Measurement of Focal length of the given lens

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Abstract: A lens is a very important optical component; lenses come in various shapes and sizes. To determine the focal length of a convex lens is a very interesting exercise. There are several ways of doing this. This experiment deals with 4 different ways of measuring the focal length of a double convex lens. We also touch upon the applications of lenses in day-to-day life and we show how teaching those applications can be made interesting.

The first method is the simplest approach where parallel rays from a source of light (source at infinity or very large distances compared to the focal length) are used. The light, after passing through the convex lens, will converge at the focal point. Measuring the distance between the lens (optical centre) and the point of focus gives the focal length of the lens.

1. Determine the focal length approximately by generating the image of a distant object on a screen.

Procedure

a. Place the lens and a screen on a bench along with a ruler to measure length.
b. Note down the reading x_1 on the scale for the position of the entre of the lens.
c. Place the screen on the bench and move it towards or away from lens so that a sharp image of a distant object i(such as a window) s formed on the screen.
d. Note down the reading x_2.
e. Calculate the focal length f (=| x_2-x_1|). Repeat these steps for more sets of readings at different positions on the table.
f. In case no optical bench is available the same idea should be used to calculate the focal length by measuring the distance between the lens and the screen directly.

[Note: At this point the teacher has to observe how the lens is positioned and how distances are measured. It often happens that the lens is not perpendicular to the optical axis. This process, if observed, should be corrected immediately and the concept clarified. It is to be noted that "marks" indicated are just guidelines, teacher can change the marks as per requirement and need of teacher.]

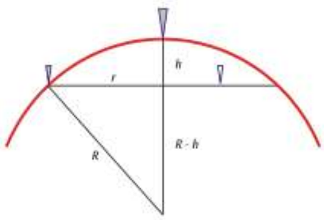
Readings:

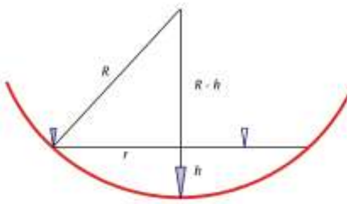
1. Position of the lens : x_1 = _________cm, Position of the sharp image : x_2 = ________cm, Focal length: f_1 = _________cm
2. Position of the lens : x_1 = __________cm, Position of the sharp image : x_2 = ________cm, Focal length: f_2 = _________________cm
3. Position of the lens : x_1 = __________cm, Position of the sharp image : x_2 = _________cm, Focal length: f_3 = ___________ cm
4. Average(of the three focal lengths measured) focal length f_4 = ______ cm (4 marks)

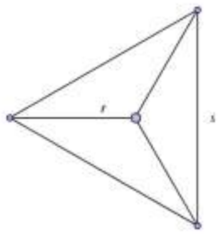
2. **Using a Spherometer measure the saggitta (h) of each curved surface of the lens.**
   The biconvex lens has a very well defined curvature of radius R on both the sides. This can be measured mechanically with a device called as spherometer.

Procedure

a. Match the “zero” on the main scale and the circular scale of the spherometer and determine the reading on the main scale.
b. Rotate the screw of the spherometer for 10 turns and note the down the new reading on the main scale (in mm). The difference in the two readings is l_m =__________mm
c. Least count of the spherometer is lm/1000. LC = __________ mm
d. Withdraw the central screw in “out” position as much as possible
e. Place the spherometer on the spherical surface of the lens in such a way that the three fixed legs of the spherometer gently touch the surface of the lens.
f. Lower the screw slowly, so that the pointed head JUST TOUCHES the centre of the lens.
g. Note down the reading x_1 on the spherometer. x_1 =_________ mm
h. Now place the spherometer on a flat surface and turn the screw so that the pointed edge of the screw JUST TOUCHES the flat surface. Note down the reading x_2=_______ mm.
i. $|x_2 – x_1|$ = h, is known as the saggitta of the curved surface.
j. Determine the average distance s, between the legs of the spherometer.
k. Repeat the process 3 times and enter the readings in the table below.
l. The procedure can be repeated for the other surface of the lens.







The expression for the radius of curvature can be derived from the geometry of construction as follows:

$R^2 = r^2 + (R-h)^2$ $R = (r^2+h^2)/2h$ $r=3^{(-1/2)}\ s$ $R = \{(s^2/6h\} + (h/2)$.

