Checking focal lenghts and imaging with thin lenses.

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Abstract

It was required to measure the focal lenghts of different lenses that are in the optics laboratory, each one of this lenses have a thoerical focal lenght provided by the fabricant; to measure and check these lenghts an experimental arrangement was placed with a rail mounted to place the lenses, a laser and a screen. The focal lenghts were measured and checked succesfully, leading us to the image formation of each lens using the same arrangement, but instead of the laser, an halogen ligh source was used. The different images and magnifications were obtained due to different distances of the lamp placement.

Keywords: Lenses, imaging, focus, focal lenght, magnification.

I. Introduction

Optical imaging and lens focus are two basic principles of geometrical optics, and both constitute the main principle of telescope and microscope construction.Thin lenses can be grouped into two categories, converging lenses an diverging lenses. A converging lens is one that causes incident parallel rays to converge at a focal point on the opposite side of the lens, and a diverging lens is one that causes incident parallel rays to emerge from the lens though they emanated from a focal point on the incident side of the lens.A thin lens is defined to be one whose thickness allows rays to refract.

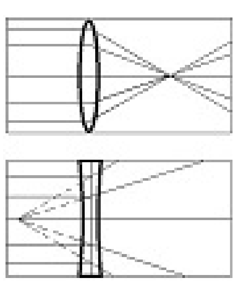

Figure 1: *Converging lens (up) and diverging lens (down)*

The distance from the lens to the focal point is called the *focal lenght*, positive for the converging lenses and negative for the diverging lenses. Sometimes the focal point of a converging lens is called a *real* focus and that of a diverging lens is called a *virtual* focus. Both types of lenses and their focal lenght are clearly shown in Figure 1.

If Snell's law is applied at both input and output surfaces of a lens of index of refraction n and input and output surface radii of curvature $R1$ and $R2$, the focal lenght f of a lens is given by,

$$\frac{1}{f} = (n-1)(\frac{1}{R1} - \frac{1}{R2}) \quad (1)$$

This equation, better known as the lensmaker's equation, is not used in simple experiments due to its complexity of getting the radii of curvature. This equation is valid for thin lenses of thickness much less than the radii of the lens surfaces. Instead we use,

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \quad (2)$$

Where f is the focal lenght of the lens, p is the axial distance form de object to the lens, q is the axial distance from the image to the lens.

Every lens forms an image, some lenses form an obvious image, but some of them form a less obvious image.In order to understand how the lenses form images, ray tracing for thin lenses must be used. Ray tracing is the technique of determining or following the paths that light rays take. From eq. 1 we can determine the position where the image will be formed; an image is said to be *real* when is formed on the opposite side where the object is and a *virtual* image is formed on the same side where the object is.

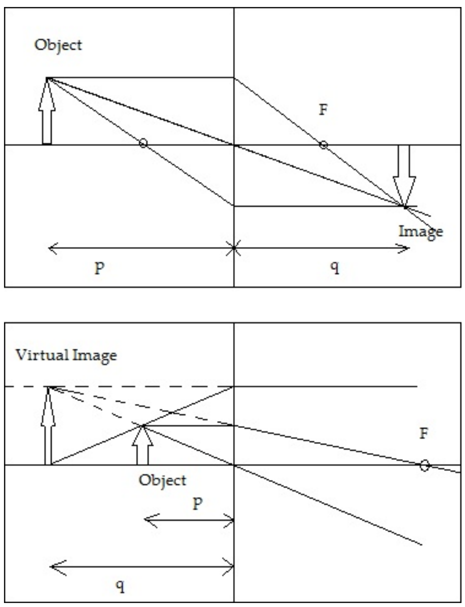

Figure 2: *Real image (up) and virtual image (down)*

The magnification for these images is given by the next relation,

$$M = -\frac{q}{p} \tag{3}$$

Where M is the ratio of the image distance q to the object distance p and the minus sign is a sign convention: it is there so that the magnification will be positive if the image is erect, and negative if the image is inverted. Note that the magnification can be either greater or less than one in magnitude.

