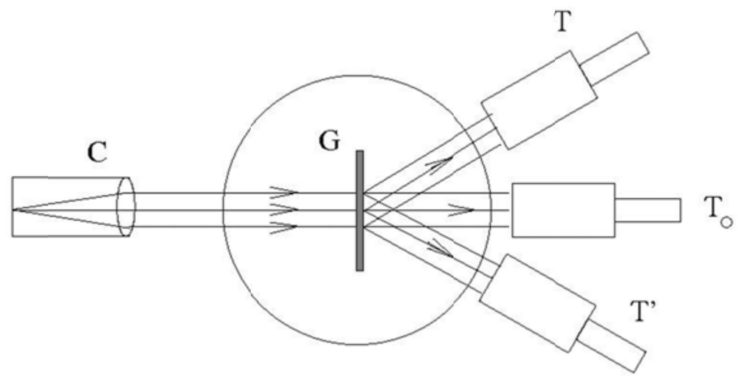


Figure 1: Derivation of the grating equation

The correction factor cos (i/ cos θ_n) is close to 1 if i is small. Even then, though, it is a good idea to measure both θ_n and $\theta_n^{`}$, and to use their average in the grating equation.

Procedure:

1- Fix the table of the spectrometer at zero degree.
2- Turn the telescope until it will be in front of the collimator.
3- Now turn the table until an image of the illuminated slit can be seen by reflection from one surface of grating. Adjust A and B until the image is at the center of the field of view.
4- Turn the telescope to the right until a set of colors appears.



5- Choose the first dispersed color of the source light used.
6- Fix the telescope at these colors and calculate the central angle of each color appears which represent$\propto_1$.
7- Repeat the steps 4,5,6 for the left side and calculate ($\grave{\propto}_1$) for each color.
8- Calculate the first dispersive angle from the relation :

$$\theta_1 = \frac{\{\alpha_1 + \grave{\alpha}_1\}}{2}$$

9- Calculate the wavelength for each color you find its dispersive angle from the relation:

$$n\lambda = d\ \sin\theta$$

Where d = width of groove.

n = order 1,2,3

λ = wavelength of the diffracted color.

10- Calculate the percentage error for each color by using

$$\text{error}\ \% = \left|\frac{\lambda_{\text{theoritical}} - \lambda_{\text{practical}}}{\lambda_{\text{theoritical}}}\right| \times 100\%$$

Discussion:

1- Discuss the reason of error.

Experiment no (9)

Determination the dispersive power of prism

Object :

Determine the dispersive power of prism.

Apparatuses:

Prism , spectrometer , halogen lamp .

Theory:

The dispersive power of a prism is a measure of how well the device separates light into its component wavelengths. Dispersive power Δ is defined mathematically as the ratio of the angular dispersion D of light exiting the prism to the total deviation angle δ.

$$\Delta = \frac{D}{\delta} = \frac{n_F - n_C}{n_D - 1}$$

where:

D = Angular separation between two reference wavelengths exiting the prism

δ = Total deviation of a third standard wavelength

n_F, n_C, and n_D = Indices of refraction measured at the three reference wavelengths

The relationship between D and δ is shown in Figure 1. Note that a prism with high deviation does not necessarily have good dispersion.

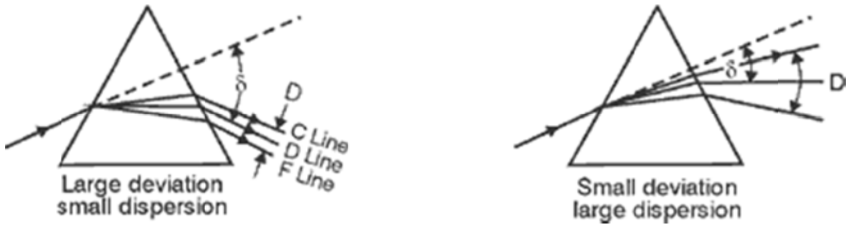


Fig. 1 Extreme cases showing the dispersion D for three wavelengths and the deviation δ for the intermediate wavelength

The reciprocal of the dispersive power is D defined as the Abbe Number. As you can see readily in Figure 1, the larger the dispersive power D, the larger is the spread D of the two reference lines (C and F) and the smaller is the deviation angle δ of the standard line (D) from the original ray direction. If instead one uses the Abbe Number to describe the dispersive character of a prism, the larger the Abbe Number, the larger is the overall deviation angle δ compared to the dispersion D of the reference C and F lines. For the left diagram of Figure 1, the prism shown has a lower dispersive power Δ and a higher Abbe Number, while in the right diagram; the prism shown has a higher dispersive power **Δ** and a lower Abbe Number. Wavelengths that are traditionally used in the definition of dispersion of optical glass come from the so-called Fraunhofer lines. These three wavelengths, designated F, C, and D, were among the lines studied by J. von Fraunhofer in the solar spectrum. They are convenient because the lines F and C lie at either end of the visible spectrum while D lines lie near the middle. The F and C lines originate from atomic hydrogen. The D line originates from atomic sodium.

Procedure :

1- Adjust the eyepiece of the telescope until the cross hairs are in sharp focus.
2- Turn the telescope towards a distant seen through an open window.Adjust the focusing screw until there is no parallax between the image of the distant object and the cross hairs.
3- Illuminate the list with light from source. Turn the telescope on to line with a collimator and view the list by light, which passes through both collimator and telescope. Adjust the collimator screw until the image of the list is clearly seen with no parallax between it and the cross hairs.
4- Place the prism ABC on the table so that one of the faces AC bounding the refracting angle A is perpendicular to the line XY joining two of the three screws XYZ as shown in figure (2).

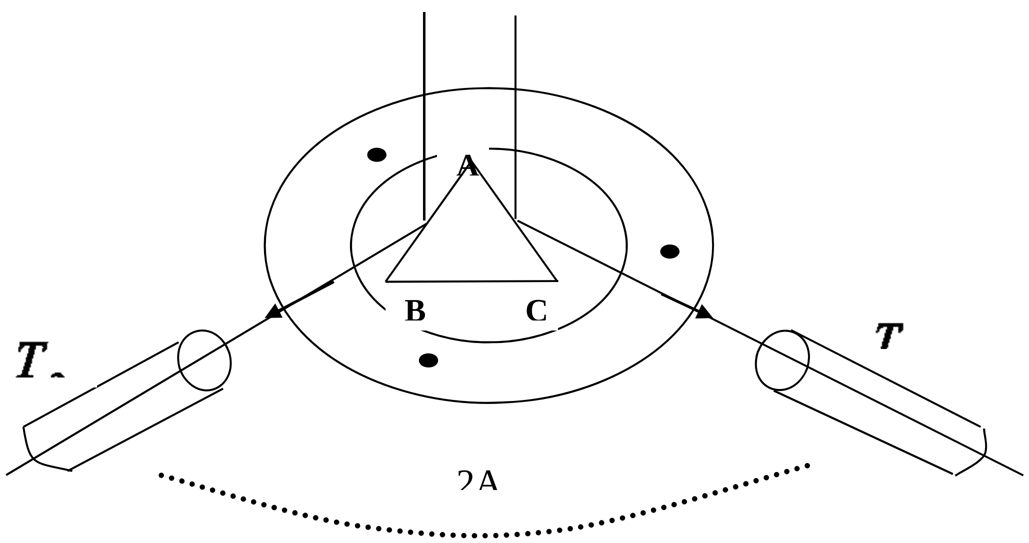


Figure (2): Prism on the spectrometer table

5- Move the telescope to observe the spectrum and particularly not the strong lines in the red and blue. Ends of the spectrum that are called the C (red) and F (blue) lines respectively.

6- As described above by suitable rotation of the prism table and the telescope set the C line in the position of minimum deviation . set the cross-hairs on the C line and read the vernier setting of the telescope β_c .

7- determine the refractive index of such color by using $n = \frac{\sin\left(\frac{\alpha+\beta}{2}\right)}{\sin\left(\frac{\alpha}{2}\right)}$

8- Repeat step above for the line β_f .

9- Find the Angular separation between two reference wavelengths exiting the prism. $D=n_f - n_c$

10- Determined the Total deviation of a third standard wavelength $\delta= n_D-1$, by measuring the deviation angle and the refractive index for the yellow line.

11- determine the dispersive power of the prism used

$$\Delta = \frac{D}{\delta} = \frac{n_f - n_c}{n_D - 1} .$$

Discussion:

1- Discuss the result of the dispersive power .

2- Describe the following terms or concepts:

a. Chromatic dispersion

b. Dispersive power

c. Abbe number

d. Lateral displacement of light beam

e. Ordinary ray

f. Extraordinary ray

3- By what way the deviation angle of the green color can measured ?

4- Discuss the variation of the velocity of different color inside the glass?

EXPERIMENT NO. (11)

Double slit diffraction pattern

Object:

- To see the interference pattern produced by coherent light passing through double-slit apertures.
- To explore how these patterns depend upon the size or separation of the apertures.
- To use the interference pattern and a known slit separation to accurately determine the wavelength of a coherent light source.

Equipment:

- He-Ne laser
- double slit
- screen

Theory:

Often known as Young's double-slit experiment, in honor of Thomas Young who performed this experiment in the early 19th century. We will illuminate two narrow slits with the same monochromatic, coherent light source. First of all, more light is going to reach the screen, and so the overall pattern to be brighter (more intense). But more interestingly, the interference pattern is seen due to the fact that the light from the two slits will travel different distances to arrive at the same point on the screen. If we consider two very narrow slits separated by a small distance d, the diffraction of the light from each slit will cause the light to spread out essentially uniformly over a broad central region and we would see a pattern such as the one depicted in Figure 1.

