Thin Lens Equation

Name:	Teammates:

Introduction

Consider a simple lens, light is refracted upon entering the lens, it travels in a straight line within the lens, and then is refracted again upon leaving the lens. Since the sides of the lens are not necessarily parallel, the light leaves the lens at a different angle from which it entered. Depending on the shape of the lens, the light is either focused or defocused.

If we approximate both sides of a lens as spherical with radii of curvature r_1 and r_2, then the focal length (d_f) of the lens when surrounded by air is given by the lens maker equation:

$$\frac{1}{d_f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

where r_1 is positive if the center of the sphere is to the right of the lens and r_2 is positive if the center of the sphere is to the left, n is the index of refraction of the lens, This formula is extremely useful for creating a lens, it is not very useful for determining the focal length of a lens that has already been created. A more practical method for finding the focal length (d_f) of a lens is by using the thin lens equation

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_f}$$

where d_o is the distance the source (object) is away from the lens and d_i is distance the image is behind the lens. This equation is applicable only for a thin lens approximation. Note that when d_o is very large, d_f is equal to d_i.

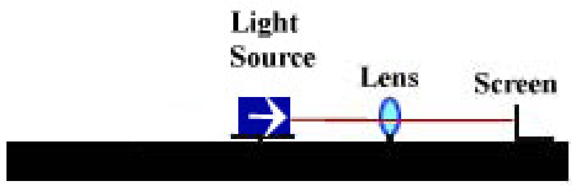

Fig: 1: Lab set up

Procedure

1. Set up the optical bench as in Fig 1 using the d_f = 200 mm focal length lens.
2. Set d_o larger then $2d_f$ and find the corresponding image by moving the screen until a focused sharp image is formed on the screen.
3. Provide the following data:

Object position on bench x_o = _____ cm Object distance d_o = _____ cm lens position on bench x_L = _____ cm

Image position on bench x_i = _____ cm Image distance d_i = _____ cm

Object height h_o = _____ mm (positive if upright, negative otherwise) Image height h_i = _____ mm (positive if upright)

4. Make the following calculations:

The focal length of the lens using the data from the previous step d_f = _____ cm

The magnification of the set-up in the previous step: $M = \frac{h_i}{h_o}$ = _____ The ratio: $-\frac{d_i}{d_o}$ = _____

5. Answer the following questions:

A. How is the size of the image compared to the size of the source (object)?

B. Was the image the same orientation of the object?

C. How does the ratio $-\frac{d_i}{d_o}$ compare to M?

D. How does the measured focal length compare to the provided focal length?

E. What happens to the image if you block part of the lens?

F. Position yourself behind the screen and remove the screen. Do still see the image?

6. Set d_o now so that it is smaller then $2d_f$ and larger then d_f and find the corresponding image.
7. Provide the following data:

Object position on bench x_o = _____ cm Object distance d_o = _____ cm lens position on bench x_L = _____ cm

Image position on bench x_i = _____ cm Image distance d_i = _____ cm

Object height h_o = _____ mm (positive if upright, negative otherwise) Image height h_i = _____ mm (positive if upright)

8. Make the following calculations:

The magnification: $M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$ = _____

9. Answer the following questions:

A. How is the size of the image compared to the size of the source (object)?

B. Was the image the same orientation of the object?

C. Position yourself behind the screen and remove the screen. Do still see the image?

10. Set d_o now so that it is smaller then d_f. Provide the following data:

Object position on bench x_o = _____ cm Object distance d_o = _____ cm lens position on bench x_L = _____ cm

11. Answer the following questions:

A. Were you able to project an image of the object on a screen?

B. Position yourself behind the lens (other side of the object). Do you now see the image? If yes, describe where does the image appear to be located?

C. How does the size of this image compare to the size of the source (object)?

D. What is the orientation of this image?

E. Why do you think this image is usually referred to as "virtual" while the images projected on the screen in the previous parts are referred to as "real"?

12. Using the thin lens equation and the provided focal length, complete the following calculations:

Image distance d_i = _____ cm   Image position on bench x_i = _____ cm

The magnification: $M = -\frac{d_i}{d_o}$ = _____   Image height h_i = _____ mm

13. Keeping the same set-up as the set-up used in part 10, add a d_f = 100 mm focal length lens to the set-up by placing it between the first lens and the screen.
14. Manipulate this second lens and the screen (without moving the first lens or the object) until a focused sharp image is formed on the screen.
15. Provide the following data:

Image position on bench x_i = _____ cm   Image distance d_i = _____ cm

Image height h_i = _____ mm (positive if upright, negative otherwise)

16. Using the thin lens equation and the provided focal length for the second lens, complete the following calculations:

Object distance d_o = _____ cm   Object position on bench x_o = _____ cm

The magnification: $M = -\frac{d_i}{d_o}$ = _____   Object height h_o = _____ mm

17. Answer the following questions:

A. How does the object position x_o compare to the image position as calculated in step 12?

B. How does the object height h_o compare to the image height calculated in step 12?

C. What does that tell you about the "object" for the 100 mm lens?

18. Replace both lenses by the un-marked concave lens. Provide the following data:

Object position on bench x_o = _____ cm Object distance d_o = _____ cm lens position on bench x_L = _____ cm

19. Answer the following questions:

A. Were you able to project an image of the object on a screen?

B. Position yourself behind the lens (other side of the object) and describe where does the image appear to be located?

C. How does the size of this image compare to the size of the source (object)?

D. What is the orientation of this image?

E. Is this image "virtual" or "real"?

F. What do you conclude about a single concave lens set-up, can it produce an image on a screen?

20. Keeping the same set-up as the set-up used in part 18, add a d_f = 100 mm focal length lens by placing it between the first lens and the screen.
21. Manipulate both lenses and the screen until a focused sharp image is formed on the screen.
22. Provide the following data:

Image position on bench x_i = _____ cm Image distance d_i = _____ cm

23. Using the thin lens equation and the provided focal length for the second lens, complete the following calculations:

Object distance d_o = _____ cm Object position on bench x_o = _____ cm

24. Use the data obtained in part 23 to complete the following calculations for the concave lens (first lens):

Image position on bench x_i = _____ cm Image distance d_i = _____ cm

25. Find the focal length of this concave lens: