<u>Focal Length of Convex Lens[B11] Lab Report</u>

Objectives of the experiment:

To determine the **focal length of a spherical convex lens**

♦ by "Lens formula method"

♦ by "Lens replacement method".

To compare both methods.

Theory:

In this experiment, we have chosen two methods to find out the focal length of a spherical lens. They are "lens formula method" and "lens replacement method". Firstly, we talk about the theory of the first method. It is known that there is a formula called Lens formula ($\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$) which stated the relationship between object distance u, image distance v and the focal length of a spherical lens. Therefore we record a few pairs of data of object and image distance in order to make use the formula to determine the focal length of the lens given.

Secondly, we talk about the "lens replacement method". If we separate a lamp housing and a screen to s cm, there must be two positions between s which can form the image on the screen by the lens according to the reversibility of the light. Therefore we can find out the focal length by the formula given ($f = \frac{s^2 - d^2}{4s}$) where d is the distance between the two lens positions.

Definition of the symbols used:

Symbols	Definition
u	Object distance
v	Image distance
f / F	Focal length of the lens
s	Separation of the lamp housing and the screen
d_1	1st lens position
d_2	2nd lens position
d	Distance between 1st lens position & 2nd lens position

Method, steps of the experiment:

Method 1 : Lens formula method

Apparatus needed :

    Metre rule x 1, white screen x 1, lamp housing x 1, convex lens x 1

1. Form the image of the object from lamp housing on the white screen by the

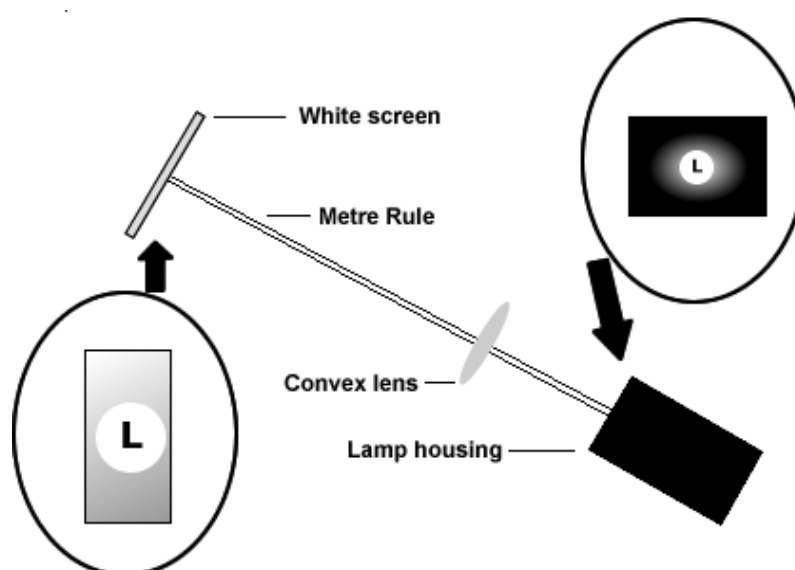   spherical convex lens.   The set up is like the following figure :

    Figure (1)

Ray diagram explaining figure 1

Figure (2)

Roughly estimate a **focal length (F)** of the convex lens by measuring the image distance (v).

2. Measure the **image distance (v)** when the **object distance (u)** is set to be **smaller than 2F**. (3 pairs of data for u<2F in order to reduce the **random error**)

Ray diagram for u>2F, u=2F, u<2F

Figure (3)

Repeat the measurement by setting the object distance (u) to be **around 2F** and **larger than 2F**. (1 pair of data for u=2F, 3 pairs of data for u>2F)

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3. Use the lens formula $\dfrac{1}{f} = \dfrac{1}{u} + \dfrac{1}{v}$ to calculate the focal length of each pair of data.

   Finally, determine the mean focal length.

Method 2 : Lens displacement method

Apparatus needed :