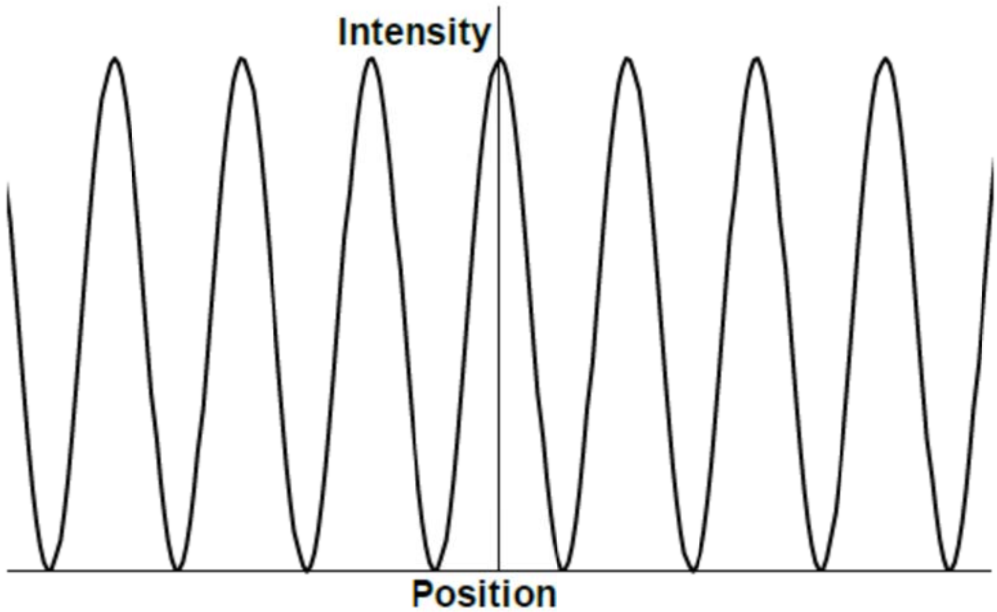


Figure 1: Idealized double-slit intensity pattern as a function of position. This is the pattern we would see if the size of the individual slits is relatively small. Single- and Double-Slit Interference

If the individual slits are somewhat larger, so that the diffraction patterns are not so spread out, we would expect to see a somewhat more complicated pattern, which shows both the diffraction pattern and double-slit interference pattern simultaneously, as depicted in Figure 2. In both cases, the maxima and minima will appear where the conditions for constructive and destructive interference are satisfied,respectively.

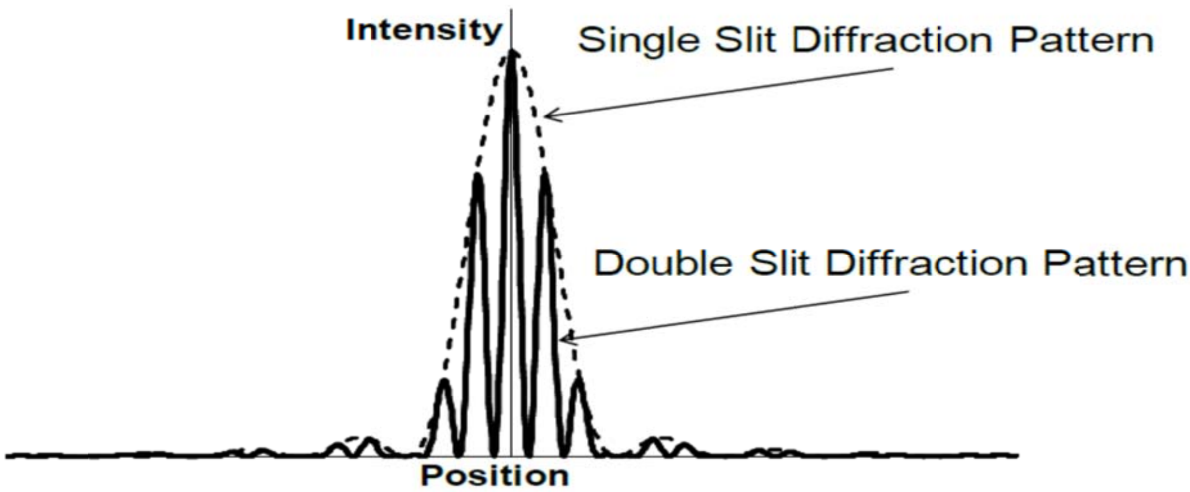


Figure 2: Actual (non-ideal) double-slit interference pattern. The maxima and minima appear where constructive and destructive interference occur, respectively, due to the path length difference between the waves propagating from each slit to the observation point (screen).

For the double-slit interference pattern, intensity maxima will be located at an angle θ relative to the central maximum, where θ will obey the relation

$$n\lambda = d\sin\theta \qquad (1)$$

The intensity minima, on the other hand, due to the double-slit interference will occur at an angle θ relative to the central maximum given by

$$\left(n+\frac{1}{2}\right)\lambda = d\sin\theta \qquad (2)$$

Procedure:

1- The double slit placed a distance (L) from the laser.
2- Arrange the distance between the double slit and the viewing screen until Young`s fringes will be observed
3- Fix the position of the screen and determine the distance between the screen and the double slit which represent (D).
4- By using a graph paper, make the center of the dark fringe by a fine pencil and fine the width of the fringe (X_n).
5- Calculate the wavelength of the laser beam from equation (1)
6- Find the percentage error of the experiment.
7- Repeat the step above for the other different value of (d).

Discussion:

1- Are the source must be coherent? Why?
2- How much the percentage error and what is the reason caused this error.

Experiment No. (4)
Law of reflection

Fig.(1): Experimental setup

Object:

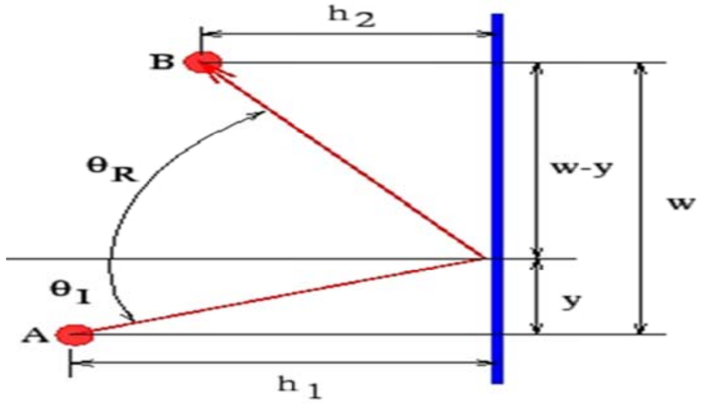
The aim of the experiment is to study the law of reflection for a plane, spherical mirrors

Equipment:

- Circular disk
- Plane mirror
- Concave mirror
- Ray optics box with single slit

Theory:

To deduce the reflection law it's possible to use again the Fermat's principle. This principle states in its simplest form that light waves of a given frequency traverse the path between two points which takes the least time to traverse. The most obvious example of this is the passage of light through a homogeneous medium in which the speed of light doesn't change with position. In this case, the shortest time is equivalent to the shortest distance between the points, which, as we all know, is a straight line. Thus, Fermat's principle is consistent with light travelling in a straight line in a homogeneous medium.



The preceding figure shows a candidate ray for reflection in which the angles of incidence and reflection are not equal. The time **t** required for the light to go from point A to point B is easy found as a function of h1, h2, y, w and c (velocity of light). If we find the minimum time by differentiating with respect to y and setting the result to zero, we obtain $\sin\theta_I = \sin\theta_R$ or

$$\theta_I = \theta_R \qquad (1)$$

Which is the law of reflection.

Procedure:

Part a: Reflection at plane mirror:

By placing the plane mirror at various incidence angles we get

Part b: Reflection at spherical mirrors:

Place the deformable mirror on the goniometric disc place. By changing its shape you can realize different shapes as concave and convex mirror and, in particular, at least approximately, as circular mirror. In all cases the goniometric disc can be rotated to observe the effect of the mirror as the direction in relationship with the incident beam varies.

Discussion:

1- What does the law of reflection state?
2- Does the law of reflection hold for curved mirrors?
3- Is the law of reflection applicable to all surfaces (smooth, rough, ...)?

Experiment No. (6)

Lenses

Object:

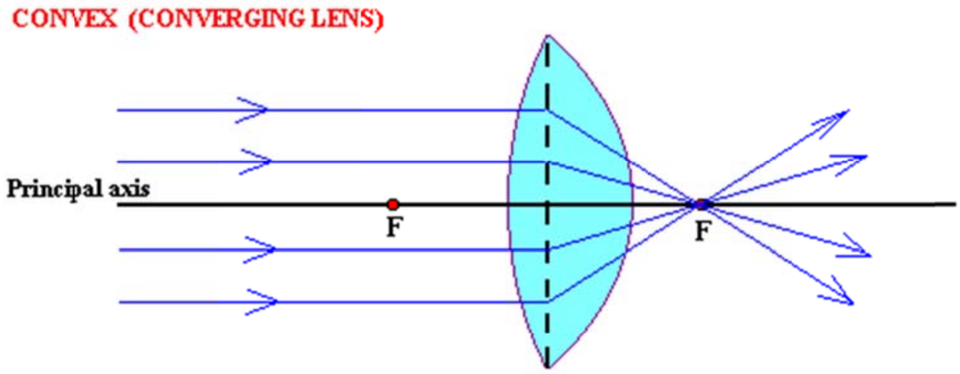
To determine the focal length of a convex and concave lenses.

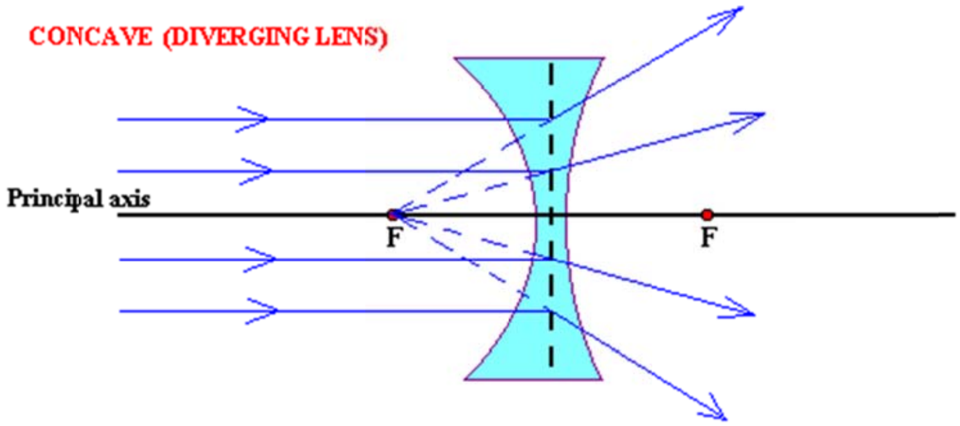
Equipment:

- Concave, and convex lens
- Optical bench
- Light source
- Ruler
- screen

Theory

The shapes of convex and concave spherical lenses are illustrated in the following figures. A radius of curvature is defined for each spherical surface of the lens, whereas a focal length f is defined for the whole lens. The center of curvature of each surface, C_1 and C_2, and the focal point F on each side of the lens are located along the principal axis. A convex lens (positive focal length) is called a converging lens because rays parallel to the principal axis converge at the focal point. A concave lens (negative focal length) is called a diverging lens because rays parallel to the principal axis appear to diverge from the focal point.

