Teacher Toolkit

Topic:

Image Formation by Lenses

Objectives:

1. Students should be able to describe the manner in which light refracts through converging and diverging lenses and explain why such refraction results in the formation of a real or a virtual image.
2. Students should be able to construct ray diagrams to demonstrate where images are formed for objects located varying distances from a lens and be able to describe the characteristics of the resulting images that are formed.
3. Students should be able to use the lens equation and the magnification ratio equation to solve problems involving the formation of images by lenses.
4. Students should be able to explain the function of a lens as a component in an optical system such as the eye, a camera, a microscope, or a telescope.

Readings:

The Physics Classroom Tutorial, Refraction and the Ray Model of Light Chapter, Lesson 5
http://www.physicsclassroom.com/class/refrn/Lesson-5/The-Anatomy-of-a-Lens

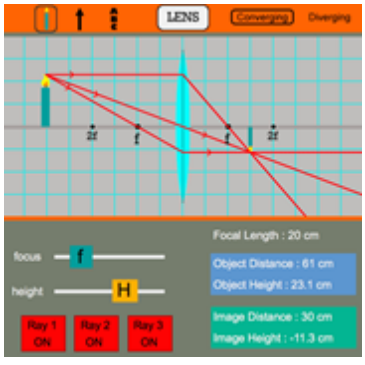
The Physics Classroom Tutorial, Refraction and the Ray Model of Light Chapter, Lesson 6
http://www.physicsclassroom.com/class/refrn/Lesson-6/The-Anatomy-of-the-Eye

Interactive Simulations:

1. Optics Bench – Lenses

   http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Optics-Bench

   The Optics Bench simulation from The Physics Classroom's Physics Interactive section provides users with an interactive Optics Bench for studying both mirrors and lenses. The lens shape can be toggled between Converging and Diverging. Object height and location can be easily modified along with the focal length of the lens. The image of the object is shown. Principal rays can be toggled on and off. Users can select a candle, an arrow, or a stack of letters as the object. The simulation is accompanied by a classroom-ready exercise that provides directions for understanding the effect of object location and focal length upon the characteristics of the image.



2. Molecular Expressions: Image Formation with a Converging Lens

http://micro.magnet.fsu.edu/primer/java/lenses/convergingglenses/index.html

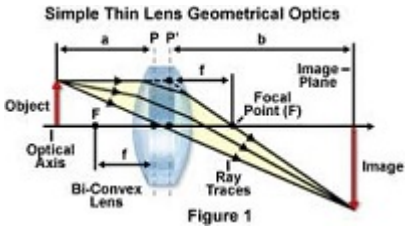


Figure 1

This simulation uses ray traces to explore how images are formed by converging lenses. Move the object back & forth along the optical axis to see the effects on the image size and placement. Object distance (p) and image distance (q) are automatically generated.

3. Molecular Expressions: Image Formation with a Diverging Lens

http://micro.magnet.fsu.edu/primer/java/lenses/divergingglenses/index.html

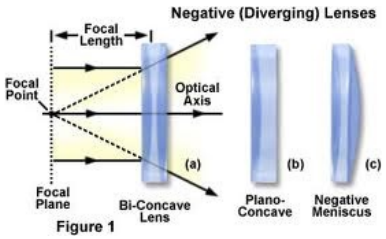
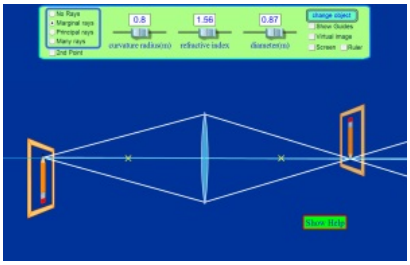


Figure 1

Companion to the resource above, this simulation explores the refraction of light through a concave (diverging) lens. Like its companion, this simulation also continuously updates the changing object distance (p) and image distance (q).

4. PhET Geometric Optics

http://phet.colorado.edu/en/simulation/geometric-optics



Robust model for exploring how images are formed by a converging lens. Choose from a variety of object shapes, then view the principal and marginal rays. You can change the lens curvature & diameter and watch what happens to focal length. Move the object to see when the image changes from real to virtual.

