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**Lab 7: Optics**

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PHYS 262 – 001

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**Objective**

The objective of this lab is to apply the theory of real objects, virtual objects, and the focal lengths of mediating lenses, and the relationships that bind these three quantities together.

**Theory**

When light passes through a lens, the direction that the light follows upon exiting the lens will have been adjusted by a factor proportional to the focal length of the lens. For a continuous area of projected light, this phenomenon results in a visible scaling either up or down of the image produced by the projection when viewed from the other side of the lens. This is known as magnification. Though this is easily described as a scaling in size, it is more accurately expressed as an illusory sort of adjustment to the distance between the object and the lens. We call the object that appears on the other side of the lens a *virtual* image, whereas the original projection is the *real* image. The distances of these images in relationship to the lens is expressed as the following.

Eq. 7-1

Where *d*0 is the distance of the real object from the lens, *di* is the distance between the virtual object and the lens, and *f* is the focal length of the lens. The focal length has a positive value for convex lenses, and opposite for concave lenses. Additionally, the virtual image distance can have a negative value if its perceived position is on the same side of the lens as the real object. The magnitude of the magnification experienced is expressed by the following:

Eq. 7-2

Where *M* is the factor of magnification, and *hi* and *h0* represent the heights of the virtual and real images respectively.

**Procedure**

For this experiment, we had at our disposal an optical bench with a centimeter ruler printed along its length, a 100 mm and 200 mm focal length lens, a screen upon which to project a magnification, and light source that projects a clear image. The light source was set up to at the 0 cm mark to project its image in a parallel direction to the bench. One of the lenses was placed on the bench; its position noted based on the ruler. At this point, an image should be passing through the lens. The screen at the end of the bench was adjusted on the bench until the inverted form of the projected image was clearly visibly cast upon it, with as little blurring or doubling as possible. Once this image was clear, the length of the image was measured. This process was repeated eight times for each lens.

**Data**

Shown below are the collections of length/distance measurements taken for each of eight runs for both lenses. Note that size measured height of the real image, *H0*, is **3 cm**.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 10 cm lens | | | | |
| Trial | d0 [cm] | di [cm] | f [cm] | Hi [cm] |
| 1 | 15 | 28 | 9.76744186 | 5.5 |
| 2 | 20 | 19.3 | 9.821882952 | 3 |
| 3 | 25 | 16.5 | 9.939759036 | 2 |
| 4 | 30 | 15 | 10 | 1.5 |
| 5 | 35 | 14 | 10 | 1.23 |
| 6 | 40 | 13.3 | 9.981238274 | 1.01 |
| 7 | 45 | 12.3 | 9.659685864 | 0.87 |
| 8 | 50 | 12.2 | 9.807073955 | 0.74 |

**Table 7-1.** The collection of centimeter measurements taken for real projection distance, virtual projection distance, the calculated focal length, and the measured height of the projected image for the image passing through the 100 mm lens.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 20 cm lens | | | | |
| Trial | d0 [cm] | di [cm] | f [cm] | Hi [cm] |
| 1 | 30 | 59 | 19.8876404 | 5.9 |
| 2 | 35 | 46.4 | 19.95086 | 3.94 |
| 3 | 40 | 40 | 20 | 2.99 |
| 4 | 45 | 36 | 20 | 2.39 |
| 5 | 50 | 33.2 | 19.9519231 | 2.01 |
| 6 | 55 | 31.4 | 19.9884259 | 1.71 |
| 7 | 60 | 30 | 20 | 1.52 |
| 8 | 65 | 29 | 20.0531915 | 1.38 |

**Table 7-2.** The collection of centimeter measurements taken for real projection distance, virtual projection distance, the calculated focal length, and the measured height of the projected image for the image passing through the 100 mm lens.

**Analysis**

**Focal Length**

Based on the data compiled into Tables 7-1 and 7-2, we can arrive at an experimental focal length by taking the intercept of the fit of the inverse value of the virtual distances versus the inverse of the real image distances, then inverting that value.

**Figure 7-1.** A plot of inverted virtual image distances versus real image distances and associated best-fit line for the 10 cm lens.

Thus, for the 10 cm lens, we have arrived at the following:

|  |  |
| --- | --- |
| Focal Length Results  10 cm lens | |
| f-1 [cm-1] | 0.1009 |
| f [cm] | 9.91 |
| %err | 0.90% |

**Table 7-3.** The experimental focal length and its error margin for the 10 cm lens.

Similarly, for the 20 cm lens:

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**Figure 7-2.** A plot of inverted virtual image distances versus real image distances and associated best-fit line for the 20 cm lens.

|  |  |
| --- | --- |
| Focal Length Results  20 cm lens | |
| f-1 [cm-1] | 0.0497 |
| f [cm] | 20.12 |
| %err | 0.60% |

**Table 7-4.** The experimental focal length and its error margin for the 20 cm lens.

**Magnification**

|  |  |  |  |
| --- | --- | --- | --- |
| Magnification – 10 cm lens | | | |
| Trial | Expected [cm] | Actual [cm] | %err |
| 1 | -1.8666667 | -1.833333333 | 0.01785714 |
| 2 | -0.965 | -1 | 0.035 |
| 3 | -0.66 | -0.666666667 | 0.01 |
| 4 | -0.5 | -0.5 | 0 |
| 5 | -0.4 | -0.41 | 0.02439024 |
| 6 | -0.3325 | -0.336666667 | 0.01237624 |
| 7 | -0.2733333 | -0.29 | 0.05747126 |
| 8 | -0.244 | -0.246666667 | 0.01081081 |

**Table 7-5.** The disparity between the expected and actual magnifications for the 10 cm lens.

|  |  |  |  |
| --- | --- | --- | --- |
| Magnification – 20 cm | | | |
| Trial | Expected [cm] | Actual [cm] | %err |
| 1 | -1.9666667 | -1.9666667 | 1.129E-16 |
| 2 | -1.3257143 | -1.3133333 | 0.00933908 |
| 3 | -1 | -0.9966667 | 0.00333333 |
| 4 | -0.8 | -0.7966667 | 0.00416667 |
| 5 | -0.664 | -0.67 | 0.00895522 |
| 6 | -0.5709091 | -0.57 | 0.00159236 |
| 7 | -0.5 | -0.5066667 | 0.01315789 |
| 8 | -0.4461538 | -0.46 | 0.03010033 |

**Table 7-6.** The disparity between the expected and actual magnifications for the 20 cm lens.

**Conclusions**

Between the magnification and focal length measurements, the results of these experiments lined up surprisingly well (compared to other labs). This is probably due to the less sensitive nature of the static light cones, lenses, and screen positions that needed to be measured. Overall, with very low error margins for the magnification comparisons, as well as very cooperative results in terms of the derived focal lengths, it is clear that these theories of optics hold up very well for macroscopic-scale experiments such as these.