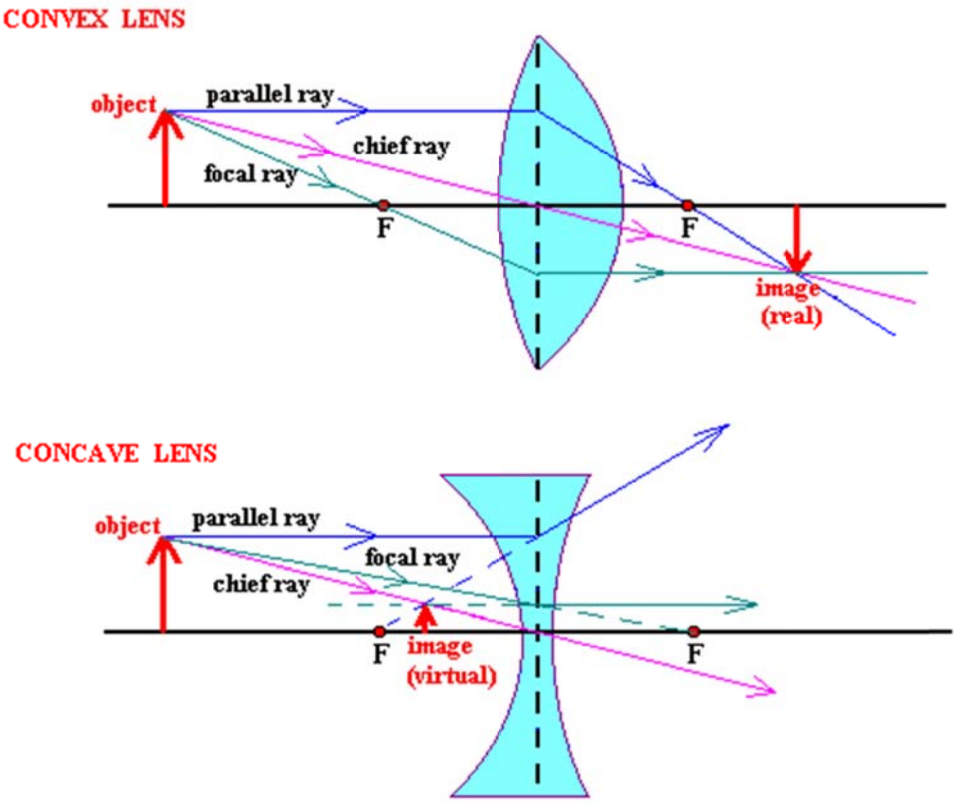




Similar to spherical mirrors, the characteristics of the images formed by spherical lenses can be determined graphically or analytically. However, in contrast to the mirror's case where the center of curvature and focal point are used in drawing diagrams, in lens' case we use the center of the lens and the focal point. [The center of curvature of each spherical surface is not used]. The chief ray through the center of a lens is undeviated.

For a convex lens, the parallel ray (parallel to the principal axis) is refracted such that it goes through the focal point on transmission through the lens. The focal ray that passes through the focal point in front of the lens (on the object side) is refracted parallel to the principal axis.

In the case of a concave lens, the parallel ray is refracted in a way such that it appears to have passed through the focal point on the object side of the lens. The focal ray that points toward the focal point behind the lens is refracted parallel to the principal axis.



If the image is formed on the side of the lens opposite to that of the object, it is real and can be observed on a screen. However, if the image is on the same side of the lens as the object, it is virtual and cannot be seen on a screen. The lens equation and magnification factor for analytically determining the image characteristics are identical to those for spherical mirrors:

$1 / d_o + 1 / d_i = 1 / f$

and the magnification

$M = h_i / h_o = - d_i / d_o$.

where d_o is the distance between the object and the lens, d_i is the distance between the image and the lens, h_o and h_i are the object height and the image height, respectively.

The sign convention for d_i and h_i is also similar. It should be noted that the lens equation applies only to thin lenses. The relationship between the focal length f and the radii of curvature R1 and R2 for a spherical lens is not as simple as for that of a spherical mirror (f = R/2). For a spherical lens, the focal length is given by what is known as the lens maker's equation:

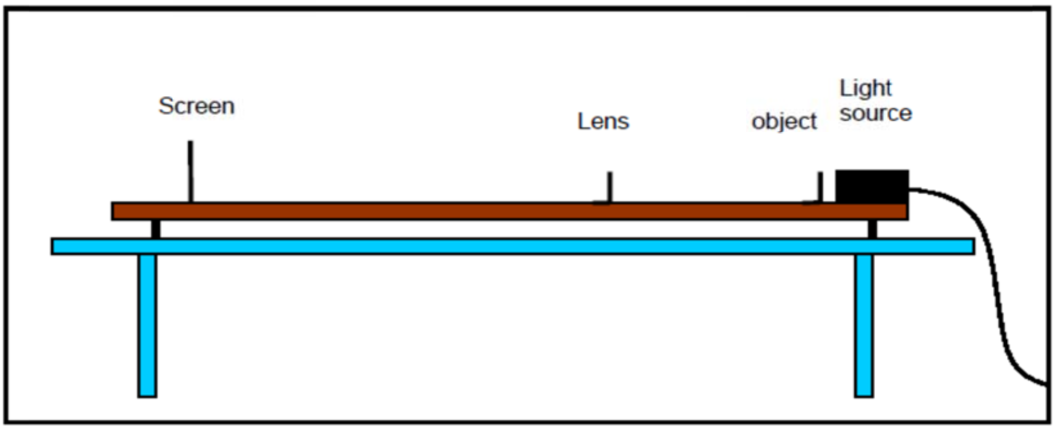
$1/f = (n - 1) [1/R_1 + 1/R_2]$

Where n is the index of refraction for the lens material, and the R's are taken positive for convex surfaces. For example: a lens made of glass with n = 1.5 and symmetrical converging lenses ($R_1 = R_2 = R$) will have f = R. However, if n = 2, then f = R/2.

Procedure:

Part A : determine the focal length of a convex lens.

1. Arrange the setup as shown in Fig. below



2. Let the lens be close to the object then start to move it towards the screen until the brightest and sharpest image is obtained.

3. Measure f which is the distance between the lens and the screen.

Part B : determine the focal length of a concave lens.

1- Set up the meter bench as before and slide the screen until the bright object is in focus in front of a convex lens.
2- Write down this position of the screen (s_1).
3- Place the concave lens of unknown focal length in this position.
4- Move the screen until the image is again in focus this is shown as screen position (s_2)
5- Now use the lens system formula to calculate the focal length of the concave lens this formula is

$$\frac{1}{f} = \frac{1}{s_1} + \frac{1}{s_2}$$

Experiment No. (3)

Measurement of refractive index of glass by using traveling telescope

Object:-

To measure the refractive index of glass by real and appearance depth.

Apparatuses:-

traveling telescope ,baker, object, piece of glass.

Theory:-

In fig(1) below look that the ray pQ that's come from point a which makes angle (i) with the normal,When the ray refracted from the surface its goes toward (QR)makes an angle (r) with the normal therefore the person who looks toward point(P) from air see it at point(P).

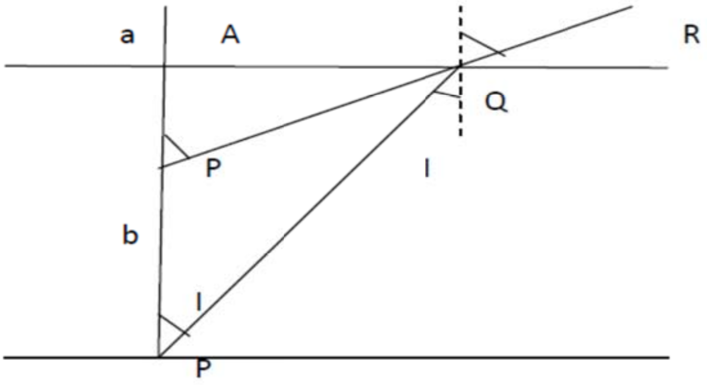


Fig.(1)

Now n=sin i/sin r=AQ/PQ/AQ/P’Q………………(1)

n=p’Q/PQ………………….(2)

n=PQ/P’Q……………………(3)

if the angle is very small then the distance

true depth=Pq=pA

appearance depth=p’Q=p’A

the refractive index =truedpth/appearance depth=Pa/P’A

Procedure:-

1- Putting the object at the glass plate.
2- Travel microscope until clear image found.
3- Read the vernia reading(x1)
4- put another glass plate above the first one and the object.

5- Then travel the microscope until clear image have been seen.
6- Measure microscope reading x2
7- Putting another object at the surface of glass plate.
8- Travel microscope until see the image.
9- measure the distance which represent(x3)

N=x3-x1/x3-x2

DISCUSSION:-

1- Explain the following (the thickness of wave plate effect on the refractive index of not)?
2- Discuss the result?

Experiment No. ( )

Microscope

Fig.(1): Set up of experiment.

Object:

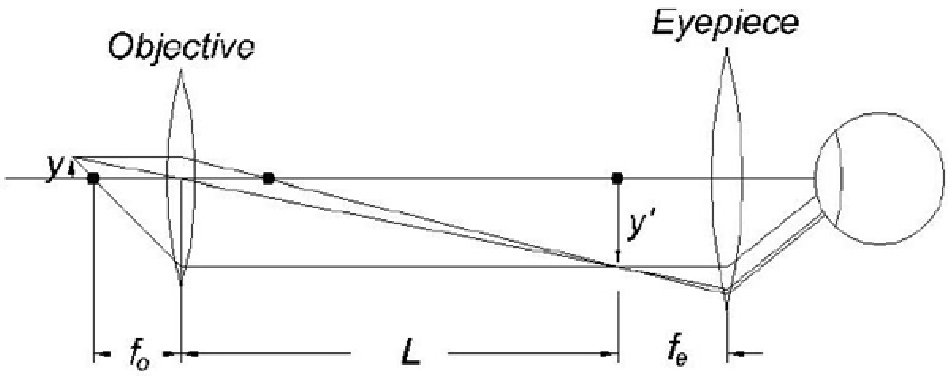
The purpose of this experiment is to demonstrate how a compound microscope functions.

Apparatus:

- Optical bench
- 2 Lens holder
- Screen
- Convergent lens of short focal length
- Convergent lens of big focal length
- Object

Theory:

The compound microscope is an instrument used to see objects that are too small for the naked eye. The compound microscope consists of two lenses called the objective and the eyepiece, arranged as shown in the figure below.



The objective lens, of focal length f_o , acts as a kind of projection lens to create image y' of object y which is just over one focal distance from the lens. The magnification of this part of the microscope is $m_0 = \frac{L}{f_0}$, where $L + f_e \approx L$ is the length of the microscope tube. Then, the eyepiece (whose focal length is f_e) acts like a simple magnifying lens on the image y' to provide an additional magnification factor of $m_e = \frac{25}{f_e}$.

The combined magnification is therefore

$$M = m_0 \, . m_e = \frac{L \, .25}{f_o f_e} \quad (1)$$

Procedure:

1- Arrange the set up as shown in fig.(1)
2- Move the lenses until a clear magnified image of a pen is obtained.
3- Measure the distance between the lenses which is L

4- Using equation (1) determine the magnification of the compound microscope.
5- Repeat steps from 2 to 4.
6- What`s the effect of changing L on the magnification.

Discussion:

1. Comment on your result?
2. If you have f=+10 cm how can you design microscope? If you can`t why?

Experiment No. ( )

Spherical Mirrors

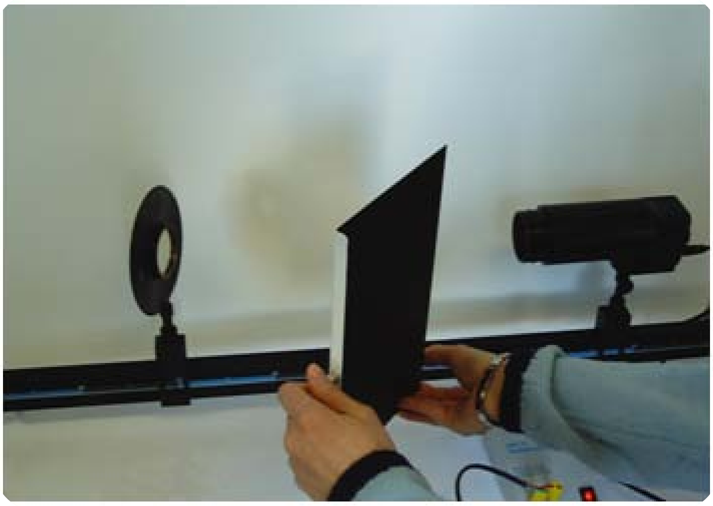


Fig.(1): experimental setup

Object:

The object of the experiment is to find the focal length of a concave mirror, convex mirror.

Equipment:

- Optical bench.
- Projector.
- Screen.
- Lens holders.
- Concave mirror of different focal lengths.

- Convex mirror.
- Converging lens of known focal length.

Theory:

A spherical mirror is a mirror which has the shape of a piece cut out of a spherical surface. There are two types of spherical mirrors: concave, and convex. These are illustrated in Fig.(2).

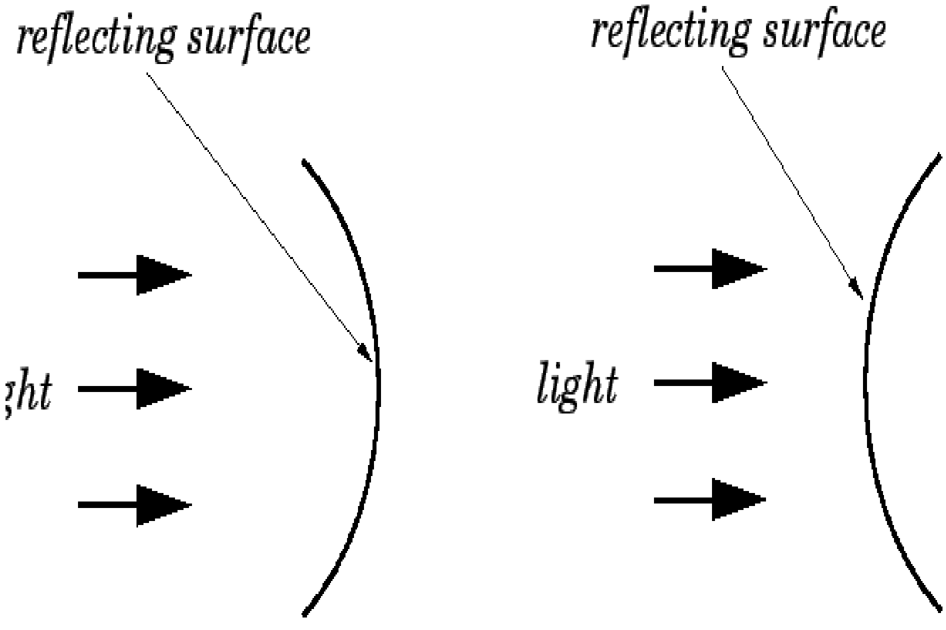


Fig.(2): A concave (left) and a convex (right) mirror

Let us now introduce a few key concepts which are needed to study image formation by a concave spherical mirror. As illustrated in Fig.(3), the normal to the center of the mirror is called the principal axis. The mirror is assumed to be rotationally symmetric about this axis. Hence, we can represent a three-dimensional mirror in a two-dimensional diagram, without loss of generality. The point V at which the principal axis touches the surface of the mirror is called the vertex. The point C, on the principal axis, which is equidistant from all points on the reflecting surface of the mirror, is called the center of curvature. The distance along the principal axis from point C to point V is called the radius of curvature of the mirror, and is denoted R. It is found experimentally that rays striking a concave mirror parallel to its principal axis, and not too far away from this axis, are reflected by the mirror such that they all pass through the same point F on the principal axis. This point, which is lies between the center of curvature and the vertex, is called the focal point, or focus, of the mirror. The distance along the principal axis from the focus to the vertex is called the focal length of the mirror, and is denoted f.

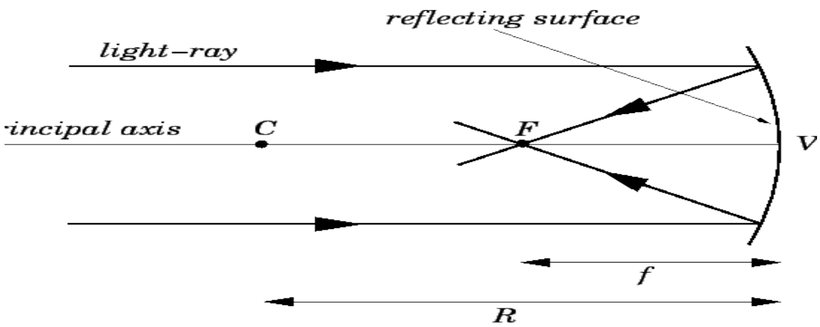


Fig.(3): Image formation by a concave mirror.

In our study of concave mirrors, we are going to assume that all light-rays which strike a mirror parallel to its principal axis (e.g., all rays emanating from a distant object) are brought to a focus at the same point F. While in convex mirror rays diverge upon reflection. So when you direct a beam of light on a convex mirror, the mirror will allow the initially parallel rays that make up the beam to diverge after striking the reflective surface.as shown in Fiq.(4)

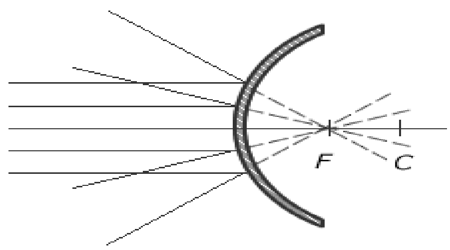


Fig.(4): Image formation in convex mirror

PROCEDURE:

Part a: Find the focal length of concave mirror:

1- Arrange the optical bench as shown in figure below:

2- Move the mirror until a clear image is formed

3- Measure the distance between the concave mirror and the screen

Part b: find the focal length of a convex mirror:

1- Set the pointed object at twice the focal length of the lens.

2- Adjust the mirror's position until the inverted image's position shows no parallax with the object.

3- By using the configuration shown below

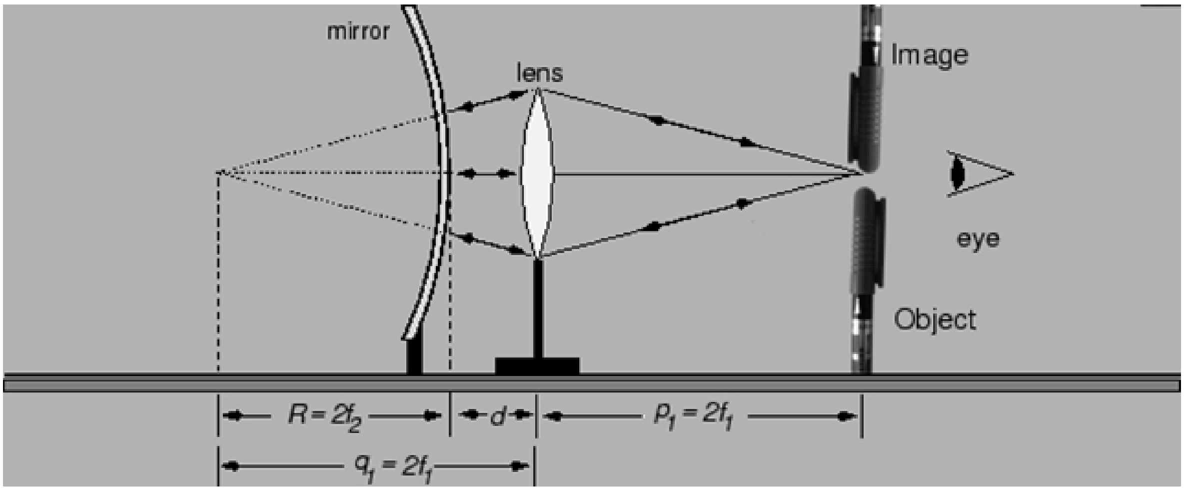
$$f_2 = f_1 - \frac{d}{2}$$

Where:

f_1 : the focal length of convex lens.

f_2 : the focal length of convex mirror.

d: the distance between the lens and a concave mirror.



