Beam Focusing Using Lenses

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Subject: Principles of Engineering
Level: Grade 11/12
Standards: **NYS: Mathematics, Science, and Technology Education**
Standard 1: Analysis, Inquiry, and Design
Standard 2: Information Systems
Standard 3: Mathematics
Standard 4: Science
Standard 5: Technology
Standard 7: Interdisciplinary Problem Solving
Schedule: 4, 80 minute classes

Objectives:

Construct a beam-focusing unit, using optics, to focus a light beam from an (Light Emitting Diode) LED onto a single spot for maximum resolution on a photoresistor.

Students will:

- Identify how each of the different types of lenses magnify and focus the light from an LED
- Determine the focal length of each lens
- Design and construct a working prototype of beam focusing unit using various lenses
- Identify 4 types of lenses
- Sense the coming beam via transmission through a photoresistor and Fischertechnik software
- Determine the beam intensity

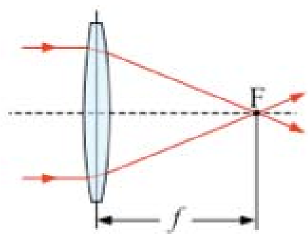
Vocabulary

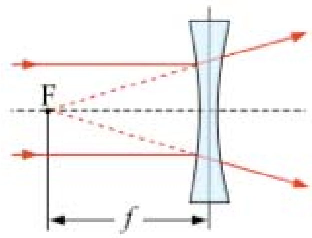
Optics
Light Diffraction
Photoresistor
LED
Concave
Convex
Focal Length
Light Columniation

Materials: Per group of 3

* LED (1)
* Fischertechnik kit
* Various magnification lenses
* Photoresistor
* Superglue
* 8.5"x11"x1/16" Black plastic sheets
* Scissors
* Exacto Knife
* Play dough
* Connecting wires (+/-)
* 9V Power Supply

Science Content for the Teacher: The focal length of an optical system is a measure of how strongly the system converges (focuses) or diverges (defocuses) light. For an optical system in air, it is the distance over which initially collimated rays are brought to a focus. A system with a shorter focal length has greater optical power than one with a long focal length; that is, it bends the rays more strongly, bringing them to a focus in a shorter distance.





$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)d}{nR_1R_2}\right]$$

$$\mathrm{FFD} = f\left(1 + \frac{(n-1)d}{nR_2}\right)$$

$$\mathrm{BFD} = f\left(1 - \frac{(n-1)d}{nR_1}\right)$$

Variables

Front focal distance (FFD) = distance from the front focal point of the system to the vertex of the *first optical surface*

Back focal distance (BFD) = distance from the vertex of the *last optical surface* of the system to the rear focal point

f = focal distance (unit of length)

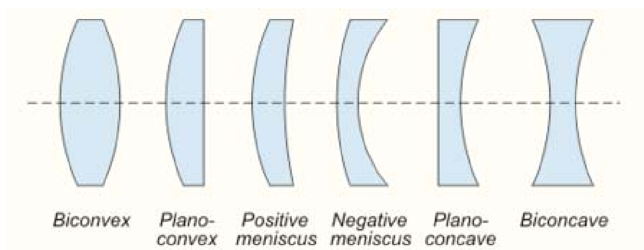
n = refractive index (=1.0003 in air)

R1, R2 = radii of curvature of lens

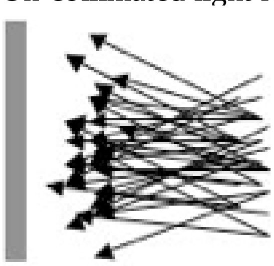
d = lens thickness

Source: wikipedia.org, data confirmed by "Text-Book of Physics" by S.E. Coleman, p.406

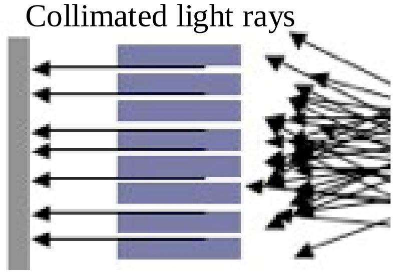
Types of lenses



Un-collimated light rays



Collimated light rays



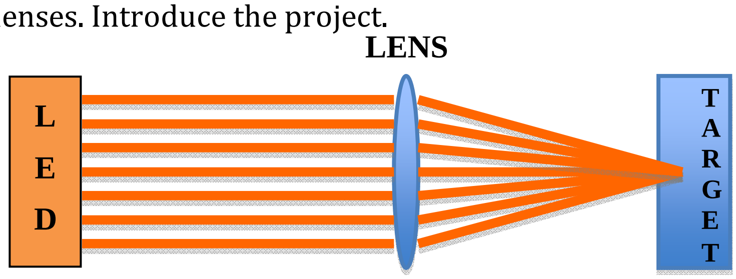
Collimated light is defined as light rays that are parallel or near parallel. A collimator may be used to obtain this affect.

Preparation:

- **Add-on to the Marble Sorting System**
  Students have been using the Fischertechnik (hardware/software) development system to create a robotic system capable of sorting 3 different colored marbles from a hopper into three bins. The system is to be fully automated.
- **Demonstrate the photoresistor to the students**
  Discuss how the photoresistor changes its resistance value when the light intensity acting upon it changes. The photoresistor constantly feeds an analog signal (in ohms), to the interface, which then can be viewed using the RoboPro software in real time.
- **Shine the LED on the photoresistor and observe the readings**
  Ask the students why the software cannot get a 100% intensity reading when the LED is 5/8" (standard distance when implementing into Fischertechnik system) away from the photoresistor.

Classroom Procedure:

***Engage (Time: 15 minutes)*:**
Begin with a PowerPoint presentation involving the properties of optic lenses (discovery, where they're used, applications, etc.) Demonstrate the LED by shining it through various lenses onto a target. Observe how the light on the target differs with the different lenses. Introduce the project.



Explore (Time: 20 minutes)*:* Have the students get into the same groups they have been working with (teams of 3) to develop their own focusing unit.

- **Determine which lenses to use**
  After the lesson on lenses and focal length determine which lens/lenses to use.
- **Determine the size of the system**
  Using the formulas given, approximate the entire size of the system by calculating the focal lengths of the selected lenses and determine a final focal point position.
- **Sketch out entire system**
  Using graph paper sketch, in detail (giving measurements), the components of your proposed system
- **Use play dough**
  Use the proposed lenses at the calculated distances to test the exact focal distance. Use the play dough to temporarily hold up the lenses. Record the results and compare the actual data to the calculated data.

Develop (Time: 240 minutes):

- **Draw using AutoDesk Inventor (3-D modeling CAD system)**
  From the approved sketch, draw system, using exact measurements, on AutoDesk Inventor. Final drawings must include: An orthographic drawing (front, top, and right side views) with dimensions properly labeled, and a cross-sectional isometric drawing (full rendered) where the top half of the system is cut off to see the internal components.
- **Physical Construction**
  Use the construction materials from the approved list (above). Have each group complete a working system to exact specs of their drawing.
- **Testing**
  Each group should test their system by hooking up the components to the Fischertechnik interface. Take readings from the phototransistor when implementing the focusing system and compare with the original results with no focusing unit.

Explain (Time: 20 minutes)
Students should record their findings in their engineer's journal to include in the data analysis portion of their written report.

Expand (Time: 40 minutes)

- Implement the completed light beam focusing system into the Marble Sorting Project. The completed prototype should fit into the entire system seamlessly. Students should design their entire system around this parameter.

- Have each group find 3 other [real world] applications where beam focusing/concentration is used. Include in written report.

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Explore	Explain	Expand/Synthesis
1	Asks intelligent questions directly relating to the subject matter. Can successfully explain concepts to other students.	Work is completed thoroughly and all components work properly. Connections are neat and enclosure is seamless.	Produces in-depth explanations using vocabulary words discussed in the lesson. Engineer's journal employs detailed descriptions.	Demonstrates critical thinking skills. Can successfully describe principles learned and how they apply.
2	Asks questions. Participates in brainstorming process giving some useful ideas.	Work is completed accurately and all components work. Connections are sloppy and enclosure looks undesirable.	Produces clear explanations using some vocabulary words. Engineer's journal employs good descriptions.	Shows an understanding of the main concepts discussed.
3	Contributes to brainstorming session. Does not have useful ideas do to lack of understanding.	Some, but not all of the components work properly. Enclosure's appearance is less than desirable.	Produces limited explanations of findings. Engineer's journal shows little detail.	Shows some understanding of the concepts but cannot apply them to other applications.
4	Does not participate.	Project does not work at all.	Unclear explanations of findings. Engineer's journal is incomplete or not easily interpreted.	Does not understand concepts learned or how they are applied.

Extension Activities:

After incorporating the developed beam focusing system into the Marble Sorting project. Determine if the system has beneficial factors in the overall precision and accuracy of overall system.

Supplemental Information:

Read pages 405-415 in "Text-Book of Physics" by S.E. Coleman. Can be viewed online at: books.google.com

Safety:

Light beams should be directed only towards the specified target. Safety glasses should be used when cutting materials and applying adhesives.

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