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Grade 10 Science: Optics Unit
Teaching the Science of Light
by Alison Foster
Teaching the Science of Light:
A Resource Guide for the Ontario Science Curriculum’s Grade Ten Academic Optics Unit

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Introduction:

The introduction of Light and Geometric Optics to the Grade Ten Academic classroom introduces a new challenge to the science classroom. As a Teacher Candidate with a concentration in Biology and English, I was presented with the challenge of creating this unit for the Science classroom. With few resources at hand within the secondary school setting, I was faced with the prospect of building a unit that was not only new to me, but to the school in general. Despite my lack of experience in this subject, I was able to use Online and Print Resources, as well as the Education Library’s resource kits, to create an introduction to optics for Grade ten students. Despite some of my setbacks in this unit, I feel this experience allows me to offer some useful resources and suggestions for teaching a successful and engaging optics unit, regardless of one’s comfort level with the material.

Within this resource guide, you will find a listing of useful resources for use in the classroom and in your personal exploration of the topic. In addition, this guide provides ideas for activities and some simple lesson plans to act as scaffolding for your unit planning. Throughout this guide, there will also be notes regarding how these resources and activities may be modified to include aspects of other science units. Lastly, some final thoughts on the optics unit will explore extensions of the topic and where one can progress from initial investigations.
The New Curriculum: What are Students Expected to Learn during this Unit?

Like all of the units outlined in the Ontario curriculum, the curriculum expectations for the Science classroom can be stated as three overarching goals: to relate science to our society and environment, to develop the skills needed for scientific enquiry, and to learn basic scientific concepts (Ontario Ministry of Education 2008)). In terms of the Light and Geometric Optics Unit, the Ministry’s goal is to develop the students’ knowledge of Physics within these three areas of learning. Therefore, the overall expectations of the Optics unit are as follows:

1. To “evaluate the effectiveness of technological devices and procedures designed to make use of light, and assess their social benefits.”

2. To “investigate, through enquiry, the properties of light, and predict its behaviour, particularly with respect to reflection in plane and curved mirrors and refraction in lenses.”

3. To “develop an understanding of various characteristics and properties of light, particularly with respect to reflection in mirrors and reflection and refraction in lenses.”

(Ontario Ministry of Education 2008)

It is with these curriculum expectations in mind that we will explore possible resources and strategies for teaching secondary students about optics. Focusing on the overall expectations of relating the topic to our society, communication about the topic, and exploring the basic concepts
of the topic will provide scaffolding for creating one’s own Optics unit within the science curriculum.

The important idea to keep in mind for this guide is that the resources presented within can be modified to accommodate a variety of classroom settings. For example, some of the resources used within this guide have been successfully modified and taught to students at the Grade Ten Locally Developed level as well as the Grade Ten Academic level. Using your own judgement, input from colleagues, and experience with the students can prove to be useful feedback when modifying the materials. Therefore, it is best to keep in mind this question while investigating the listed resources: how can these resources be used to provide my students with what they need in the classroom?
Beginning your Search: Resources for Students and Teachers

Necessary steps to take in the proper planning of a unit include identifying the overall expectations, defining the overall goals that you have for the students, and choosing appropriate assessment methods. Another integral aspect of the process is acquiring resources that will provide the teacher with a thorough background on the subject as well as materials that can be used within the classroom. With that in mind, these resources have been chosen on the basis of their educational value, ability to engage a diverse audience, and applicability to exploring optics.

Print Resources:

Finding up-to-date, effective print resources is a useful first step in collecting resources. The list provided below includes useful materials for the classroom.

- **Light (Robertson, William: NSTA Press):** From the “Stop Faking it!” Series, *Light* is a fantastic introduction to teaching Optics. Written entirely for teachers, the text presents information on the history of optics, how light waves behave, mirrors, lenses, the human eye, and optics at the atomic level. Excellent analogies are included in each section, providing useful prompts for the classroom. One particularly effective aspect of the text is the inclusion of guided learning tools; each chapter provides an introduction that asks the reader to brainstorm or perform small experiments. A fantastic resource to prepare inexperienced and experienced teachers alike.

- **Optics: A Teacher’s Guide to Light and Optics (Lynch, Merv):** Let’s Talk Science is a charitable organization dedicated to exploring science education using hands-on activated and enquiry-based learning. Their teacher’s guide provides detailed activities for use with a variety of groups in addition to background
information for each activity. The materials lists are clear and include easy-to-find resources. The book is accompanied by a CD-ROM that contains lesson plan guidelines, worksheets, and additional information regarding the lessons.

- **Making Physics Fun (Prigo, Robert):** although this book is targeted at students in grades K-8, the information presented is applicable to the secondary classroom. In addition to providing an introduction to light and waves for the reader, the book offers everyday examples of the concepts, enquiry questions, and short activities that can be modified to accommodate a grade ten curriculum. The enquiry questions are particularly helpful; placed at the end of each chapter, they offer a wonderful opportunity to gauge student comprehension and engage students in active scientific enquiry.

- **The Optics Book: Fun Experiments with Light, Vision, and Color (Levine, Shar and L. Johnstone):** This book clearly and concisely offers a range of activities; organized by topic, these activities all offer varying degrees of complexity. A complete materials list at the beginning of the book allows the user to recreate all of the activities, making the activities accessible and, for the most part, inexpensive. In addition, the activities can be completed in a variety of environments and offer little risk in the lab setting.

- **Five Easy Lessons: Strategies for Successful Physics Teaching (Knight, Randall):** A helpful guide that helps the educator to integrate active enquiry into their own physics units. Two chapters are devoted to Optics (Geometric and Physical) and break down each new concept into easy-to-follow sections: student objectives, pedagogical approach, sample reading quiz/enquiry questions, and sample exam
questions. The book is dedicated to creating an active learning model; in essence, the student constructs their learning through engagement with the material rather than discussion or lecture-style learning (Knight 48). The Section title “A Dozen Things you can do to Change Physics Education” offers multiple approaches to teaching physics using different approaches to active learning. A must-read for teachers beginning their teaching careers in science.

- **Light and Sound (Goldsmith, Mike):** Although the language and presentation of information is geared toward an elementary classroom, this book provides a fantastic opportunity for ELL students to develop their knowledge of physics vocabulary. The information provided in the resource includes the basic introduction to light and geometric optics; included in the text are short activities that could be completed by students in the classroom or at home, allowing for more exploration opportunities. A useful resource modifying instruction.

- **Opticks (Newton, Isaac):** A reproduction of Sir Isaac Newton’s treatise on the properties of light. Within the text, Newton provides a brief overview of how the 18th century scientific community perceived the properties of light, but also offers his own viewpoint on the topic. Excerpts can be taken from this resource as part of relating optics to society, technology, and the environment.

- **Physics for Kids: 49 Easy Experiments with Optics (Wood, Robert):** Offers the teacher a range of experiments for use in the optics unit. Although some of the activities are difficult to acquire materials for, the simple layout and clear illustrations make them easily adaptable to the more contemporary classroom. Lab safety is
covered adequately in this book as each experiment includes lab safety symbols; it provides excellent review of lab safety for students.

- **City of Light: The Story of Fiber Optics (Hecht, Jeff):** A text focusing on the history and application of fibre optics. Chronicling the development of this technology from the 19th century to the late 20th century, this text offers a comprehensive but understandable lesson on how fibre optics works, its history, and its benefits. This could be used as part of an “optics in everyday life” lesson, addressing the science and society component of the curriculum. Conversely, this text would be a useful resource should an independent study unit be introduced within the classroom.

- **Optics Demystified: A Self-Teaching Guide (Gibilisco, Stan):** A good starting point for reviewing optics that presents the overlying concepts of optics. The text includes many of the equations associated with optics and provides questions at the end of the chapter to gauge understanding. Many of the questions at the end of the chapter could be easily adapted for formative assessment in the classroom. The combination of equation-based and fact-based questions provides ample practice for both the teacher and the students.

- **Color and Light in Nature (Lynch, David and K. Livingstone):** A useful resource to keep in the classroom as a reference or to incorporate into classroom activities. The book offers an in-depth, illustrated look at light and color phenomena as they occur in nature; some time is also spent exploring the concept of vision, including the biology of the visual sense organs and how humans perceive colour. A section titled “naked eye astronomy” provides the information needed to create some at-home
enquiry activities for students to complete and reflect upon. Overall, the vivid illustrations and descriptions make this resource a wonderful way to engage with light and optics in nature.

Overall, these resources can be used to address all of the primary curriculum requirements. The variety of activities, information, and enquiry questions within this selection are excellent scaffolding for one just beginning their optics unit.

*Online Resources:*

With the advent of technology becoming an integral part of many classrooms, having online resources with which to work can round out daily lessons. Online resources were selected following these simple parameters: ease of use, able to appeal to a diverse audience, and scientific accuracy.

- **WebTOP: The Optics Project** ([http://webtop.msstate.edu/](http://webtop.msstate.edu/)): Created by the Department of Physics and Astronomy at Mississippi State University, webTOP is a downloadable program that allows the user to recreate images of optical phenomena on their desktop. The site has many topic modules available, including “the eye,” “lenses,” “scattering,” and “mirrors.” Every model within the system is completely interactive, 3-dimensional, and, in most cases, animated. Although this program can be a bit confusing to operate at first, the downloadable instructions teach the user how to manipulate images as well as record modules to accompany the images for later use. This is a useful tool for preparing lectures about light and geometric optics. The interactive features of the program allow for active enquiry by students, an especially useful feature during group work or small technology-based labs.
• **SPIE: International Society for Optical Engineering** ([http://spie.org/](http://spie.org/)): an excellent site for teachers, this organization offers an entire section to educators. Featured in this section are free downloadable posters, informational videos, and a CD-Rom about careers in optics. The resource page is especially useful, as it links to related pages containing activities and lesson plans for a variety of age and skills levels. The “publications” page is an especially useful source, as it offers journal articles and online texts for review.

• **Hands-on Optics: Making an Impact with Light** ([http://www.hands-on-optics.org](http://www.hands-on-optics.org)): This site offers resources to teach six modules within the optics unit. Within each unit, students have the opportunity to explore multiple subjects while using optics to facilitate their learning. The how-to guide offers materials lists, activity ideas, and reviews of concepts in order to facilitate lesson planning. Modules on the site address the topics of lasers, lenses, the nature of light, communicating using light, working with kaleidoscopes, and polarization.

• **Molecular Expressions: Science, Optics, and You** ([http://micro.magnet.fsu.edu/index.html](http://micro.magnet.fsu.edu/index.html)): Focused on the topic of microscopy and how lenses work, this site is particularly helpful when lessons involve the behaviour of light in relation to lens shape. Included in this site are activities that can be completed in groups or independently, resources that detail the history of the study of optics, teacher resources for most of the activities, and comprehensive guides to the development of microscopy. This
site is particularly effective when discussing the technology aspect of optics and how these concepts have benefitted contemporary society.

- **Exploring the Science of Light** ([http://www.optics4kids.com/](http://www.optics4kids.com/)): produced by the Optical Society of America, this site is targeted toward Junior/Intermediate students. Light and Geometric Optics is presented in a well-organized table, giving the student options as to what to explore first. One particularly helpful aspect of the site is the section devoted to reference materials for students. The materials used are accurate and accessible with potential for use in enquiry and active learning exercises. Examples such as optical illusions are readily available on the site. Tutorials on the site are useful for formative assessment activities.

- **Operation Physics: Children’s Science Misconceptions** ([http://www.amasci.com/miscon/opphys.html](http://www.amasci.com/miscon/opphys.html)): This site has been compiled by educators in order to better address the science-related misconceptions that can pervade a topic. The site includes an extensive “light” section. For example, the site lists that, “Light from a bulb only extends outward a certain distance, and then stops. How far it extends depends on the brightness of the bulb” (Beatty). Reviewing common misconceptions can indicate some areas that may require more time during the unit.
Activities for the Classroom

After one has established the overall goals of the unit, explored assessment methods, and collected relevant resources, the next feasible step is to consider what tasks to use in order to gauge student development and engage active enquiry within the classroom setting. Below is a list of short, engaging activities that are equally insightful as short introductions to the day’s lessons or supplements to a larger demonstration or lab.

<table>
<thead>
<tr>
<th>Title</th>
<th>Liquid Light: Experimenting with Total Internal Reflection</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(Adapted from The Optics book (Levine and Johnston))</td>
</tr>
</tbody>
</table>

**Curriculum/ Learning Goals**

- Analyse a technological device that uses the properties of light.
- Demonstrate an understanding of the properties of light.
- Investigate how this experiment is useful to society.

**Materials**

- Empty 12 oz. Metal can
- Can opener
- Hammer and Nail
- Black Construction Paper
- Masking Tape
- Water and bucket
- Flashlight

**Procedure**

1. Remove the top from the empty can using the can opener. Cover the sharp edges with tape.
2. Hammer the nail near the bottom of the can in order to make a single hole. Remove the nail.
3. Form the piece of construction paper around the flashlight in a cone shape; secure with masking tape. This should form a cone around the top of the flashlight that directs the beam.
4. Secure tape on the hole in the can.
5. Fill the can with water; Place the flashlight over the can so that the cone prevents light from escaping. Position the bucket so that it may catch the water; turn off the lights in the room.
6. Remove the tape from the can; allow the water to empty out of the can and record any observations you have.

<table>
<thead>
<tr>
<th>Follow-up Questions/Extensions</th>
<th>1. Total internal reflection is used in technology as a way of transferring huge amounts of data quickly and accurately. How do you think this affects our school? Our homes?</th>
</tr>
</thead>
<tbody>
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<td>2.</td>
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<table>
<thead>
<tr>
<th>Title</th>
<th>Investigating Light: Making Rainbows using Simple Tools! <em>(Adapted from The Optics Book (Levine and Johnston)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Curriculum/ Learning Goals</strong></td>
</tr>
<tr>
<td></td>
<td>• To investigate the properties of light in order to explain common phenomena.</td>
</tr>
<tr>
<td></td>
<td>• Focus on the behaviour of light in the presence of reflective surfaces.</td>
</tr>
<tr>
<td></td>
<td><strong>Materials</strong></td>
</tr>
<tr>
<td></td>
<td>• A clear glass or plastic container</td>
</tr>
<tr>
<td></td>
<td>• A small mirror</td>
</tr>
<tr>
<td></td>
<td>• Modelling clay or mild adhesive</td>
</tr>
<tr>
<td></td>
<td>• A piece of white cardboard</td>
</tr>
<tr>
<td></td>
<td>• Water.</td>
</tr>
<tr>
<td></td>
<td><strong>Procedure</strong></td>
</tr>
<tr>
<td></td>
<td>1. Place a small piece of adhesive near one of the edges of the tray. Rest the mirror so that it is on an angle against the container’s side; press the mirror down slightly into the adhesive.</td>
</tr>
<tr>
<td></td>
<td>2. Take the container out to a sunny, outdoor area. Fill the container almost to the top with water.</td>
</tr>
<tr>
<td></td>
<td>3. Adjust the container so that the sunlight hits the mirror.</td>
</tr>
</tbody>
</table>
4. Once the mirror is reflecting sunlight, start moving the piece of cardboard around in front of the mirror. With time, you should be able to see a light pattern reflected on the cardboard. Observe your results and record data.

**Follow-up Questions/Extensions**

- Use this activity as a warm-up or review of the light spectrum. Why do we see so many colours within white light?
- Can you think of any other events you have seen that are like what we saw today? (e.g. rainbows from a hose, after a storm, etc.)