Supplementary Materials from PhET: Student guide, Power Point Warm-Up Questions

http://phet.colorado.edu/en/contributions/view/2852

5. Molecular Expressions: Lens Shape

http://micro.magnet.fsu.edu/primer/java/scienceopticsu/variablelens/index.html

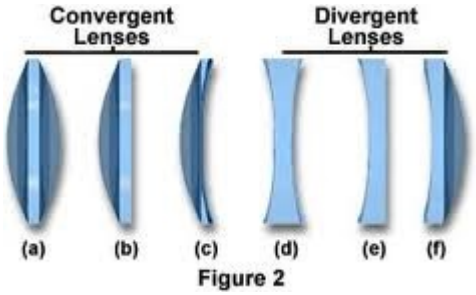


Figure 2

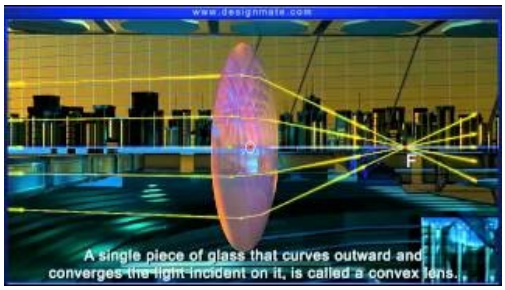
Very simple, but effective way to explore the connection between lens shape and light refraction. Two sliders let you produce shapes ranging from a thick bi-convex lens to a thin bi-concave lens. Build your lens and watch the incident rays converge or diverge. (Great conceptual tool for beginners.)

Video and Animation:

1. Converging Lenses: Designmate

   https://www.youtube.com/watch?v=R-uMcngNsSk&list=UUy8jYKZEavfitnik_IwgUpQ

   Beautifully animated 7-minute video explores the refractive function of the convex lens in a way that just can't be conveyed in still images. Concepts are well-reinforced with explanations of relevant vocabularies: focal point, focal length, and principal axis.



2. Light and Lenses: Using Lenses to Form Images

   https://www.youtube.com/watch?v=TroFa0HrA5Q

   Well executed professionally-produced video from Education Commons -- takes a deep dive into light refraction through convex lenses. Demonstrates how to use and draw ray diagrams in a manner comprehensible to the novice. *Appropriate for beginners and for students with reading disabilities.*

3. PBS Learning Media: Cow's Eye Dissection

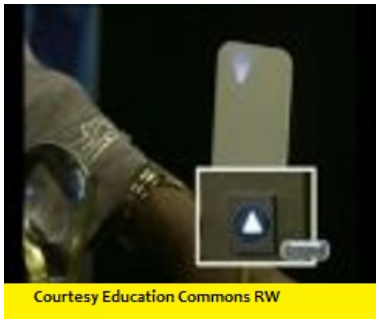
   http://www.pbslearningmedia.org/resource/lsps07.sci.life.stru.coweye/cows-eye-dissection/

   Before you dismiss this as too juvenile, it's a good way to show light refraction through a mammal's lens without going to biology lab. It's segmented into 13 videos showing the sclera, cornea, iris, pupil, lens, retina, and optic nerve. As you peer through the cow's lens, you can see an inverted image.

4. Light and Lenses: Images and Convex Lenses

   https://www.youtube.com/watch?v=nLC86OwDXD0

   Companion to #2 above, this video could be utilized in a flipped lesson. It demonstrates with great clarity how to draw a ray diagram when an object is placed in front of a convex lens. Includes animated ray diagrams that will help students understand the concept of real vs. virtual image.



Labs and Investigations:

1. The Physics Classroom, The Laboratory, Exploring Lenses Lab
   Students look through converging and diverging lenses at the image of nearby and distant objects and describe their orientation and relative size.
2. The Physics Classroom, The Laboratory, L•O•S•T Art of Image Description
   Students place a converging lens on an optics bench and investigate how the object location affects the characteristics of the image that is formed.
3. The Physics Classroom, The Laboratory, Lens Equation Lab
   Students collect data for the dependence of the image distance upon the object distance for a converging lens. By plotting and analyzing the data, an equation relating these two quantities is derived.

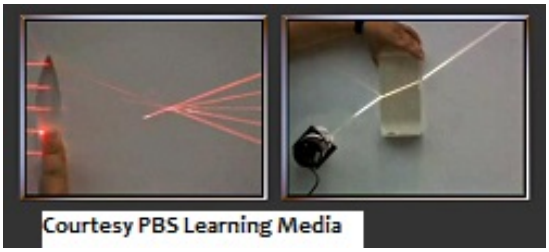
Link: http://www.physicsclassroom.com/lab#refrn

Demonstration Ideas:

1. PBS Learning Media: Refraction of Light Demo

   http://www.pbslearningmedia.org/resource/lsps07.sci.phys.energy.refractdemo/refraction-of-light-demonstration/

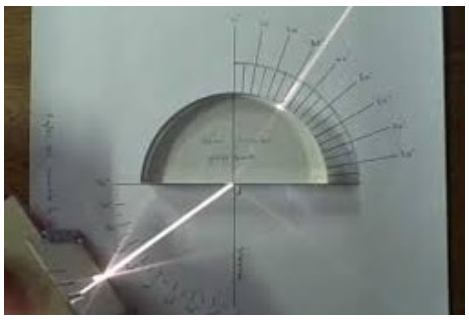
   Nicely packaged interactive activity adapted from the Rutgers Physics/Astronomy Education Research Group. Clearly shows the convergence of light beams through a convex lens, divergence of beams through a concave lens, and light interaction with a transparent rectangular glass block. *Allow 10-15 minutes.*