Discussion:

1- Discuss the result of both part? Compare between each type?

2- Compare between concave and convex mirror?

3- Give some application of using concave and convex mirror?

Experiment No. (   )

Newton's rings.

Fig1: Experimental Setup

Object:

Interference study and finding He-Ne wavelength by using Newton's rings.

Equipments:-

1. He Ne Laser.
2. Plano- convex lens. With along focal length.
3. Convex lens.

Theory:-

When a parallel beam of monochromatic light is incident normally on a combination of a Plano-convex lens L and a glass plate G, as shown in Fig.3, a part of each incident ray is reflected from the lower surface of the lens, and a part, after refraction through the air film between the lens and the plate, is reflected back from the plate surface. These two reflected rays are coherent; hence they will interfere and produce a system of alternate dark and bright rings with the point of contact between the lens and the plate as the center. These rings are known as Newton's ring.

For a normal incidence of monochromatic light, the path difference between the reflected rays (see Fig.3) is very nearly equal to 2μt where μ and t are the refractive index and thickness of the air-film respectively. The fact that the wave is reflected from air to glass surface introduces a phase shift of π. Therefore, for bright fringe

$$2\mu t = \left(n + \frac{1}{2}\lambda\right); n = 0,1,2,3, \dots\dots \quad (1)$$

and for dark fringe

$$2\mu t = n\lambda \ ; n = 0,1,2,3, \dots\dots. \quad (2)$$

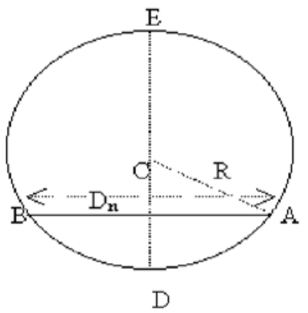


Fig. 2 Geometry used to determine the thickness of the air-film

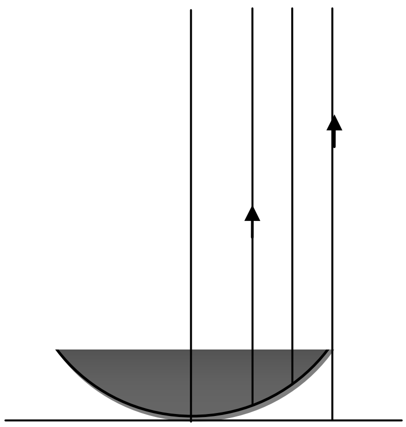


Fig. 3

For n^{th} (bright or dark) ring (see Fig. 2), we also have:

$$\frac{D_n^2}{4} + (R - t)^2 = R^2 \qquad (3)$$

Where D_n = the diameter of the n^{th} ring and R = the radius of curvature of the lower surface of the Plano-convex lens. On neglecting t^2, equation (3) reduces to

$$D_n^2 = 8tR \qquad (4)$$

From equations (1) and (4), we get,

$$D_n^2 = 4\left(n + \frac{1}{2}\right)\frac{\lambda R}{\mu} \ , for\ n^{th}\ bright\ ring \qquad (5)$$

$$D_{n+m}^2 = 4\left(n + m + \frac{1}{2}\right)\frac{\lambda R}{\mu} \ , for\ (n+m)^{th}\ bright\ ring \qquad (6)$$

Similarly, from equations (2) and (4), we obtain

$$D_n^2 = \frac{4n\lambda R}{\mu}, for\ n^{th}\ dark\ ring \qquad (7)$$

$$D_{n+m}^2 = \frac{4(n+m)\lambda R}{\mu} \ , for\ (n+m)^{th}\ dark\ ring \qquad (8)$$

Thus for bright as well as dark rings, we obtain

$$R = \frac{\mu(D_{n+m}^2 - D_n^2)}{4m\lambda} \qquad (9)$$

Since $\mu = 1$ for air-film, above equation gives

$$R = \frac{(D_{n+m}^2 - D_n^2)}{4m\lambda} \qquad (10)$$

Procedure:-

1. Set the equipments as shown in fig (1) and be carful not to touch the lenses surfaces and optical filters.

2. turn power on of the laser source and try to get the interference fringes and notice them on the screen in a clear way). Try to put the optical

center, of the interference fringes on the equidistance of the millimeter scale which occurs on the screen.

3. Measure the diameter of the bright rings starting from ring (3). And arrange your measurements according to the following table:-

Notice: Inter the graph scale in the calculations.

λ_1		
n	D_n	D_n^2
3		
4		
5		
6		

4. Draw the graph relation between (D^2_n) and (n) then find the slope.

5. Find the wave length (λ) of the used light which transmits from the laser by using the Eq (10), taking in your consideration that lens radius is (R= 12.141mm).

Discussion:-

1- Draw the graph relation on the paper.

2. In equipments arraignment, the interference fringes which occur on the screen belong to transmitted light from the lens and the glass plate and not belong to the reflected light from the lens and the glass plate, so the bright fringes diameters must be measure (which accrue on the screen which depend on the following law). ((The optical path difference between interfere waves must be equal on even number of the wave (O.P.d = $n\lambda$)It is same law for the dark rings of interference fringes

which is resulted from the reflected light waves from the convex surface of the lens and glass plate surface. What is the relation between the two?

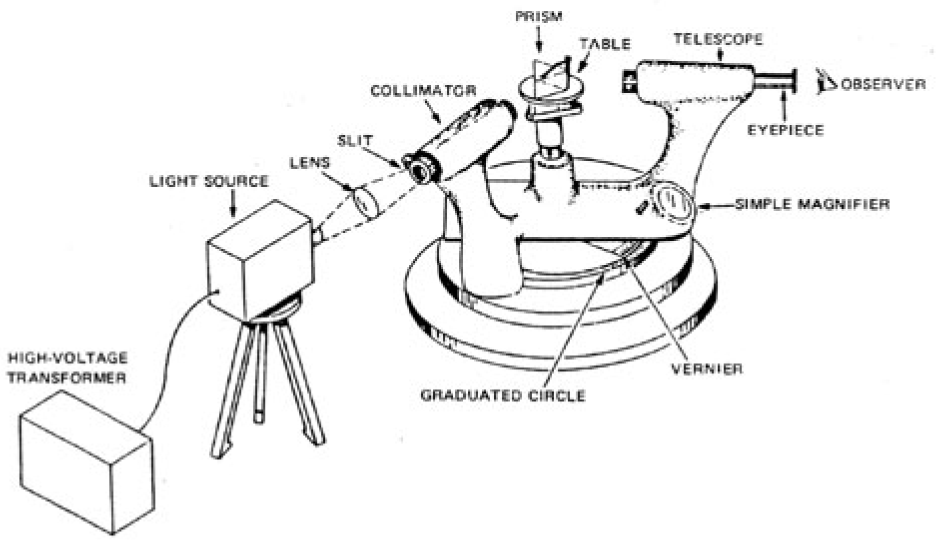
3. Why the fringes are circled and not parallel lines?

4. What is the graph which would equation ($R = \frac{(D_{n+m}^2 - D_n^2)}{4m\lambda}$) take when you measure the ring radius instead of the diameter and the discuss the experimented mistake.

University of Technology
Laser & Optoelectronics Engineering Department
optoelectronics engineering branch

Experiment No. ( )

Prism



Object:

To find the following parameters for the prism :

1- Apex angle of the prism.

2- Refractive index of the prism.

Equipment:

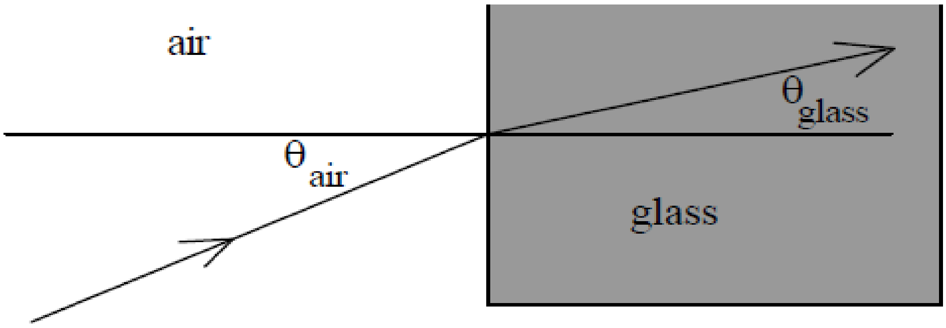
- Spectrometer
- Prism
- Light source

Theory:

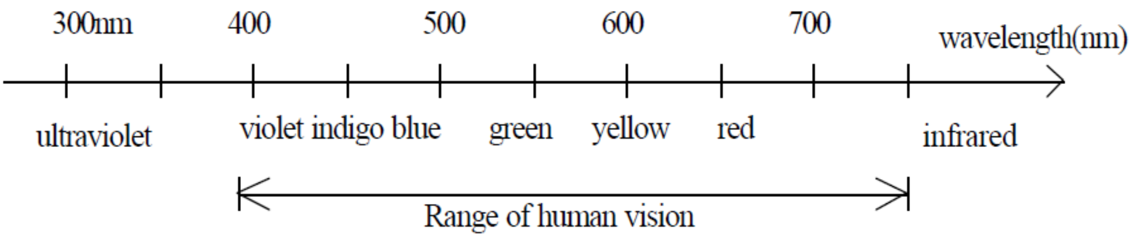
When a beam of light is transmitted from air to glass, the ray is bent according to Snell's law

$n\sin\theta_{air} = n\sin\theta_{glass}$ (1)

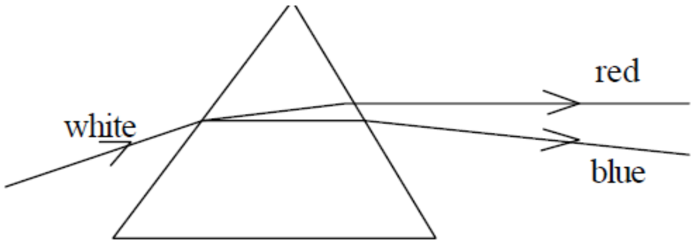
Where the angles are measured from the surface normal (the line perpendicular to the surface) and n is the index of refraction of the glass. The index of refraction is a dimension-less number and is a measure of how strongly the medium bends light. The greater n is, the more the light is bent. The index of refraction of air is 1. For glass, n varies from 1.3 to 1.8, depending on the type of glass and on the wavelength of the light.

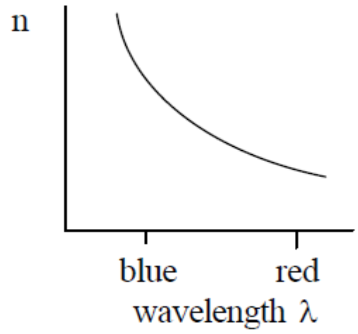


White light is made up of all the colors of the rainbow - red, yellow, green, blue, and violet. Different colors correspond to different wavelengths. Human eyes are sensitive to light with wavelengths in the range 390 nm (violet) to 750 nm (red)



Glass has a greater index of refraction at shorter wavelengths, that is, it bends blue light more than red light. So a prism can be used to disperse white light into its component colors.





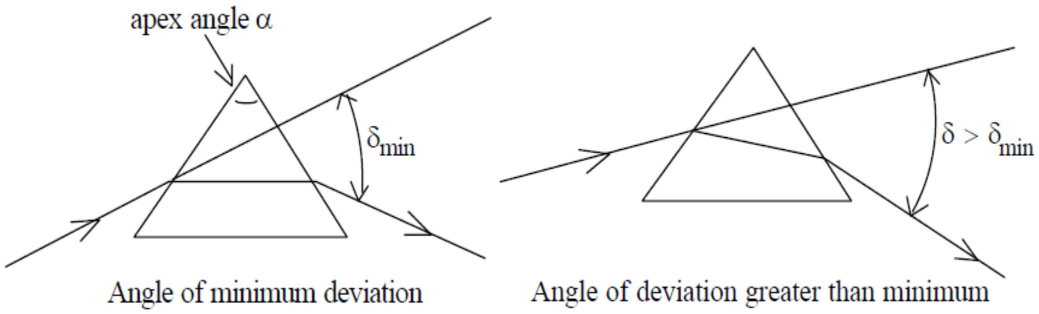
In this experiment, we will use a prism spectrometer to measure the dispersion angle of various wavelengths.

The device we are using is called a prism spectrometer because, once the prism is calibrated, it can be used to measure the wavelengths of the lines in the spectra produced by various atoms. The spectra contain bright lines at particular wavelengths, which correspond to light emitted during the transition between different energy states of the atoms. You see distinct lines because the atoms exist only in distinct, quantized energy states. Trying to explain the data from such experiments the existence and pattern of sharp spectral lines led to the development of quantum mechanics.

When a ray of light is refracted by a prism, the angle between the incoming and outgoing rays is called the angle of deviation (δ_m). For a given prism and a given wavelength, the value of b depends on the angle between the incoming ray and the surface of the prism. δ_m is minimum when the angles of the incoming and outgoing rays make equal angles with the prism surfaces. In this special

symmetric case, the prism's index of refraction (n) is related to δ_m and the apex angle of the prism (α) by

$$n = \frac{\sin[(\alpha + \delta_m)/2]}{\sin \alpha/2}$$



Procedure:

Part (a) : measurement the apex angle of prism.

1- Adjust the eyepiece of the telescope until the cross hairs are in sharp focus.

2- Place the prism on the table so that the apex angle of the prism faces the collimator and the parallel light from the collimator reflected from the both sides of the prism.

3- Fix the prism and turn the telescope to the right until a sharp image of bright slit can be seen, fix the telescope. Measure the angle of such point which represent β

4- Fix the prism and turn the telescope to the left until a sharp image of bright slit can be seen, fix the telescope. Measure the angle of such point which represent $\beta^{`}$

5- Find the apex angle of the prism from the relation

$$\alpha = (\beta + \beta^{`})/2$$

Part (b) measurement the refractive index of the prism

1- Fix the prism on the table of the spectrometer so that the incident ray on one face passing through it will refract from the other face .

2- Turn the table of the prism in specific direction and follow the image , after a short period you will see (in spite of turning the table in the same direction), the image will stop and reverse its direction . This point of reversing direction represents the place at which the(minimum deviation) occurs, measure it (γ) .

3- Remove the prism and turn the telescope only until it becomes in straight line with the collimator , look from the telescope for the coincide of crossing hair with the bright slit image . Measure this angle ($\gamma^{`}$).

4- Measure the angle of minimum deviation (δ_m) from: $\delta_m = |\gamma^{`} - \gamma|$.

5- Calculate the value of refractive index from the equation:

$$n = \frac{\sin[(\delta_m + \alpha)/2]}{\sin(\alpha/2)}$$

Discussion:

1- Discuss the value of apex angle.

Experiment No. (1)

Refractive index of glass

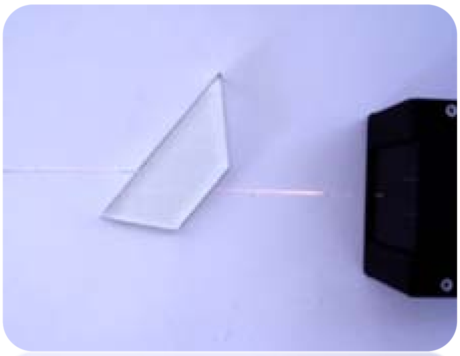


Fig. (1): Experimental setup

Object:

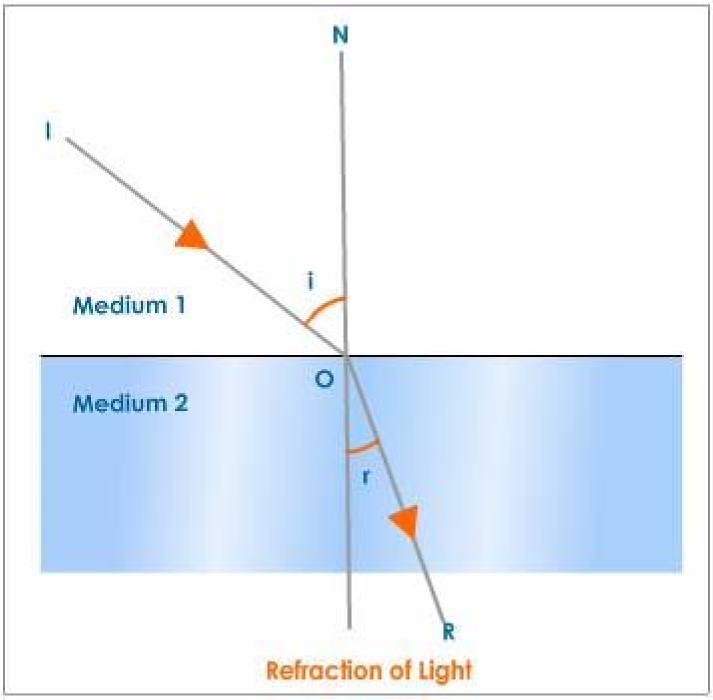
The aim of the experiment is to study the refraction index of a glass

Equipment:

- Circular disk
- Trapezoidal prism
- He-Ne laser

Theory:

refractive index, also called index of refraction, measure of the bending of a ray of light when passing from one medium into another. If *i* is the angle of incidence of a ray in vacuum (angle between the incoming ray and the perpendicular to the surface of a medium, called the normal), and *r* is the angle of refraction (angle between the ray in the medium and the normal), the refractive index n is defined as the ratio of the sine of the angle of incidence to the sine of the angle of refraction; *i.e.*, $n = \sin i / \sin r$. Refractive index is also equal to the velocity c of light of a given wavelength in empty space divided by its velocity v in a substance, or $n = c/v$.



Procedure:

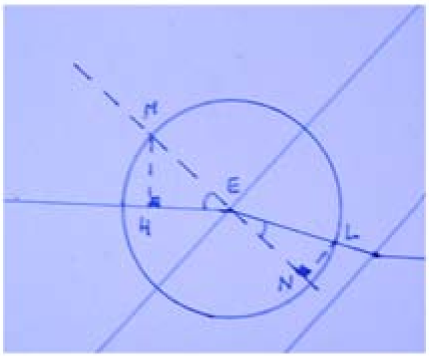
1- Align the setup as shown in fig.(1).

2- Using the thumbtacks, fix a sheet of paper on the wooden plane and lay the glass block, resting on the wider faces, at the centre.

3- Draw the outline of the glass block on a piece of paper. Two pins A and B determine the direction of an incident ray on a face of the glass block. The two pins are fixed on the working plane so that the straight line passing through them forms with the edge of the block a determined angle.

4- Looking beyond the glass block, find the position for which the two pins, seen through the glass block, are aligned, then fix two other pins O and P to determine this new straight line. Verify that the two pins are aligned on the straight line determined by the other two.

5- Take away the glass and draw the lines as shown in the figure and a circumference of any radius centred in E.



6- From Snell`s law we have that:

$$n = \frac{HM}{LN}$$

Discussion:

1- Define refractive index.
2- Discuss your result.
3- Did you think that the density of glass effect the refractive index of it? Explain.

Experiment No. (2)
Refractive index of water

Fig.(1): Experimental setup

Object:

The aim of the experiment is to study the refraction index of a water.