II. Methods and Materials

In order to demonstrate the focal lenghts for some lenses, we used the Pasco Basic Optics System, which includes the following lenses and other devices:

- +200mm lens
- +100mm lens
- +250mm lens
- -150mm lens
- 1.2m optics track
- 650nm diode laser
- Halogen light source
- Viewing screen and half screen

I. Experiment I

The first expriment consists in getting the focal lenght for every lens using the Gauss method. To apply this method the diode laser most be our light source, placed where the optics track begins, the lens will be placed on an arbitrary distance q from the laser, a viewing screen will be slid through the track until the point where the laser is focused is found. The distance from the lens to the point where the laser is focused is the focal lenght f and most be confirmed with the factory specification. This experimental arrangement is shown below in figure 3.

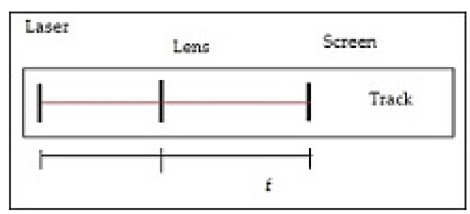

Figure 3: *Experimental arrangement 1*

II. Experiment II

The second experiment used a similar arrangement as the first one, but instead of a diode laser, an halogen light source was used as the object. The light source was placed at different distances from de lens: $2f$, $2.5f$ and $1.5f$ (like described in Figure 4), it is expected that each of the distances will give a different magnification for the images obtained by the lens used. After applying the methods described, we got the results shown in the next section of this paper.

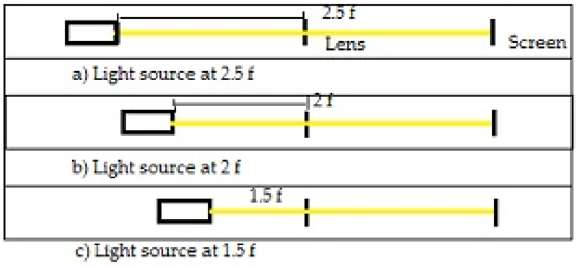

Figure 4: *Experimental arrangement 2*

III. Results

The results obtained for both experiment 1 and experiment 2, are shown in the tables below.

Table 1: *Exp 1 results*

Lens	Category	Average f
+250mm	converging	250mm
+200mm	converging	200mm
+100mm	converging	100.2mm
-150mm	diverging	-84.2mm

From the results of Table 1. we verified the focal lenghts for all the lens included in our experiment except for the diverging lens, which gave us an experimental number too far from the specified by the fabricant. The average focal lenght was obtained by sampling from five tests.

Table 2: *Exp 2 results*

Lens	Obj. dist.	Image dist.	M
+250mm	2 f	2 f	-1.02
	2.5 f	1.688 f	-0.6752
	1.5 f	3.08 f	-2.0533
+200mm	2 f	2.15 f	-1.075
	2.25 f	1.875 f	-0.8556
	1.5 f	3.25 f	-2.1667
+100mm	2 f	2.26 f	-1.13
	2.5 f	1.8 f	-0.74
	1.5 f	3.7 f	-2.4667
-150mm	2 f	0.753 f	0.373
	2.5 f	0.693 f	0.277
	1.5 f	0.846 f	0.564

As shown in Table 2, we obtained the images and magnifications for all the lenses, however the diverging lens created inverted virtual images, which goes against the theory. According to equation (3) a positive sign on the image magnification will result on an erect image, not an inverted one. The theoretical results presented in Table 2 indicate that the experiment may gave been poorly made.

IV. Conclusion

On this experiments we could understand the behavior of light rays which go through a lens, this behavior depends on the properties of the lens, like its category (converging or diverging). Also, we understood the importance of the image construction due to a lens and how it changes with respect to the lens being used.

For the diverging lens we had, was very diffucult to verify its focal lenght and its magnification, this because all the experimental results we obtained from it diverged from the expected theoretical results and the lens factory specifications. We do not really know if the experiment and data collection was badly made, or there was an error with the factory specifications, or fabrication of the lens. Except for this problem, all went well and we could check focal lenghts and imaging with thin lenses.

References

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