　Metre rule x 1, white screen x 1, lamp housing x 1, convex lens x 1

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1. Separate the **lamp housing** and the **screen** to **s cm which is about 5F**.　Move the lens away from the lamp housing slowly to the place where the **sharpest** image is formed one the screen.　Record the **position of the lens (d_1)**.
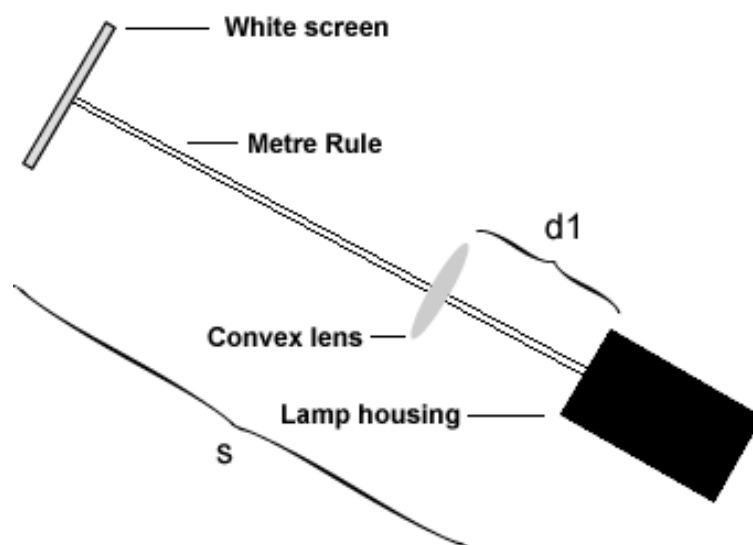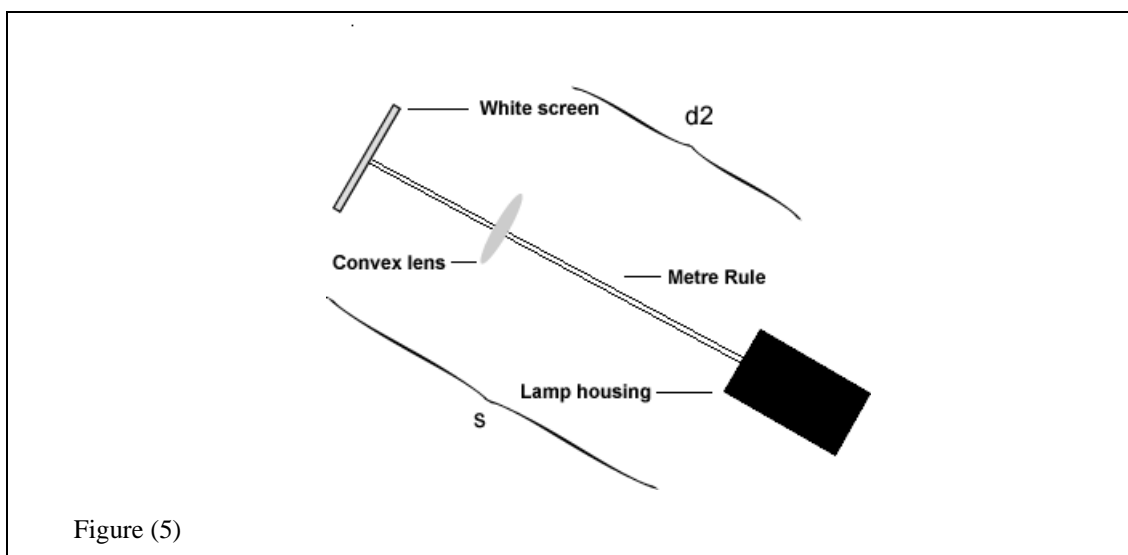

   White screen

   Metre Rule

   d1

   Convex lens

   Lamp housing

   s

   Figure (4)

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2. Continue to move the lens away from the lamp housing until a sharp image is formed on screen again.　Record the **new position of the lens (d_2)**

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Figure (5)

3. Repeat the measurement by adjusting **the distance between lamp-housing and the screen (s)** to roughly about **5.4F, 5.8F, 6.2F and 6.6F**.

4. Calculate the focal length of the convex lens by using the formula given.

$$f = \frac{s^2 - d^2}{4s}, \text{ where } d = |d_1 - d_2|$$

Finally, determine the mean focal length.

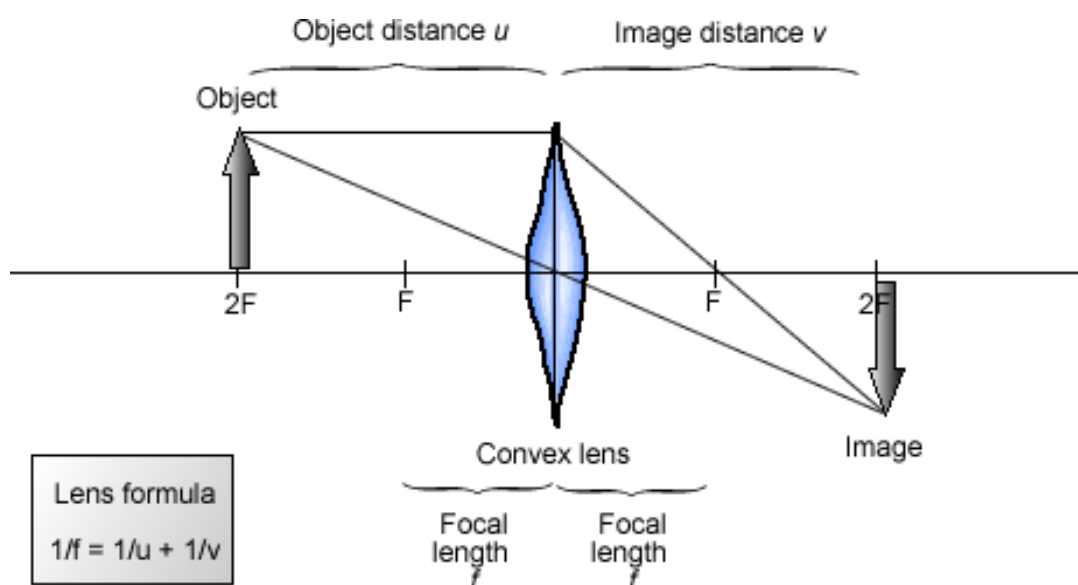## Data and data analysis:

Method 1: Lens formula method

Figure (6)

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Estimated focal length F of the convex lens = 10 cm

	Object distance u / cm	Image distance v / cm	$\dfrac{1}{u}$ / cm^{-1}	$\dfrac{1}{v}$ / cm^{-1}	$\dfrac{1}{f}$ / cm $(\dfrac{1}{u}+\dfrac{1}{v})$	Focal length f / cm
	17	24	0.059	0.042	0.10	9.90
u < 2F	15	28	0.067	0.036	0.10	9.71
	12	44	0.083	0.023	0.11	9.43
u = 2F	20	19.3	0.050	0.052	0.10	9.80
	25	16.3	0.040	0.061	0.10	9.90
u > 2F	30	15	0.033	0.067	0.10	10.00
	35	14	0.029	0.071	0.10	10.00
Mean Focal length / cm						**9.82**

Method 2: Lens replacement method

Figure (7)
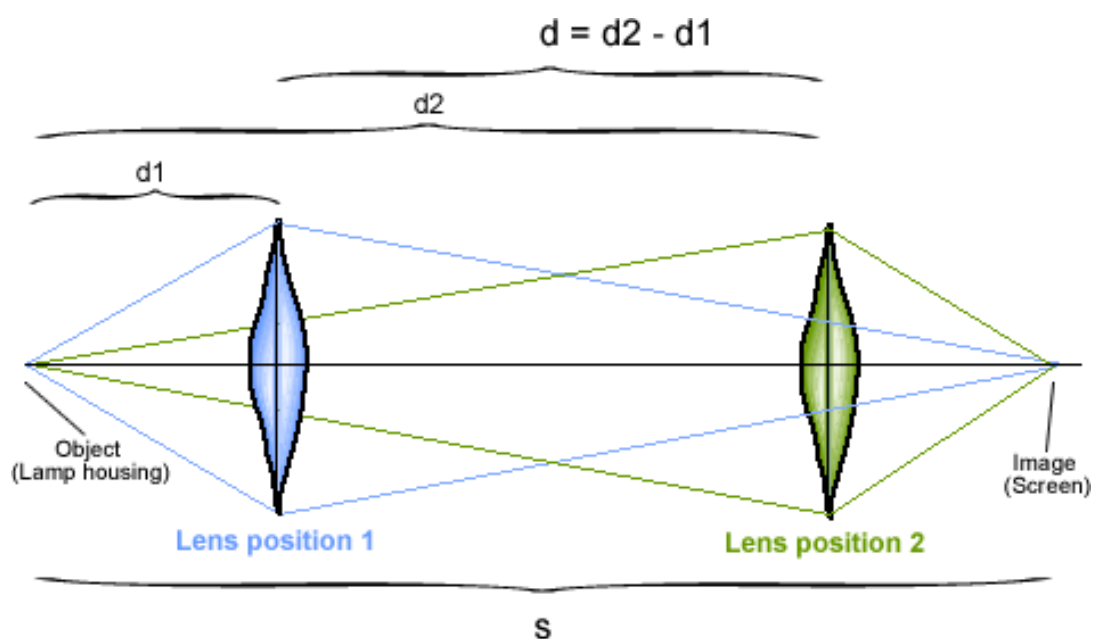
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	Distance between lamp housing & screen s / cm	Lens position 1 d_1 / cm	Lens position 2 d_2 / cm	d / cm ($|d_1 - d_2|$)	Focal length f / cm ($\frac{s^2 - d^2}{4s}$)
s = 5F	50	36	13	23	9.86
s = 5.4F	54	41	13	28	9.87
s = 5.8F	58	45	12.5	32.5	9.95
s = 6.2F	62	49.8	12	37.8	9.74
s = 6.6F	66	54	11.5	42.5	9.66
Mean Focal length / cm					**9.76**

Difficulties, and errors:

In the whole experiment, the biggest difficulty is to judge at which screen position or lens position can form the sharpest image as the image was small and dim, which I think it is the major source of error.   Moreover, when we decided at the point that can form the sharpest image but the image seemed to become sharper when the lens or screen was moved a little bit.   Sometimes there is quite a large range which can form a sharp image so that we pay more attention in the change of the sharpness of the image in order to obtain a more accurate data.   As a matter of fact, there is another possible error source that the measurement of object and image distance involved the centre of the lens which is not accessible from outside.   This could produce a minor inaccuracy, so the calculation of uncertainty is necessary.

The uncertainty (mean deviation) of the data obtained in 1st method:

$$\text{Mean deviation} = \frac{\sum |x_i - \text{mean}|}{f}, \text{ where } x_i \text{ is each focal length, f is no. of data}$$

$$= \frac{|9.9 - 9.82| + |9.71 - 9.82| + |9.43 - 9.82| + |9.8 - 9.82| + |9.9 - 9.82| + 2|10 - 9.82|}{7} = 0.15 \, \text{cm}$$

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The uncertainty (mean deviation) of the data obtained in 2nd method :

$$\text{Mean deviation} = \frac{\sum |x_i - \text{mean}|}{f}, \text{ where } x_i \text{ is each focal length, f is no. of data}$$

$$= \frac{|9.86 - 9.76| + |9.87 - 9.76| + |9.95 - 9.76| + |9.74 - 9.76| + |9.66 - 9.76|}{5} = 0.06\,\text{cm}$$

Discussion:

From the uncertainty of the both methods calculated above, we may conclude that the second method "lens-displacement method" can obtain a more accurate result with less mean deviation which means the random error is less.   However, we need to use an appropriate method under different situations.   "Lens formula method" is good for the situation that the lens is convenient to be moved while "lens displacement method" is more favorable for the lens which is fixed.   For instance, we would prefer the second method to measure the focal length of the lens of a camera as the lens can be extended or hidden easily.

In method 2, we are given a formula $f = \dfrac{s^2 - d^2}{4s}$ to calculate the focal length. Here, we want to make use of the lens formula to prove the formula given.
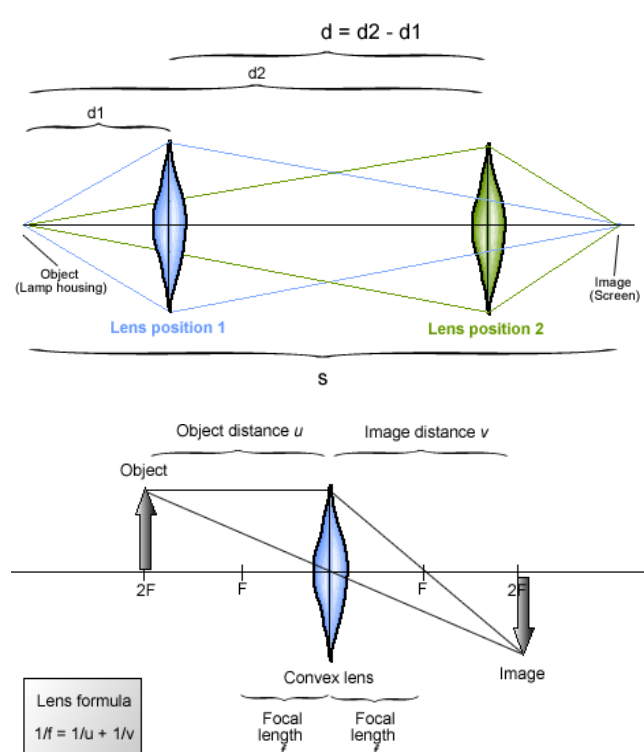
$$u = \frac{s - d}{2}$$

$$v = \frac{s - d}{2} + d = \frac{s + d}{2}$$

Consider lens formula,

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

$$\frac{1}{f} = \frac{2}{s - d} + \frac{2}{s + d}$$

$$\frac{1}{f} = \frac{2(s + d) + 2(s - d)}{(s - d)(s + d)}$$

$$\frac{1}{f} = \frac{4s}{s^2 - d^2}$$

$$\therefore f = \frac{s^2 - d^2}{4s}$$

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Conclusion:

We can conclude the focal length of the convex lens which are **9.82cm** (found by

"**lens formula method**", uncertainty is 0.15cm) and **9.76cm** (found by "**lens**

displacement method", uncertainty is 0.06cm).

~ The End ~

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