06. REFRACTION OF LIGHT AT CURVED SURFACES

Questions and Answers

1. A man wants to get a picture of a zebra. He photographed a white donkey after fitting a glass, with black stripes on to the lens of his camera. What photo will he get? Explain.

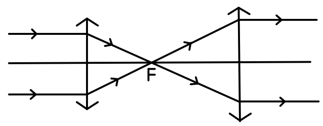
A. The photographer will not get the zebra photo. He can get the photo of white donkey behind black stripes with less intensity. The black stripes blocks the light rays from the object, so the intensity of image reduced.

2. Two converging lenses are to be placed in the path of parallel rays so that the rays remain parallel after passing through both lenses. How should the lenses be arranged? Explain with a neat ray diagram.

A. (i) The incident ray which is parallel to the axis of convex lens, passes through the focus after refraction.

(ii) The incident ray which passes through the focus of convex lens, gets refraction and move parallel to the axis.

(iii) Let two lenses are arranged on a common axis such that their focuses coincides with each other. Then the rays incident parallel to the first lens get refraction and converges at focus. The rays from focus incident on the second lens get refraction and move parallel to the axis.



3. The focal length of a converging lens is 20cm. An object is 60cm from the lens. Where will the image be formed and what kind of image is it?

A. Converging lens means convex lens.

For convex lens 'u' taken as negative.

Focal length (f) = 20cm

Object distance (u) = -60cm

Image distance (v) = ?

Lens formula : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

➔ $\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} + \frac{1}{-60} = \frac{1}{20} - \frac{1}{60} = \frac{60-20}{20 X 60} = \frac{40}{1200}$

➔ $\frac{1}{v} = \frac{1}{30}$ ➔ v = 30cm

Here Object is placed beyond C. So image is formed between F and C. It is real, inverted and diminished.

4. A double convex lens has two surfaces of equal radii 'R' and refractive index n = 1.5. Find the focal length 'f'.

A. Let radius of curvatures of double convex lens are R_1 and R_2.

Given $R_1 = R_2 = R$

Refractive index (n) = 1.5

Focal length of the lens (f) = ?

Lens maker's formula : $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

for double convex lens

R_1 is positive and R_2 is negative.

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

$\frac{1}{f} = (1.5 - 1)\left(\frac{1}{R} + \frac{1}{R}\right) = 0.5 \text{ x } \frac{2}{R} = \frac{1}{R}$

f = R

focal length is equal to the radius of curvature.

5. Write the lens maker's formula and explain the terms in it.

A. Lens maker's formula : $\frac{1}{f} = (n_{ba}-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

f = Focal length of the lens

$n_{ba} = \frac{n_b}{n_a}$ = Relative refractive index of lens with respect to surrounding medium

n_b = Refractive index of lens material

n_a = Refractive index of surrounding medium

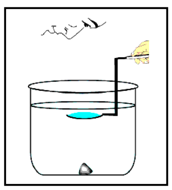
R_1 = Radius of curvature of first surface

R_2 = Radius of curvature of second surface

If surrounding medium is air then $n_a = 1$, Then $n_b=n$ is the absolute refractive index of the lens.

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

6. How do you verify experimentally that the focal length of a convex lens is increased when it is kept in water?



A. Take a lens whose focal length is known. Take a cylindrical vessel whose height must be much greater than (4 times) the focal length of the lens.

Keep a black stone inside the vessel at its bottom. Now pour water into the vessel up to a height (equal to 'f'). Now dip the lens horizontally using a circular lens holder. Set the distance between stone and lens that is equal to or less than focal length of lens. Now look at the stone through the lens. We can't see the image of stone.

Now increase the distance between lens and stone until you can see the image of the stone. This shows that the focal length of lens has increased in water. Thus we conclude that the focal length of lens depends upon the surrounding medium in which it is kept.

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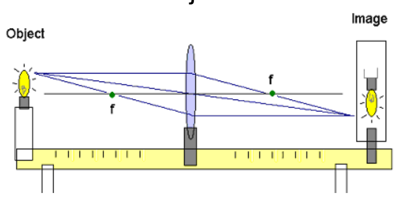
7. How do you find the focal length of a lens experimentally?

A. Take a V-stand and place it on a long table at the middle. Place a convex lens on the V-stand. Light a candle and arrange it on a candle stand such that the flame lies along the principal axis of the lens. Adjust the screen at other side of the lens until we get the clear image of the flame on it.

Measure the distance between the optical centre of lens (centre of V-stand) and candle flame and denote it as ‘u’. Measure the distance between the centre of the lens and image and denote it as ‘v’. Calculate the focal length of the given convex lens by using the formula f = $\frac{uv}{u+v}$

Check the result by repeating experiment for some different object distances.



8. Harsha tells Siddhu that the double convex lens behaves like a convergent lens. But Siddhu knows that Harsha’s assertion is wrong and corrected Harsha by asking some questions. What are the questions asked by Siddhu?

A. Siddhu may asked the following questions:

(i) What happened when a light ray passes through a convex lens?

(ii) Are the light rays converges when they incident on the convex surface of a plano convex lens?

(iii) Are the light rays diverges when they incident on the concave surface of a plano concave lens?

(iv) What happened when light rays incident parallel on the convex surface on a plano convex lens?

(v) How many curved surfaces does a double convex lens has?

(vi) Let some light rays incident on the double convex lens. What happened at first convex surface and at concave surface?

(vii) Is a double convex lens acts as a convergent lens?

9. Assertion (A): A person standing on the land appears taller than his actual height to a fish inside a pond.

Reason (R): Light bends away from the normal as it enters air from water.

Which of the following is correct? Explain.

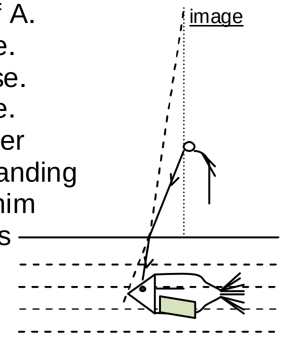
a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true and R is not the correct explanation of A.

c) A is true but R is false.

d) Both A and R are false.

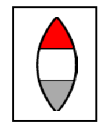
e) A is false but R is true.



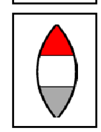
A. Let a fish inside the water in a pool. A person is standing at the edge. If fish saw him through water, he seems to be taller than his actual height. Because the light ray travels from rarer medium (air) to denser medium (water) gets refraction and bends towards the normal. And it seems to be coming from distant point for the fish.

Hence Choice “ ” is the correct answer.

10. A convex lens is made up of three different materials as shown in the figure. How many of images does it form?



A. If a convex lens is made up of three different materials as shown in figure. As the three materials have different refractive indices with different focal lengths, they form three images.



11. Can a virtual image be photographed by a camera?

A. Yes. A virtual image can be photographed by a camera.

For example: Plane mirror forms virtual images. We can take the photos of images formed by plane mirror.

12. You have a lens. Suggest an experiment to find out the focal length of the lens.

A. Same answer of 7th Question

13. Let us assume a system that consists of two lenses with focal length f_1 and f_2 respectively. How do you find the focal length of the system when

i) two lenses are touching each other

ii) they are separated by a distance ‘d’ with common principal axis.

A. **Case(i)** Let two lenses having focal lengths f_1 and f_2 respectively are touching each other. The focal length of the system is ‘f’. Then

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

Case(ii) Let two lenses having focal lengths f_1 and f_2 respectively are separated by a distance ‘d’ on a common principal axis. The focal length of the system is ‘f’. Then

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

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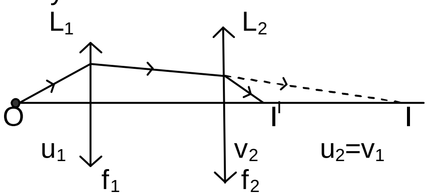
13. Let us assume a system that consists of two lenses touching each other with focal length f_1 and f_2 respectively. Derive a formula for finding the focal length of the system.

A. Let two convex lenses L_1 and L_2 are in contact such that their separation is very small. The focal lengths of the two lenses are f_1 and f_2 respectively.



Let an object 'O' is placed at a distance u_1 from the lens L_1. Assume that the image 'I' can be collected at a distance v_1.

Convex lens formula : $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

$$\frac{1}{f_1} = \frac{1}{v_1} + \frac{1}{u_1} \quad \text{..........(1)}$$

The image 'I' serves as a virtual object for the second lens L_2. Assume that the distance between L_2 and the virtual object is $u_2 = -v_1$ (as the gap between lenses is negligible).

L_2 forms the image I^{I} at a distance v_2.

Then $\frac{1}{f_2} = \frac{1}{v_2} + \frac{1}{u_2}$

$$\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{v_1} \quad \text{..........(2)}$$

Add (1) and (2) : Then $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{u_1} + \frac{1}{v_2}$ .....(3)

Now if we replace the two lenses with one lens having focal length 'f' such that it forms the image at v_2 of the object placed at u_1.

So $\frac{1}{f} = \frac{1}{v_2} + \frac{1}{u_1}$.......... (4)

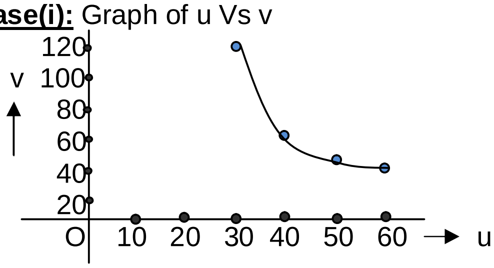
(3) = (4) ➔ $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

16. Use the data obtained by activity (finding u, v, f of a convex lens) in table of the lesson and draw the graphs of u Vs v and $\frac{1}{u}$ Vs $\frac{1}{v}$

A. Observations from the activity with convex lens:

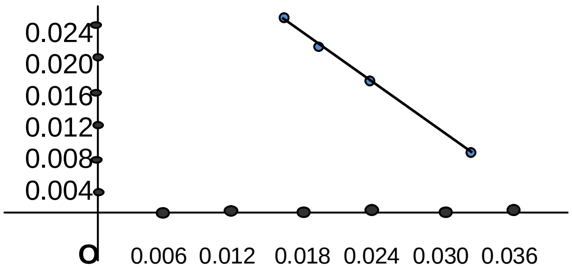
Object distance (u)	Image distance (v)	Focal length (f)
30	120	24
40	60	24
50	46	24
60	40	24

Case(i): Graph of u Vs v

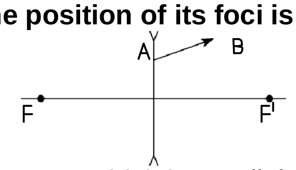


Case(ii): Graph of $\frac{1}{u}$ Vs $\frac{1}{v}$

(u)	(v)	$\frac{1}{u}$	$\frac{1}{v}$
30	120	0.033	0.008
40	60	0.025	0.017
50	46	0.020	0.022
60	40	0.017	0.025

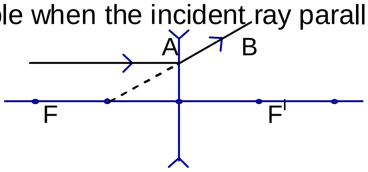


17. Given figure shows ray AB that has passed through a divergent lens. Construct the path of the ray up to the lens if the position of its foci is known.

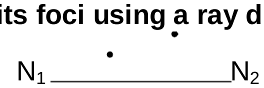


A. The incident ray which is parallel to the axis of a concave lens, seems to be diverges from the focus after refraction.

In the given figure, if ray AB extended backward, it seems to be diverging from 'F'. So It is possible when the incident ray parallel to the axis.

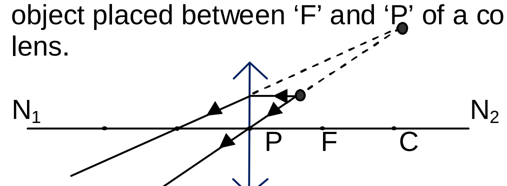


18. Given figure shows a point light source and its image produced by a lens with an optical axis N_1N_2. Find the position of the lens and its foci using a ray diagram.

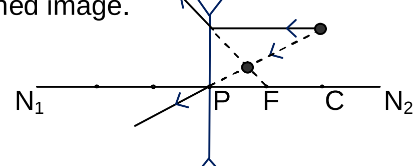


A. In the given figure, one dot represents the object and the other represents image.

Case(i) Erect, enlarged image is formed when object placed between 'F' and 'P' of a convex lens.



Case(ii) Concave lens always forms erect, diminished image.



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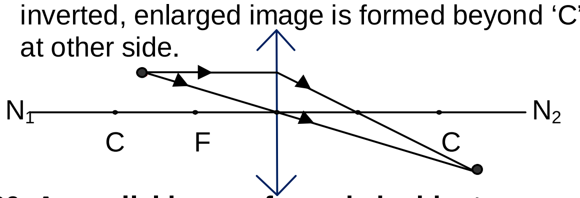
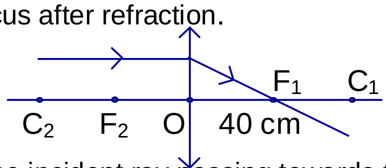
19. Find the focus by drawing a ray diagram using the position of source S and the image S[I] given in the figure.

A. In the given figure, the dots represents that the image is inverted and enlarged. It is possible only when an object is placed between 'F' and 'C' of a convex lens then the inverted, enlarged image is formed beyond 'C' at other side.

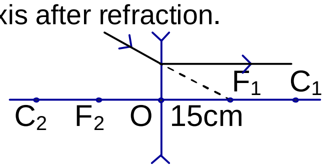


20. A parallel beam of rays is incident on a convergent lens with a focal length of 40cm. Where should a divergent lens with a focal length of 15 cm be placed for the beam of rays to remain parallel after passing through the two lenses? Draw a ray diagram.

A. (i) The incident ray which is parallel to the axis of convex lens, passes through the focus after refraction.

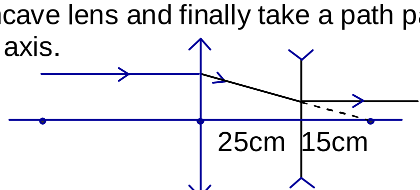


(ii) The incident ray passing towards the focus of a concave lens will take a path parallel to the axis after refraction.



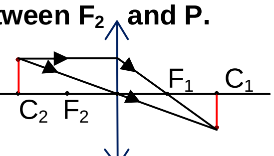
Now : Focal length of convex lens = 40cm
Focal length of concave lens = 15cm

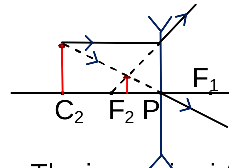
Let we arrange the convex and concave lenses on a common axis such that the distance between the two lenses is 25cm. The parallel incident rays on convex lens converges to its focus after refraction. The refracted rays passes towards the focus of concave lens and finally take a path parallel to the axis.



21. Draw ray diagrams for the following positions and explain the nature and position of image. i) Object is placed at C_2 ii) Object is placed between F_2 and P.

A. **<u>Case(i):</u>** When object is placed at C_2 of a convex lens, the image formed at C_1. The image is real, inverted and same size as object.

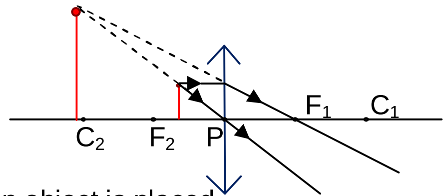




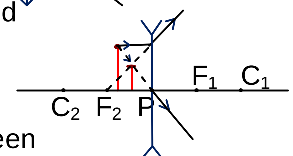
When object is placed at C_2 of a concave lens, the image is formed at the object side between Focus and optic centre.

The image is virtual, erect and diminished.

<u>Case(ii):</u> When object is placed between F_2 of P of a convex lens, the image is formed at the object side. The image is virtual, erect and enlarged.



When object is placed between F_2 of P of a concave lens, the image is formed at the object side between focus and optic centre. The image is virtual, erect and diminished.



22. How do you appreciate the coincidence of the experimental facts with the results obtained by a ray diagram in terms of behaviour of images formed by lenses?

A. The results obtained by the experiments are same as the ray diagrams. It is very nice. Because

(i) we can estimate the formation of images by microscope and telescopes by using ray diagrams.

(ii) We are able to declare the properties of images by ray diagrams without doing experiment.

(iii) If we know the focal length of a lens, we can tell where the image is formed and the properties of image for an object placed at different distances.

23. Find the refractive index of the glass which is a symmetrical convergent lens if its focal length is equal to the radius of curvature of its surface.

A. For symmetrical convergent lens $R_1 = R_2 = R$

Focal length of lens (f) = R

Lens maker's formula : $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

for double convex lens

R_1 is positive and R_2 is negative.

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

$\Rightarrow \frac{1}{R} = (n-1)\left(\frac{1}{R} + \frac{1}{R}\right)$

$\Rightarrow \frac{1}{R} = (n-1)\left(\frac{2}{R}\right)$

$\Rightarrow 1 = 2n - 2 \Rightarrow 2n = 3 \Rightarrow n = \frac{3}{2} = 1.5$

Refractive index of lens (n) = 1.5

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24. Find the radii of curvature of a convexo – concave convergent lens made of glass with refractive index n=1.5 having focal length of 24cm. One of the radii of curvature is double the other.

A. Let the centre of curvatures of convexo-concave lens are R_1 and R_2

Given that $R_2 = 2R_1$

Focal length of lens (f) = 24cm

Refractive index of the lens (n) = 1.5

Lens maker's formula : $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

for convexo-concave lens

R_1 is positive and R_2 is positive.

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

➔ $\frac{1}{24} = (1.5-1)\left(\frac{1}{R_1} - \frac{1}{2R_1}\right)$

➔ $\frac{1}{24} = (0.5)\left(\frac{2-1}{2R_1}\right)$

➔ $2R_1 = 12$ ➔ $R_1 = 6cm$

$R_2 = 2R_1 = 12cm$

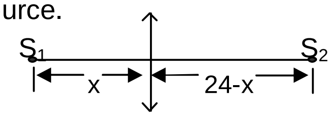
Radii of curvatures of lens are R_1=6cm,R_2=12cm

25. The distance between two point sources of light is 24cm .Where should a convergent lens with a focal length of f=9cm be placed between them to obtain the images of both sources at the same point?

A. Distance between two sources (d) = 24cm

Focal length (f) = 9cm

Let the lens be placed at a distance 'x' cm from the first source.



Lens formula : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

For getting both images at same place there are two possibilities only. Either virtual image of S_1 or S_2 can be formed.

Let the image of two sources can be collected at 'v' distance from lens at S_2 side.

<u>For the first source :</u>

Object distance (u) = -x

Image distance (v) = v

Focal length (f) = 9cm

Now : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ ➔ $\frac{1}{9} = \frac{1}{v} + \frac{1}{X}$ …………(1)

<u>For the first source :</u>

Object distance (u) = -(24-x)

Image distance (v) = -v

Focal length (f) = 9cm

Now : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ ➔ $\frac{1}{9} = -\frac{1}{v} + \frac{1}{24-X}$ …..(2)

Add (1) + (2), we get $\frac{2}{9} = \frac{1}{X} + \frac{1}{24-X}$

➔ $\frac{2}{9} = \frac{24}{X(24-X)}$

➔ $\frac{1}{9} = \frac{12}{24X-X^2}$

➔ $24x - x^2 = 108$

➔ $x^2 - 24x - 108 = 0$

➔ $x^2 - 18x - 6x - 108 = 0$

➔ $x(x-18) - 6(x-18) = 0$

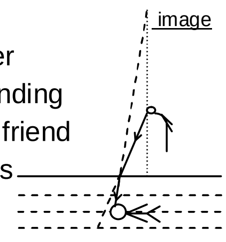
➔ $(x-18)(x-6) = 0$

➔ $x-18 = 0$ or $x-6 = 0$

➔ x = 18cm or 6cm.

So the lens should be placed either at 18 cm or at 6cm from the first source.

26. Suppose you are inside the water in a swimming pool near an edge. A friend is standing on the edge. Do you find your friend taller or shorter than his usual height? Why?



A. Let I am inside the water in a pool. A friend is standing at the edge. If I saw my friend through water, he seems to be taller than his actual height. Because the light ray travels from rarer medium (air) to denser medium (water) gets refraction and bends towards the normal. And it seems to be coming from distant point for the swimmer.

<u>* ADDITIONAL QUESTIONS *</u>

27. Derive lens formula.

28. Name different types of lenses. Draw the diagrams of the lenses.

29. What is the focal length of the double concave lens kept in air with two spherical surfaces of radii R_1 = 30cm and R_2 = 60cm. Take the refractive index of lens as n = 1.5.

30. How does an air bubble behaves inside water?

31. A fish is rising up vertically inside a pond with a velocity 4 cm/s and notices a bird, which is diving downward and its velocity appears to be 16cm/s. What is the real velocity of diving bird if refractive of water is 4/3.

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