MAPPING THE INVISIBILITY REGION USING LENSES (SNC2D1, SNC2P1)

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Students are invited to form groups (2-3 students in a group) to devise a ‘cloaking’ device, based on the You tube video of Professor Howell and his graduate student Joseph Choi from University of Rochester in New York . Students are first brought to learn the rules for drawing light rays through a converging lens in a Gizmos animation. Inquiry-guided worksheets instruct students to view the You tube and engage in a conversation of where cloaking is of value and how does it work. They are to map the regions where cloaking works by plotting their data on graph paper.

GRADE LEVEL/COURSE CODE:

Grade 10 Academic Science (SNC2D1): Grade 10 Applied Science (SNC2P1)

STRAND(S) AND UNIT(S):

Physics; Light and applications of optics.

OVERVIEW:

Students are invited to form groups (2-3 students in a group) to devise a ‘cloaking’ device, based on the You tube video of Professor Howell and his graduate student Joseph Choi from University of Rochester in New York . Students are first brought to learn the rules for drawing light rays through a converging lens in a Gizmos animation. Inquiry-guided worksheets instruct students to view the You tube and engage in a conversation of where cloaking is of value and how does it work. They are to map the regions where cloaking works by plotting their data on graph paper.

INQUIRY FOCUS:

How does a converging lens produce an image?

What are the benefits of achromatic lenses compared to normal ones?

What are their applications?

How does cloaking work?

Why are certain areas not amenable to cloaking (invisibility feature)?

Why would cloaking be beneficial to humans? What kind of problems can be solved with cloaking?

TIMELINE:

Day 1-Students use the Gizmos to draw rays through a convex lens and for an achromatic lens

Day 2-Students devise a cloaking 'experiment'

Day 3-Students will finish drawing the graph and writing up of the report. They will collaborate and reflect on the limitations of the experiment and possible improvements.

BIG IDEAS:

- Light has characteristics and properties that can be manipulated with mirrors and lenses for a range of uses.
- Society has benefited from the development of a range of optical devices and technologies.

OVERALL EXPECTATIONS:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A1.1 formulate scientific questions about observed relationships, ideas, problems, and/or issues, make predictions, and/or formulate hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., a microscope, laboratory glassware, an optical bench) and materials (e.g., prepared slides, an aquarium, lenses, pH paper) for particular inquiries

A1.3 identify and locate print, electronic, and human sources that are relevant to research questions

A1.5 conduct inquiries, controlling some variables, adapting or extending procedures as required, and using standard equipment and materials safely, accurately, and effectively, to collect observations and data

A1.6 gather data from laboratory and other sources, and organize and record the data using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables,laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely

SNC2D1

E2. investigate, through inquiry, the properties of light, and predict its behaviour, particularly with respect to reflection in plane and curved mirrors and refraction in converging lenses;

E3. demonstrate an understanding of various characteristics and properties of light, particularly with respect to reflection in mirrors and reflection and refraction in lenses.

SNC2P1

E2. investigate, through inquiry, properties of light, and predict its behaviour in mirrors and as it passes through different media;

E3. demonstrate an understanding of characteristics and properties of light, particularly with respect to reflection and refraction and the addition and subtraction of colour

SPECIFIC EXPECTATIONS:

SNC2D1

E1.2 analyse a technological device that uses the properties of light (e.g., microscope, retroreflector, solar oven, camera), and explain how it has enhanced society

E2.1 use appropriate terminology related to light and optics

E2.5 predict, using ray diagrams and algebraic equations, the position and characteristics of an image produced by a converging lens, and test their predictions through inquiry.

E3.5 describe the characteristics and positions of images formed by converging lenses (e.g., orientation, size, type), with the aid of ray diagrams

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)

SNC2P1

E2.4 predict the qualitative characteristics of images (e.g., location, orientation, size, type) formed by converging lenses, test their predictions through inquiry, and draw ray diagrams to record their observations

E3.8 explain how the properties of light or colour are applied in the operation of an optical device (e.g., a reflecting telescope, stop lights, stage lights)

KEY CONCEPTS:

refraction, focal point, principal axis, achromatic lens, converging (convex) lens, dependent and independent variables

PRIOR SKILL SETS:

Students must be able to key in values to equations.

They must know the concept of dependent and independent variables in a graph, and the guidelines in drawing a proper scientific graph, (reading the x and y values).

They must be able to work in collaborative groups.

PRIOR KNOWLEDGE:

Students must be able to follow instructions, both written and verbal.

Refraction is the bending of light as light passes from a less dense to a more dense material and vice-versa.

They must be able to represent light rays as lines with an end arrow.

MATERIALS AND EQUIPMENT:

Day 1-availability to internet access, laptop, Gizmos account, pencil, paper and eraser.

Day 2- Achromatic lenses and metal rail are available from **https://www.surplusshed.com/pages/item/l14575.html** (https://www.surplusshed.com/pages/item/l14575.html)

Other sources of achromatic lenses can be found at

i. https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=120 (https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=120)
ii. https://www.newport.com/c/lenses

1.Six cemented doublet achromats (2 single achromats and 2 double achromats), 34 mm

diameter

2. a metal rail

3. white sheets

4. 1-metre ruler

5. a wooden support onto which the metal rod was attached to

6. 4-6 transparent tape fillers

7. metal paper clips (3.1 cm in length)

8. pencil and eraser and a ruler (30 cm)

9. graph papers

10. calculator

11. a screen with lines

SAFETY:

The metal rail support holding the lenses in an upright position has sharp square edges and students are not to poke each other with it.

They must handle the lenses with care as they are made out of glass.

INSTRUCTIONAL PLANNING AND DELIVERY:

This activity has one knowledge-building lesson, one day of open inquiry, and one optional day of lab writing up. Each day consists of one period.

DAY 1-PROPERTIES OF CONVEX (CONVERGING) LENSES AND ACHROMATIC LENSES

In groups of 2-3 students, students have to answer a knowledge based worksheet to gain information from the given text (enhance literacy skills). They must be getting accustomed to animation and drawing the light rays going through the converging lenses. Some of the weaker students in the applied class may need guidance, hence collaborative groups must be created. Why are the rays behaving like this and how are they different from mirrors? What is refraction and why did it take place here? Can students think of applications of lenses they have seen in their daily lives?

It is encouraged for each student to have a laptop or computer to enhance their computer skills. Androids and iphones can be used instead of computers.

DAY 2- BASED ON THE VIDEO, STUDENTS CAN GET INFORMATION AND QUESTION THE PROCESS OF CLOAKING AND ITS POSSIBLE APPLICATIONS.

The focal lengths of lenses are given so the students can set up their own cloaking device. This experiment gives the opportunity for students to realize that science is not that straightforward and they will have the chance to devise their own set up. The teacher may want to confirm the t1 and t2 distances before the setting up. Some students may have problems with mathematical equations, so these may be taken up (or provide hints to groups) before the students can proceed to the next step.

DAY 3- MAPPING OUT THE CLOAKING AREA ON GRAPH PAPER.

Most students must have worked with plotting graphs by now, but some may need to be reminded of the axes. They are advised to check with the rubric to make sure that nothing has been missed. Due to the limitations of perfect lenses (double achromatic lenses were received by two singles glued together), some of the plotted points may not be perfectly on the straight lines, but they should depict the general trends. Students will be asked to critically think of ways of improving the experiment based on their mistakes or errors they must have committed.

STUDENT GUIDED-INQUIRY SUPPORT RESOURCES:

1. Cloaking Powerpoint slides with concepts of refraction and converging lenses. The Powerpoint also provides detailed instructions for set-up used in this investigation.
2. Day 1 learning convex lenses and achromatic lenses worksheet
3. Day 2 Building a cloaking optical device worksheet

RELATED BACKGROUND RESOURCES AND/OR LINKS:

1. Website where the lenses and rail can be bought **https://www.surplusshed.com/pages/item/l14575.html** (https://www.surplusshed.com/pages/item/l14575.html)
2. Textbook with the terminologies and exercises for lenses: ***Science Connections 10*** *by Nelson 2011*
3. Textbook with terminologies for refraction and lenses: **Science Perspectives 10** by Nelson 2010
4. A comparison of white light splitting by a single lens and an achromatic lens and information on achromatic lenses can be found from the following website https://www.edmundoptics.com/c/achromatic-lenses/652/# (%20https:/www.edmundoptics.com/c/achromatic-lenses/652/%23)
5. Gizmos, an important learning resource, provides animation on the operation of converging lenses and students can learn from it at their own pace https://www.explorelearning.com (https://www.explorelearning.com)
6. Application and improved characteristics of achromatic lenses can be found at this site https://www.edmundoptics.com/resources/application-notes/optics/why-use-an-achromatic-lens/ (https://www.edmundoptics.com/resources/application-notes/optics/why-use-an-achromatic-lens/)
7. Before carrying out the experiment, students are required to watch a 3-minute video on the cloaking device. The website provides details on the 'cloaking experiment' carried by Joseph Choi in Professor Howell's research group from University of Rochester (good for students who choose not to listen to the video). The video is available from YouTube™ (https://www.youtube.com/watch?v=vtKBzwKfP8E (https://www.youtube.com/watch?v=vtKBzwKfP8E) or search 'The

Rochester Cloak' on YouTube™) or from http://www.rochester.edu/newscenter/watch-rochester-cloak-uses-ordinary-lenses-to-hide-objects-across-continuous-range-of-angles-70592/ (http://www.rochester.edu/newscenter/watch-rochester-cloak-uses-ordinary-lenses-to-hide-objects-across-continuous-range-of-angles-70592/)

