1. Details of Module and its structure

Module Detail	
Subject Name	Physics
Course Name	Physics-04 (Physics Part-2, Class XII)
Module Name/Title	Unit-06, Module- 07(B) Optics Experiments Chapter-09: Ray Optics and Optical Instruments
Module Id	leph_20907_eContent
Pre-requisites	Reflection refraction ,reflection at curved surfaces, refraction at curved surfaces , mirror and lens formula , real and virtual image
Objectives	After going through the module the learner will be able to: • Know the optics laboratory equipment • Understand the principle for the following experiments **7(A)** **a)** To Study the nature and size of image formed by a convex lens ii) concave mirror using a candle and a screen **b)** To Determine the focal length of convex lens by plotting graphs between u and v, between 1/u and 1/v **c)** To Determine the focal length of concave mirror by plotting graphs between u and v, between 1/u and 1/v **7(B)** **d)** To determine the focal length of a convex mirror using a convex lens **e)** To find the focal length of a concave lens using a convex lens **f)** To find the refractive index of a liquid by using a convex lens and a plane mirror
Keywords	Focal length of concave mirror, Focal length of convex mirror, focal length of convex lens, focal length of concave lens ,refractive index of a liquid using a convex lens and a plane mirror.

2. Development Team

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1. UNIT SYLLABUS

UNIT-06: Optics

Chapter–09: Ray Optics and Optical Instruments

Ray optics Reflection of light; spherical mirrors; mirror formula; refraction of light; total internal reflection and its applications; optical; fibers; refraction at spherical surfaces; lenses; thin lens formula; lens maker's formula; magnification, power of a lens; combination of thin lenses in contact; refraction and dispersion of light through a prism.

Scattering of light – blue color of sky and reddish appearance of the sun at sunrise and sunset

Optical instruments – microscopes and astronomical telescopes (refracting and reflecting) and their magnifying powers

Chapter-10: Wave Optics

Wave optics: wave front and Huygens's principle, reflection and refraction of plane wave at a plane surface using wave fronts. proof of laws of reflection and refraction using Huygens's principle. Interference, Young's double slit experiment and expression for fringe width, coherent sources and sustained interference of light; diffraction due to a single slit width of central maximum; resolving power of microscope and astronomical telescope. Polarisation, plane polarised light, Malus's law, Brewster's law, uses of plane polarised light and polaroid.

2. MODULE WISE DISTRIBUTION OF UNIT SYLLABUS 15 MODULES

Module 1	• **Introduction** • **How we will study optics - plan** • **Light facts** • **Ray optics, beams** • **Light falling on surfaces of any shape texture** • **Peculiar observations**

Module 2	• Reflection of light • Laws of reflection • Reflection of light by plane and spherical surfaces • Spherical Mirrors aperture, radius of curvature, pole principal axis • Focus, Focal length, focal plane • Image – real and virtual • Sign convention • The mirror equation, magnification • To find the value of image distance v for different values of object distance u and find the focal length of a concave mirror • Application of mirror formula
Module 3	• Refraction of light • Optical density and mass density • Incident ray, refracted ray, emergent ray • Angle of incidence, angle of refraction angle of emergence • To study the effect on intensity of light emerging through different colored transparent sheets using an LDR • Refractive index • Oblique incidence of light, Snell's law • Refraction through a parallel sided slab Lateral displacement, factors affecting lateral displacement • To observe refraction and lateral displacement of a beam of light incident obliquely on a glass slab • Formation of image in a glass slab
Module 4	• Special effects due to refraction • Real and apparent depth • To determine the refractive index of a liquid using travelling microscope • Total internal reflection • Optical fibers and other applications
Module 5	• Refraction through a prism • Deviation of light - angle of deviation • Angle of minimum deviation • Expression relating refractive index for material of the prism and angle of minimum deviation • To determine the angle of minimum deviation for given prism by plotting a graph between angle of incidence and angle of deviation • Dispersion, spectrum
Module 6	• Refraction at spherical surfaces • Radius of curvature

	• Refraction by a lens • Foci, focal plane, focal length, optical center, principal axis • Formation of images real and virtual • Lens maker's formula • Lens formula and magnification • Sign convention • Application of lens formula • Power of lens • Combination of thin lenses in contact
Module 7 A and B	**7A** • To study the nature and size of image formed by a i) convex lens ii) concave mirror using a candle and a screen • To determine the focal length of convex lens by plotting graphs between u and v, between 1/u and 1/v • To determine the focal length of concave mirror by plotting graphs between u and v, between 1/u and 1/v **7B** • To determine the focal length of a convex mirror using a convex lens • To find the focal length of a concave lens using a convex lens • To find the refractive index of a liquid by using a convex lens and a plane mirror
Module 8	• Scattering of light – Blue color of sky, Reddish appearance of the sun at sunrise and sunset, Dust haze
Module 9	• Optical instruments • Human eye • Microscope • Astronomical telescopes reflecting and refracting • Magnification • Making your own telescope
Module 10	• Wave optics • Wave front • Huygens's principle shapes of wave front • Plane wave front • Refraction and reflection of plane wave front using Huygens's principle • Verification of Laws of refraction and reflection of light using Huygens's principle
Module 11	• Superposition of waves

	• Coherent and incoherent addition of waves
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MODULE- 07(B)

3. We have divided module 7 into two parts

Module- 7(A)

- **Know the optics laboratory equipment**
- **Understand the principle for the following experiments**

a) **To Study the nature and size of image formed by a**
   i) **convex lens**
   ii) **concave mirror using a candle and a screen**

b) **To Determine the focal length of convex lens by plotting graphs between u and v, between 1/u and 1/v**

c) **To Determine the focal length of concave mirror by plotting graphs between u and v, between 1/u and 1/v**

Module- 7(B)

a) To determine the focal length of a convex mirror using a convex lens
b) To find the focal length of a concave lens using a convex lens
c) To find the refractive index of a liquid by using a convex lens and a plane mirror

4. INTRODUCTION

In module 07(A), we dealt with optics experiments in the physics laboratory. You learnt the interesting method of removal of parallax to find the image of a pin; its location was found by an image locator pin

Doing the same with convex mirror or concave lens is not possible. This is because they produce virtual images.

a) To find the focal length of a convex mirror, using a convex lens

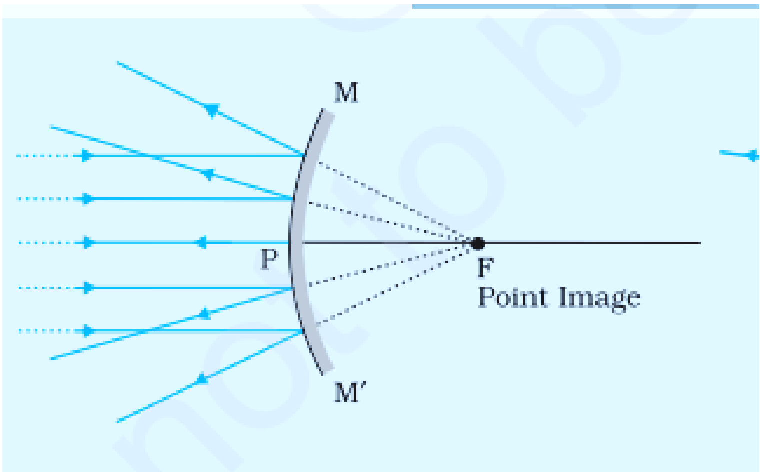


Figure shows if an object is at infinity. A highly diminished and point size image is located at the focus behind the mirror the image is virtual and cannot be obtained on a screen. There is hence no way to obtain its rough focal length.

It is the symmetry due to laws of reflection that we can draw a ray diagram for a convex surface of a single center of curvature. This means the convex surface is uniform and the radius of curvature remains the same for all points of incidence of light.

APPARATUS AND MATERIAL REQUIRED

- **An optical bench with uprights for holding lens, mirror and two needles,**
- **Two needles (pins),**
- **A thin convex lens,**
- **A convex mirror,**

- **Index needle (may be a knitting needle or a pencil sharply pointed at both ends), a metre scale**
- **A spirit level.**

PRINCIPLE

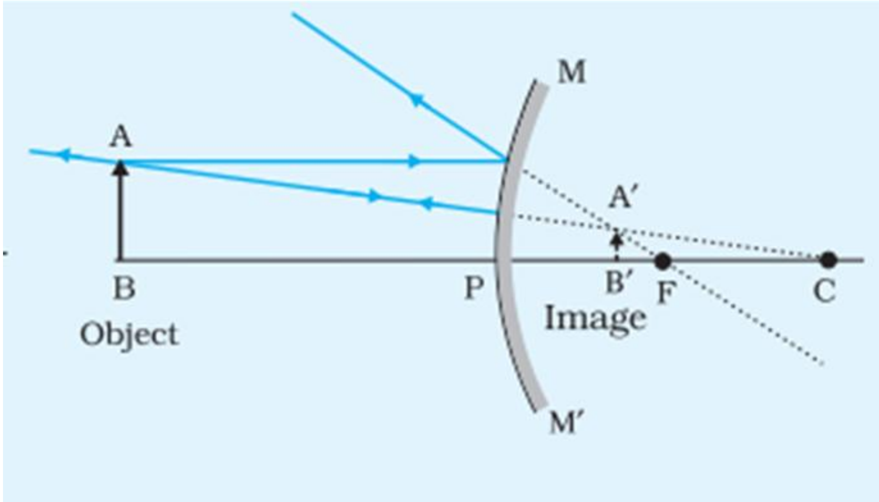


Figure illustrates the formation of image of an object AB by a convex mirror MM′ (having a small aperture) in two different situations.

If the object is in front of the convex mirror a diminished virtual image is formed between the pole and the focus behind the mirror

The image formed by a convex mirror is virtual and erect.

