Principles of Physics I (PHY111)

Lab

Experiment no: 6

Name of the experiment: Determination of the focal length of a convex lens by displacement method with the help of an optical bench

Theory

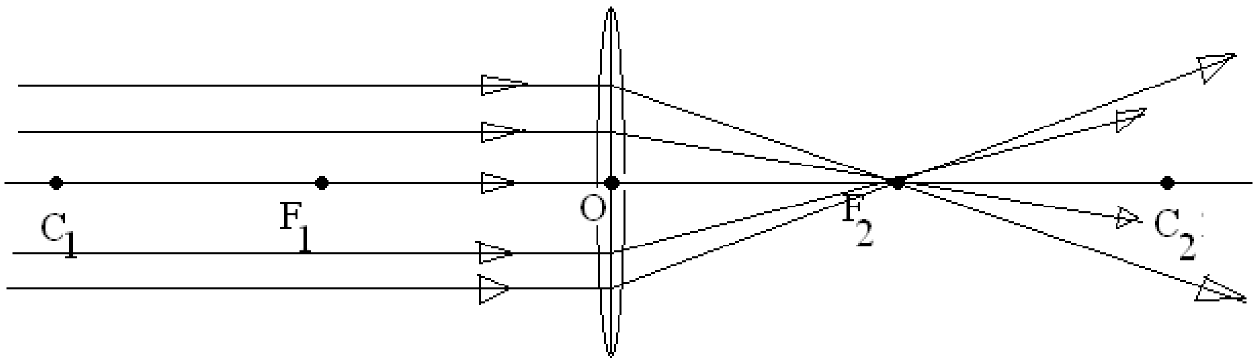


Figure 1: A convex lens

Figure 1 shows a convex lens, which makes a parallel beam of light converging. C_1, C_2 are the centers of curvature of the lens. O is the optical centre of the lens. So, C_1C_2 is the principal axis of the lens.

The point on the principal axis on which a beam of light which are parallel to the principal axis, converges, after being refracted by the lens, is said to be the focus point of the lens. In the above figure we see F_2 is the focus point of the lens. If the beam came from the right side it would converge at point F_1. So F_1 and F_2 are the two principal foci of the lens. Length of the line joining the optical centre, O and the principal focus F_2 or F_1 is the focal length of the lens. Therefore OF_1 and OF_2 are the focal length of the lens.

In this experiment we will deduce the focal length of a given convex lens. We use an optical bench. An object, a lens and a screen (where the image will be produced) are attached to a cylindrical rod and they can be moved along this rod of the optical bench. There is a meter scale parallel to the rod to measure the position of the object, lens and screen.

In figure 2 an object, a lens and a screen where the image is formed are shown. AB is the principal axis of the lens. The object is kept at point A and the screen is kept at point B. The distance between the object and the screen (image) is *D*. It is observed that image of the object on the screen can be formed for two different positions-O_1 and O_2 of the lens between A and B. The separation between O_1 and O_2 is *x*.

It can be shown that the focal length of the lens, $f = \dfrac{D^2 - x^2}{4D}$ (1)

In this experiment we workout x for different values of *D*. Then calculate the values of *f* for each case. Finally take the average value of *f* as the result.

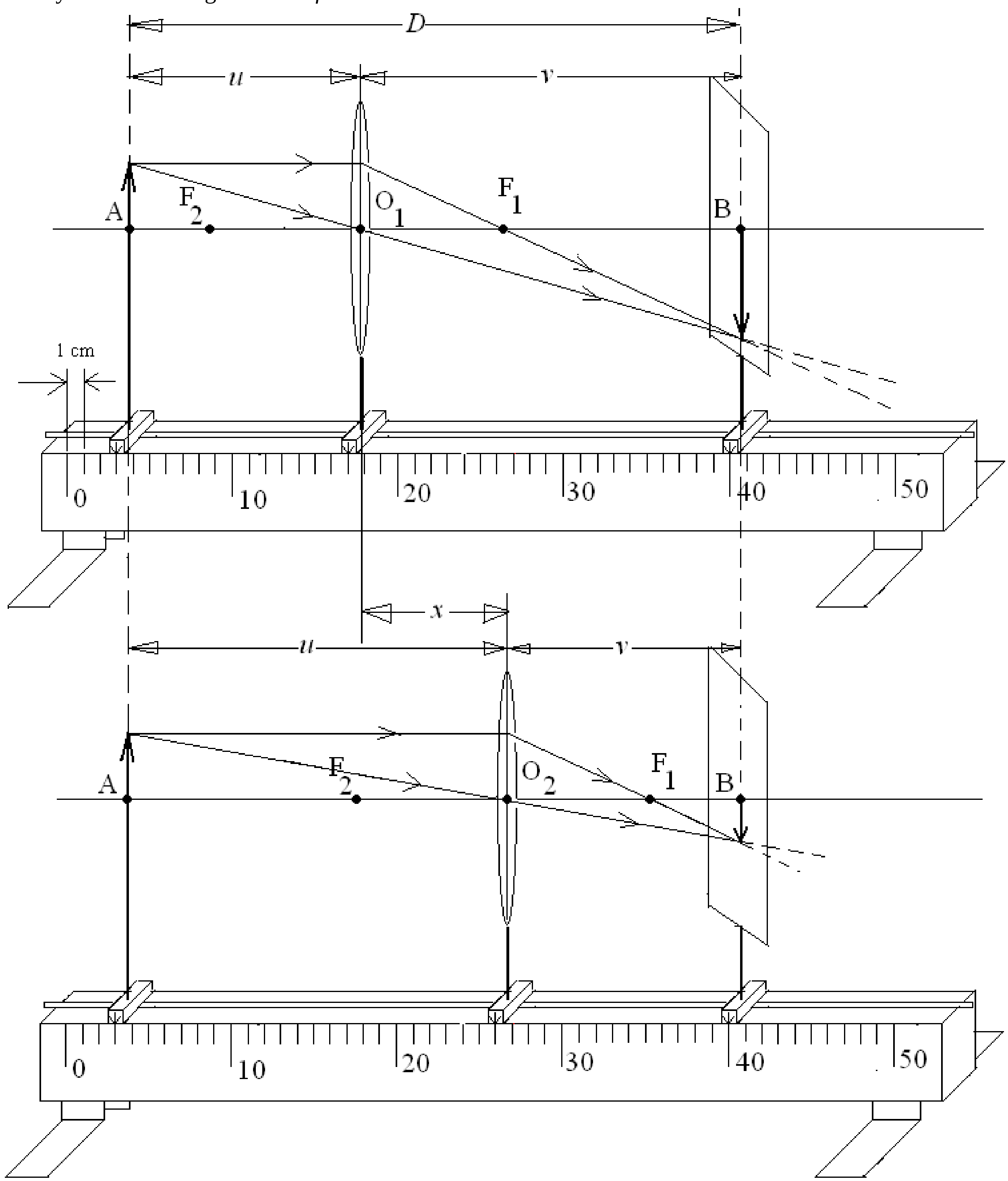


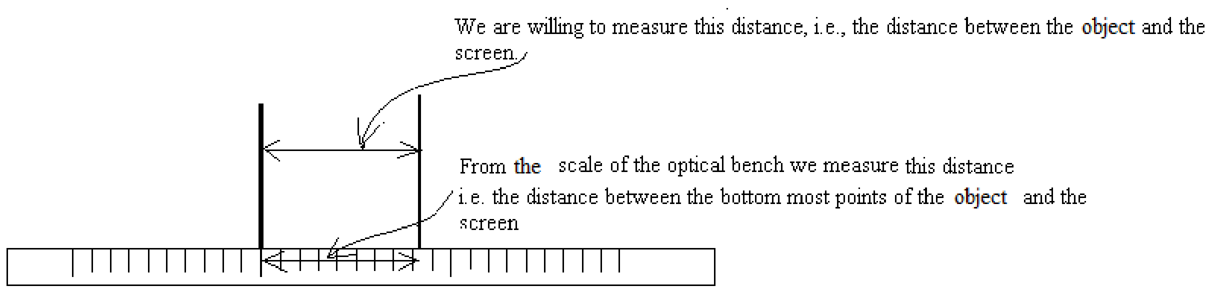
Figure 2: Optical bench with object at point A, screen at point B and lens at points $O_{1,2}$.

Apparatus

Optical bench, object, lens, screen, source of light and index rod (a pen)

