Experiment - 13 : Focal length of (i) Concave Mirror (ii) Convex mirror (iii) Convex lens, using the parallax method.

To find the value of v for different values of u in case of a concave mirror and to find its focal length by plotting graphs between u and v.

To perform the experiment, we require an optical bench with three uprights (zero end upright fixed, two outer uprights with lateral movement), concave mirror, a mirror holder, two optical needles (one thin, one thick), a knitting needle and a half metre scale.

Theory

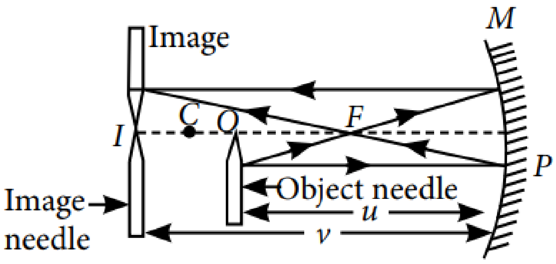
From mirror formula, $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

We have, $f = \frac{uv}{u+v}$

where, f = focal length of concave mirror

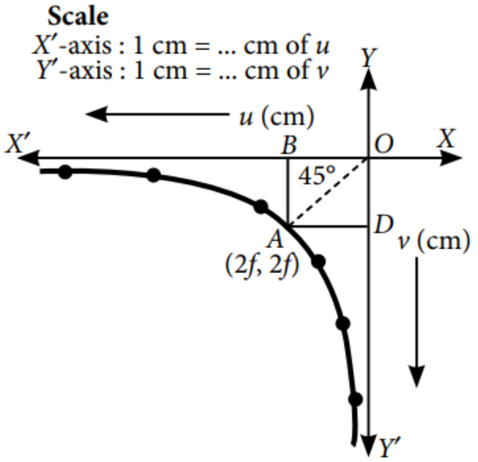
u = distance of object needle from pole of the mirror

v = distance of image needle from pole of the mirror.



Calculations of Focal Length Using Graph

u-v Graph : Select a suitable but the same scale to represent u along X′-axis and v along Y′-axis. According to sign conventions, in this case u and v both are negative. Plot the various points for different sets of values of u and v from the observation table. The graph comes out to be a rectangular hyperbola as shown in figure.



Graph between u and v

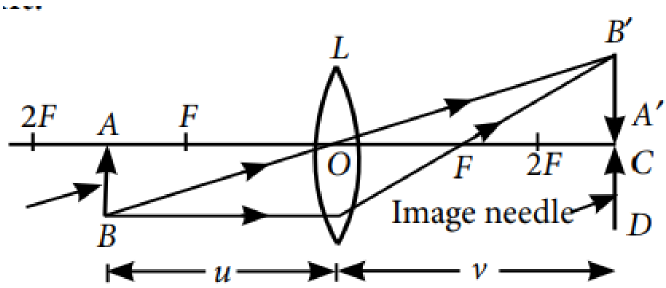
Draw a line OA making an angle of 45° with either axis (i.e., bisecting ∠Y′OX′) and meeting the curve at point A. Draw AB and AD perpendicular on X′ and Y′-axis respectively. The values of u and v will be same for point A. So, the coordinates of point A must be (2f, 2f) because for a concave mirror u and v are equal only when the object is placed at the centre of curvature.

Hence, u = v = R = 2f

(iii) To find the focal length of a convex lens by plotting graphs between u and v, or between $\frac{1}{u}$ and $\frac{1}{v}$.

To perform the experiment, we require an optical bench with three uprights (central upright fixed, two outer uprights with lateral movement), a convex lens with lens holder, two optical needles, (one thin, one thick) a knitting needle and a half metre scale.

The following ray diagram explains the essence of this experiment.



Theory

The relation between u, v and f for a convex lens is

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

where, f = focal length of convex lens

u = distance of object needle from optical centre of the lens

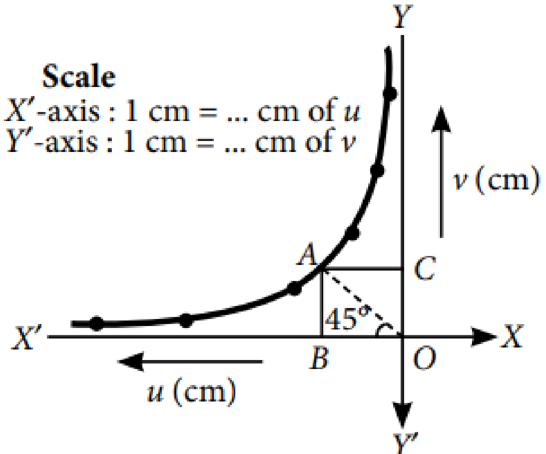
v = distance of image needle from optical centre of the lens.

Note: According to sign-convention, u has negative value and v has positive value. Hence, f is positive.

Plot a graph between u and v.

Calculation of Focal Length by Using Graphs

u-v Graph : Select a suitable but the same scale to represent u along X′-axis and v along Y-axis. According to sign conventions, in this case, u is negative and v is positive. Plot the various points for different sets of values of u and v from observation table. The graph comes out to be a rectangular hyperbola as shown in figure next.



Graph between *u* and *v*

Draw a line OA making an angle of 45° with either axis (i.e., bisecting ∠YOX′) and meeting the curve at point A. Draw AB and AC perpendicular on X′-and Y-axes, respectively.

The values of u and v will be same for point A. So, the coordinates of point A must be (2f, 2f), because for a convex lens, when u = 2f, v = 2f.

