Objective:

To find the focal length of a convex lens by plotting graphs between u and v and between 1/u and 1/v.

Apparatus:

An optical bench with three uprights (central fixed, two outer uprights with lateral movement), a convex lens with lens holder, two optical needles and a half meter scale.

Precautions:

1. Tips of the object and image needles should lie at the same height as the centre of the lens.
2. Parallax should be removed from tip to tip by keeping eye at a distance at least 30 cm away from the needle.
3. The object needle should be placed at such a distance that only real, inverted image of it is formed.
4. Index correction for u and v should be applied.

Ray diagram:

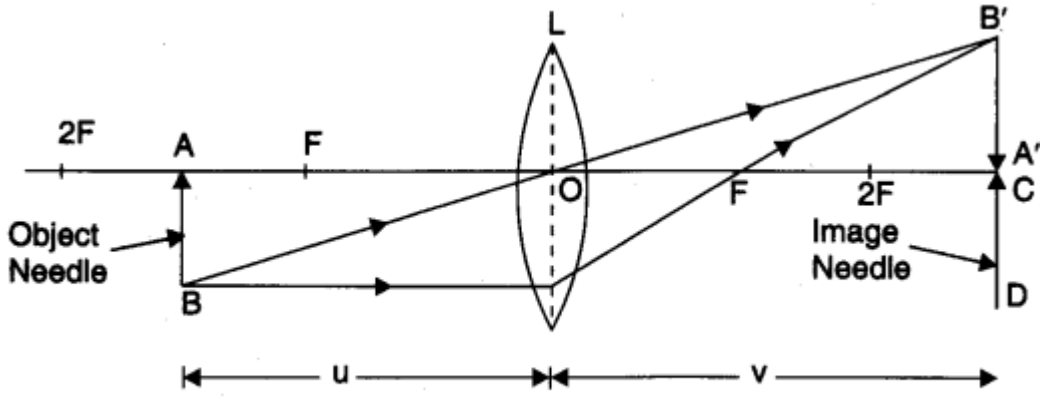

Fig. Focal length of convex lens.

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 lens.

v = distance of image needle from lens.

Note: According to sign-convention, u has negative value and v has positive value for convex les. Hence, f comes positive.

Procedure:

1. Mount object needle, lens and image needle uprights on the optical bench.
2. Tip of the object needle, image needle and optical centre of lens must be in straight line parallel to optical bench.
3. Place the object needle on left side of lens so as to get its inverted image of it.
4. Now place image needle on right side of lens and remove the parallax between image of object and image needle.
5. Note down the position of object needle, lens and image needle in table.
6. For more reading move object needle slightly and again remove parallax between image of object needle and image needle keeping lens position fixed and note down the positions of object needle, image needle and lens.
7. In this way take at least five readings.

Table for u, v; $\frac{1}{u}$ and $\frac{1}{v}$

Serial No. of Obs. (1)	*Position of*			*Observed distance*		*Corrected distance*		$\frac{1}{u}$	$\frac{1}{v}$
	Object needle A (cm) (2a)	*Lens O (cm) (2b)*	*Image needle C (cm) (2c)*	*OA = u (cm) (3a)*	*OC = v (cm) (3b)*	*u (cm) (4a)*	*v (cm) (4b)*	*(cm^{-1}) (5)*	*(cm^{-1}) (6)*
1.									
2.									
3.									
4.									
5.									
6.									

Calculations:

Calculations of focal length by graphical methods.

1) **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:

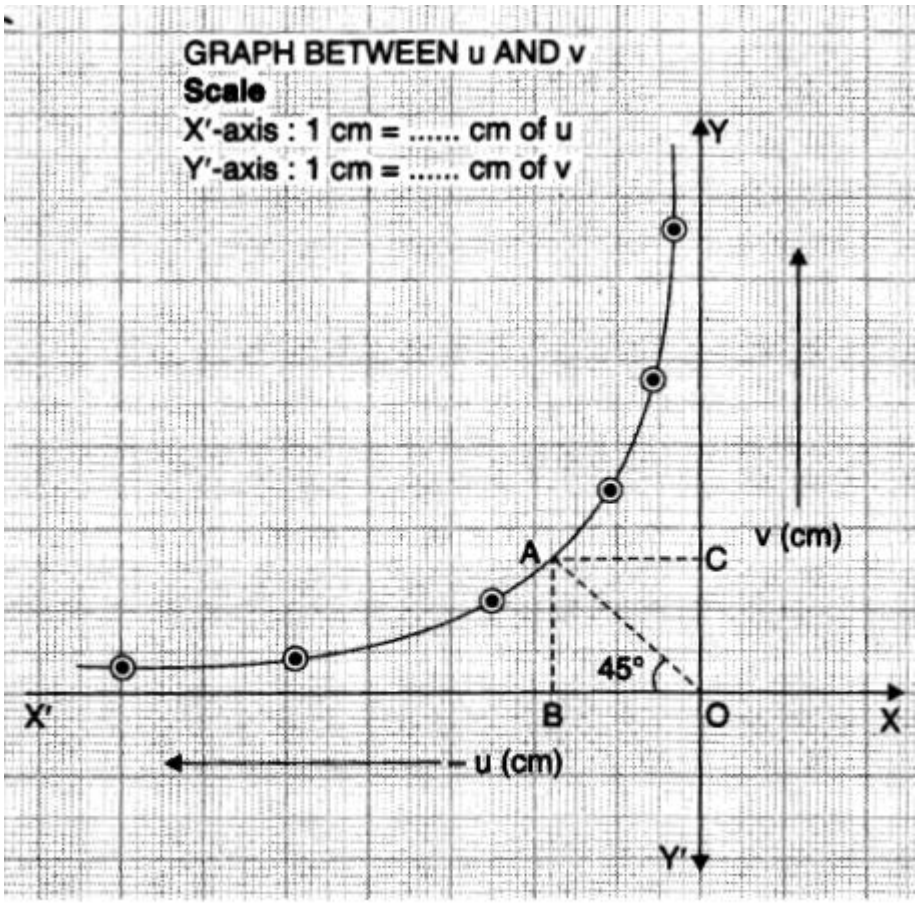

Fig. Graph between u and v. It is a rectangular hyperbola.

Draw a line OA making an angle 45^0 with either axis (i.e., bisecting $\angle YOX'$) and meeting the curve a point A. Draw AB and AC 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 convex lens, when u =-2f, v=2f.

Hence, $|OB| = |OC| = 2f$ or $OC=2f, OB=-2f$

$$\therefore \quad f = \frac{OB}{2} \quad \text{and also} \quad f = \frac{OC}{2}$$

$\therefore$ Mean value of f = …… cm

From Lens formula applied at point A

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

As u =- v, $\frac{1}{f} = \frac{2}{u}$ or $\frac{2}{v}$ and $f = \frac{u}{2}$ or $\frac{v}{2}$

Hence , half the value of either coordinate of A (i.e., distance OB) gives the focal length of the convex lens.

$$f = \frac{OB}{2} = ...cm$$

∴ Mean value of f = - …… cm

2) $\frac{1}{u}$ **and** $\frac{1}{v}$ **Graph** Select a suitable but the same scale to represent $\frac{1}{u}$ along X'-axis and $\frac{1}{v}$ along Y-axis. By sign conventions $\frac{1}{u}$ is negative and $\frac{1}{v}$ is positive. Plot the various points for different sets of values of $\frac{1}{u}$ and $\frac{1}{v}$ from the observation table. The graph comes out to be a straight line as shown in Figure

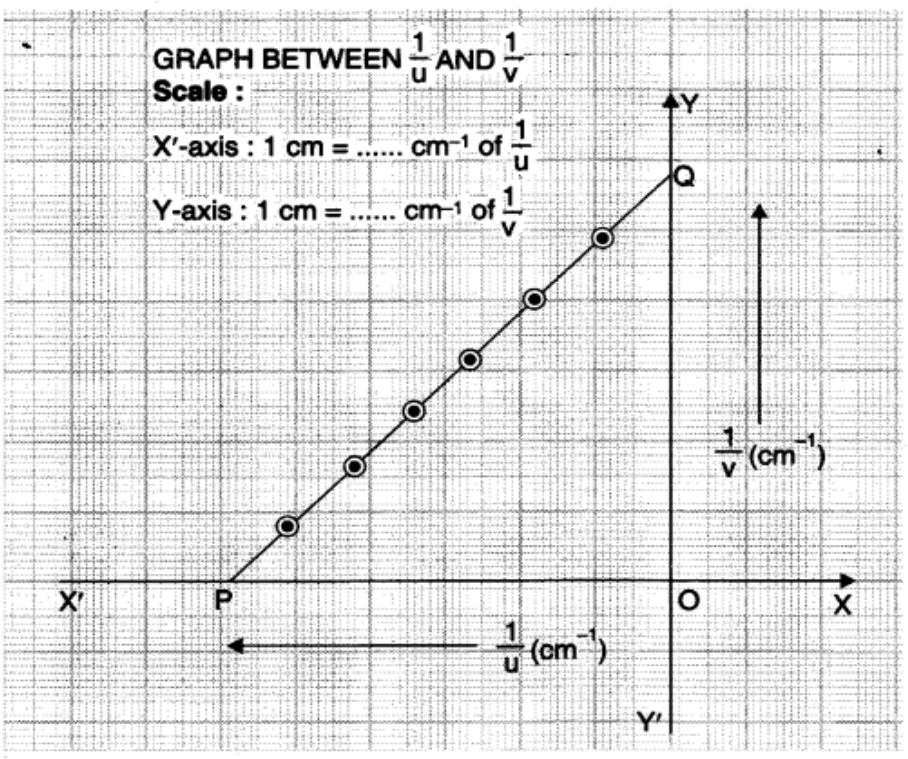

Fig. Graph between $\frac{1}{u}$ and $\frac{1}{v}$. It is a straight line.

3) The straight line cuts the two axes OX' and OY at an angle of 45^0 at points P and Q respectively and making equal intercepts on the aces. Measure the distance OP and OQ.

Then focal length, $f = \frac{1}{OP} = \frac{1}{OQ}$

= ……cm

From the mirror formula,

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

(a) If $\frac{1}{u} = 0, then$ $\frac{1}{v} = \frac{1}{f}$

Thus, intercept $OQ = \frac{1}{v} = \frac{1}{f}$

(b) If $\frac{1}{v} = 0, then$ $\frac{1}{u} = \frac{1}{f}$

Thus, intercept $OP = \frac{1}{u} = \frac{1}{f}$

Result:

The focal length of the given convex lens as determined from:

(u-v) graph = ……cm

$\frac{1}{u} - \frac{1}{v}$ graph = ……cm

Calculations = ……..cm

Sources of error:

1. The uprights may not be the vertical.
2. Parallax removal may not be perfect.