Calculate the radii of curvature of each surface using the above formula.
The focal length of the lens is f = 2R for a symmetrical lens in a homogeneous isotropic medium on both sides.

Readings for radius of curvature:

Table 1:

Sr. No	s/cm	h/cm	Radius of curvature/cm	Focal length/cm
1			R_5 =	f_5 =
2			R_6 =	f_6 =
3			R_7 =	f_7 =

Average of (f_5, f_6 and f_7) f_8 = ____________ cm (4 marks)

[Note: This technique is a direct measurement, using geometrical applications. This technique also strengthens the student's concept of using a micrometer screw gauge and the concepts behind the construction of lenses.]

3. **The focal length of a double convex lens is given by the formula (1/v) + (1/u) = (1/f),** where u is the distance between the object and the lens, v is the distance between the image and the lens.

Procedure

a. Take an index pin and place it on one side of the lens. The lens and the pin should be upright.
b. Place a second pin on the location where you expect the image of the first pin to be formed. The lens and the pins should be in a straight line. The tips of the pins should be on the optical axis of the lens.
c. Now remove the parallax between the tip of the image of the first pin and the tip of the second pin by adjusting the distance of the second pin from the lens.
d. Measure the object distance u and image distance v, from the lens.
e. Choose suitable values of u and determine the corresponding values of v for the given convex lens.
f. Take suitable number of readings.

Table 2:

Sr. No	u/cm	v/cm	1/u cm^{-1}	1/v cm^{-1}
1				
2				
3				
4				
5				
6				

7				

(3.5 marks)

Plot suitable graphs of 1/v versus 1/u and determine the slope of the graph and the focal length of the lens from the intercepts.

7 points on the graph (3.5 marks)

Graph plotting (3.5 marks)

Slope of graph= (0.5 mark)

X intercept of the graph = (0.5 mark)

Y intercept of the graph = (0.5 mark)

Focal lengths f_9 = (0.5 mark)

f_{10} = (0.5 mark)

[Note: In this method care should be taken to explain to the students the concept of parallax and the method of removing parallax. The term 'removing parallax' should be used after the student has understood the concept of 'parallax'. Use of light source should be avoided as the image formation with light source is very easy but it denies the student to opportunity to understand the concept of image formation. Here it is also essential for the teacher to observe that student takes 7 readings. It is generally accepted that 7 data points are sufficient to determine if the trend of graph is a straight line or a curve. After the relationship between 1/v and 1/u is established as a straight line and is related to the equation y = mx + c, it can be seen that the graph has a slope of -1, intercepts on each axis will be equal to 1/f.

In addition, a graph of v against u can be plotted and the focal length of the lens can be determined by locating the point where u = v = 2f]

4. **Magnified and diminished images method**

If the distance between the object and the screen is more than four times the focal length of the lens, then there are two positions of the lens between the object and the screen where the object will form an image on the screen. The image formed on the screen will be once magnified and once diminished. The focal length of the lens is given by:

$f = (l^2 – d^2) / 4l$,

Where l = distance between the object and the screen and d = distance between the two positions of the lens. The object and the image can be replaced by two pins the technique of removing parallax, as described in part 3 above.

Procedure

1. Using the approximate value of the focal length of the convex lens determined earlier, place the screen at a suitable distance (l) from the source.
2. Introduce the lens between the screen and the object and adjust its position so that the clear image obtained on the screen is once diminished and once magnified.
3. Measure the distance (d) between these positions of the lens.
4. Note down the distances u_1 & u_2. (Please specify meaning)
5. Repeat the procedure for suitable number of times.

Table 3: (5 marks)

Sr. No	u_1/cm	u_2/cm	d/cm	l/cm	f/cm
1					
2					
3					
4					
5					

Plot a suitable graph and determine the focal length of the lens from the graph. (2.5 marks)
Focal length of the lens f_{11}= (0.5 marks)

[This technique is an extension of method 3. As in method 3, use of light source will make the experiment extremely simple but rob the student of the opportunity to understand process of image formation in depths (?). This method gives very good results when the distance between image and object pin is more than 4.5f.]

Result:

Focal length of lens

f_4	
f_8	
f_9	
f_{10}	
f_{11}	

(1 mark)

[Note: the article also shows suggested distribution of marks with 0.5 mark least count. The same can be modified with a least count of 0.25mark. Also the total can marks can be revised as per the amount of task to be performed according to the time available.]