Hence, AB = AC = 2f or OC = OB = 2f

$\therefore f = \dfrac{OB}{2}$ and also $f = \dfrac{OC}{2}$ $\therefore$ Mean value of $f =$ ____cm

MCQs Corner

Experiment – 13

55. To find the focal length of a convex mirror, a student records the following data.

Object Pin	Convex Lens	Convex Mirror	Image Pin
22.2 cm	32.2 cm	45.8 cm	71.2 cm

The focal length of the convex lens is f_1 and that of mirror is f_2. Then taking index correction to be negligibly small, f_1 and f_2 are close to

(a) $f_1 = 7.8$ cm $\quad f_2 = 12.7$ cm

(b) $f_1 = 12.7$ cm $\quad f_2 = 7.8$ cm

(c) $f_1 = 15.6$ cm $\quad f_2 = 25.4$ cm

(d) $f_1 = 7.8$ cm $\quad f_2 = 25.4$ cm

56. In an optics experiment, with the position of the object fixed, a student varies the position of a convex lens and for each position, the screen is adjusted to get a clear image of the object. A graph between the object distance u and the image distance v, from the lens, is plotted using the same scale for the two axes. A straight line passing through the origin and making an angle of 45° with the x-axis meets the experimental curve at P. The coordinates of P will be

(a) (2f, 2f) (b) (f/2, f/2) (c) (f, f) (d) (4f, 4f)

57. A concave lens of focal length f forms an image which is n times the size of the object. The distance of the object from the lens is

(a) $(1 - n)f$ (b) $(1 + n)f$

(c) $\left(\frac{1+n}{n}\right)f$ (d) $\left(\frac{1-n}{n}\right)f$

58. A convex lens of focal length f is placed somewhere in between an object and a screen. The distance between the object and the screen is x. If the numerical value of the magnification produced by the lens is m, the focal length of the lens is

(a) $\frac{mx}{(m+1)^2}$ (b) $\frac{mx}{(m-1)^2}$

(c) $\frac{(m+1)^2}{m}x$ (d) $\frac{(m-1)^2}{m}x$

59. A convex lens of focal length f produces a real image x time the size of an object, then the distance of the object from the lens is

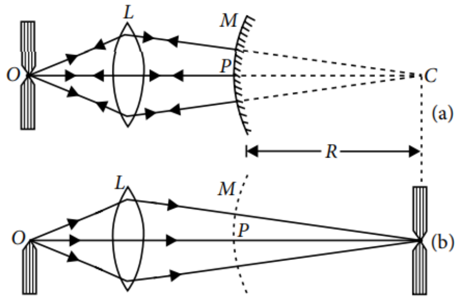
(a) $(x - 1)f$ (b) $(x + 1)f$ (c) $\{(x + 1)/x\}f$ (d) $\{(x - 1)/x\}f$

Answer Key

55. (a) 56. (a) 57. (d) 58. (a) 59. (c)

Hints & Explanation

55. (a) : The given figures shows the experimental set up to find the focal length of convex mirror using convex lens.



$\therefore$ For lens, $u_1 = -(32.2 - 22.2)$ cm $= -10$ cm
$v_1 = (71.2 - 32.2)$ cm $= 39$ cm

$$\therefore \quad \frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{39} + \frac{1}{10} = \frac{49}{390}$$

$$\text{or} \quad f_1 = \frac{390}{49}\text{ cm} \approx 7.8\text{ cm}$$

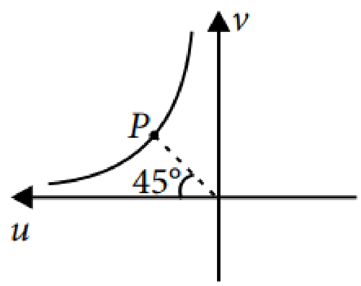
$\therefore$ For mirror, $R = (71.2 - 45.8)$ cm $= 25.4$ cm

$$\text{or} \quad f_2 = \frac{25.4}{2}\text{ cm} = 12.7\text{ cm}$$

56. (a) : According to New Cartesian coordinate system used in our 12th classes, for a convex lens, as u is negative, the lens equation is

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

One has to take that u is negative again for calculation, it effectively comes to



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

If u = radius of curvature, $2f$, $v = 2f$ *i.e.*, $\frac{1}{2f} + \frac{1}{2f} = \frac{1}{f}$.

v and u are have the same value when the object is at the centre of curvature. The solution is (a).

According the real and virtual system, u is + ve and v is also +ve as both are real. If u = v, u = 2f = radius of curvature.

$$\therefore \frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{2f}+\frac{1}{2f}=\frac{1}{f}$$

The answer is the same (a). (The figure given is according to New Cartesian system).

57. (d) : For concave lens

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \text{ or } \frac{u}{v}-1 = \frac{u}{f} \text{ or } \left(\frac{1}{n}-1\right)=\frac{u}{f}$$

$$\therefore \quad u = \left(\frac{1-n}{n}\right)f\ .$$

58. (a) : $x = -u + v$ ...(i)

$$m=\frac{f}{(f+u)}=\frac{(f-v)}{f}$$

For real image, m is negative

$$\therefore -m = \frac{f}{(f+u)} \text{ or } -mf - mu = f$$

$$\text{or } u = \frac{-(m+1)}{m}f \text{ and } -m = \frac{(f-v)}{f} \text{ or } -mf = f - v$$

$$\text{or } v = (m+1)f \;\therefore\; x = (m+1)f + \frac{(m+1)}{m}f \text{ or } f = \frac{mx}{(m+1)^2}$$

59. (c) : $x = (v/u)$ and $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$$\therefore \quad v = f\left(1-\frac{v}{u}\right) = f(1-x)$$

since the image is real, hence it is inverted and so x is negative.

$\therefore$ u = f {1 + x}/x