University of Technology

Laser and Optoelectronics Engineering Department

Enginnering Physics Lab
First Year

Lec. Wasan Abdalsatar Hekmat
Asist.Prof. Dr.Suad Mahmmod Kadhim

2025-2024

Enginnerig Physics Lab
First Stage

1. *The law of Reflection & Refraction.*
2. *Lenses.*
3. *Determination of the refractive index of a liquid by a liquid lens method.*
4. *Laser Beam Divergence Angle.*
5. *Measuring the Wavelength of He-Ne Laser using a Simple Ruler.*
6. *Mirrors*
7. *Michelson Interferometer.*
8. *Photoelectric Effect.*

Experiment (1)

The law of Reflection and Refraction

Objective:-

This work is used to prove the law of reflection and law of Refraction

Apparatus:

Plane mirror, Piece of glass, He-Ne laser, stand for path tracing.

Theory:-

(A) Reflection:-

It has been known along ago that light reflecting off of a smooth shiny object does so following a simple rule: The angle of reflection with respect to the normal to the surface equals the angle of incidence:

$$\theta'_1=\theta_1 \;\ldots\ldots(1)$$

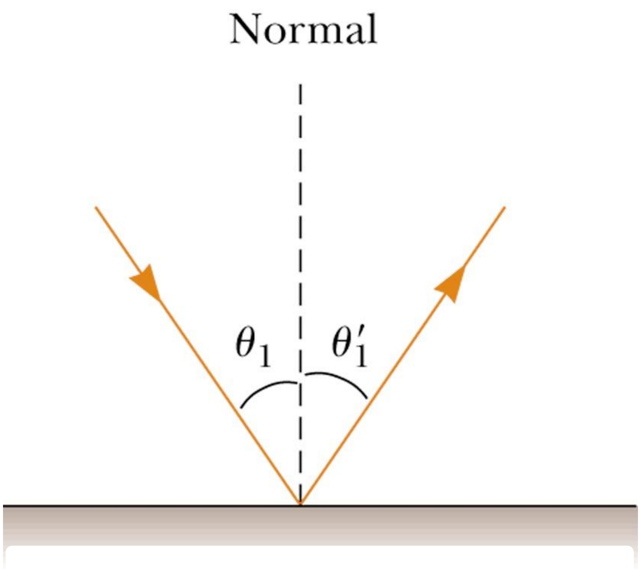


Figure (1): The incident & reflection angle

The Law of Reflection:

i) The angle of incidence is equal to the angle of reflection.

ii) The incident ray, the reflected ray and the normal to the mirror at the point of incidence all lie in the same plane.

<u>Procedure:-</u>

1. Arrange the experimental set up as shown in Fig. (2).

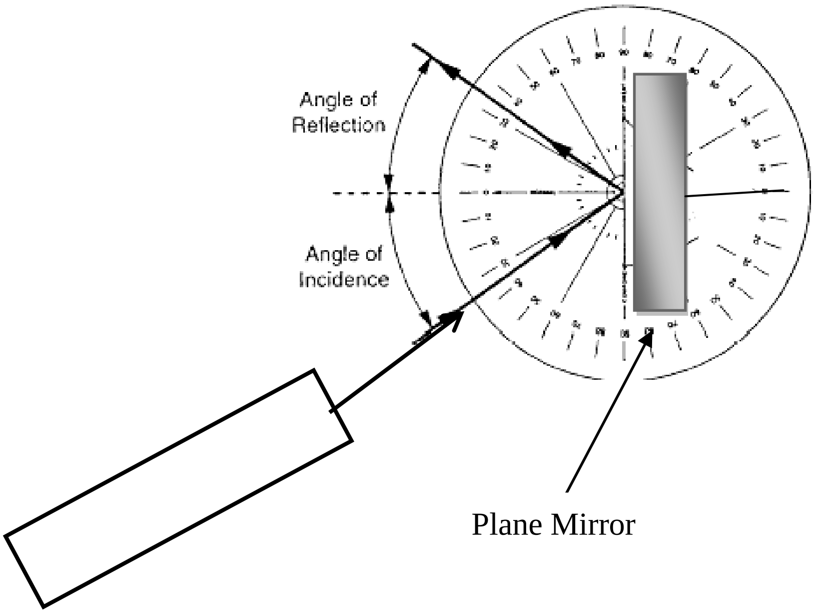


Figure (2): The setup of reflection

2. Put the laser light and check the ray make a 90 with the plane mirror.
3. Turn the light left with (10-80) in step of 10 angle with the perpendicular to the surface of the mirror.
4. Make a table and record the results which represent the angle of reflection.

Angle of incident	Angle of reflection
10	
20	
30	
40	
50	
60	
70	
80	

Discussion:-

Q1:-What is the source of error in your experiment?

Q2:-Define: The angle of reflection and the angle of incidence?

Q3:- A ray of light is intended on a plane surface separating two transparent substances of indices 1.60 and 1.40. The angle of incidence is 45^o and the ray originates in the medium of higher index. Compute the angle of reflection?

(B) Refraction:-

When light hits a transparent medium, part of it usually travels into the medium, but with a change in direction.

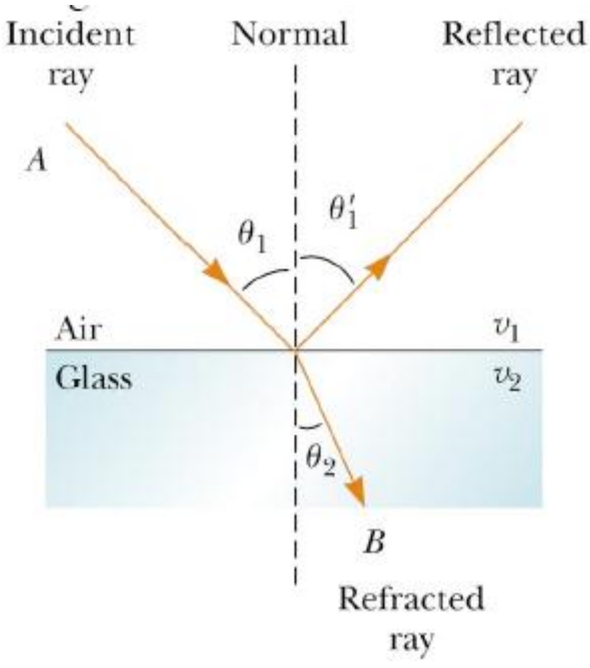


Figure (3): Refraction at ray boundary

The ray that gets bent and travels through the medium is said to be *refracted*, and the process is called *refraction*. Note that the incident ray, refracted ray, and reflected ray all lie in the same plane, normal to the surface of the interface of the two media.

The Law of Refraction:-

i) The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.

(II) The ratio of the sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media.(This law is also known as Snell`s law of refraction.)

Refractive index :-

$$\text{Index of Refraction} \qquad n \equiv \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}} = \frac{c}{v}$$

When light passes from one medium into another the frequency f remains constant (or else waves would have to be selectively created or destroyed). So if v changes and f is constant, then λ must also change, since :

$$V = f\lambda$$

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1}$$

Finally:

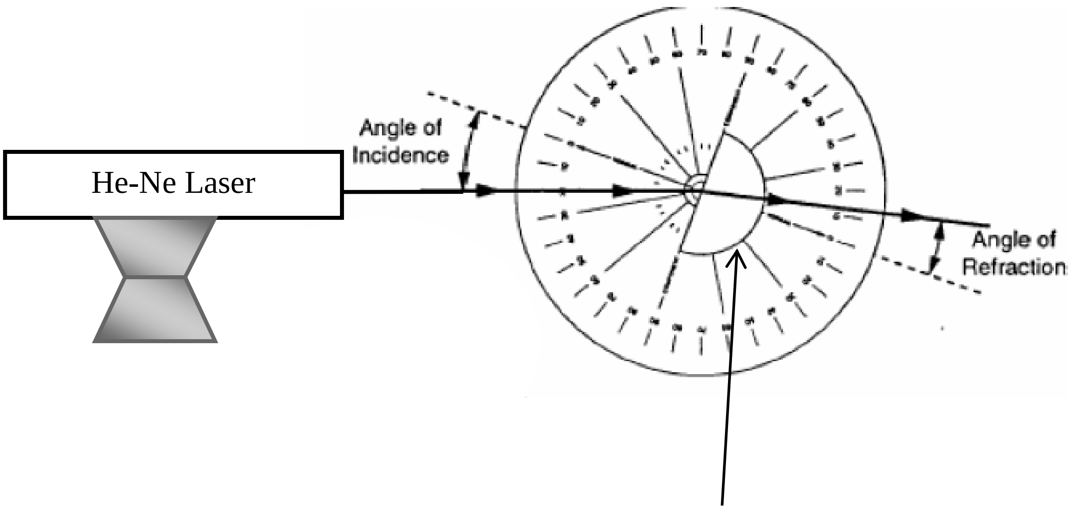
$$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \frac{n_1}{n_2} \quad \Rightarrow \quad n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \ldots\ldots\ldots (2)$$

This will be the form of ***Snell's Law of Refraction*** that we will usually use.