2. Snell's Law of Refraction

   https://www.youtube.com/watch?v=yfawFJCRDSE

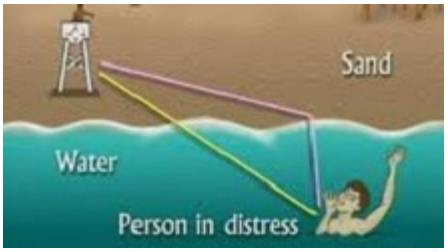
   Good resource if you don't have an optics kit. Video demonstrates light being shone through a glass block shaped like a half-circle. Underneath the glass a paper template allows the demonstrator to train the light to accurate angles of incidence. Watch the refraction as the light source is moved in 5-degree increments.



3. PBS Learning Media: Observing Refraction of Light

   http://www.pbslearningmedia.org/resource/lsps07.sci.phys.energy.lightrefract/observing-refraction-of-light/

   We like this short video/demo for two reasons: 1) It gives a great analogy of light taking the fastest path, and 2) It features Christine Jones, senior astrophysicist at the Harvard-Smithsonian Center for Astrophysics.



Minds On Physics Internet Modules:

The Minds On Physics Internet Modules are a collection of interactive questioning modules that target a student's conceptual understanding. Each question is accompanied by detailed help that addresses the various components of the question.

1. Refraction and Lenses, Ass't RL7 - Converging vs. Diverging Lenses
2. Refraction and Lenses, Ass't RL8 – Converging Lenses – Ray Tracing
3. Refraction and Lenses, Ass't RL9 – Converging Lenses – Image Characteristics
4. Refraction and Lenses, Ass't RL10 – Diverging Lenses – Ray Tracing
5. Refraction and Lenses, Assignment RL11 – Diverging Lenses – Image Characteristics

Source: http://www.physicsclassroom.com/mop

Conceptual Building Exercises:

1. The Curriculum Corner, Refraction and Lenses, Lenses
2. The Curriculum Corner, Refraction and Lenses, Ray Diagrams for Converging Lenses
3. The Curriculum Corner, Refraction and Lenses, Ray Diagrams for Diverging Lenses

Source: http://www.physicsclassroom.com/curriculum/refrn

Problem-Solving Exercises:

1. The Calculator Pad, Refraction and Lenses, Problems #19-32

Source: http://www.physicsclassroom.com/calcpad/refrn

Science Reasoning Activities:

1. Science Reasoning Center, Refraction, Lens Magnification Lab
   Source: http://www.physicsclassroom.com/reasoning/refraction

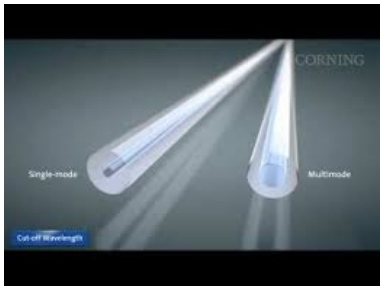
2. ACT Test Center, Depth of Field
   Source: http://www.physicsclassroom.com/actprep

Real Life Connections:

1. Corning, Inc: Fiber 101

   http://www.corning.com/uploadedFiles/OpticalFiber/Assets/Video/Optical%20fiber_animation_FINAL_360_300k.wmv

   Without being too commercial, this 6-minute video explores the basics of optical fiber, its composition, and its capabilities. Animations clearly show how light rays undergo total internal reflection within the core of the

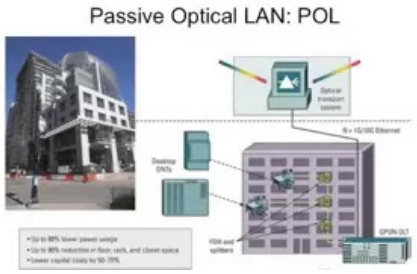


cable. Fiber optics is a field of promise for both engineers and people with 4-year degrees.

2. Fiber Optic Association: Where are the Jobs in Fiber Optics?

   https://www.youtube.com/watch?v=8tJhCTxnMoQ

   Career exploration of jobs in fiber optics that do not require a doctorate but DO require knowledge of physics. Wireless communications come to mind immediately, but this 22-minute video also looks at energy, security, manufacturing, and entertainment. Not the glitziest video, but gives solid information.



