

Aim

Determination of the focal length of a convex lens • u-v method

THE EXPERIMENT

To determine the focal length of a thin convex lens by measuring the object and image distances for several sharp real images.

A sharp image is the starting point. I will take several pairs of readings, calculate the focal length for each pair, and then find their mean.

Student details	Fill before starting
Name	_____
Course / semester	B.Sc. Physics / _____
Roll number / batch	_____
Experiment number	_____
Date of experiment	_____
Teacher's signature	_____

What I will measure

U: distance from the object to the optical centre of the lens.

V: distance from the optical centre to the sharp image on the screen.

f: focal length of the lens. All distances are recorded in centimetres.

RECORD INTEGRITY

This is a practice template. The blank observation table is for actual readings. The sample readings are examples only and must not be submitted as measurements.

Apparatus

Set up the optical bench before taking readings.

Apparatus	Use
Thin convex lens with holder	Forms a real image of the object.
Optical bench with scale	Keeps positions aligned and allows distance readings.
Illuminated arrow or cross-wire object	Provides a bright, well-defined object.
White screen with upright	Receives the real image.
Metre scale / bench scale	Measures object, lens and screen positions.
Spirit level, if available	Checks that the bench is level.

Before I begin

- Check that the lens is clean and the holders are steady.
- Bring the object centre, optical centre and screen centre to the same height.
- Record the least count of the bench scale and any known index correction.
- Use a bright object indoors. Never look at the Sun through the lens.

INSTRUMENT NOTES

Least count = _____ cm

Lens identification = _____

Index correction, if applicable = _____ cm

Setup notes

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Theory

A real image forms when the object is beyond the principal focus.

A convex lens bends parallel light rays towards its principal focus. When the object is placed beyond F_1 , rays from its tip meet on the other side of the lens and form a real, inverted image.

LENS FORMULA

Cartesian convention: $1/f = 1/v - 1/u$

For this arrangement, $u < 0$ and $v > 0$.

Using positive distances $U = |u|$ and $V = v$:

$1/f = 1/U + 1/V$, so $f = UV / (U + V)$.

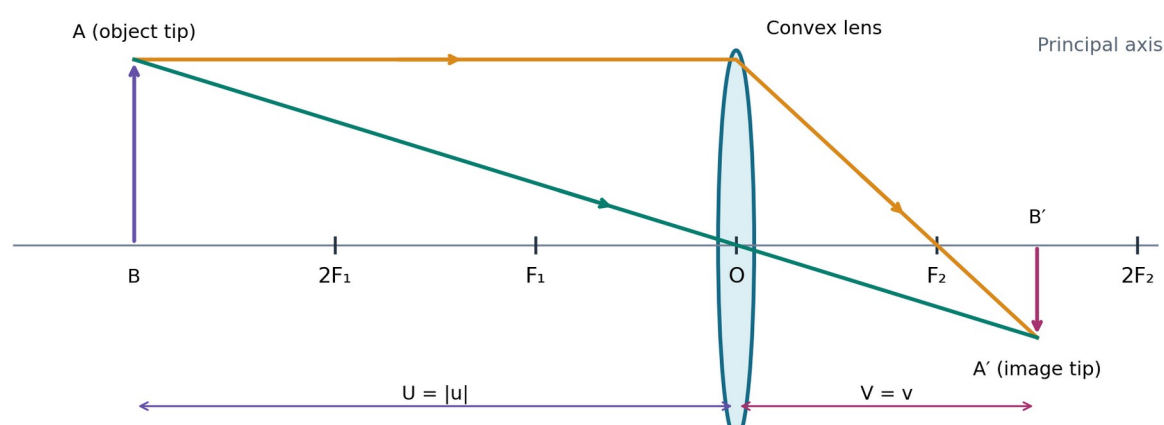


Figure 1. Object AB lies beyond $2F_1$. Its real, inverted image $A'B'$ lies between F_2 and $2F_2$. Diagram is schematic, not to scale.

Reading the rays

The gold ray starts parallel to the principal axis and refracts through F_2 . The green ray passes through the optical centre O without changing direction in the thin-lens approximation.

At $U = V = 2f$, the image and object have the same size. If U increases, V moves closer to f . This gives a useful check on the readings.

Procedure

Take at least six pairs of readings.

01. Mount the illuminated object, convex lens and screen on the bench. Keep their centres at the same height.
02. Estimate the focal length by forming a sharp image of a distant, non-solar object on the screen. Treat this only as a rough guide.
03. Place the object beyond the estimated focal length. Keep the lens fixed and move the screen until a sharp, inverted image appears.
04. Read the bench positions of the object (x_o), lens (x_l) and screen (x_s). Read the scale from directly above the mark.
05. Calculate $U = x_l - x_o$ and $V = x_s - x_l$. Apply any measured index corrections before using these distances.
06. Change the object position and focus again. Take at least six distinct readings, including positions on both sides of $2f$ where the bench allows.
07. For every pair, calculate $f = UV / (U + V)$. Find the arithmetic mean of the individual focal lengths.
08. Enter the mean, unit and measurement uncertainty required by the laboratory in the result section. Keep the actual readings separate from the sample data.

FOCUS CHECK

Move the screen a little to either side of the best position. The chosen position should give the clearest image, not merely the brightest patch.

Observation table

Actual readings first. Sample readings are kept separate below.

Least count: _____ cm Index correction(s): _____

A. Actual lab readings - leave blank until measured

Trial	x_o (cm)	x_l (cm)	x_s (cm)	U (cm)	V (cm)	f (cm)
1						
2						
3						
4						
5						
6						

U and V are the corrected positive distances. $f = UV / (U + V)$.

B. SAMPLE DATA - illustrative only

NOT MEASURED

These ideal example readings show how the calculation works. They do not establish the focal length of your lens. No experimental uncertainty can be inferred from them.

Trial	x_o (cm)	x_l (cm)	x_s (cm)	U (cm)	V (cm)	f (cm)
1	10.0	60.0	81.4	50.0	21.4	14.99
2	15.0	60.0	82.5	45.0	22.5	15.00
3	20.0	60.0	84.0	40.0	24.0	15.00
4	25.0	60.0	86.3	35.0	26.3	15.02
5	30.0	60.0	90.0	30.0	30.0	15.00
6	35.0	60.0	97.5	25.0	37.5	15.00

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Calculation

Worked example using SAMPLE DATA only.

Trial 3

Object position $x_o = 20.0$ cm

Lens position $x_l = 60.0$ cm

Screen position $x_s = 84.0$ cm

STEP 1 • DISTANCES

$$U = 60.0 - 20.0 = 40.0 \text{ cm}$$

$$V = 84.0 - 60.0 = 24.0 \text{ cm}$$

STEP 2 • FOCAL LENGTH

$$f = UV / (U + V)$$

$$= (40.0 \times 24.0) / (40.0 + 24.0)$$

$$= 960.0 / 64.0$$

$$= 15.0 \text{ cm}$$

Mean for the six sample trials

$$\text{Mean } f = (14.99 + 15.00 + 15.00 + 15.02 + 15.00 + 15.00) / 6$$

$$= 90.01 / 6$$

$$\approx 15.00 \text{ cm (sample mean, rounded).}$$

The extra decimal places in the table show the arithmetic, not the accuracy of a real experiment. Report actual precision from your scale and focusing uncertainty.

My calculation from actual readings

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Result

Write the measured result only after completing the blank table.

ACTUAL EXPERIMENT

The mean focal length of the given convex lens is:

$\bar{f} = \underline{\hspace{2cm}}$ cm

Uncertainty, if evaluated = $\pm \underline{\hspace{2cm}}$ cm

Sample result - not an experimental finding

For the illustrative data, the calculated mean focal length is approximately 15.00 cm. This value must not replace the result obtained with the student's own lens.

Does the result make sense?

- The focal length should be positive for this converging lens.
- Every real-image reading should have $U > f$ and $V > f$.
- At $U \approx V$, both distances should be close to $2f$.
- Individual f values should be reasonably close. A large outlier calls for a focus or scale-reading check.

UNCERTAINTY NOTE

Variation between repeated readings and the precision of the position measurements both matter. Follow the laboratory's required uncertainty method. Do not claim zero error because the sample values agree.

Teacher's remarks

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Precautions

Small changes in alignment or focus can affect the result.

01. Keep the object, optical centre and image centre on the same horizontal line.
02. Keep the lens vertical and the screen perpendicular to the principal axis.
03. Measure distances from the optical centre, not from the edge of the holder.
04. Avoid parallax when reading the bench scale.
05. Choose the sharpest image and repeat the focusing check before recording.
06. Keep the object beyond the focal length so that a real image forms on the screen.
07. Use corrected distances if the bench uprights have a measured index error.
08. Keep the lens fixed while reading one object-image pair.
09. Do not use direct sunlight or look at the Sun through the lens.

COMMON MISTAKE

Do not average U and V first and then use the lens formula. Calculate f for each trial, then average those focal lengths.

One difficulty I noticed

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Viva questions

Short answers for revision before the practical.

1. Why is a convex lens called converging?

It brings rays parallel to its principal axis to a real focus.

2. What is the lens formula?

$1/f = 1/v - 1/u$, using the Cartesian sign convention.

3. Why is u negative here?

The object lies to the left of the lens, opposite the direction of incident light.

4. Why do we use U and V in the table?

They are positive distance magnitudes, so $f = UV / (U + V)$.

5. Can a real image be formed on a screen?

Yes. The light rays actually meet at the image position.

6. What happens when the object is between the lens and F_1 ?

The image is virtual, upright and enlarged; it cannot be caught on a screen.

7. Where is the image when the object is at $2F_1$?

At $2F_2$, real, inverted and the same size as the object.

8. Why take several readings?

They help check consistency and reduce the effect of random reading errors.

9. What does a ray through the optical centre do?

It passes approximately undeviated through a thin lens.

10. What happens to V when U becomes very large?

V approaches f.

Reference: NCERT Physics Laboratory Manual, Experiment 10. The record uses a screen-based version of the u-v method; the NCERT manual also describes image-needle and graph methods.

ncert.nic.in/pdf/publication/sciencelaboratorymanuals/classXII/physics/lelm308.pdf