8. A ray diagram showing how cloaking works, provided by Harvard University presentation.https://sciencedemonstrations.fas.harvard.edu/presentations/paraxial-ray-optics-cloaking (https://sciencedemonstrations.fas.harvard.edu/presentations/paraxial-ray-optics-cloaking)
9. Applications of convex lenses can be found at https://www.math.ubc.ca/~cass/courses/m309-01a/chu/Applications/apps.htm (https://www.math.ubc.ca/~cass/courses/m309-01a/chu/Applications/apps.htm)

ASSESSMENT OPPORTUNITIES:

ASSESSMENT FOR AND AS LEARNING IS PROVIDED IN THE DAY 1_LEARNING ABOUT LENSES WORKSHEET

(marks are indicated there for the teacher to record for future reference). Students must draw light rays for an image from the Gizmos animation. They will be discussing their answers in pairs and then present their information in groups of 4 students on chart paper to be posted in class (the teacher can also be informed about student's misconceptions or weaknesses at that point). The application of achromatic lenses, as part of a new technology will arouse their interest and instigate questions about why we need to develop better lenses and how does refraction affects the properties of images formed. Here, again the splitting of white light can be discussed and if there is a glass prism in class, students can observe the effect of refraction of white light.

ASSESSMENT OF LEARNING:

It is assumed that the students already had a formative assignment on graphs before. Here, it will be important for the students to be able to analyze their data and communicate them via clearly drawn graphs. They can also formulate their conclusions and also what were the limitations of the experiment. The lab is a good opportunity for students to come up with their own lab set up and to test it, based on the values of the focal lengths. The lab will test their patience and also incite wonder about the disappearing part and how lenses can work wonders. Students will be brought to analyze, perform and evaluate their results, an important part of scientific lab experiments.

FUTURE OPPORTUNITIES / EXTENSIONS:

This lab provides many extensions, in the form of guest speakers (invite professor Howell in a video 'interview' on future outcomes of this technology and its applications). I did not get the chance to do that, but this would be a fun activity.

In this activity, only one part of the cloaking region was investigated (between F1 and F2). For the above average students, they can map out the cloaking of the whole apparatus by using the tape with the metal clip.

Other achromatic lenses with different focal lengths can be investigated to make sure that the formula is valid. Students can also find a relationship between the best cloaking area and focal length combinations.

We could also have a research project on applications of cloaking in the real world and what has been done so far (stealth technology).

PITFALLS

1. The height of the object (wire attached to tape filler) cannot be higher than half of the diameter of the lens due to the refraction of rays
2. The distances between the lenses are very important and must be precise to ensure cloaking

3. The rail must be attached to a wooden structure as attempts to use without a wooden structure resulted in the objects falling over.
4. The experiment when repeated with normal lenses (not achromatic) resulted in blurred images and it was hard for students to identify the boundaries of cloaking.

WATCH THE VIDEO
01:31 min

(//www.youtube.com/embed/ZzstsnOeLoo?width=800&height=450&iframe=true)

RESOURCES

- The Rochester Cloak (https://www.youtube.com/watch)
- 1. invisibility cloak powerpoint slides (https://connex.stao.ca/sites/default/files/1_invisibility_cloak_final_version.pdf)
- 2 Teacher's guidelines Cloaking__stao__final_version (https://connex.stao.ca/sites/default/files/2_teachersguidelinescloaking_stao_final_version.docx)
- 3 day1_learning convex lenses student worksheet final edit (https://connex.stao.ca/sites/default/files/3_day1_learning_convex_lenses_student_worksheet_final_edit.docx)
- 3 day1_learning convex lenses _teacher final edit (https://connex.stao.ca/sites/default/files/3_day1_learning_convex_lenses_teacher_final_edit_.docx)
- 4 day2_Building cloaking device student worksheet final edit (https://connex.stao.ca/sites/default/files/4_day2_building_cloaking_device_student_worksheet_final_edit_1.docx)

- 4 day2_Building cloaking device student worksheet final edi_ pdf version (https://connex.stao.ca/sites/default/files/4_day2_building_cloaking_device_student_worksheet_final_edit_1.pdf)
- 4.1 Day2_marking Scheme_Cloaking Lab (https://connex.stao.ca/sites/default/files/4.1_day2_marking_scheme_cloaking_lab.docx)
- 4 appendix1_cloaking2018 (https://connex.stao.ca/sites/default/files/4_appendix1_cloaking2018.pdf)
- 4.2 gridlines (https://connex.stao.ca/sites/default/files/4.2_gridlines.docx)

ELEMENT

- Inquiry (/expert-elements/inquiry)

(/classroom-catalysts) RETURN TO CATALYSTS (/classroom-catalysts)