Procedure:-

1. Arrange the experimental set up as shown in Fig. (4).



glass piece.

Figure (4): The setup of reflection

2. Put the laser light and check the ray make a 90 with the plane mirror.
3. Turn the light left with (10-80) in step of 10 angle with the perpendicular to the surface glass piece.
4. Make table and record the result which represent the angle of refraction.

Incident angle(θ_1)	Refraction angle(θ_2)	Refractive index(n_2)
10		
20		
30		
40		
50		
60		
70		
80		

5. Find the refractive index in (n_2) by applying equation (2).
6. Find the percentage error (p.e) of (n):

$$p.e = ((n_{th} - n_{exp})/n_{th}) \times 100\%$$

Where:

n_{exp}: experimental value

n_{th}: theoretical value of refractive index of glass (1.5).

__Discussion:-__

Q1:-Discuss the source of error in your experiment.

Q2:-Define the refraction angle and refractive index?

Q3:- Let material **A** be water and material **B** a glass with index of refraction 1.5 if the incident ray makes an angle of (45^o) with the normal, find the reflective and refractive angle.

Experiment (2)

Lenses

Objective:-

This experiment is aimed to find the focal length of the convex lens using two methods:

A. Direct method (auto-collimation method).

B. Graphical method (displacement method).

Apparatus:-

Bromine tungsten lamp, Convex lens (L), Illuminated object (P), Optical bench, Two axis tilt holder, Flat mirror (M).

Theory:-

Lens: is a piece of glass or other transparent material shaped so that it can produce an image by refracting light that comes from an object.

Lenses are used for many purposes (in eye classes to improve vision)

. Lenses are of two types:

i) Convex lens (converging):- is thicker in the middle and thinner at the edges. Rays of light parallel to the principal axis after refraction through a convex lens meet at a point (converge) on the principal axis. There are three types:

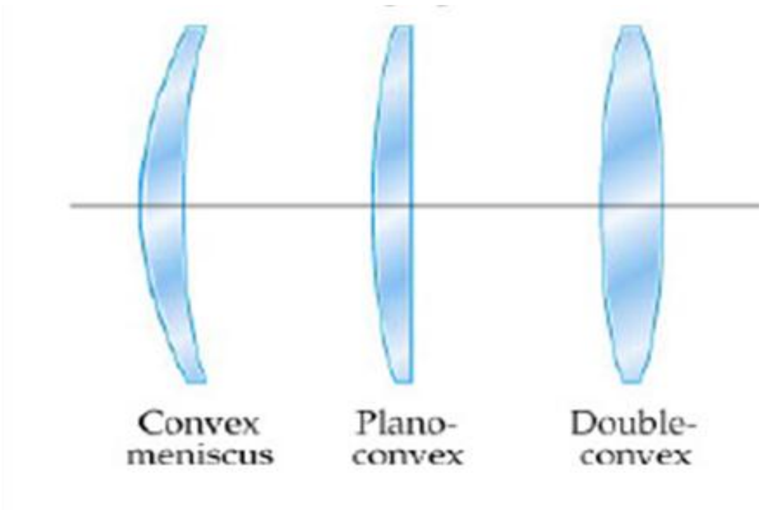


Figure 1

Type of convex lens

ii) Concave lens (diverging):- is thin in the middle and thicker at the edges. Rays of light parallel to the principal axis after refraction get diverged and appear to come from a point on the principal axis on the same side of the lens. There divided into three types:

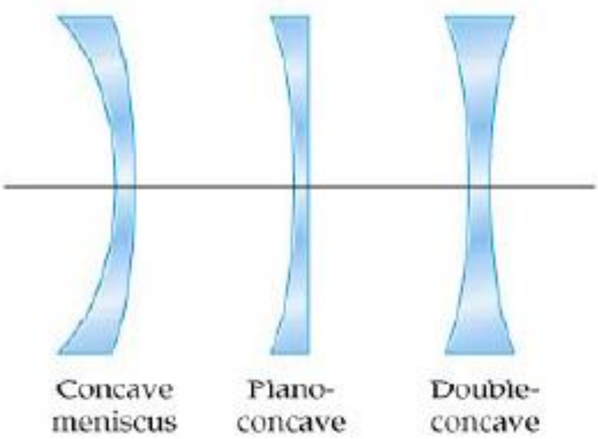


Figure 2

Type of concave lens

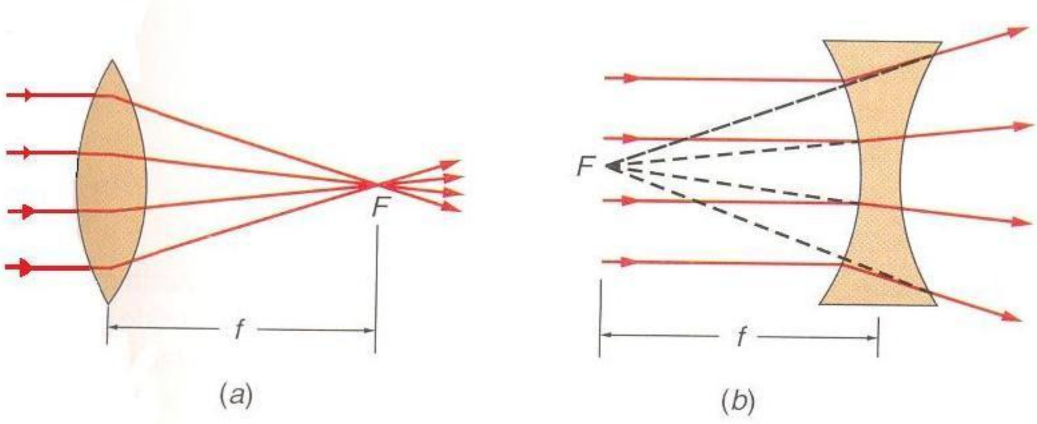


Figure 3

a) Convex Lens ***b) Concave Lens.***

convex lens(converging) brings a parallel beam of light to a single focal point (F),here F is called a real focal point because the light rays pass through it and the distance from the lens to (F) is called the focal length of the lens.

Also any ray from the object is refracted by the lens would change into a parallel ray, once reflected by the plane mirror and again refracted by the lens Shown in Fig. (4).

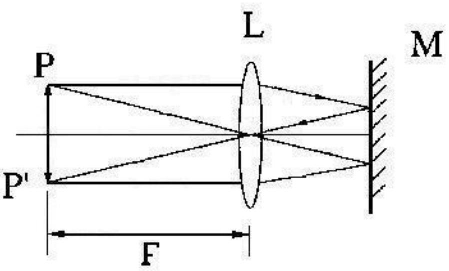


Figure 4

Procedure:-

A. Auto –collimation method:

To find the focal length (f) for the convex lens align all components in same height as shown in Fig. (5,6).