**Recommended Text(s)**


<table>
<thead>
<tr>
<th>Title</th>
<th>The Disappearing Penny Trick</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Curriculum/Learning Goals</strong></td>
<td>Students will see if light travels in a straight line</td>
</tr>
<tr>
<td></td>
<td>Explore the concept of refraction and how it can affect how we perceive objects.</td>
</tr>
<tr>
<td></td>
<td>Observe an experimental set-up and, using their observations, consider what occurred.</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td>Small Cup</td>
</tr>
<tr>
<td></td>
<td>Small piece of putty/adhesive</td>
</tr>
<tr>
<td></td>
<td>Penny</td>
</tr>
<tr>
<td></td>
<td>Water</td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
<td>1. Place a small piece of adhesive on the penny; press the penny into the bottom of the cup.</td>
</tr>
<tr>
<td></td>
<td>2. Gradually move away from the cup, stopping just when the penny gets out of sight.</td>
</tr>
<tr>
<td></td>
<td>3. Have a partner slowly pour the water back into the cup. What do you observe as the water level rises?</td>
</tr>
</tbody>
</table>
**Follow-up Questions/Extensions**

- How did the addition of water change the path of the light?
- Do you think that thicker substances would change the results of your experiment? Why or why not?

**Recommended Text(s)**


While these activities are merely a starting point for classroom investigations, they address the behaviours of light during reflection and refraction. Given that reflection and refraction can be a somewhat challenging concept as the subject matter becomes more complex, these activities gradually introduce the topic while still allowing for active enquiry.
Sample Lesson Plans: What can I do with the Resources I Have?

Once the framework of the unit has been established, the individual lesson plans present the next challenge. A reliable method of lesson planning emphasizes variety: variety in the lesson content, variety in the activities, and variety in terms of assessment. The following lesson plans are extensions of the activities provided and are also able to stand on their own. They have been scaled back in complexity in order to accommodate for the personal needs of the educator as well as the classroom.
Sample Lesson Plan #1: Investigating Lenses

**Instructional Expectations and Opportunities:**

**Expectations:**
- **E1.1:** analyse a technological device or procedure related to human perception of light (e.g., eyeglasses, contact lenses, infrared or low light vision sensors, laser surgery), and evaluate its effectiveness
- **E2.1:** use appropriate terminology related to light and optics, including, but not limited to: angle of incidence, angle of reflection, angle of refraction, focal point, luminescence, magnification, mirage, and virtual image.
- **E3.6:** identify ways in which the properties of mirrors and lenses (both converging and diverging) determine their use in optical instruments (e.g., cameras, telescopes, binoculars, microscopes)

**Required Materials:**
- Convex and concave lenses
- Meter sticks
- Masking Tape
- White Paper
- Candles
- Braces for candles, lenses, and paper
- Safety goggles
- Reading glasses of varying strengths

**Content and Teaching Strategies:**
1. Begin the class by writing an investigation question on the board “How do glasses work?” Allow the class to work in small groups and brainstorm for 3-5 minutes.
2. **Discussion:** Provide a brief introduction of what will be studied that day. Linking the objectives to the class discussion, discuss how the path of light can change when it comes into contact with another substance. How dense the substance is will determine how the light will bend.
3. **Activity: Flipping a Candle Upside Down without Touching it!**
   a. During this activity, students will work in small groups and investigate which types of lenses could be used to produce a clear, upside-down image of a candle on a piece of paper.
   b. Demonstrate how adjusting the distance between the lens and the object may affect the size and clarity of the object.
   c. While they investigate, groups must record what type of lens they use (convex of concave), how many, and the distance between the lens, and object, and the image.
   d. Allow the groups to work as a team, ensuring that all groups are recording their trials and recording the type and number of lenses, as well as the distances.
e. Bringing the group back together, record the class data on the board; what trends can be seen in the class results? What do these results tell us about how lenses modify images?

4. **Consolidation:** If time allows, provide some background information about ray diagrams, tying it into the activity. Frame it as the method that we can use to predict how and image will change in response to lens shape and focal length.

