LAB 13 — 05/01/2025

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Introduction: Lenses are an essential component in optics, being the way we interpret the world. If the lens of a camera can distort its picture, it is not unreasonable to expect that the lenses in our eye are capable of changing our view of the world. Understanding the ways in which differing lenses alter the image we perceive is paramount in understanding the accuracy of our view of the world. Within this lab we intend to investigate the ways in which lenses alter the paths of the light rays that pass through them.

Problem 1: Focal Lengths

Materials: Meter stick, set of lenses numbered 1-6, light source, meter stick.

Methods/Procedures: Each lens has a different focal length. 1-5 are converging lenses and 6 is a diverging lens. For 1-5, find a very distant light source, like the light from outside a window, and find the distance from an opaque surface required for the image to come into focus. Measure this distance as it is the focal point. For lense 6, use the closer light source. Find the point at which the image through the lens halves in size in order to find the focal point and measure this distance

Data/Results: Lens 1 had a focal length of 25cm, 2 and 3 had focal lengths of 20 cm, 4 and 5 had a focal length of 10 cm. Lens 6 had a focal length of 15cm.

Data Analysis: The reason that the focal length of the converging lenses could be found by measuring the distance between the lens and the point where the light focuses is because the light will focus at the focal point, hence the name. Figure 1 provides a light ray diagram for the converging lens. The reason that the light source must be far away from the lens is so that the wavefronts resemble plane waves with virtually no curvature. This creates the conditions for parallel light waves entering the lens to then be converged. This is how a telescope works except that a second converging lens will return them to parallel.

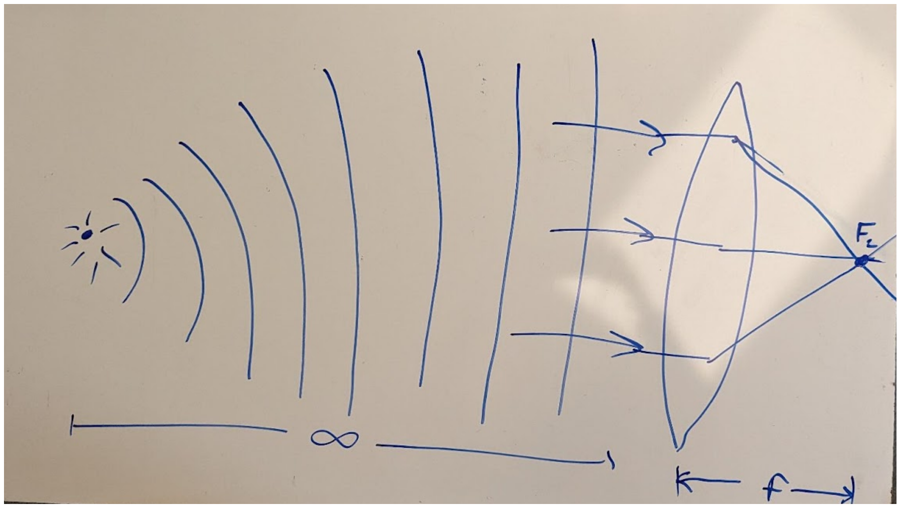

Figure 1

The diverging lens's focal point being found at the point where the image halves in size can be seen in the ray diagram in figure 2. An object at or closer than the focal distance will change size as the lens changes distance from it. At the focal length, this will be ½ the original size. The reason that the image appears smaller is because the virtual image, found by tracing the refracted rays, will appear smaller. The linear line dictating this relationship can be found by tracing from top of the extended object to the point where the optical axis meets the center of the lens. This is the reason that a diverging lens can widen the field of view as it approaches the eye.

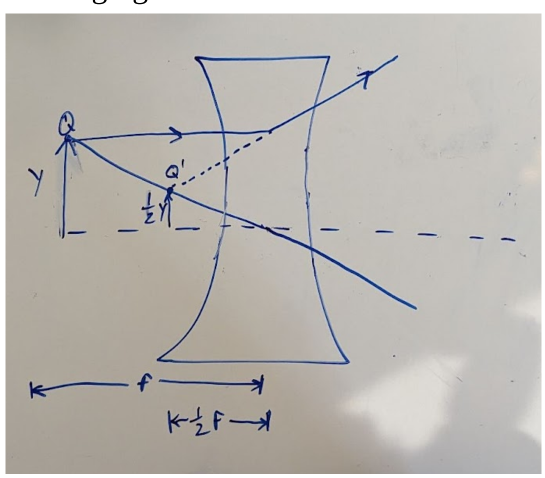

Figure 2

Problem 2: Near and Far

Materials: Human eyes, phone camera, meter stick.

Methods/Procedures: While keeping your fingerprint in focus, bring your finger as close as possible to your eye before it unfocuses. Measure this distance as the near point. Do the same in the opposite direction to find the far point. Repeat using a phone camera as well.

Data/Results: The measured near point distances: Jonah (with glasses), 9.2 cm. Alec, 7.0 cm. Elias, 10.5 cm. Phone, 8.5 cm.

Data Analysis: Given the distance from the lens to the retina, 2.5 cm, the focal length can be calculated using the thin lens formula.

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f}$$

Calculated focal length for each person: Jonah (with glasses), 1.966 cm. Alec, 1.842 cm. Elias, 2.019 cm. The optical power is given by $P = 1/f$ (units converted to meters): Jonah, 50.9 dpt (diopter). Alec, 54.3 dpt. Elias, 49.5 dpt.

We were unable to measure our far points because they were beyond the length of our arms and can be assumed to be infinite. In this case, our focal lengths were all infinite. The optical power is the reciprocal: 0. The difference in power here is technically "infinite", but if we were able to more accurately measure our far points, it would likely be with-in healthy limits, as our near points were all close to the human average of 11 cm (Wikipedia).

Elias' phone's near point was 8.5 cm away from the lens, giving an optical power, assuming that the lens is no more than 0.1 cm away from the sensor, of: 1011.8 dpt. This power is much higher than the human eye and it is mainly caused by the short distance between the camera's lens and the sensor. We again did not get to measure the far point, but the camera's accommodation is likely much greater than the human eye given the magnitude of the optical power for the near point.

Conclusion:

Starting by confirming the behavior of both converging and diverging lenses, we measured 5 separate converging lenses focal points to be 25cm, 20cm, 20cm, 10cm and 10cm. Through this we were able to determine the general behavior in which light waves interact with a lens, though only for a distant light source. We also investigated the properties of a diverging lens, determining the distance for a ½ magnification for our lens to be around 15cm, we understand this phenomenon to be due to the virtual image, which can be located by tracing the path the light rays would take while being refracted by the lens, appearing smaller. We also investigated the concepts of near and far points, alongside lens power. We found the lens power of the human eye, with respect to the average near point around 10-11 cm away from the lens, to be around 50 dpt (in-line with the real value of 40-60 dpt). Through lenses we view the world, understanding their behavior is essential for the development of laser technologies, digital cameras and important for understanding biology. Understanding the ways in which evolution has mastered lenses, mixed with the concepts we can prove through simple experimentation, we can refine our understanding of optics.