Equipment:

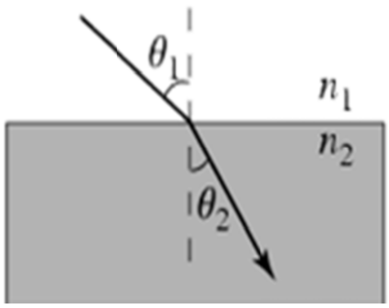
- Circular disk
- Refraction index vessel
- He-Ne laser

Theory:

A light beam that strikes the plane surface of the optical body undergoes a change in direction according to Snell's law

$$n_1 \sin\left(\theta_1\right) = n_2 \sin(\theta_2) \qquad (1)$$

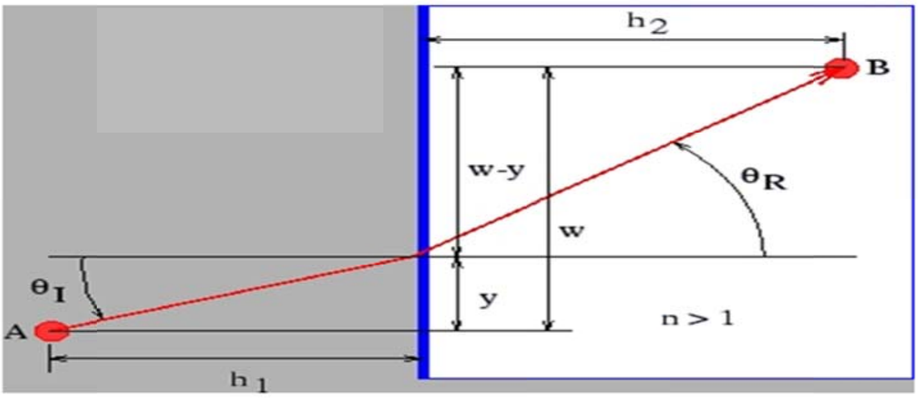
Where n_i (i=1, 2) are the refraction indexes of the two media and θ_i (i=1, 2) are the angles between the beam and the perpendicular to the surface.



Since the refraction index of air is nearly 1 we can write also

$$\sin\left(i\right) = n \cdot \sin(r) \qquad (2)$$

Where n is the refraction index of the substance we want investigate, i is the angle of incidence and r is the angle of refraction. To deduce Snell's law it's possible to use Fermat's principle. This principle states, in its simplest form that light waves of a given frequency, choose the path between two points which takes the least time to traverse. The most obvious example of this is the passage of light through a homogeneous medium in which the speed of light doesn't change with position. In this case, the shortest time is equivalent to the shortest distance between the points, which, as we all know, is a straight line. Thus, Fermat's principle is consistent with light travelling in a straight line in a homogeneous medium. The speed of light in a medium with refractive index n is c/n where c is its speed in a vacuum. Thus, the time required for light to go some distance in such a medium is n times the time light takes to go the same distance in a vacuum.



Referring to the preceding figure, the time required for light to go from A to B this time becomes function of the variables h1, h2, y, w, c, n

By finding the minimum time, this results in the condition

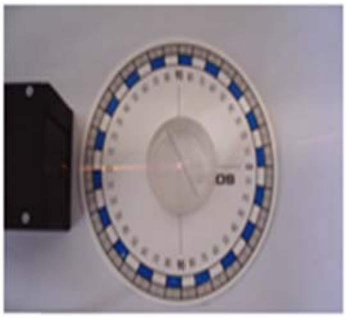
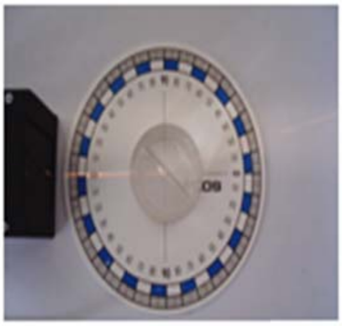
$$\sin\theta_I = n \cdot \sin\theta_R$$

We recognize this result as the Snell's law.

PROCEDURE:

By placing the refraction index vessel (with water at 20°C) at different angles of incidence from the light beam



we get the following experimental data where the last column is calculated using equation (2).

Angle of incidence [degree]	Angle of refraction [degree]	Refraction index
5		
15		
25		
35		
45		
55		

Discussion:

1- Discuss your result

Experiment No. (10)

Single slit diffraction

Object:

- To see the interference pattern produced by coherent light passing through single-slit apertures.
- To explore how these patterns depend upon the size of the apertures.
- To use the interference pattern and a known slit size to accurately determine the wavelength of a coherent light source.

Equipment:

- He-Ne laser
- Slit
- Ruler
- Screen

Theory:

Nowhere is the wave nature of light demonstrated more clearly than in the phenomenon of interference. Many kinds of waves exhibit interference: light waves, sound waves, water waves, and so on. The underlying physics is relatively simple: when several different waves arrive at the same point in space at the same time, they pass right through each other. But at the point where the waves overlap, the total wave strength there is just the sum of the individual waves' strengths at that point. We say that these waves obey the superposition principle.

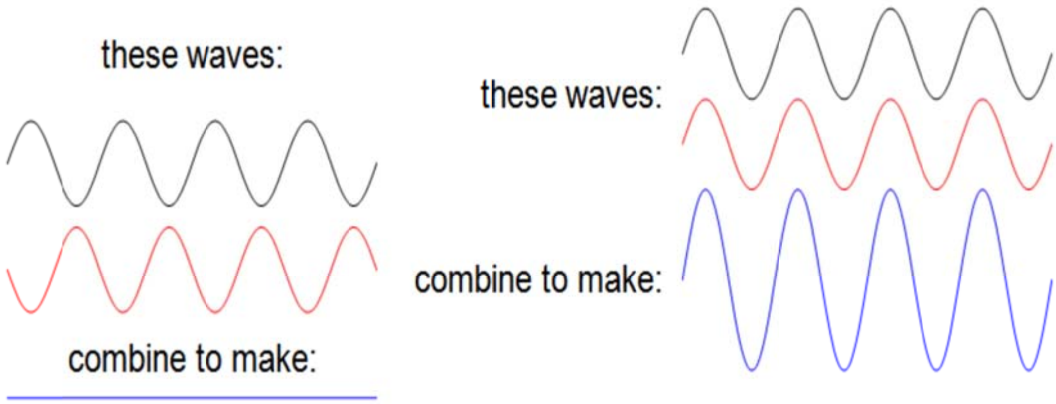


Figure 1 Superposition of equal-amplitude, equal-frequency waves. In (a), the two waves are in phase, and the result is constructive interference. In (b), the two waves are 180° out of phase, resulting in destructive interference.

If we restrict our attention to just two waves at a time, and make the assumptions that these waves have the same amplitude and frequency, then we can see two limiting cases of interest to us. When the waves are in phase, or in other words, when the oscillations of the waves match up exactly, we can see that the waves will constructively interfere, and the net wave amplitude will be doubled, as shown in Figure 1(a). If, at the other extreme, the two waves are exactly 180° out of phase, the waves will destructively interfere. In this case, the net wave amplitude is zero, meaning that the waves have perfectly canceled each other out, as shown in Figure1 (b).

One way in which waves can drift out of phase with respect to each other is if they travel different distances to arrive at the same point. As a specific example, we observe that when monochromatic, coherent light passes through a narrow aperture, it spreads out into the region which we would classify as the shadow of the slit. The spreading of light after passing through an aperture such as this is known as diffraction. A top-down cartoon of this phenomenon is depicted in Figure 2 below.

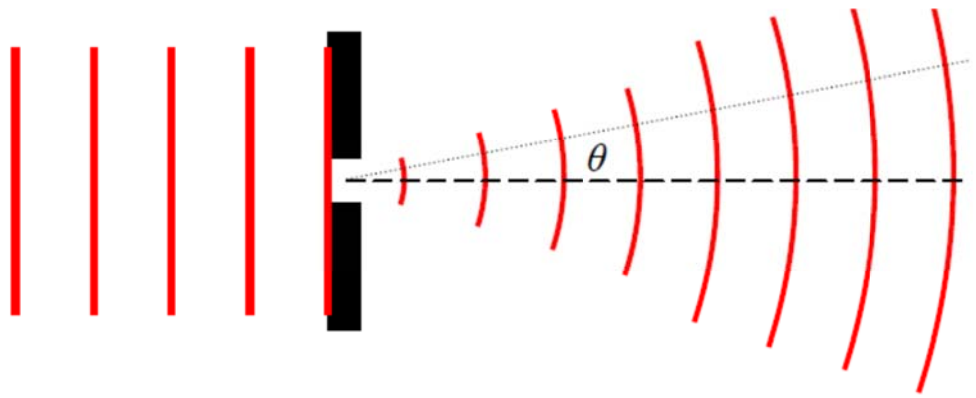


Figure 2 The spreading of a wave as it passes through an aperture whose width is comparable to the wavelength of the wave is known as diffraction. The pattern will be most intense along the forward direction (represented as a dashed line.) We will be interested in how the intensity varies as we look at various angles θ away from the center.

As the light passes through each point of the opening, it spreads out in all directions, interfering, in some sense, with itself. In our minds, we imagine that each point in the opening is a new source of a wavelet of light. Due to their slightly different starting positions, each of these wavelets will travel minutely different distances to arrive at the same point in space. This will introduce a phase difference in the multitude of waves arriving at that location. Where the waves are generally all arriving out of phase with each other, the net wave amplitude will approach zero. Where the waves are generally arriving in phase, we expect the net wave amplitude to be large. With only a single slit, though, only points directly in front of the opening along the direction of propagation will generally arrive all in phase, so we expect to see a bright central spot, surrounded by fainter, alternating bands of bright and dark areas, where constructive and destructive interference occur, respectively.

From the discussion above, we see that light passing through a single slit will create an alternating pattern of bright and dark areas, which we could equivalently describe as an alternating pattern of high and low intensity. We will often choose to visualize an interference pattern by showing its intensity as a function of position, for instance, of a diffraction pattern shining on a screen, as is shown in Figure 3.

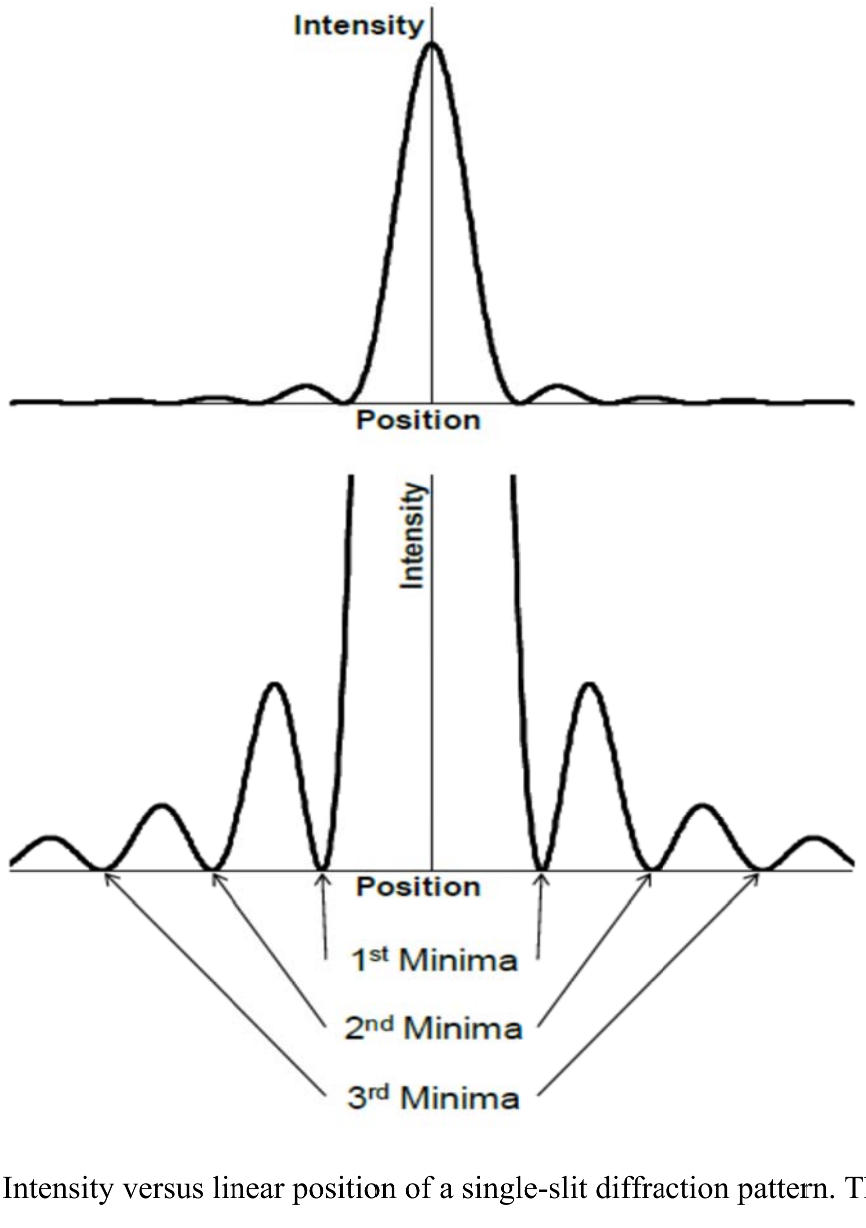


Figure 3 Intensity versus linear position of a single-slit diffraction pattern. The single-slit pattern will consist of a large, central bright spot, flanked symmetrically by alternating dark and bright areas. The central maximum will be at least ten times brighter than any of the side maxima. Inset: A zoomed-in display of the side maxima and minima. We count the minima outward from the central maximum, symmetric across the center.

In the single slit pattern, the angular position of the maxima cannot be described via a simple trigonometric expression, but the minima (dark spots) can. We find that the single-slit minima will be located at an angle θ away from the central maximum where θ must satisfy

$$n\lambda = d\sin\theta \qquad (1)$$

with d representing the slit width, λ the wavelength of the light, and where n is an integer which labels the minima, counting outward from the center as depicted in Figure 3. In general, angles are more difficult to measure than distances, and so we will often not attempt to ascertain the angular position of the minima directly, but will rather focus on their linear position, at some constant distance D away from the slit. This arrangement is typically shown in a top-down view, as is shown in Figure 4. From that figure, we can see how to relate the linear distance y of a maximum or minimum relative to the central maximum and the angle θ that the maximum or minimum makes with respect to the central maximum. Using trigonometry, we can see that they are related by:

$$y = D\tan\theta \qquad (2)$$

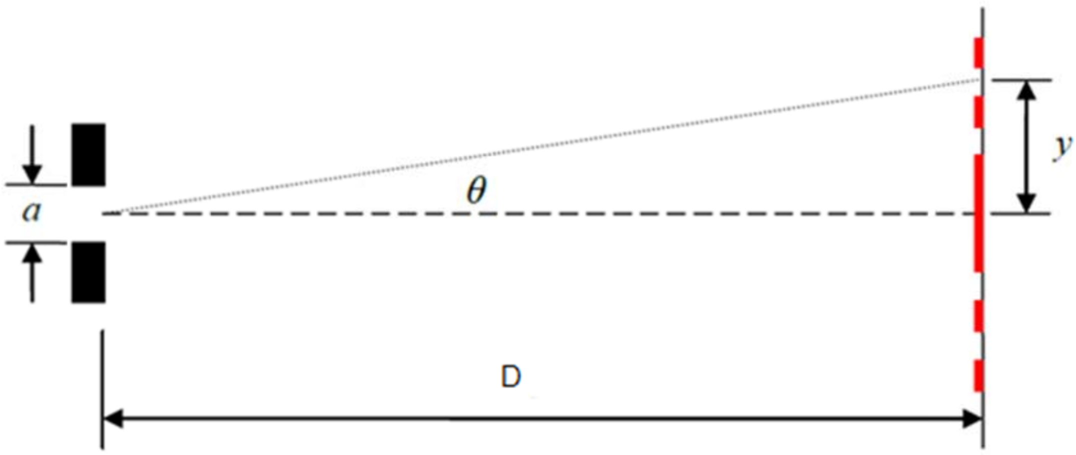


Figure 4 Measuring the linear position of the 2nd-order minimum to the left of the central maximum. The interference pattern produced by the single slit is allowed to shine on a screen a uniform distance L away from the slit. We can then measure the linear location of the minima, and using trigonometry, determine at which angles, with respect to the central maximum, these minima are located.

Procedure:

1- The slit is placed at a distant (L) from the laser.

2- Adjust the screen until the interference pattern appears clear on the screen.

3- Determine the distance between the single slit and screen which represent (D)

4- Fix the bright central fringe (n_0) by using a graph paper.

5- Obtain the distance between the middle of the central fringe and the middle of the first fringe (X_1). Repeat that for three orders (X_1, X_2, X_3).

6- Plot $n\lambda$ vs $\sin\theta$

7- Determine λ using equation (1).where θ is small angle so

$$\sin\theta = \tan\theta = \frac{X_n}{D}$$

8- Calculate the percentage error using:

$$percentage\ error = \frac{\lambda_{theoritical} - \lambda_{experimental}}{\lambda_{theorritical}} \times 100\%$$

Discussion:

1- What`s the effect of changing the width of the slit on the fringes?

2- What`s the effect of changing the position of the single slit on the fringes?

3- How much the percentage error and what is the reason caused this error.

University of Technology
Laser & Optoelectronics Engineering Department
optoelectronics engineering branch

Exp. No. (   )

Total reflection in triangular prism

Object:

The aim of the experiment is to study the total reflection phenomenon.

Equipment:

- Hartl apparatus
- Trapezoidal prism
- Slide with slits

Theory:

A prism is said to be at total reflection if the light that enters inside it with an appropriate direction undergoes at least one total reflection before coming out from the prism: that happens when the light, in its path inside the prism, meets one of the surfaces of the prism with an angle of incidence larger than the critical angle.

Procedure:

Put the triangular prism on the disc, along the path of the parallel rays beam, as shown in the following figures:

Fig. 1

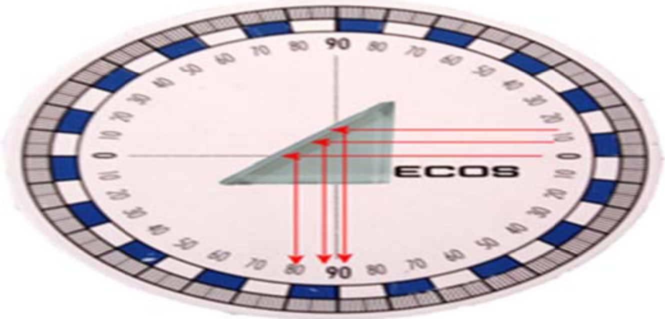


Fig. 2

Fig. 3

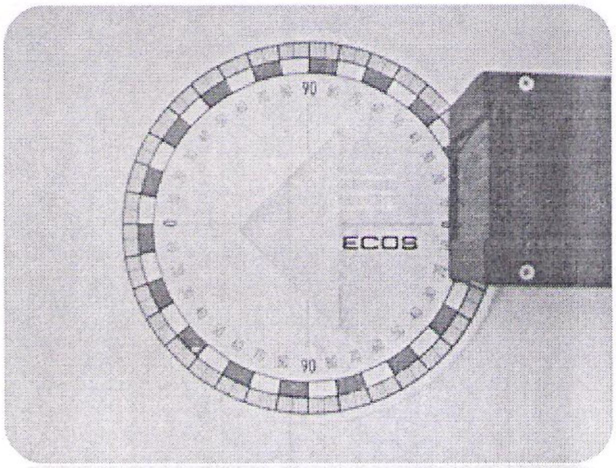
- In the first case (Fig. 1), thanks to the special symmetry of the system, the refracted rays come out from the prism with an angle (with respect to the face perpendicular) equal to the first incidence angle. In particular, if the incident rays are parallel to the face on which the total reflection happens, the rays that come out maintain the original direction.
- In the second case (Amici's prism) no deviation appears on the two equal faces of the prism and the rays are bent only on the third face, by which they are totally reflected. The beam comes out bent 90° from the original direction (Fig. 2).
- In the third case (Porro's prism) the rays enter and exit perpendicularly to the hypotenuse of the prism, while they are bent twice, for total reflection, on the other faces. The beam that comes out maintains the original direction, but its direction of propagation results will be reversed (Fig. 3)

Discussion:

1- Comment on your result?
2- Discuss each case of your procedure?

Exp. No. (7)

Total reflection in triangular prism



Object:

The aim of the experiment is to study the total reflection phenomenon.

Equipment:

- Hartl apparatus
- Trapezoidal prism
- Slide with slits

- In the first case (Fig. 1), thanks to the special symmetry of the system, the refracted rays come out from the prism with an angle (with respect to the face perpendicular) equal to the first incidence angle. In particular, if the incident rays are parallel to the face on which the total reflection happens, the rays that come out maintain the original direction.
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Discussion:

1- Comment on your result?
2- Discuss each case of your procedure?