Teacher Toolkit - 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, Lessons 5 and 6

Interactive Simulations:

1. Image Formation with a Converging Lens http://micro.magnet.fsu.edu/primer/java/lenses/converginglenses/index.html
   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.
2. Image Formation with a Diverging Lens http://micro.magnet.fsu.edu/primer/java/lenses/divergingglenses/index.html
   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).
3. 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.
4. Physlet Physics: Virtual Optics Bench http://www.compadre.org/Physlets/optics/illustration35_1.cfm
   Flexible model lets users add various optical elements (lens, mirror, aperture) and light sources (beam, object, point source) and watch the effects. With the wide array of tools, this sim can be customized for novice or more advanced learners.
5. Molecular Expressions: Lens Shape http://micro.magnet.fsu.edu/primer/java/scienceopticsu/variablelens/index.html
   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: http://www.physicsclassroom.com/lab#refrn

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.

Demonstration Ideas: (Full descriptions and links in the Complete Toolkit at TPC's Teacher Toolkit website)

1. PBS Learning Media: Refraction of Light Demo
2. Snell's Law of Refraction
3. PBS Learning Media: Observing Refraction of Light

Minds On Physics Internet Modules: http://www.physicsclassroom.com/mop

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

1. Refraction and Lenses, Assignment RL7 - Converging vs. Diverging Lenses
2. Refraction and Lenses, Assignment RL8 – Converging Lenses – Ray Tracing
3. Refraction and Lenses, Assignment RL9 – Converging Lenses – Image Characteristics
4. Refraction and Lenses, Assignment RL10 – Diverging Lenses – Ray Tracing
5. Refraction and Lenses, Assignment RL11 – Diverging Lenses – Image Characteristics

Conceptual Building Exercises:

The Curriculum Corner, Refraction and Lenses, http://www.physicsclassroom.com/curriculum/refrn
1. Lenses 2. Ray Diagrams for Converging Lenses 3. Ray Diagrams for Diverging Lenses

Problem-Solving Exercises: http://www.physicsclassroom.com/calcpad/refrn

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

Science Reasoning Activities:

1. Science Reasoning Center, Lens Magnification http://www.physicsclassroom.com/reasoning/refraction
2. ACT Test Center, Depth of Field http://www.physicsclassroom.com/actprep

Real Life Connections (See the complete toolkit at TPC's Teacher Toolkit website for links and details.)

1. Corning, Inc: Fiber 101
2. Fiber Optic Association: Where are the Jobs in Fiber Optics?

Common Misconceptions (See the complete toolkit at TPC's Teacher Toolkit website.)

Elsewhere on the Web (See the complete toolkit at TPC's Teacher Toolkit website.)

Standards:

A. Next Generation Science Standards (NGSS) – Grades 9-12
Performance Expectations - Waves and Their Applications in … : HS-PS4-1
Disciplinary Core Ideas - Electromagnetic Radiation: MS-PS4.B.i and **MS-PS4.B.ii**
Crosscutting Concepts: Patterns and **Systems and System Models**
Science and Engineering Practices: #1, #4, #5, #6, and #8

B. Common Core Standards for Mathematics (CC) – Grades 9-12
(See the complete toolkit at TPC's Teacher Toolkit website for details.)

C. Common Core Standards for English/Language Arts (ELA) – Grades 9-12
Key Ideas and Details RST.11-12.2 and **RST.11-12.3**
Craft and Structure RST.11-12.4
Integration of Knowledge and Ideas RST.11-12.9
Range of Reading and Level of Text Complexity RST.11-12.10

D. College Ready Physics Standards (Heller and Stewart)
(See the complete toolkit at TPC's Teacher Toolkit website for details.)