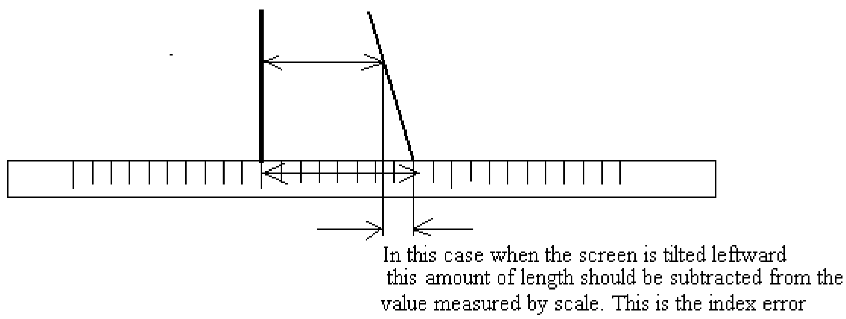
Procedure

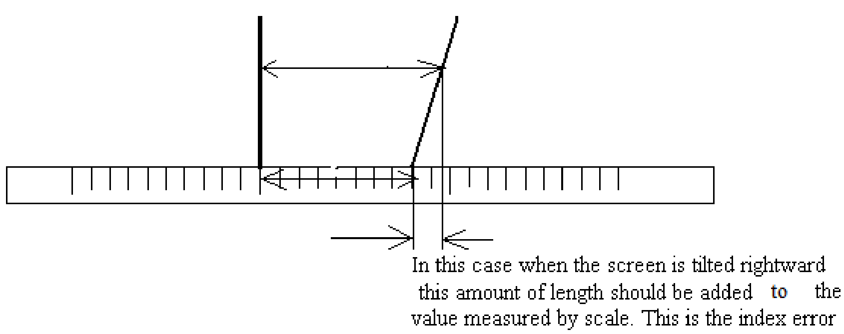
1. At first see whether there is any index error in the arrangement or not.



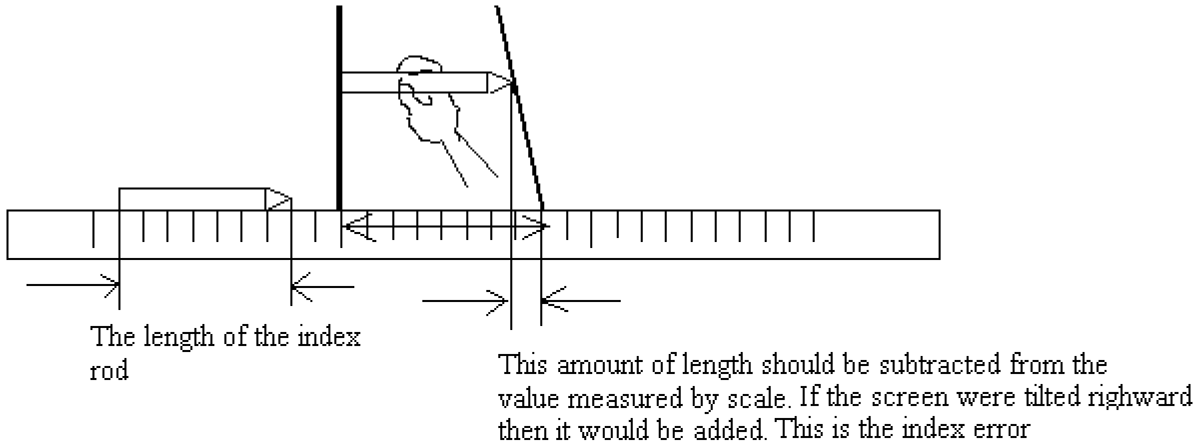
If both of the object and the screen are perpendicular to the scale of the optical bench then both of the distances are equal.

Due to the systemetic error the object and the screen may not be perpendicular to the optical bench. Hence, the two distances may not be equal.





Take an index rod (which may be your pen). Make sure that the rod is straight. Measure the length of the index rod (you may use the scale of the optical bench to do so).



Hold the index rod horizontally parallel to the scale such that one end of the index rod touches the object and the other end touches the screen. Now measure the separation between the bottoms of the object and the screen by using the scale of the optical bench. If you find any discrepancy between this separation and the length of the index rod then you have to make index correction as described in the above shown figure.

2. Turn on the light.

3. Estimate the value of the focal length. Keep the lens at any distance away from the object. Measure the separation between the object and the lens, u using the meter scale of the optical bench. Adjust the position of the screen by moving it leftward or rightward to find a sharp image of the object on it. Measure the separation between the screen (image) and the lens, v in the same way. Now using the equation what you wrote in the answer of question (*i*) find the focal length, f of the lens. This is the estimated value of the focal length.

4. Now take the reading of the position of the object (A) by using the scale, e.g., for figure 2 it is 3cm. Write it down in the data table. Throughout the experiment it will always remain fixed.

5. Keep the screen at a position (B) such that the distance between the object and the screen (AB) is greater than four times the estimated value of the focal length. Take the reading of the position of the lens (B), e.g., for figure 2 it is 40 cm.

6. Take the lens close to the object. Then begin moving it gradually rightward until you see a sharp magnified image of the object on the screen. Stop here and take the reading of the position of the lens O_1 and write it down on the data table. For figure 2 it is 17cm.

7. Again start moving it gradually towards the screen until you see a sharp small image of the object on the screen. Stop here and take the reading of the position of the lens O_2 and writhe it down on the data table. For figure 2 it is 26 cm.

8. Now move the screen rightward for 2cm. Repeat the steps 6 and 7 for this new position of the screen.

9. In the same way keep moving the screen rightward in an interval of 2 cm and repeat steps 6 and 7 for each of the new position of the screen.