Therefore, its focal length cannot be directly as in the case of concave mirror.

However, it can be determined by introducing a convex lens in between the object and the convex mirror

An object AB is placed at point P′ in front of a thin convex lens such that its real, inverted and magnified image A′B′ is formed at position C on the other side of the lens
Now, a convex mirror is introduced between the convex lens and point C and so adjusted that the real and inverted image A′B′ coincides with the object AB at point P′.

This is possible if the light rays starting from the tip of the object (as shown in the figure), after passing through the lens, fall normally on the reflecting surface of the convex mirror and retrace their path.

Any normal ray (perpendicular) to a spherical surface has to be along the radius of that sphere, thus, point C must be the centre of curvature of the convex mirror.

Therefore, the distance PC is the radius of curvature R and half of it would be the focal length of the convex mirror.

That is, **F = R/2**

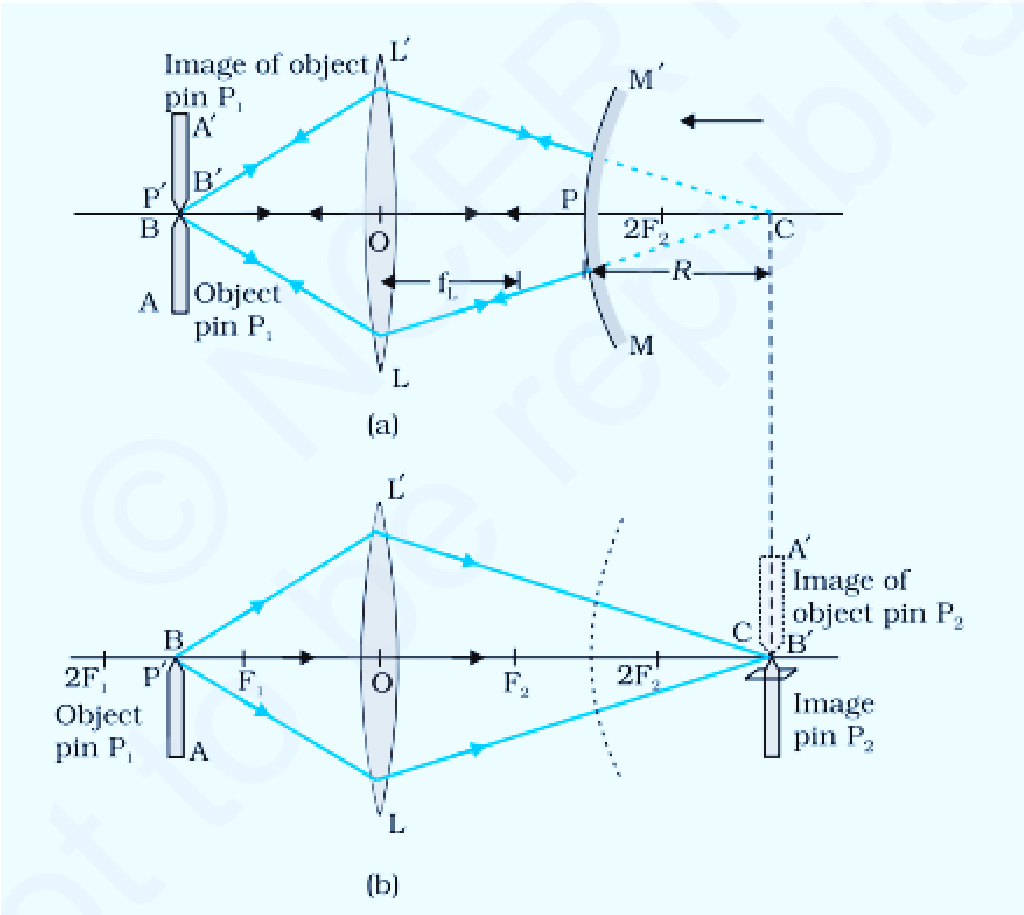


Figure shows image formed by

a) Convex mirror (MM') and convex lens (LL') image A'B' its position coincides with object AB at p', or position of pin P_1
b) Convex lens of object AB in the position of pin P_2

PROCEDURE

1. **In case, if the focal length of the given thin convex lens is not known then approximate value of its focal length should be estimated first.**

2. **Place the optical bench on a rigid table or on a platform. Using the spirit level, make it horizontal with the help of levelling screws provided at the base of the bench.**

   This is done so that the alignment of the principal axis is parallel to the bench, which has the scale for measurement.