Common Misconceptions

1. Image Formation and the Role of the Lens

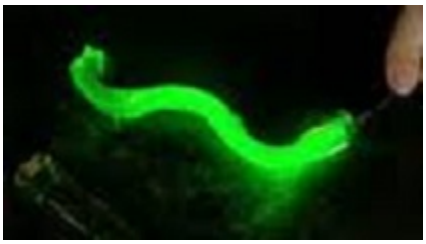
   Many students believe that only a portion of the lens is involved in creating the a single portion of an image. Their impression is that if half of a lens is used instead of a full lens, then only half of an image is formed. The fact is that a multitude of light rays from a single point on the object will pass through the lens at various locations. For this reason, the removal of a section of the lens will not result in the removal of a section of the image.

2. Virtual Images

   Many students are under the false impression that virtual images cannot be seen (despite the fact that they look at one everyday in a plane mirror). Virtual images are formed when light rays diverge after passage through a lens; as such virtual images are located at a location where the refracted rays are not actually arriving. This means that they cannot be projected onto a sheet of paper. But if one were to look through the lens at the virtual image location, they will sure enough see the upright image of the object.

Elsewhere on the Web:

1. Science Channel: Gelatin Fiber Optics
   http://www.sciencechannel.com/tv-shows/head-rush/videos/head-rush-gelatin-fiber-optics.htm
   Very short (1.5 minute) video/demo asks a question: What will happen to a beam of light from a laser pointer if shined into a squiggly length of gelatin? Answer: it "bounces around" due to total internal reflection in a way similar to optical fibers. Try it as a warm-up question.



   Companion Lesson Plan from PBS Learning Media

   http://www.pbslearningmedia.org/resource/ate10.sci.phys.energy.lpoptic/fiber-optics/

Standards:

A. Next Generation Science Standards (NGSS) – Grades 9-12

Performance Expectations - Waves and Their Applications in Technologies for Information Transfer:

- **HS-PS4-1**: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Disciplinary Core Ideas - Electromagnetic Radiation

- **MS-PS4.B.i:** When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- **MS-PS4.B.ii** : The path that light travels can be traced as straight lines, except at surfaces between different transparent material and the frequency (color) of the light.

Crosscutting Concepts

Patterns:

- Empirical evidence is needed to identify patterns (HS)

Systems and System models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions – including energy, matter, and information flows – within and between systems. (HS)

Science and Engineering Practices

Practice #1: Developing and Using Models

- Use a model to provide mechanistic accounts of phenomena.
- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

Practice #4: Analyzing Data

- Analyze data using computational models in order to make valid and reliable scientific claims.

Practice #5: Using Mathematics and Computational Thinking

- Use mathematical representations of phenomena to describe explanations.
- Create a computational model or simulation of a phenomenon, process, or system.

Practice #6: Constructing Explanations

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Practice #8: Obtaining, Evaluating, and Communicating Information

- Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

B. Common Core Standards for Mathematics (CC) – Grades 9-12

Standards for Mathematical Practice:

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Model with mathematics.

High School Algebra – Seeing Structure in Expressions

- **A-SSE.2**: Use the structure of an expression to identify ways to rewrite it.

High School Algebra – Creating Equations

- **A-CED.4**: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

High School Functions – Interpreting Functions

- **F-IF.4**: For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities.

High School Functions – Building Functions

- **F-BF.1.a**: Determine an explicit expression, a recursive process, or steps for calculation from a context.

High School Geometry – Expressing Geometric Properties with Equations

- **G-GPE.6**: Find the point on a directed line segment between two given points that partitions the segment in a given ratio.

C. Common Core Standards for English/Language Arts (ELA) – Grades 9-12

Key Ideas and Details

- **RST.11-12.2** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

Craft and Structure

- **RST.11-12.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11—12 texts and topics.

Integration of Knowledge and Ideas

- **RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Range of Reading and Level of Text Complexity

- **RST.11-12.10** By the end of grade 12, read and comprehend science/technical texts in the grades 11—CCR text complexity band independently and proficiently.

D. College Ready Physics Standards (Heller and Stewart)

Standard 4: Energy Transfer and Storage

Objective 4.4: Radiant Energy Interactions (Middle School)

- **M.4.4.2** Light sources radiate energy continually from each point on the source in all directions. The light travels in straight lines outward until it encounters and interacts with other objects in the surroundings.

Objective 4.4: Radiant Energy Interactions (High School)

- **H.4.4.1** Light energy interactions with solid barriers or the interface between two materials exhibit patterns of reflection, refraction, diffraction, and interference similar to the interactions of mechanical waves with barrier sand interfaces.
- **H.4.4.2** When light energy from a source ($E_{incident}$) reaches a boundary between materials with different optical properties (such as air to water), a portion of the energy is reflected at the boundary ($E_{reflected}$), and a portion of the energy passes through the boundary into the material ($E_{material}$). At such a boundary, the conservation of energy principle can be mathematically represented.
- **H.4.4.7** Light energy passing through a transparent material is absorbed and then reemitted by each atom in its path. Consequently light has a slower speed through materials than the speed of light in a vacuum. The speed of light between atoms, however, is the constant speed of light in a vacuum.