10. For each of the readings find $x = O_2 - O_1$, measured value of D = B – A,

the corrected value of D = (B-A) ± index correction and the focal length, f

11. Finally, find out the average value focal length and the power of the lens.

Read carefully and follow the following instructions:

- **Please READ the theory carefully, TAKE printout of the 'Questions on Theory' and ANSWER the questions in the specified space BEFORE you go to the lab class.**
- **To get full marks for the 'Questions on Theory' portion, you must answer ALL of these questions CORRECTLY and with PROPER UNDERSTANDING, BEFORE you go to the lab class. However, to ATTEND the lab class you are REQUIRED to answer AT LEAST the questions with asterisk mark.**
- **Write down your NAME, ID, THEORY SECTION, GROUP, DATE, EXPERIMENT NO AND NAME OF THE EXPERIMENT on the top of the first paper.**
- **If you face difficulties to understand the theory, please meet us BEFORE the lab class. However, you must read the theory first.**
- **DO NOT PLAGIARIZE. Plagiarism will bring ZERO marks in this WHOLE EXPERIMENT. Be sure that you have understood the questions and the answers what you have written, and all of these are your own works. You WILL BE asked questions on these tasks in the class. If you plagiarize for more than once, WHOLE lab marks will be ZERO.**
- **After entering the class, please submit this portion before you start the experiment.**

Name: ______________________ ID: _______________ Sec: ___ Group: __ Date: __________

Experiment no: ___

Name of the Experiment: ____

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Questions on Theory

*1) What is the focal length of a lens? [1]

Ans:

*2) If *u* is the distance between the object and the optical centre of the lens, *v* is the distance between the image and the optical centre of the lens and f is the focal length of the lens; then what is the relationship among *u*, *v* and *f*? [1]

Ans:

*3) Look at the Figure 2. $AO_{1,\,2} = u$, $BO_{1,2} = v$ and $AB = D$. Clearly, $v=D-u$. Put $v=D-u$ in the equation relating u, v and f which you wrote as an answer of question (2). Show that $u = \dfrac{D \pm \sqrt{D^2 - 4Df}}{2}$ [Hint: We know that the solution of the quadratic equation $ax^2 + bx + c = 0$ is $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ you can use this result] [1]

Ans:

*4) Write $u_1 = \dfrac{D - \sqrt{D^2 - 4Df}}{2}$ (which is AO_1 of Figure 2) and $u_2 = \dfrac{D + \sqrt{D^2 - 4Df}}{2}$ (which is AO_2 of figure 2). If $x = |u_2 - u_1|$, then show that $f = \dfrac{D^2 - x^2}{4D}$ [1]

5) What will happen if $D < 4f$? [1]

Ans:

- **Draw the data table(s) and write down the variables to be measured shown below (in the 'Data' section), using pencil and ruler BEFORE you go to the lab class.**

- **Write down your NAME and ID on the top of the page.**
- **This part should be separated from your Answers of "Questions on Theory" part.**
- **Keep it with yourself after coming to the lab.**

Data:

Table 1: Index error (λ) for *D*

Length of the index rod, *l* (cm)	Separation between the bottoms of the object and the screen when the two ends of index rod touches the object and the screen, *d* (cm)	Index error in *D* $\lambda = l - d$ (cm)

Table 2: Readings for *D* and *x*

Position of object, A (cm)	Position of image B (cm)	Position of lens for magnified image, O_1 (cm)	Position of lens for small image, O_2 (cm)	Separation between O_1 and O_2, *x* (cm)	Apparent separation between object and image, D' (cm)	Corrected separation between object and image, $D = D' + \lambda$ (cm)	Focal length $f = \frac{D^2 - x^2}{4D}$ (cm)

- **READ the PROCEDURE carefully and perform the experiment by YOURSELVES. If you need help to understand any specific point draw attention of the instructors.**
- **DO NOT PLAGIARIZE data from other group and/or DO NOT hand in your data to other group. It will bring ZERO mark in this experiment. Repetition of such activities will bring zero mark for the whole lab.**
- **Perform calculations by following the PROCEDURE . Show every step in the Calculations section.**
- **Write down the final result(s).**

Calculation:

Result:

- **TAKE printout of the ‘Questions for Discussions’ BEFORE you go to the lab class. Keep this printout with you during the experiment. ANSWER the questions in the specified space AFTER you have performed the experiment.**
- **Attach Data, Calculations, Results and the Answers of ‘Questions for Discussions’ parts to your previously submitted Answers of ‘Questions on Theory’ part to make the whole lab report.**
- **Finally, submit the lab report before you leave the lab.**

Name: ___________________________ ID: __________________

Questions of Discussions

1) From theory you see that D should be greater than 4*f*. Will you face any difficulty to detect the image if D is too high? [0.5]

Ans:

2) Does the focal length depend on color? [0.5]

Ans:

3) Why the index correction for *x* is not necessary? [1]

Ans: