TITLE: THE THIN LENS FORMULA

AIM: To determine the focal length of a thin convex lens.

NOTE: In optical experiment, always arrange the optical centres of mirrors or lenses to be in line with the object used.

APPARATUS: light source, convex, lens holder, screen, metre rule, object.

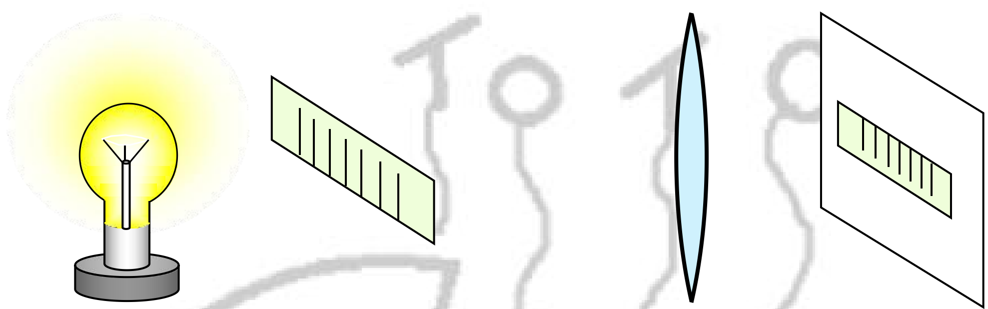

Figure 8.1

THEORY

The lens equation is

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \tag{8.1}$$

Given that an object placed a distance u from a lens forms an image at distance v away from the lens. The magnification is given by

$$m=\frac{v}{u} \tag{8.2}$$

PROCEDURE

1. The apparatus was set up as shown in figure 8.1 above
2. The lens was mounted in the lens holder and moved towards the screen until a sharp, diminished and inverted image was seen on the screen.
3. The distance of u and v was measured, and the procedure was repeated for at least two different distances between the object and the screen.
4. Then the lens holder was set up until a sharp, magnified, and inverted image on the screen was seen. Again the distance u and v was measured. The procedure was repeated for atleast two different distances between the object and the screen.

Table 8.1 Measurements for magnified image

Object distance u(cm)	Image distance v (cm)	$m = \frac{v}{u}$	$\frac{1}{u(cm^{-1})}$	$\frac{1}{v(cm^{-1})}$	F(cm)
36	14	0.39	0.028	0.071	10.1
37	13	0.35	0.027	0.077	9.62
38	12	0.32	0.026	0.083	9.12

Table 8.2 Measurements of magnified image

Object distance u(cm)	Image distance v (cm)	$m = \frac{v}{u}$	$\frac{1}{u(cm^{-1})}$	$\frac{1}{v(cm^{-1})}$	F(cm)
32	18	0.56	0.031	0.056	11.52
31	19	0.61	0.032	0.053	11.78
30	20	0.67	0.033	0.05	12

1.Diminished image

a.i. Focal length f_1

From equation 8.1 $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$$f_1 = \frac{uv}{u+v}$$

$$f_1 = \frac{36 \times 14}{36 + 14}$$

$$= \frac{504}{50}$$

$$= \mathbf{10.1cm}$$

ii. Magnification M_1

From equation 8.2 $m = \frac{v}{u}$

$$m = \frac{14}{36}$$

$$= \mathbf{0.39}$$

b.i. Focal length f_2

from equation 8.1 $f_2 = \frac{uv}{u+v}$

$$f_2 = \frac{37 \times 13}{37 + 13}$$

$$= \frac{481}{50}$$

=**9.62cm**

ii. Magnification M_2

From equation 8.2 $m_2 = \frac{v}{u}$

$$m_2 = \frac{13}{37}$$

$$= \mathbf{0.35cm}$$

c.i. Focal length f_3

From equation 8.1 $f_3 = \frac{uv}{u+v}$

$$f_3 = \frac{38 \times 12}{38 + 12}$$

$$= \frac{456}{50}$$

$$= \mathbf{9.12cm}$$

ii. Magnification M_3

From the equation 8.2 $m_3 = \frac{v}{u}$

$$m_3 = \frac{12}{38}$$

=0.32

2.Magnified

a. i. Focal length F_4

from equation 8.1 $f_4 = \frac{uv}{u+v}$

$$f_4 = \frac{32\times18}{32+18}$$

$$= \frac{576}{50}$$

$$= \mathbf{11.52cm}$$

ii. Magnification M_4

From equation 8.2 $m_4 = \frac{v}{u}$

$$= \frac{18}{32}$$

$$= \mathbf{0.56}$$

b.i. Focal length f_5

from equation 8.1 $f_5 = \frac{uv}{u+v}$

$$= \frac{31\times19}{31+19}$$

$$= \frac{589}{50}$$

$$= \mathbf{11.78cm}$$

ii. Magnification M_5

From equation 8.2 $m_5 = \frac{v}{u}$

$$= \frac{19}{31}$$

$$= \mathbf{0.61}$$

c. i. Focal length F_6

From equation 8.1 $f_6 = \frac{uv}{u+v}$

$$= \frac{30 \times 20}{30 + 20}$$

$$= \frac{600}{50}$$

$$= \mathbf{12cm}$$

ii. magnification M_6

from equation 8.2 $m_6 = \frac{v}{u}$

$$= \frac{20}{30}$$

$$= \mathbf{0.67}$$

3.focal length from the graph

a. Reduced $\mathrm{f} = \frac{1}{0.095+0.028}$

$$= \frac{1}{0.123}$$

$$= \mathbf{8.13cm}$$

b. Magnified

$$\mathrm{f} = \frac{1}{0.062 + 0.033}$$

$$= \frac{1}{0.095}$$

$$= \mathbf{10.5cm}$$

4.Mean

$$\sum \mathrm{f} = (10.1 + 9.62 + 9.12 + 11.52 + 11.78 + 12)$$

$$\sum \mathbf{f} = \mathbf{64.14cm}$$

$$\text{mean f} = \bar{\mathrm{f}} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{f_i}$$

$$\text{where N} = 7,\ \sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{v_i} = \mathrm{f_1} + f_2 + .\,.......\,. + \mathrm{f_6} = \sum \mathrm{f} = 64.14$$

$$\therefore\ \bar{f} = \frac{1}{6}(64.14)$$

$$= \mathbf{10.7cm}$$

5.Mean deviation

$$\overline{\delta f} = \frac{1}{N}\sum |(f_i - \bar{f})|$$

$$\therefore\ \overline{\delta f} = \frac{1}{6}[|10.08 - 10.69| + |9.62 - 10.69| + |9.12 - 10.69| + |11.52 - 10.56| + |11.78 - 10.69| + |12 - 10.69|]$$

$$\overline{\delta f} = \frac{1}{6}(0.61 + 1.07 + 1.57 + 0.83 + 1.09 + 1.31)$$

$$\overline{\delta f} = \frac{1}{6}(6.48)$$

$$\underline{\overline{\delta f} = \mathbf{1.08cm}}$$

6.Standard deviation

$$\sigma = \sqrt{\frac{1}{(N-!)}\sum |(f_1 - \overline{f})^2|}$$

$$= \sqrt{\frac{1}{6-1}\sum [(0.61)^2 + (1.07)^2 + (1.57)^2 + (0.83)^2 + (1{,}09)^2 + (1.31)^2]}$$

$$= \sqrt{\frac{1}{5}\sum (0.37 + 1.14 + 2.46 + 0.69 + 1.19 + 1.72)}$$

$$= \sqrt{\frac{1}{5}(7.57)}$$

$$= \sqrt{1.514}$$

$$= \mathbf{1.23cm}$$

7.Standard error

$$\sigma_{m=\frac{\sigma}{\sqrt{n}}}$$

$$= \frac{1.23}{\sqrt{6}}$$

$$= \frac{1.23}{2{,}45}$$

$$= \mathbf{0.5cm}$$

Thus, our final answer is F=11 $\pm$ 0.5*cm*

Answers to questions

1.It is necessary to have an inverted image because that’s the real image.

Discussion

In determining the focal length several measures of v(image distance) and u(object distance) were taken for both the magnified and reduced images to come up with the main value because some values are affected by both systematic and random error. These values were used to determine the focal lengths. The mean was 10.7cm and the mean deviation was 1.08cm.To determine how close the sample average is to the individual values, the standard deviation was calculated which was 1.23cm and the standard error was 0.5cm.The standard error being relatively small gives an indication that the mean is relatively close to the true value.

Conclusion

The focal length was determine using the thin lens formula,$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ .The focal length was found to be $11 \pm 0.5cm$.This tells us that the true mean is most likely to be between 10.5cm and 11.5cm.

REFERENCES

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J.R. Taylor, An Introduction to Error Analysis (University Science Books, Mill Valley, California, 1982).