Lesson Plan

Title
Focusing on Lenses
Primary Subject Area
Physics: Geometric Optics
Grade Level
11-12
Overview
Students will investigate what parameters can be varied to focus a lens or lens pair at different distances and magnifications. They will be able to describe the differences in the ways that an eye, a camera, and a telescope use lenses and will be able to create models of each. Students will learn about adaptive optics and how it can be used to improve an image.
Approximate Duration
Two 85 minute periods.
MA Frameworks
4.4 Describe qualitatively the basic principles of reflection and refraction of waves. 6.5 Explain the application of electromagnetic signals in fiber optic technologies, including critical angle and total internal reflection.
Interdisciplinary Connections
Biology: • The manner in which the lens of an eye focuses an image on the back of the retina is described by lens equations. • Adaptive optics can be used to image the back of the retina by compensating for the distortion that results from the light passing through the eye itself. Photography: • Cameras make use of geometric optics to focus and zoom an image. Astronomy: • Telescopes both magnify and amplify an image. Adaptive optics is used to minimize distortion due to the atmosphere.
Lesson Objectives
• To be able to find the focal length of a lens by focusing on a distant object and by finding the relationship between the distance from the lens to the object and the distance from the lens to the image. • To be able to magnify an image using a single lens and a pair of lenses. • To be able to create models of the eye, a camera, and a telescope. • To understand how adaptive optics is used to improve images.
Lesson Materials and Resources
• Lens Ray Tracing Diagrams • Lens Lab Handout
Technology Tools and Materials
• Vernier Dynamics System • Optical Expansion Kit • LoggerPro Software
Background Information
Refraction The speed of light in a vacuum is c, 3.0×10^8. When light travels through a medium its speed is given by $v = c/n$ where n is the index of refraction of the medium. When it crosses a boundary of two media at an angle the light bends. The angles between the rays of light and a line perpendicular to the boundary are related by Snell's law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$.

Types of lenses/Focal length

The curvature of the surface of a lens and its index of refraction will cause light to bend as it passes through the lens. When parallel rays of light enter a lens that is thicker in the center than at the edges (a converging lens), the light is bent and all beams converge at the focal point on the opposite side of the lens. If the lens is thinnest at its center (a diverging lens) then beams of light entering it will bend away from the center line. If you extend these lines they will intersect at a point (the focal point) on the same side of the lens as the entering light. The distance from the lens to the focal point is called the focal length.

Focus and Magnification

Rays of light entering a lens from an object that is a distance d_o from the lens will be focused at a distance d_i from the lens. The location of the image can be found by the equation $1/f = 1/d_i + 1/d_o$. The magnification of the image will depend on the ratio of the distances: $M = -d_i/d_o$. The distance to the image is negative when it is on the same side of the lens as the object (a virtual image). Otherwise, if the image is on the opposite side of the lens then a real image is formed. The sign of the magnitude indicates whether the image will be upright (positive M) or inverted. Real images are inverted and virtual ones are upright.

Useful Vocabulary

New Vocabulary Word	Meaning
Focal length	The distance from a lens at which rays coming from a distant source are refracted to intersect at a single point.
Field of View	The area that can be viewed through a lens, measured in degrees.
Adaptive Optics	The use of deformable mirrors and a wavefront sensor to minimize the distortion of a wavefront and provide a clearer image.

Essential Questions to be answered; Grand Challenges

What affects where an image will be in focus?

How do lenses magnify images?

What is different about the ways that eyes, cameras, and telescopes use optics to focus images?

Misconceptions

The eye and the camera use the same focusing mechanism.

Lesson Procedures

1) Opener: Show a picture of an eye, a camera, and a telescope and ask what they have in common and how they differ. Assuming students can identify that they all use lenses, ask what a lens does and how these focusing systems use lenses.

2) Introduce ray diagrams to show how and why a lens generates a focused image. Have students draw the refracted beams building on their knowledge of Snell's Law. Demonstrate beams being refracted through a converging lens and through a diverging lens by shining a laser through a lens in the presence of a humidifier so the path of the laser is visible.

3) Lab Part I: Finding focal length by focusing a distant object.

- Find the focal length of various lenses by holding a lens in front of a screen and moving the lens away from or toward the screen until an image for a distant object appears on the screen. Measure the distance between the lens and the screen. This is the focal length.
- Repeat with different lenses.
- Draw a ray diagram for the experiment.

4) Lab Part II: Finding focal Length by finding the relationship between image and object distances.

- On the Vernier optics track set up a light source, a lens, and a screen. Place the lens a selected distance from the light source. Record this distance as the object distance. Move the screen until the image projected by the light source is in focus. Record the distance from the lens to the screen as the image distance. Record the size of the image on the screen.
- Repeat the experiment for at least five different object distances and graph the reciprocal of the object distance vs. the reciprocal of the image distance.
- Use your graph and your knowledge of lenses to find the focal length of the lens.
- Find the relationship between the distances, the focal length and the size of the image.
- Calculate where the lens should be placed so the image size is twice the object size and use the optics bench to check your calculation.

5) Lab Part III: Two lens systems

- Position two lenses between the light source and the screen to create an image that is twice the object size. What are the focal lengths and distances of the lenses?

6) Research/Lecture about the operation of eyes, cameras, zoom lenses, telescopes.
7) Create models of these using the optics bench. For example, for an eye keep the light source, lens, and screen in the same place and figure out what can be changed to get an image in focus.
8) Lecture/Video on adaptive optics.

Assessment Procedures

- Lab report
- Lens quiz
- Optics test

Accommodations/Modifications

Reproducible Materials

Explorations and Extensions

Lesson Development Resources

Reflections

Contact Information

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