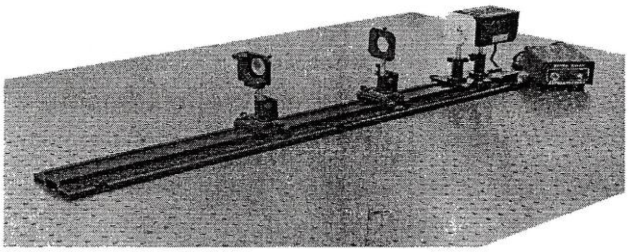


Figure 5

The set up of Auto –collimation method

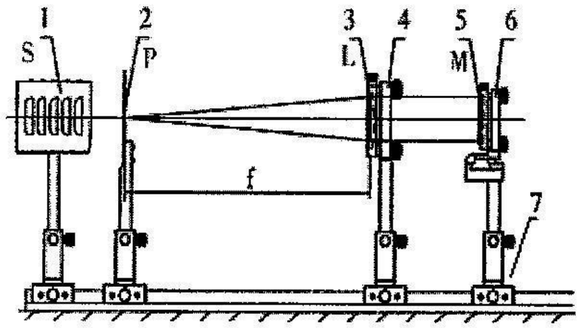


Figure 6

1. Move lens (L) back and forth till a clear image of the object on (P) is observed on the back surface of (P).

2. Adjust axis of mirror (M) and finely move (L) till the image is clearest and is the same size as the object.
3. Write down the locations of (P) and (L) as (S_1) and (S_2).
4. calculate the focal length:

$$\mathbf{f=S_2-S_1}$$

B: - Graphical method:-

1. To find the focal length (f) for the convex lens align all components in same height as shown in Fig. (7,8).

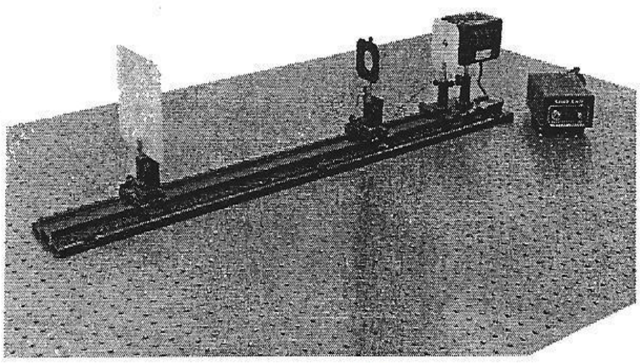


Figure 7

The set up of Graphical method method

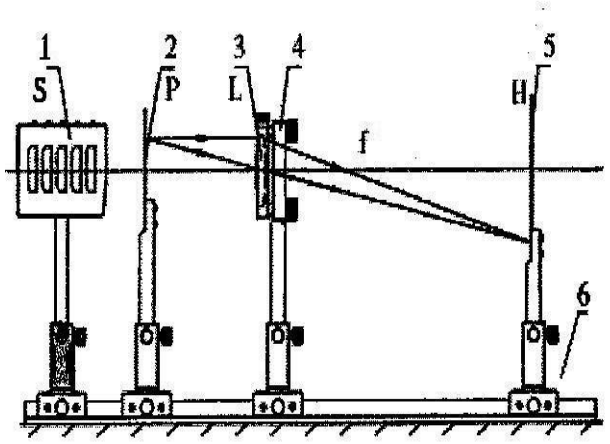


Figure 8

2. Move lens (L) back and forth till a clear image of the object on (P) is observed on the screen (H).
3. Measure the distance between the object and leans also the distance between the lens and screen (u and v respectively).
4. Move the lens to obtain another clear image and record the results.
5. Repeat step (4) for three times.
6. Arrange you results as shown in table below:

u	**v**	**1/u**	**1/v**	**1/u+1/v=1/f**

Where:

u: is the distance between the object and the lens.

v: is the distance between the image and the lens.

f: is the focal length of lens.

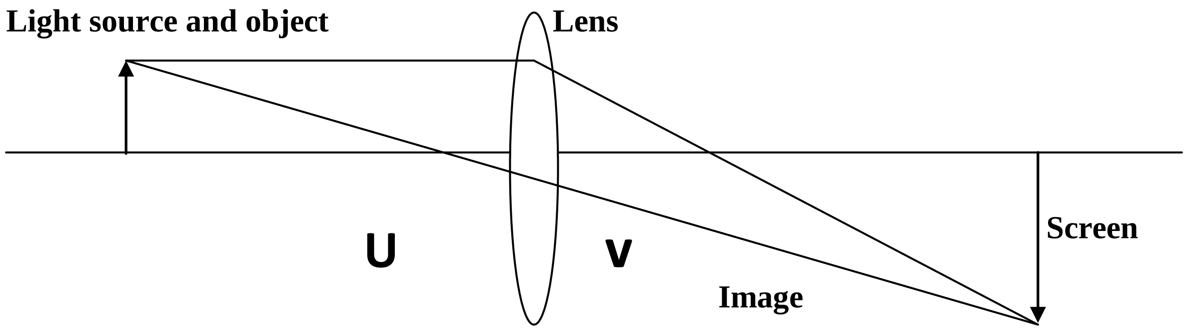


Figure 9

7. Plot a graph of 1/u in x-axis and 1/v in y-axis to find focal length (f).

Discussion:-

Q1:-which method you prefer to find the focal length? And why?

Q2:-What is the function of the convex lens in the optical system.

Q3:-Explain the six cases for producing an image by a convex lens.

Experiment (3)

Determination of the refractive index of a liquid by a liquid lens method

Objective:-

Determine the refractive index of a liquid.

Apparatus:-

Convex lens, liquid, plane mirror, retort stand with clamp and pin, meter rule.

Theory:-

A spherometer: is an instrument for the precise measurement of the radius of a sphere. This experiment is one of the most important experiments to find the refractive index for all the liquids. As we know that the light pass in vacuum with constant speed which is equal 3×10^8 M/Sec (300000 Km/Sec) and the light pass also in different material which is transparent like (Air, water, glass) because the atoms of this material has ability to absorb the light and retransmission and dispersion it, for this reason the light pass through different materials in different speeds less than its speed in vacuum.

The speed of light depend on the nature of material, for that reason when the light pass from one medium to another, a change in speed will occur and change in direction happened, this phenomena called refraction, and controlled by "Snell's law of refraction "and to explain the change in light speed when it pass from vacuum to certain medium, we used a physical quantity called refractive index or index of refraction of material (n) is the ratio of the light speed in vacuum to its speed in a material .

Below are the materials having the values of refraction index are more than one because the speed of light in vacuum is large than its speed in materials:

Refraction index	**Material**
1.501	C_6H_6
1.461	CCL_4
1.362	CH_3OH
1.333	H_2O

Let the focal length of the convex (glass) lens be f1 and the focal length of the combination of this lens and the Plano concave liquid lens be f. then:

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2} \qquad \text{..........} \quad (1)$$

Since f_1 and f are known, the value of (f_2) can be calculated from (1).

Now $\frac{1}{f_2}=(n_\ell-1)(\frac{1}{r}+\frac{1}{\infty})=\frac{n_\ell-1}{r}$ (where f_2 and r are both negative)

i.e. $$n_\ell=1+\frac{r}{f_2} \qquad \text{..........} \quad (2)$$

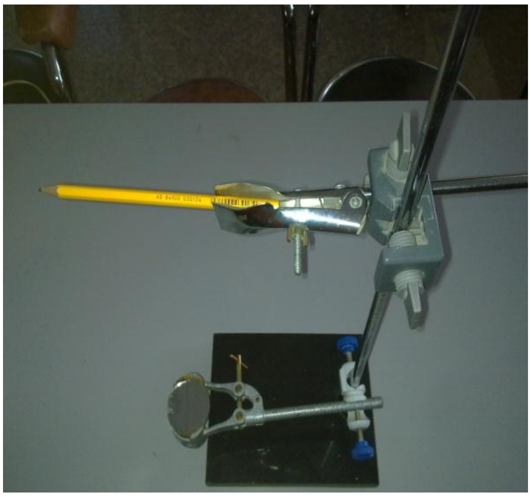


Figure (1): The experimental setup

Procedure:-

1:- The plane mirror is placed on the base of the stand with the pin held horizontally by the clamp above see figure (1 and 2).