**Assessment and Evaluation:**
- Small group and personal interaction during group work to assess participation/gauge understanding.
- Discussion at the end of class
- Extension: written response to today’s activity to address performance in students who are not as strong in verbal communication.

**Possible Reflections:**
- Would changing the order of the ideas presented improve the lesson in anyway?
- What are some methods of integrating written feedback that would improve the assessment strategies used?
- Consider tomorrow’s lesson: be ready to introduce and take class through the concept of ray diagrams.

Sample Lesson #2: Why is the Sky Blue?

Instructional Expectations and Opportunities:

Expectations:
- **E2.1:** use appropriate terminology when communicating ideas about optics, including scattering, refraction, electromagnetic spectrum, and
- **E3.2:** describe properties of light, and use them to explain naturally occurring optical phenomena (e.g., apparent depth, shimmering, a mirage, a rainbow).
- **E3.8:** describe properties of light, and use them to explain naturally occurring optical phenomena (e.g., apparent depth, shimmering, a mirage, a rainbow).

Required Materials:
- A clear glass or beaker
- Water
- Milk
- Sheets of black paper
- A source of bright light e.g a flashlight
- A stirring rod or spoon
- Lab instructions and questions

Content and Teaching Strategies:
1. Begin class by discussing the sky and the atmosphere with the class. Ask for their hypotheses as to why the sky is blue. Record these hypotheses on the board.
2. Introduce the class to the lab that they will be completing. Take this time to hand out lab information sheet and go over what they will be investigating. In other words, they will be testing their hypotheses.
   a. Have the students fill their clear container ¾ of the way with water. Tell them that this is the atmosphere of a distant planet and that it is clear due to no substances being in the atmosphere.
   b. Have students place the black paper behind the beaker and shine the flashlight through. The flashlight is the sun shining through the atmosphere. What do they notice about the atmosphere?
   c. Add milk, a small amount at a time, until the liquid is cloudy but the black paper can still be seen. Repeat the previous step, shining the flashlight through the container.
      i. What changes can be seen?
      ii. What colour did the water change?
      iii. Which beaker was more like our atmosphere on Earth, the first or the second beaker? Explain your answer.
   d. Have the students move the flashlight up and down in front of the beaker and tell them to record their results; what colour changes do they see?
   e. Long-answer question: From what you have observed today and, based on your prior knowledge, explain why the sky would be different colours at different times of day. Did your hypothesis agree with the results? Use diagrams to support your answer.
**Consolidation:** Students should take the time to record their results and answer the questions accompanying the lab. At the end of class, students may hand in their lab questions.

**Assessment:**
- Observation-based assessment to determine comprehension during the activity.
- Assess written work in order to assess performance.

**Possible Reflections:**
- How will we build on today’s lesson? Possibilities include review of ray diagrams to review today’s lab, discussion of refraction, and review of the electromagnetic spectrum.

**Lesson Adapted From:** Bosak, Susan V. *Science Is...A source book of fascinating facts, projects and activities. Second Edition.* Richmond Hill; Scholastic Canada and Markham; The Communication Project. 1991.
Conclusion:

Although what has been presented in this guide is by no means exhaustive, the resources and ideas offered are designed to give an education new to the Optics unit a scaffolding on which to build their own unit. The strength of offering such a resource guide is in its flexibility; by providing a basic structure from which to develop one’s lesson plans and overall unit, the unit can be modified to suit a variety of classrooms and work environments.

The benefit of integrating both print and online resources into unit planning is due to the opportunities that these resources offer. The integration of technology within the classroom is beneficial to the developing science student, as the need for students to readily learn using technology becomes more apparent within the curriculum (Fredrick 2010). Given the opportunity, it would have been wonderful to expand upon how these resources can be integrated into one’s lesson plans. Despite this setback, however, I feel that, as a potential educator, the resources offered within this guide can produce a fruitful and engaging Grade Ten Optics unit.
Resources Cited:


