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LAB REPORT: HUMAN EYE, A BIOPHYSICS LABORATORY

1 Overarching Goal

The human eye can be described as a complex optical instrument that focuses light rays using a muscular tissue (the eye lens) and a light-sensitive layer that converts the focused light into electrical signals transmitted to the brain. The focus of this lab report is to utilize the knowledge of our previous labs on geometriclens modeling to apply it at a fundamental level to generalize the behaviour of the human eye and study is relation to common eye disseases.

2 Theory

As light travels through space, its interaction with matter affects the speed at which the electromagnetic waves that carry it move through a medium. These interactions produce refraction, a phenomenon that can be described at the macroscopic scale by Snell's law, $n_1 sin(\theta_1) = n_2 sin(\theta_2)$, where n_1 and n_2 are the indices of refraction of the two media, and θ_1 and θ_2 are the angles measured with respect to the normal to the surface. Rather than tracking individual light–matter interactions, this description allows the overall bending of light to be predicted using simple geometric relationships.

In the geometrical optics approximation, the propagation of light through refracting surfaces is modeled using rays, which trace the direction of light and provide an intuitive picture of how images are formed. This ray-based model makes it possible to describe complex optical systems using a small set of distances and angles. When applied to ideal lenses and restricted to small angles relative to the optical axis, these relationships reduce to the thin-lens equation:

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

where:

- f is the focal length (in m)
- d_o is the object distance (in m)
- d_i is the image distance (in m)

This equation provides a direct way to predict where an image will form once the focal length of the lens is known.

The focal length itself depends on the physical properties of the lens. This dependence is described by the lens maker's equation,

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where:

- n is the index of refraction of the lens material and
- R_1 and R_2 are the radii of curvature of the lens surfaces.

Although highly simplified, together these model captures the essential behavior of many real optical systems. In particular, it provides a useful framework for understanding the human eye as an imaging system, where changes in lens shape and focal length determine how light is brought into focus on the retina. In the case of the human eye, the lens is flexible, and surrounding muscles can change its curvature. By altering the radii of curvature, the eye effectively changes its focal length, allowing objects at different distances to be brought into focus on the retina.

3 Apparatus

3.1 Homemade Eye Model

Our setup for this section consisted of a "screen" (a plane where the light was focused), a convex lens placed 20 cm from the screen, and an object placed 22.5 cm from the convex lens. All measurements were conducted in a dark environment to allow for greater precision.

3.2 Variable Lens Model

Fixed Lens Test

Before beginning the experiment, we tested the PASCO eye model by placing a 400 mm focal length lens in the SEPTUM slot and positioning an object 50 cm from the lens.

Variable Lens

Afterwards, the variable lens was filled with water until its membrane was flat. The connecting tube was then attached to a syringe, which was filled approximately three-quarters full. The tube was reconnected to the variable lens, replacing the previous 400 mm lens in the setup.

4 Purpose of Each Activity

Activity 1.

To construct a simplified physical model of the human eye and establish its correspondence with the geometrical optics framework introduced in the theory section, identifying how the retina, lens, and optical axis are represented within the thin-lens approximation.

Activity 2.

To incorporate a variable-focus lens into the eye model in order to simulate the eye's ability to accommodate, directly applying the thin-lens equation to demonstrate how changes in focal length affect image formation on the retina.

Activity 3.

To quantitatively determine the magnitude of the focal length adjustment required for proper retinal imaging, using the thin-lens equation to relate object distance, image distance, and lens focal length in the context of the human eye.

Activity 4.

To analyze common eye diseases by interpreting them as deviations from the idealized optical model, using the thin-lens and lens maker's equations to understand how changes in curvature or effective focal length lead to impaired vision.

5 Method

1. Step 1
2. Step 2
3. Step 3

6 Data

6.1 Variables and Hypothesis

- **Independent Variable:**

- **Dependent Variable:**
- **Control Variables:**
- **Hypothesis:**

6.2 Measured Data

Table 1: Measured Data

Quantity	Value	Units
Sample 1	0.00	m
Sample 2	0.00	m

7 Calculations

$$y = mx + b$$

8 Results

- Result 1: 0.00 units
- Result 2: 0.00 units
- Absolute/Percent Error: 0%

9 Conclusion & Questions

- Conclusion point 1
- Conclusion point 2

Questions

1. Answer to question 1

2. Answer to question 2

10 Above and Beyond