2:-The convex lens is then placed on the mirror, and its focus is found by locating the position of the pin where it coincides with its own image. By measuring from this point to the lens, its focal length (f_1) is found.

3:- The lens is now removed, and a few drops of liquid are placed on the mirror. On placing the convex lens on the liquid, a combination of a convex (glass) and a Plano-concave (liquid) lens results.

4:- The focal length (f) of the combination is found as above, and the focal length (f_2) of the liquid lens calculated from f and f_1 (eq. (1)).

5:- The radius of curvature (r) of the lens surface in contact with the liquid is now obtained by a spherometer and its equal to 6.7cm

6:- Calculate the refractive index of liquid from equation (2).

7:- Find the percentage error of (n):

$$\mathbf{p.e= ((n_{th}-n_{exp})/n_{th})\times 100\%}$$

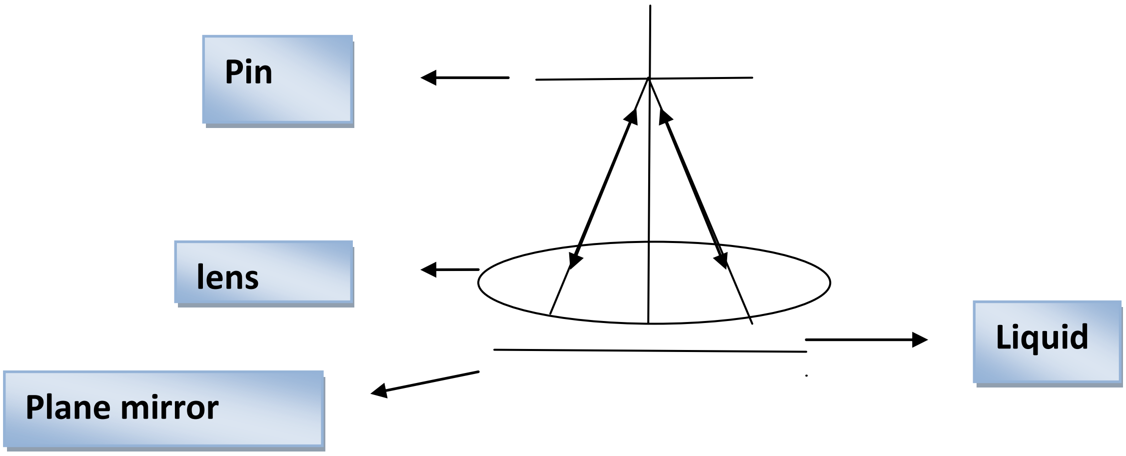


Figure (2): Schematic diagram of the experimental.

Discussion:-

Q1:- Discuss the results in the experiment?

Q2:- What is the effect of the convex lens in this experiment?

Experiment (4)

Laser beam divergence angle

Objective:-

This work is used to determine and reduce the divergence angle of a He-Ne laser with and without beam expander.

Apparatus:-

He-Ne laser, Beam expander, screen

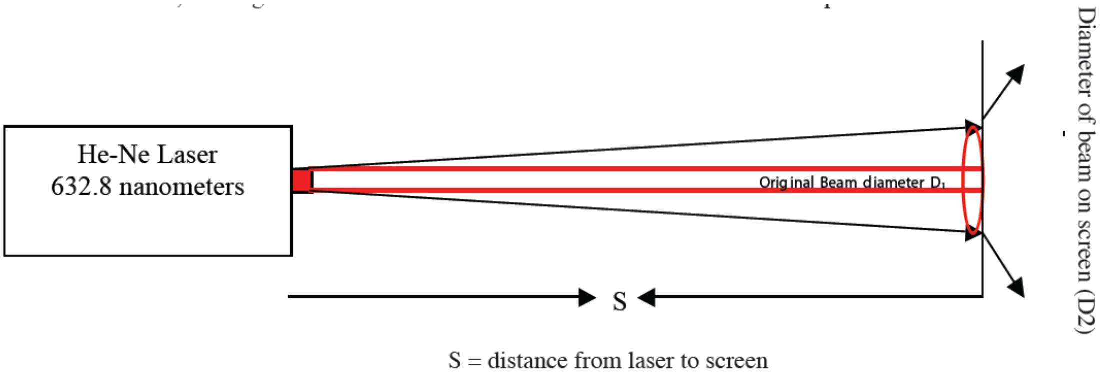
Theory:-

The laser (light amplification by stimulated emission of radiation) is a device that produces a strong beam of photons by stimulated emission.
A laser beam is coherent, very narrow and intense.
The directionality of the laser beam is expressed in terms of the full angle beam divergence, which is twice the angle that the outer edge of the beam makes with the center of the beam as shown in Fig. (2), the divergence tells us how rapidly the beam spreads when it is emitted from the laser.
Consider a monochromatic beam of light of “infinite” extent, which passes through a circular aperture of diameter D. The beam, will now diverge by an amount dependent on the size of D.

Procedure:-Part A:- Without beam expander:

1. Determine (D_1) which represents the aperture diameter of He-Ne laser.
2. Place the He-Ne laser at distance of about (S=500 mm) from the screen as in Fig. (1)

3. Determine the diameter of the beam on screen (D_2).



Figure(1): The setup without beam expander.

4.Increase the distance (S) from (500 to 3000)mm and tabulate your results in the table below:

S (mm)	D1(mm)	D2 (mm)	D3=D2-D1
500 ⋮ 3000			

5. Plot a graph between D3 as a function of S and find the slope.
6. Slope = tan θ

Where:

θ: Divergence angle.

Part B:-With beam expander.

Repeat all the steps in Part A but S is the distance between beam expander and the screen. See fig.(2).

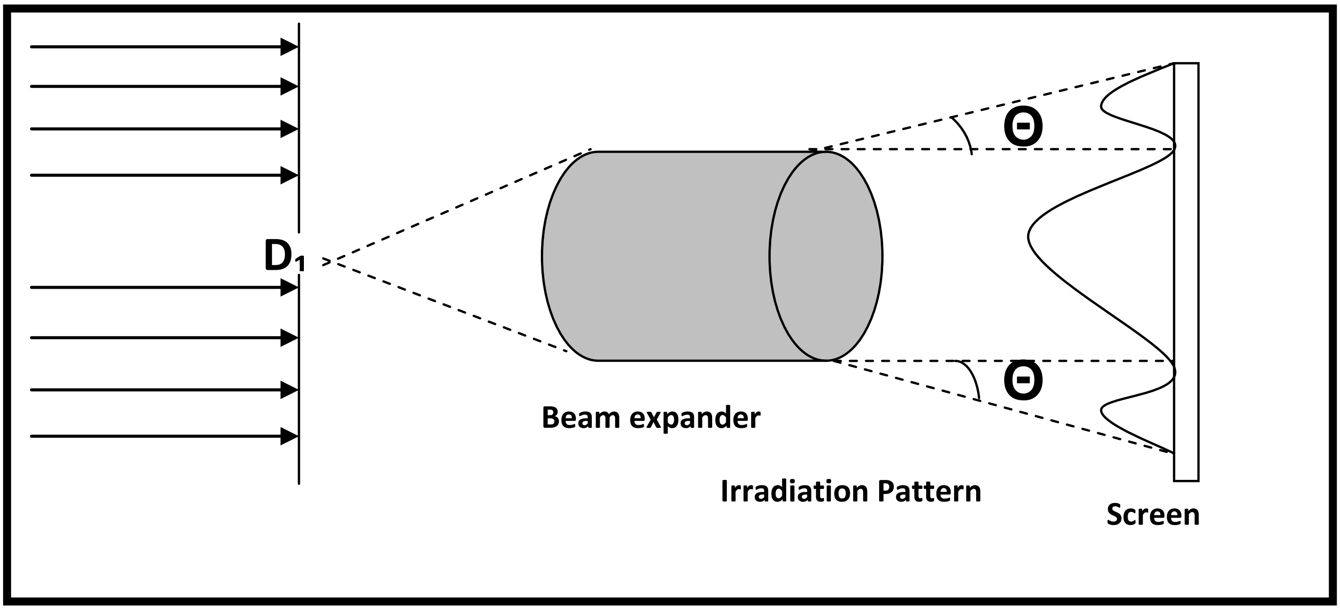


Figure (2): Beam divergence from a circular aperture.

Discussion:-

Q1:-What is the reason for laser beam divergence?

Q2:- What are the main properties of laser beam?

Q3:- A laser has a divergence of 0.2 milliradians (mrad): and the power of the beam is 5 mW, what is the intensity at a point at 2 m distance from the laser?

Q4:- The divergence of laser a beam after sending through a telescope is 10^{-6} rad .What is the diameter of the spot formed on the moon's surface if the laser is directed towards the earth? (The average distance the from the earth to the moon is $3.8*10^{5}$Km).

Experiment (5)

Laser Wavelength Measurement with a Simple Ruler

Objective:-

To calculate the wavelength of Laser using a simple ruler as a diffraction grating.

Apparatus:-

He-Ne Laser, metallic ruler, Screen,

Theory:-

Diffraction is the bending of light around the edge of an object. The amount of bending is quite small but depends on the size of the opening relative to the wavelength of the light.

In this experiment, we will use a steel ruler to measure the wavelength of laser beam. The laser produces a narrow intense beam of monochromatic (i.e., single wavelength) light. The ruler has a shiny, metallic finish. Consequently, if the laser light reflected from the surface ruler, it behaves like a mirror with the angle of reflection equal to the angle of incidence.
Light from a laser has such a high degree of spatial and temporal coherence (what deos these terms mean?) that if it is aimed at a steel ruler, the ruler markings can act as a diffraction grating which producing a series of bright spots on the vertical screen. The positions of the diffracted beams can be enable to determined the wavelength of laser light simply.

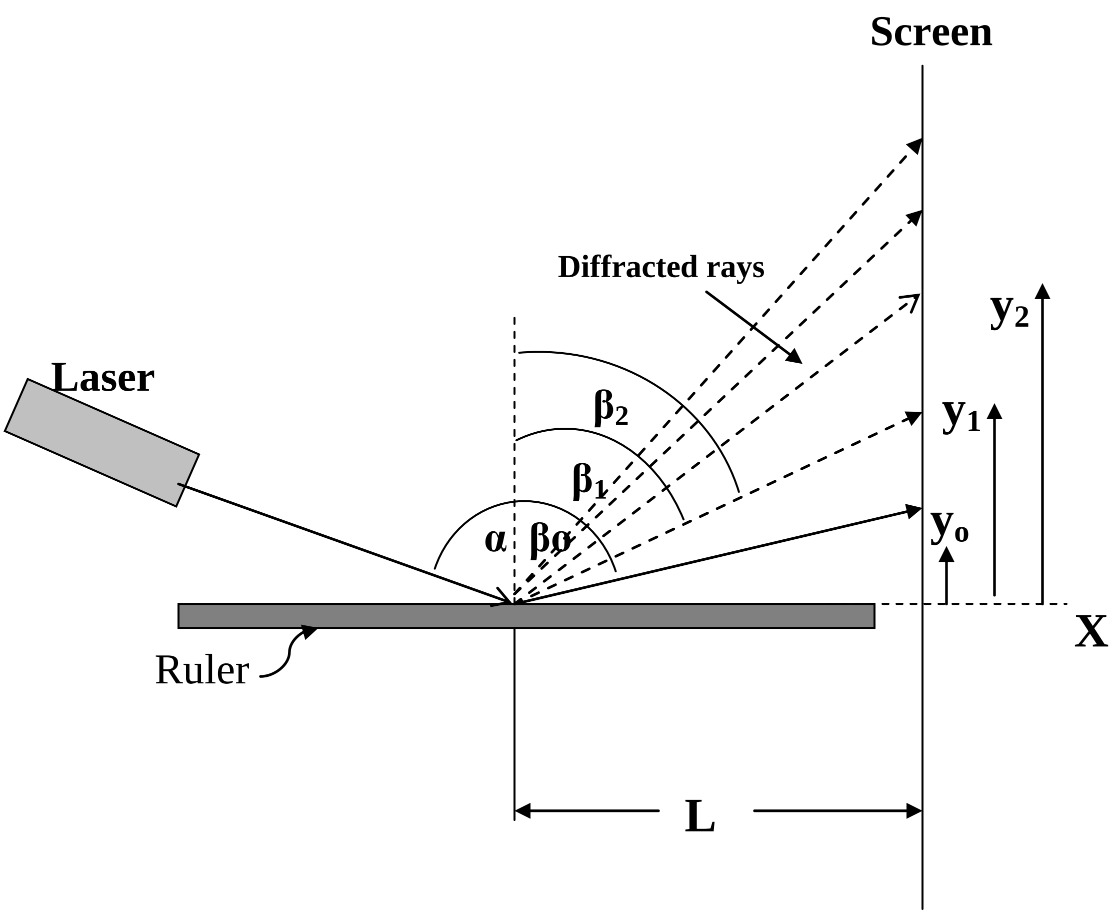


Figure (1): The experimental setup

In this case, the waves are normally incident on the surface but they are incident with a small angle and the waves reflect from between the marking. It is possible for interference to occur.

Procedure:-

1.Assemble the set up according to figure (l).

2.Fixed the laser source on the magnetic mount in such a way that the beam will make a small angle with the ruler.

3.Record the distance (L) which represent the distance between ruler (where the light striks it) and screen.

4.Record the distance (d) : the smallest distance between neighboring marks on the ruler.

5. Mark on the screen the hight of the spots of light (Y_o ,Y_1 , Y_2 ,….) as shown in figure (l).

6. Plot a graph of Y^2_n against the order of diffraction n.

7.Determined the gradient which equals to $2\lambda L^2/d$ from this you can calculate the wavelenght of laser λ.

8.Calculate perecentage error of (λ) . p.e= $((\lambda_{th} - \lambda_{exp})/ \lambda_{th}) \times 100\%$

λ_{th}=632.8 nm of He-NeLaser

Discussion:-

Q1:- What is the source of error?

Q2:- Explain the Diffraction phenomenon.

Experiment (6)

Mirrors

Objective:-

1:-To find the focal length of a concave mirror by two methods:-

A:-Direct method.

B:-Graphical method.

Apparatus:-

Light source, concave mirror, object and screen.

Theory:-

The reflection can occur at an interface between two transparent materials or at a highly polished surface of an opaque material such as a metal, in which case the surface is usually called a mirror.

We have three types of mirrors:-

1. Concave mirror.
2. Convex mirror.
3. Plane mirror.

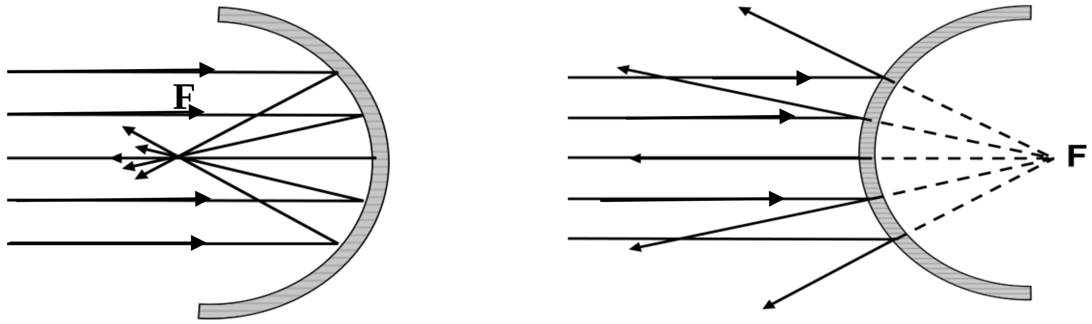
Concave and convex mirror also called spherical mirror.

Spherical mirror is a curved mirror which is a part of a hollow sphere.

1) Concave mirror :- is a spherical mirror whose reflecting surface is curved inwards. Rays of light parallel to the principal axis after reflection from a concave mirror meet at a point (converge) on the principal axis.

2) Convex mirror :- is a spherical mirror whose reflecting surface is curved outwards. Rays of light parallel to the principal axis after reflection

from a convex mirror get diverged and appear to come from a point behind the mirror.



Concave mirror ***Convex mirror***

Figure (1): Types of mirror

Terms used in the study of spherical mirrors(very important) :-

i) Center of curvature :- is the centre of the sphere of which the mirror is a part (C).

ii) Radius of curvature: - is the radius of the sphere of which the mirror is a part (CP).

iii) Pole :- is the centre of the spherical mirror (P).

iv) Principal axis :- is the straight line passing through the centre of curvature and the pole (X-Y).

v) Principal focus :- In a concave mirror, rays of light parallel to the principal axis after reflection meet at a point on the principal axis called principal focus(F).

In a convex mirror, rays of light parallel to the principal axis after reflection get diverged and appear to come from a point on the principal axis behind the mirror called principal focus (F).

vi) Focal length :- is the distance between the pole and principal focus (f). In a spherical mirror the radius of curvature is twice the focal length.

$$R=2f \quad \text{or} \quad f=\frac{R}{2}$$

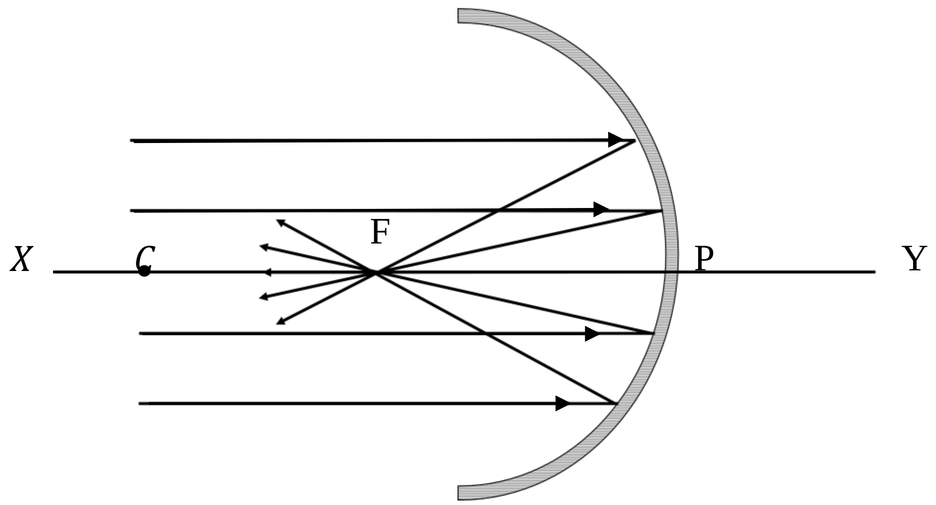


Figure (2)

C – centre of curvature ***CP – radius of curvature***

P – pole ***XY – principal axis***

F – principal focus ***PF – focal length***

A spherical reflection has image-forming properties similar to those of a thin lens, you can see a spherical mirror of radius of curvature (r) in Fig. (3).

In this case the focal length of spherical mirror can see in equation (1):

$$f=\frac{r}{2} \quad \ldots\ldots. (1)$$

Where:

f: focal length, r: is the radius of curvature of mirror.

But in graphical method one can find the focal length by using equation (2):

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \quad \ldots\ldots\ldots (2)$$

Where:

u: Distance between object and mirror.

v: Distance between mirror and screen.

f: Focal length.

<u>Procedure:-</u>

A:-Direct method:

1. To find the focal length place the concave mirror facing the object and screen with object in the same level as shown in Fig.(1):

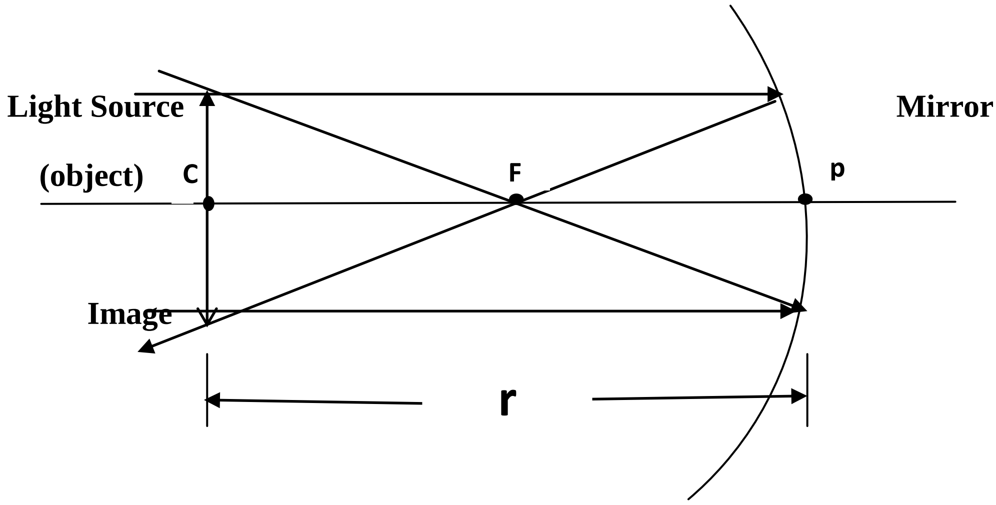


Figure (3): ***The setup of Direct Method.***

2. Adjust the position of mirror until a sharp and screen image coincides with the object.
3. Measure the distance between the bottom of the mirror and the object.
4. Find the focal length (f) of the mirror by applying equation (1).
5. Find the percentage error (p.e) of the focal length.

$$\mathbf{p.e = ((f_{th} - f_{exp})/f_{th}) \times 100\%}$$

B:-Graphical method:

1. Place the object at a distance u from the concave mirror.
2. Fix the concave mirror and move the screen as shown in Fig. (4).

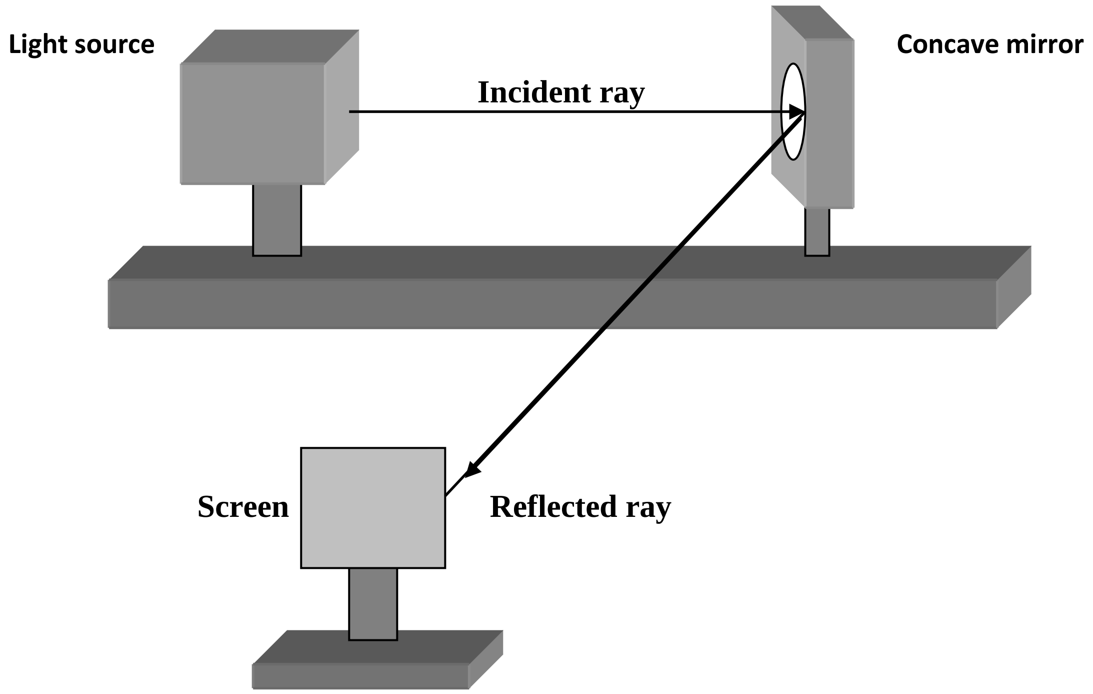


Figure (4): ***The setup of Graphical Method.***

3. Take six reading for u and the corresponding v.

u	v	1/u	1/v	1/f=1/u + 1/v	f	Image properties for each case

u: Distance between object and mirror.

v: Distance between mirror and screen.

f: Focal length.

4. Plot a graph of 1/u in x-axis and 1/v in y-axis to find focal length (f).

5. Find the percentage error (p.e) of the focal length.

$$p.e = \left(\left(f_{th} - f_{exp}\right)/f_{th}\right) \times 100\%$$

Discussion:-

Q1:-Which method you prefer to find the focal length? And why?

Q2:-Explain the six cases for producing image formed by concave mirror.

Q3:-Prove that $f=r/2$ when $u=v=r$.

Experiment (7)

(Michelson Interferometer)

Objective:-

(A): Interference Fringes Observation

(B): Calculate the refractive index of glass using Michelson Interferometer.

Apparatus:-

Use the system with its accessories as shown in Figure (1) below

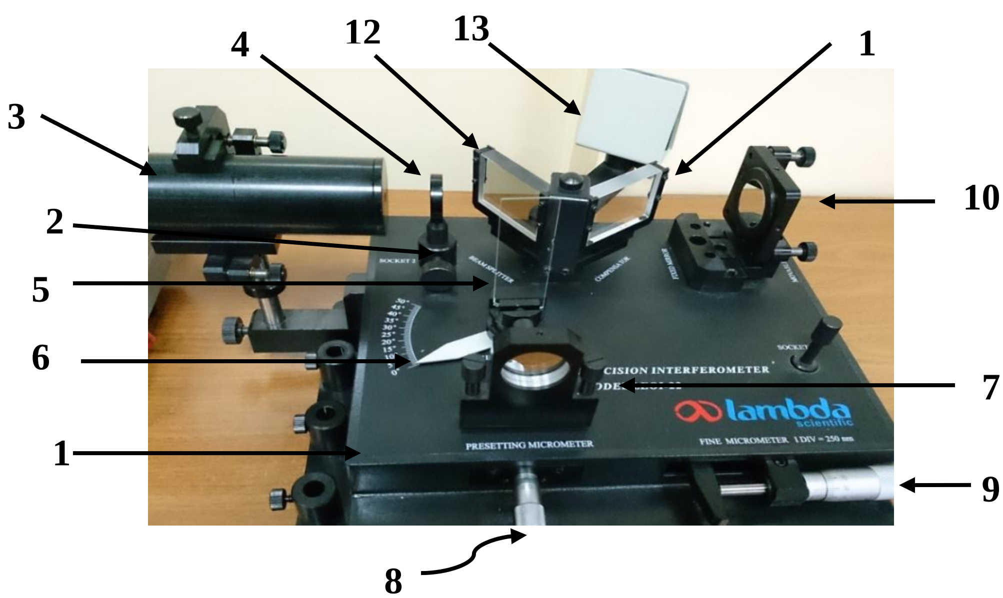


Figure (1)

1. Main Stage
2. Socket 2 for beam expander
3. He-Ne Laser
4. Beam Expander
5. Transparency Slice
6. Rotation Pointer and Socket 3
7. Fixed Mirror
8. Presetting Micrometer
9. Fine Micrometer
10. Movable Mirror
11. Compensator
12. Beam Splitter
13. Two in one screen

Theory:-

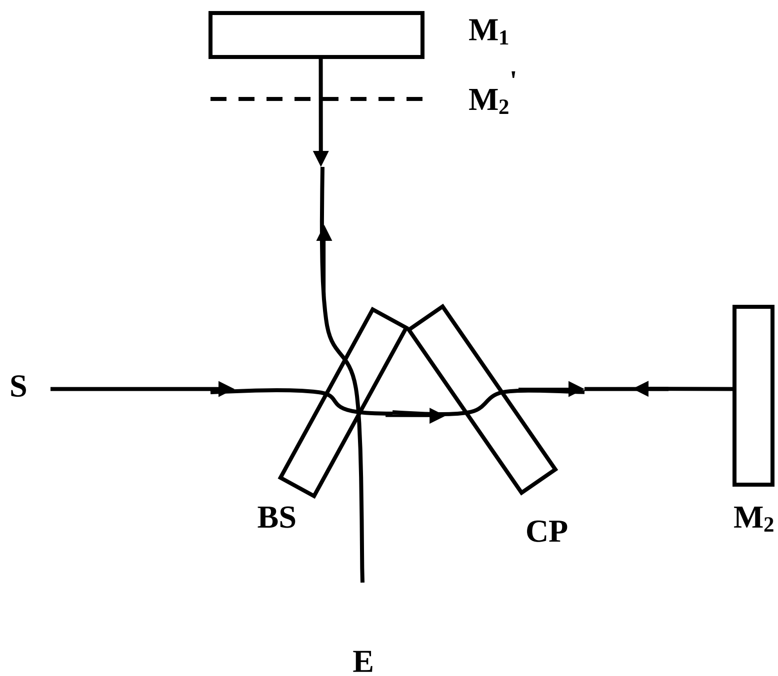


Figure (2) :Michelson interferometer

The above figure shows a schematic diagram of Michelson interferometer. The beam of light from the light source **(S)** strikes the beam-splitter **(BS)**, which reflects 50% of the incident light and transmits the other50%.The incident beam is therefore split into two beams; one beam is reflected toward the fixed mirror **(M_1)** ,the other is transmitted toward the movable mirror **(M_2)** .

Both mirrors reflect the light directly back toward the beam-splitter **(BS)**.The light from **(M_1)** is transmitted through the beam-splitter **(BS)** to the observer's eye **(E)**, and the other light from **(M_2)** is transmitted through the compensator plate **(CP)** and reflected from the beam-splitter **(BS)** to the observer's eye **(E)**.

Since the beams are from the same light source, their phases are highly correlated. When a beam expander is placed between the light source and the beam-splitter, the light rays spread out, and an interference pattern of dark and bright rings, or fringes, can be seen by the observer.

In above figure, **(M_2')** is the virtual image of (**M_2),** and the light path of the Michelson interferometer can be seen as the light path of the air plate between **(M_1)** and **(M_2')**.

The compensator plate **(CP)** parallel to the beam -splitter **(BS)** has the same thickness and refractive index with the **(BS)**. Because the light paths of the two beams are equal, and different light waves have the same retardation, and it is easy for observing the white-light interference.

When place a transparency slice in one optical arm of the Michelson interferometer, light path of this arm will changes as the transparency slice is rotating .The difference of the light path can be determined by counting the number of the fringes disappeared or appeared. And the light path has a relation to the rotating angle **(θ)**, the thickness **(d)** and the refractive index **(n)** of the slice.

If the entrance light is perpendicular to the transparency slice at first, and after rotating an angle **(θ)**, the change of the number of fringes is **(N)**.The refractive index **(n)** is given by:

$$n = \frac{n_0^2\, d \sin^2\theta}{2n_0\, d(1-\cos\theta)-N\lambda}$$

Where:

λ : is the wavelength of the He-Ne Laser(632.8 nm).

n_0 : is the refractive index of air.

N=number of fringes

d=………………..

θ=…………………

Procedure:-

1. Place He-Ne laser and fixit with mount with a He-Ne Laser in the mounting hole on the side stage and turn on.
2. Place beam expander in (socket 2).Adjust the height of the laser tube to let the beam hit the center of the beam expander. Remove the beam expander.
3. View the beam spot on the beam splitter; it should be approximately in the middle of the beam splitter, and view also on the movable mirror. Adjust the laser tube until the beam spots on both the beam splitter and movable mirror are at the same height.
4. Place the two in one screen in the extension in (socket 1) and face the white screen towards the beam splitter .A beam spot will be seen on the screen which comes from the fixed mirror. There are also other spots on the screen with less brightness due to multiple reflections. Align the center of the white screen with the brightest beam spot.
5. Adjust the movable mirror until the two bright spots coincide with each other at the center of the white screen.
6. Position the beam expander into (socket 2) with the lens lock facing the beam splitter .If the expanded beam spot is not immediately incident on the movable mirror then adjust the laser tube. The fringe pattern can be observed on the white screen.
7. Place the transparency slice clip in the mounting hole in (socket3). Mount the transparency slice on the clip .Adjust the clip and the rotational pointer and make sure that the slice is approximately perpendicular to the optical

path. If you not achieve fringes on the screen adjust the movable mirror to get a set of clear fringes on the white screen.

8. Slowly rotate the rotation stage. Count the number of fringe translations that occur as you rotate the table to an angle θ (at least 10 degree).
9. Calculate the refractive index of glass by using the relation below:

$$n = \frac{n^2_0\, d \sin^2\theta}{2n_0\, d(1-\cos\theta)-N\lambda} \qquad \text{………..(1)}$$

10. Calculate percentage error of (n). p.e= $((n_{th}-n_{exp})/n_{th}) \times 100\%$
n_{th}=1.5 of transparency slice.

Discussion:-

Q1:- Discuss the source of error in your experiment.

Q2:- Explain the working principles work of Michelson interferometer

Q3:- Define the refractive index.

Q4:- What is the function of the beam splitter.

Q5:-By Michelson interferometer we can determine

1)Wave length of sodium D-Lines

2)Refractive index of air

(True or False)

Experiment (8)

The Photoelectric Effect

Objective:-

This work is used to measure the plank's constant and work function.

Apparatus:-

Use the system with its accessories as shown in Fig.(1) below.

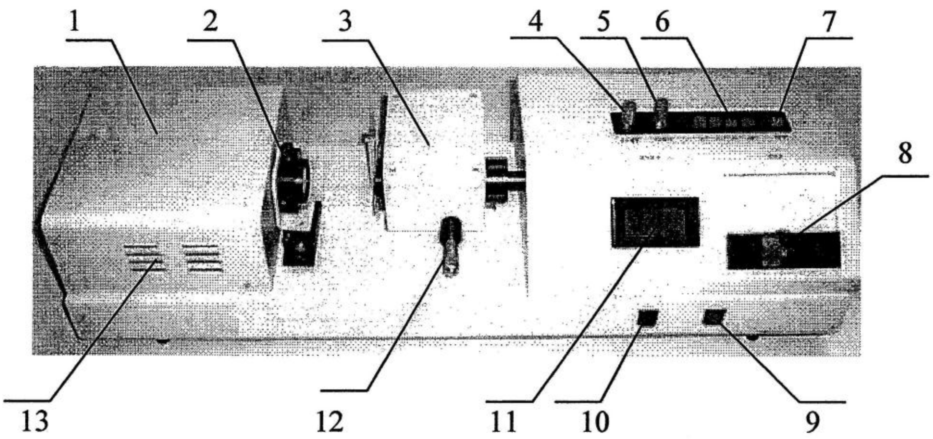


Fig. 1

1-Tungsten-halogen lamp box.
2-Condenser lens.
3-Monochromator.
4-Zeroing adjustment.
5-Voltage adjustment.
6-Current amplification range switches.
7-Voltage polarity switch.
8- Microampere meter.
9- Measurement switch.
10- Lamp switch.
11- DC voltage digital display.
12-Wave length adjuster.
13-Traverse stage of condencer.

Theory:-

In Fig. (2) Shown a schematic diagram of the basic apparatus for studying the photoelectric effect. When the light incident on a clean metal surface (Cathode(C)) electron are emitted some of these electrons strike the second metal plates (Anode(A)) constituting an electric current between the plates. The maximum energy of the emitted electrons can be measured.

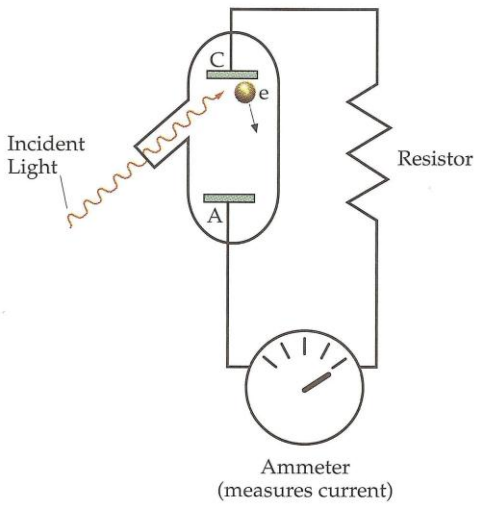


Fig. (2) Schematic diagram of a photoelectric effect.

Einstein suggested that this experimental result can be explained if light energy is quantized in small bundles called "photons". The energy of each photon is given by:

$$E = h\nu \text{ ……….. } (1)$$

Where:

h: is the Plank's constant

ν: is the incident light frequency

When incident light frequency is below the threshold frequency (or cut-off frequency) in photoelectric effects there is no photoelectron emitted.

The maximum kinetic energy of the electrons emitted is given by:

$$\left(\frac{1}{2} mv^2\right)_{max} = h\nu - \Phi \quad \text{.......(2)}$$

Where:

m: mass of electron (9.109×10^{-31} Kg)

v: initial speed of photoelectron emitting from metal surface

The quantity Φ called the work function which is the minimum energy necessary to remove an electron from a metal surface so:

$$E = h\nu - \Phi \quad \text{........ (3)}$$

In the case of zero potential difference between anode and cathode photoelectrons still transmit to the anode to form a photocurrent due to some photoelectrons having maximum kinetic energy. But when the potential difference is at a negative value (U_s), then no electrons transmit to the anode and hence the photocurrent is zero.

$$e\,U_s - \frac{1}{2} mv^2 = 0 \quad \text{........(4)}$$

Replace equation (4) in to equation (2) we have:

$$e\,U_s = h\nu - \Phi \quad \text{.......(5)}$$

Where:

U_s: cut-off potential of the photoelectric effect or (cut-off voltage)

Procedure:-

A: measuring the Plank's constant:

1. Turn on the tungsten-halogen lamp.
2. Loosen condenser locking screw, move condenser backwards and forwards to focus the light on to the surface of the entrance slide the lock it.
3. Use the horizontal adjustment screw to make the focused spot in to the entrance slit.
4. Turn on the measure switch and allow a warm up for around 25 -30 min. Block the entrance slit of the monochromeator by turning a plate in front of it.
5. Adjust the voltage meter to zero volt and then make fine adjustment On the zeroing to set the ampere meter to zero.

Note: Once the zero point of the ampere meter is set never turn zeroing knob again during measurement.

6. Set voltage polarity switch to ''-''.
7. Select the wave length between (430 , 460 and 490)nm.
8. Select the amplification range switch in 10^{-5} µA.

9. Apply DC voltage at different intervals biased on current changes at various stages and read the corresponding current values.
10. Make some experiments at different wavelengths with suitable intervals.
11. Record data in the following table:

λ_1		λ_2		λ_3	
V(v)	**I(μA)**	**V(v)**	**I(μA)**	**V(v)**	**I(μA)**

12. Plot between I-V characteristic curves and find the cut-off voltage from the graph.
13. find the cut-off voltage U_s at selected wavelengths and fill in the following table:

Wavelength(nm)			
Frequency(ν)X10^{14} (Hz)			
Cut-off voltage U_s (v)			

14. Plot a graph between U_s and ν based on the data on the above table. Designate the x-axis to be frequency and y-axis to be cut-off

voltage.

15. Find the slop = K= ($\Delta U_s/\Delta \nu$).
16. Find the Plank's constant from slop =K= h/e:

 So h=K*e

Where:

e: an electron charge (1.602 X10^{-19} C)

B: measuring the work function:

17. Determine the work function (Φ) of the material from equation (5).
18. Determine cut-off frequency of the cathode material:

$$h\nu_o = \Phi$$

<u>Discussion:-</u>

Q1:-Discuss the source of error in your experment.

Q2:- what is the meaning of Planck's constant, work fuction, cut-off frequency.

Q3: What are effect of the following on the emitted electrons from the metals :

1-The intensity of the incident light(when $V_{S\ and}$ f are constant).

2-The frecuency of the incident light (when V_S and intensity are constant).