3. **Place the uprights mounted with pin P1 (object pin), convex lens LL′, and convex mirror MM′ on the horizontal optical bench [Fig (a)**

4. **Check that the lens, mirror and pin P_1 are vertically placed on the optical bench. Also verify that the tip of the pin, optical centre O of the convex lens LL′ and pole P′ of the convex mirror MM′ lie on the same horizontal straight line, parallel to the optical bench.**

5. **Determine the index correction between upright holding of the convex mirror and image pin respectively, using an index needle.**

   Watch video

6. **Place the object pin P_1 from the convex lens LL′ at a distance slightly greater than the focal length of the lens.**
   To ensure formation of real enlarged image

7. **Adjust the position of the convex mirror MM′ till the light rays reflected back from the mirror pass through the lens and form a real and inverted image coinciding with the object pin P_1, as shown in Fig. (a).**
   This occurs when the rays starting from the tip of pin P_1, after passing through the lens strike the mirror normally and are reflected back along their original paths. Remove the parallax between the image and object pins.

8. **Read the position of uprights holding the object pin P_1, convex lens LL′ and convex mirror MM′ and record the observations in the observation table.**

9. **Remove the convex mirror from its upright and fix image pin P_2 on it. Adjust the height of pin such that the tip of it also lies on the principal axis of the lens.**

   That is, the tips of the pins P_1 and P_2 and the optical centre O of the convex lens, all lie on a straight horizontal line parallel to the length of the optical bench.

10. **You may put a small piece of paper on image pin P_2 to differentiate it from the object pin P_1.**

11. Using the method of parallax and without changing the position of lens LL′ and object pin P_1, adjust the position of image pin P_2 on the other side of the lens so that it coincides with the real and inverted image of the object pin P_1 formed by the convex lens [Fig.(b)]. Note the position of the image pin.

12. Repeat the experiment by changing the separation between the pin P_1 and lens LL′ and the mirror MM′. In this manner, take five sets of observations.

OBSERVATIONS

1. Focal length of the convex lens, f (estimated/given) = ... cm
2. Actual length of the index needle, l = ... cm
3. Observed length of the index needle l' = Position of mirror upright – position of pin upright on the scale = ... cm
4. Index correction, e = Actual length – observed length ($l - l'$) = ... cm

Observation table for radius of curvature

Sl. No.	Upright position of				Observed $R' = c - d$ (cm)	Corrected R Observed $R' + e$ (cm)	Focal length f (cm)	Δf (cm)
	Object pin P_1 a (cm)	Convex lens LL′ b (cm)	Convex mirror MM′ c (cm)	Image pin P_2 d (cm)				
1								
2								
--								
5								
					Mean			

CALCULATIONS

Calculate the mean value of radius of curvature of the convex mirror, R, and determine its focal length using the following relation f = R/2 = ... cm

PRECAUTIONS

- **The uprights supporting the pins, lens and mirror must be rigid and mounted vertically.**

- **The apertures of the given convex lens and convex mirror should be small, otherwise the image formed will be distorted.**

- **Eye should be placed at a distance of about 25 cm or more from the image pin.**

- **Optical bench should be horizontal. The tips of pins, centre of convex lens and pole of the mirror should be at the same horizontal level.**

THINK ABOUT THESE

- **The tip of the inverted image of the object pin should just touch the tip of the image pin and must not overlap. This should be ensured while removing the parallax.**

- **Only one eye should be used to remove parallax, the other should be kept closed.**

- **Personal eye defects may make removal of parallax tedious.**

- **The convex mirror should preferably be front-coated. Otherwise multiple reflections may take place.**

- **It may not be possible to perform this experiment with just any convex lens. The focal length of the lens used in this experiment should neither be too small nor too large. Why?**

- **If focal length of the concave mirror is determined, by using convex lenses of different focal lengths, do you expect any change in the result? If yes, what type of change? If not, why not?**

- **How will the result change if a convex lens of different refractive indices were used?**

- **If the convex lens selected for the experiment has focal length less than that of the convex mirror, how would this selection limit the experiment?**

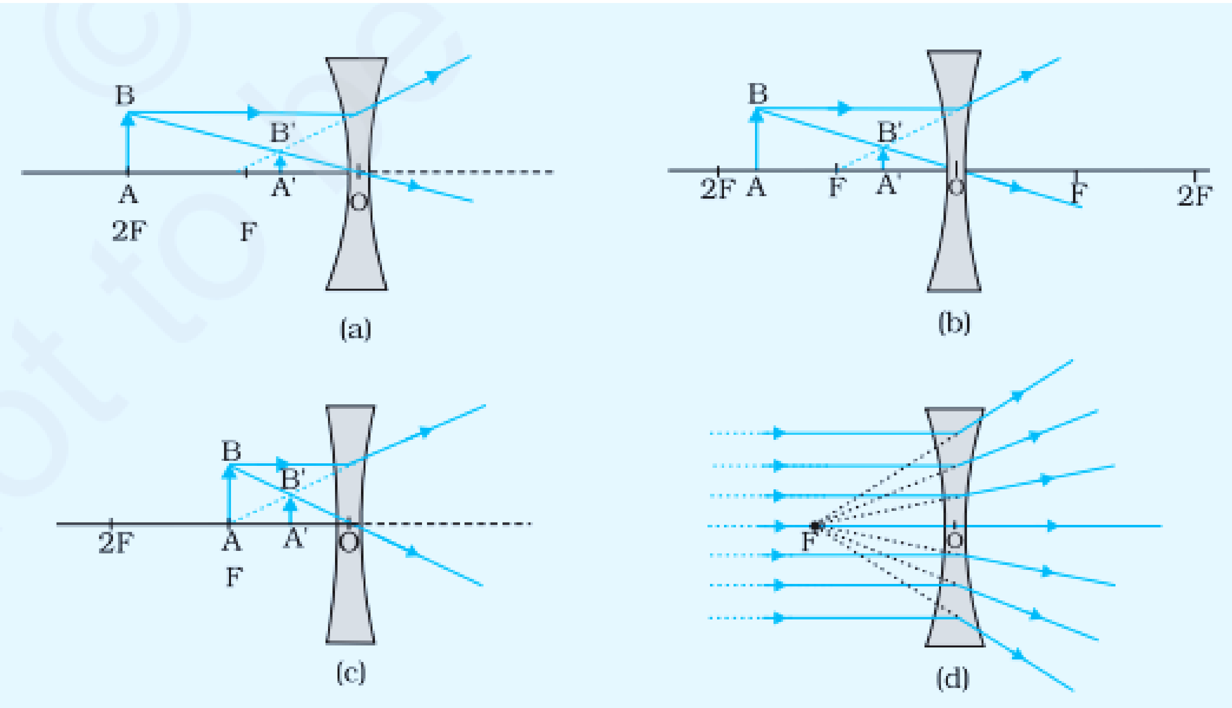
b) To find the focal length of a concave lens with the help of a convex lens

APPARATUS REQUIRED

1. **An optical bench with uprights for holding the lenses and two needles,**
2. **a thin concave lens,**
3. **a convex lens of focal length (~15 cm) smaller than that of the concave lens,**
4. **index needle (may be a knitting needle),**
5. **a metre scale**
6. **a spirit level.**

PRINCIPLE

Figures (a), (b), (c) and (d) illustrate the formation of image A′ B′ of an object AB by a concave lens.

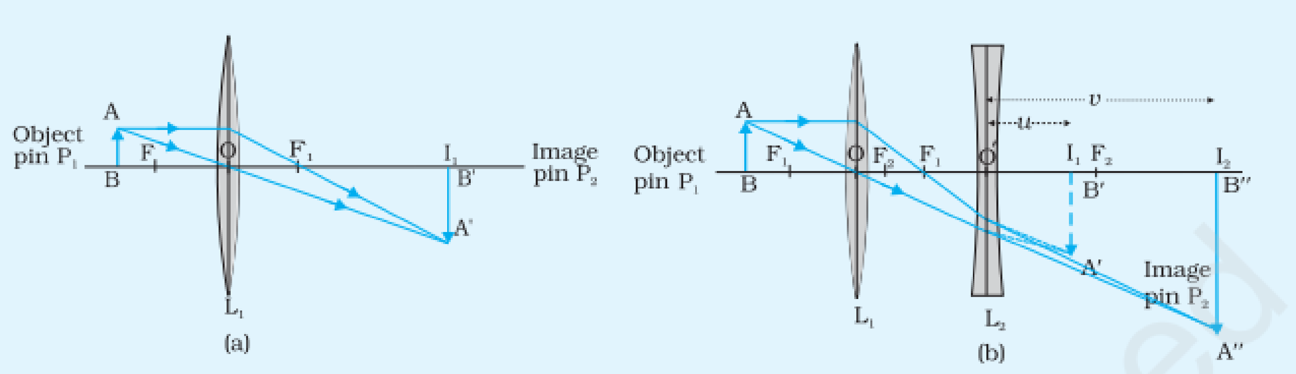


Images formed by a concave lens for object in different positions

It is clear that the image formed by a concave lens is always virtual and erect in these cases.

Therefore, its focal length cannot be determined directly.

However, it can be determined indirectly by introducing a convex lens in between the object and the concave lens and producing a real image as illustrated in Fig.



Formation of image a) by a convex lens and b) by a combination of convex lens and convex lens

A convex lens L_1 converges the light rays starting from the object AB to form a real and inverted image A′B′ at position I_1 [Fig. (a)].

If a concave diverging lens L_2 is inserted between the lens L_1 and point I_1 as shown in Fig. (b),

for concave lens L_2 image A′ B′ behaves as virtual object.

A real and inverted image A″ B″ is formed at point I_2 by the diverging lens L_2.

Thus, for the concave lens L_2

the distances O′ $_1$1 and O′ I_2 would be the distances u and v, respectively.

It is important to note that the focal length of convex lens L_1 must be smaller than the focal length of the concave lens L_2.

because

The second image A″ B″ is formed only when the distance between lens L $_2$ and first image A′B′ is less than the focal length of L_2.

The focal length of the concave lens L 2 can be calculated from the relation

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

Here for the concave lens both distances u and v are positive and since u will be found to be less than v, f will always be negative.

PROCEDURE

i) **In case, if the focal length of the given thin convex lens is not known then rough value of its focal length (f) should be estimated first to ensure that its focal length is less than that of the concave lens.**

ii) Place the optical bench on a rigid platform and using the spirit level, make it horizontal with the help of levelling screws provided at the base of the bench.

iii) Place the uprights mounted with pin P_1 (object pin), convex lens L_1, and another pin P_2 (image pin) on the optical bench. You may put a small piece of paper on image pin P_2 to differentiate it from the image of object pin P_1 [Fig. (a)].

iv) Check the collinearity of the tip of pin P_1, optical centre O of convex lens L_1, and the tip of image pin P_2 along a horizontal straight line which is parallel to the length of the optical bench. In this condition the planes of lens and both the pins would be perpendicular to the axis of the lens.

v) For the determination of the index correction, bring a mounted pin close to the concave lens L_2.

Adjust the index needle (a sharp edged knitting needle would also serve the purpose) horizontally such that its one end touches one of the curved surfaces of the lens and the other end touches the tip of the pin. Note the positions of the two uprights on the scale provided on the optical bench. The difference of the two would give the observed length of the index needle.
The actual length between the tip of the pin and optical centre O′ of the lens L_2 would be length of the index needle (as measured by a scale) plus half of the thickness of the lens at its optical centre. The difference of the two lengths is the index correction. (If the concave lens is thin at the centre, its thickness at the centre can be ignored).

vi) Separate the object pin P_1 from the convex lens by a distance slightly greater than the focal length f of the lens.

vii) Locate its real and inverted image at point I_1 on the other side of the lens by removing the parallax between the image pin P_2 and image of the object pin P_1 [Fig.(a)].

viii) Read the positions of the uprights holding the object pin P_1, convex lens L_1, and image pin P_2 (i.e. point I_2). Record these observations

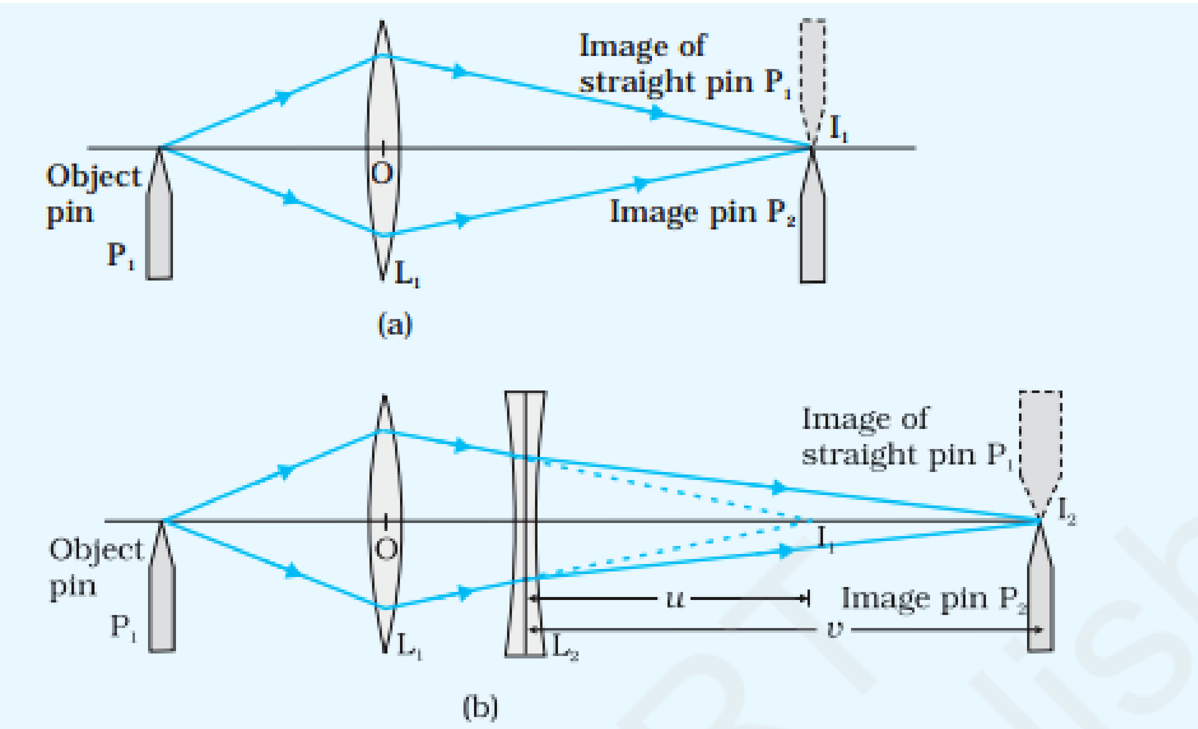
ix) From now on, do not change the position of the convex lens L_1 and the position of the object pin P_2 . Insert the concave lens L_2 in between the convex lens L_1 and image pin P_2. Now the image of object pin will shift further from the convex lens L_1 to a point I_2 (say). Adjust the position of the concave lens so that the point I_2 is sufficiently away from the point I_1.

x) **In case the image formed by the combination of convex and concave lenses is not distinctly visible, try to see it on moving the concave lens nearer to the point I_1 and to locate the image by using a pencil held in hand, and keeping the image pin P_2 at point I_1 as a guide to decide which way to shift the concave lens L_2.**

After having seen the clear image at point I_2 and ensured that it lies within the range of the optical bench, move image pin P_2 to locate the image (or point I_2) more accurately using the method of parallax [Fig.(b)]. Since the image forming at I_2 is quite enlarged, it can be blurred.

xi) **Note the position of uprights holding the concave lens and image pin P_2, i.e., point I_2. Note the readings in the Observation Table.**

xii) **Change the position of upright holding the object pin P1 and repeat the steps 6 to 10. Take five sets of observations.**



Notice the alignment required for the experiment

OBSERVATIONS

1. Focal length of the convex lens, f = ... cm
2. Length of the index needle as measured by the scale, s = ... cm
3. Thickness of the thin concave lens (given) at its optical centre, t = ... cm
4. Actual length between the optical centre O of the lens and tip of the pin, l = s + t/2 = ... cm

5. Observed length of the index needle, l′ = Distance between the pole of the lens and tip of the pin = Position of lens upright - position of pin upright on the scale = ... cm

6. Index correction, e = l – l′ = ... cm

Sl. No.	Position of										
	Object pin upright P_1, a (cm)	Convex lens L_1 upright, b (cm)	Image formed by L_1, point I_1, c (cm)	Concave lens L_2 upright, d (cm)	Image formed by L_1 and L_2, point I_2, g (cm)	Observed u = c – d (cm)	Observed v = g – d (cm)	Corrected u = Observed u + e (cm)	Corrected v = Observed v + e (cm)	f = uv/(u – v) (cm)	Δf (cm)
1											
2											
..											
5											
									Mean		

CALCULATIONS

Use

$$f = \frac{uv}{u - v}$$

Formula after considering the sign convention

The focal length of the concave lens using the formula f = … cm

RESULT

The focal length of the given concave lens is (f ± Δf) = ... ± ...cm. Here f is mean value of the focal length.

PRECAUTIONS

- **The concave lens must be placed near the convex lens. In fact, the second image I2 is formed only when the distance between concave lens L2 and first image I1 (which acts as virtual object for the concave lens) is less than the focal length of the concave lens.**

- **Since the image formed at I 2 is quite enlarged, it can be blurred. Therefore, it would be preferable to use a thin and sharp object pin and shine it with light using a lighted electric bulb.**

- **The convex lens and the pin P1 must not be disturbed during the second part of the experiment.**

- **A diminished, real and inverted image of the image pin P2 might also be formed by the light rays reflecting from the concave surface of the lens L 2. It should not be confused with the bold and bright image formed by the combination of convex and concave lenses.**

THINK ABOUT THESE

- **If tip of object pin and optical centre of the lens are not aligned properly (if not brought at the same horizontal level), image tip and image of object pin tip will not touch each other. There may be some gap between the two or there could be overlap between the two. In such situations, there can be error in removing parallax and it will lead to errors in the result.**

- **For greater accuracy we should use sharply pointed object pin.**

- **As concave lens diverges the rays, the image formed by a concave lens alone will not be real and cannot be taken on a screen. To converge these diverging rays to form a real image, convex lens is used**.

- **Diverging rays from concave lens can be made to fall normally on a concave mirror to get the real image formed at the point where object is placed. Hence, the focal length of the concave lens can be found by using a concave mirror also.**

- **Since the image I2 is quite enlarged, it can get blurred by chromatic aberration of the two lenses. Thus it is better to put a screen behind object pin P1 and thus do the entire experiment with one colour of light instead of with white light. For the same reason, pin P1 should be quite thin and sharp compared to pin P2.**

c) To find the refractive index of a liquid by using a convex lens and a plane mirror

APPARATUS

1. **Plane mirror**
2. **Convex lens of about 20 cm focal length**
3. **One pin in a cork holder**
4. **A retort stand**
5. **A table of convenient height**

PRINCIPLE

In this method, a real and inverted image coincides with the object placed on the principle focus point of a convex lens.

The rays from **an object pin placed at principle focus of a convex lens,** emerges out parallel to the principle axis.

When these rays fall normally on a plane mirror placed horizontally below the convex lens, they retrace their path and form an image at the focus.

Now if the space between the convex lens and the plane mirror is filled with a liquid (water) we have two lenses in combination

- **The convex lens**
- **The plano-concave water lens**

The combined focal length F will require adjustment of the pin to again be moved along the principle axis to remove parallax between the pin and the image of the pin

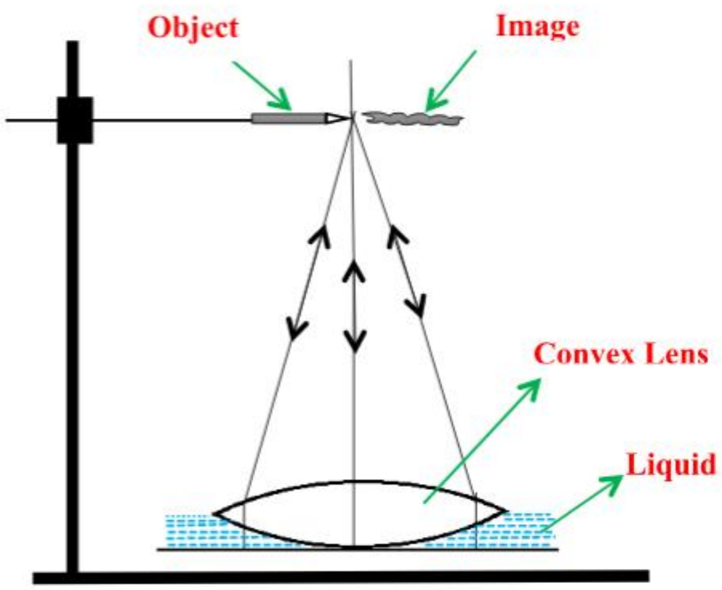


Figure shows image formed by a bi convex (equi-convex –radius of curvature of both surfaces are equal) backed by a plane mirror coinciding with the object, with water between the lens and mirror

When a convex lens is placed over some drops of the given liquid on a plane mirror, a plano-concave liquid lens is formed between the lens and the mirror.

If f_1 is the focal length of the convex lens and F is the focal length of the combination of **glass convex lens and plano-concave liquid lens**, the focal length of the liquid lens f_2 is given by,

Using thin lens formula for combination of lenses

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$f_2 = \frac{Ff_1}{f_1 - F}$$

If R is the radius curvature of the face of the convex lens which is in contact with the liquid, then the refractive index of the liquid is,

Lens maker's formula
For the LIQUID(water) lens

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

$R_1 = R, R_2 = \infty$

$$\frac{1}{f_2} = \frac{n}{R} - 1$$

$$\mathbf{n} \quad = 1 + \frac{\mathbf{R}}{\mathbf{f_2}}$$

For assistance with procedure see-
https://www.youtube.com/watch?v=Hcnk9sxTLek

THINK ABOUT THIS

- **If the two surfaces of the glass lens are not equal**
- **Plane mirror is not horizontal**
- **A dropper should be used to put water between the glass lens and plane mirror**
- **After removing parallax between the pin and its image, the height of the pin should be taken both from the top of the glass lens and the top of the plane mirror.**
- **Can we find the refractive index of oil by this method?**
- **Retort stand should hold the object pin horizontally, why and how can we ensure this?**

EXAMPLE

The focal length of a convex lens is 10 cm and that of a concave lens is 50 cm. The two lenses are placed in contact. An object is placed at a distance of 25 cm from the combination. Find the position of the image.

SOLUTION:

the focal length F of the combination is

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$f_1 = 10\ cm\ and\ f_2 = -50\ cm$$

$$\frac{1}{F} = \frac{1}{10} - \frac{1}{50} = \frac{2}{25}$$

The object is placed at 25 cm infront of this combination. Thus, for this combination, we have $u = -25\ cm, v = ?$

By the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{v} - \frac{1}{-25} = \frac{2}{25}$$

$$\frac{1}{v} = \frac{2}{25} - \frac{1}{25} = \frac{1}{25}$$

$$v = 25$$

The image is formed at a distance of **25 cm** behind the combination.

EXAMPLE

A small object is placed at a distance of 15 cm from two coaxial thin lenses in contact. The focal length of each lens is 25 cm. what will be the distance between the object and its image when both the lenses are convex?

SOLUTION:

If f is the focal length of the combination, then

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Here $f_1 = f_2 = 25\ cm\ (both\ the\ lenses\ are\ convex)$

$$\frac{1}{f} = \frac{1}{25} + \frac{1}{25} = \frac{2}{25}$$

$$f = 12.5\ cm$$

If the image is at a distance v from the combination of lenses, then

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Here u = -15 cm, f = 12.5 cm

$$\frac{1}{v} - \frac{1}{-15} = \frac{1}{12.5} = \frac{2}{25}$$

$$\frac{1}{v} = \frac{2}{25} - \frac{1}{15} = \frac{1}{75}$$

$$v = +75\ cm$$

The object is at a distance of 15 cm on one side and the image is at a distance of 75 cm on the other side of the lens. Hence the distance between the object and the image is **15 + 75 = 90 cm**

SUMMARY

In this module we have learnt

- Indirect methods of determination of focal a length of a convex mirror using convex lens
- Indirect methods of determination of focal a length of a concave lens using convex lens
- Indirect methods of determination of refractive index of water using a convex lens and a plane mirror and forming a combination of lenses and using the lens maker's formula of a convex mirror using convex lens
- Application of concepts learnt in the unit of ray optics in the laboratory experiments