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Optics / Lab Activity

This lesson's Neat-o Interdisciplinary Idea is optics.

Often, optics is a topic covered in a physics class, not necessarily in an Earth science class. However, having a good grasp about how light waves are refracted and reflected at the interface between two materials will help us later when we have to visualize how seismic waves travel through the Earth. That's why we're going to have a little optics lab experiment here. The ultimate overriding objective in this lesson is for you to make your own observations using real seismic data and be able to picture in your head how seismic waves travel through the Earth's mantle. Before we jump straight into an activity that uses seismic data, let's back up and make sure we understand some principles of optics.

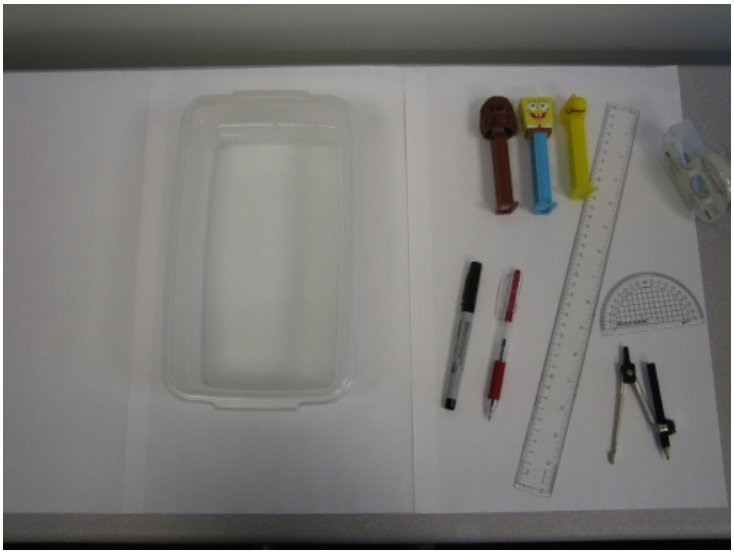
Lab Activity

In this activity, we will calculate the index of refraction of water by measuring the angles of incidence and refraction of light as it passes from air to water.

What you will need:

- Tank of water. A square or rectangular food storage container works well, as long as you can see through it and it is big enough. A fish tank would work really well, too. NOTE: You really do want to find a container that is big enough. If you can't or don't want to or it's not in your budget, it's okay, but just recognize that you are going to have a longer discussion of error and uncertainty at the end of the exercise. Why? Because if your container is too small, you won't be able to make observations over a wide range of angles of incidence.
- Paper
- Pen
- Straightedge
- Protractor
- Compass
- Three objects that you can see well when looking through the water. Upside down pushpins or screws work. I'm going to use Pez dispensers in my example.

The photo below shows my collection of materials for this activity.



Materials needed for this activity: I taped three big sheets of paper to the top of the table, I have a food storage container filled with water, a straightedge courtesy of Wes who has the office next door to me, a Sharpie marker, a compass, a protractor, and three Pez dispensers (Woodstock, Chewbacca, and SpongeBob SquarePants).

Directions

1. Save the Optics Lab worksheet [1] to your computer. You will use this document to record your work in the remaining steps. The worksheet is in Microsoft Word format. You can use another format if you want to. You will submit your worksheet at the end of the activity, so it must be in a word processing, text, or image format I can open. Ask me if you think you have a weird format.

2. Mark the location of the tank of water on the paper.
3. Put one of your objects on one side of the tank of water so that if you look through the tank from the other side, you can see it through the water. I'm going to use Woodstock (see photo of step 3):

Illustration of step 3. Woodstock is standing on the left side of the tank of water.

4. Look from the other side of the tank at your first object and cover one eye (see photo of step 4):

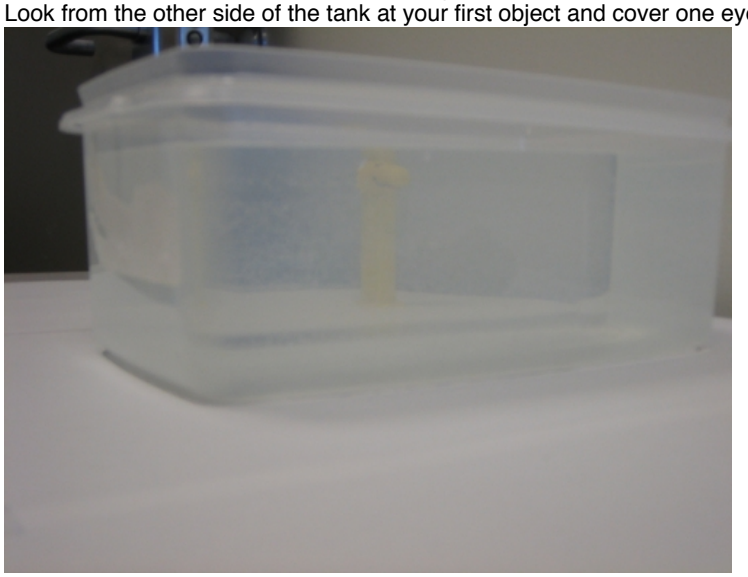


Illustration of step 4. I can see Woodstock through the tank full of water.

5. Now put one of your other two objects between your eye and the tank so that your first object is completely eclipsed (see photos).

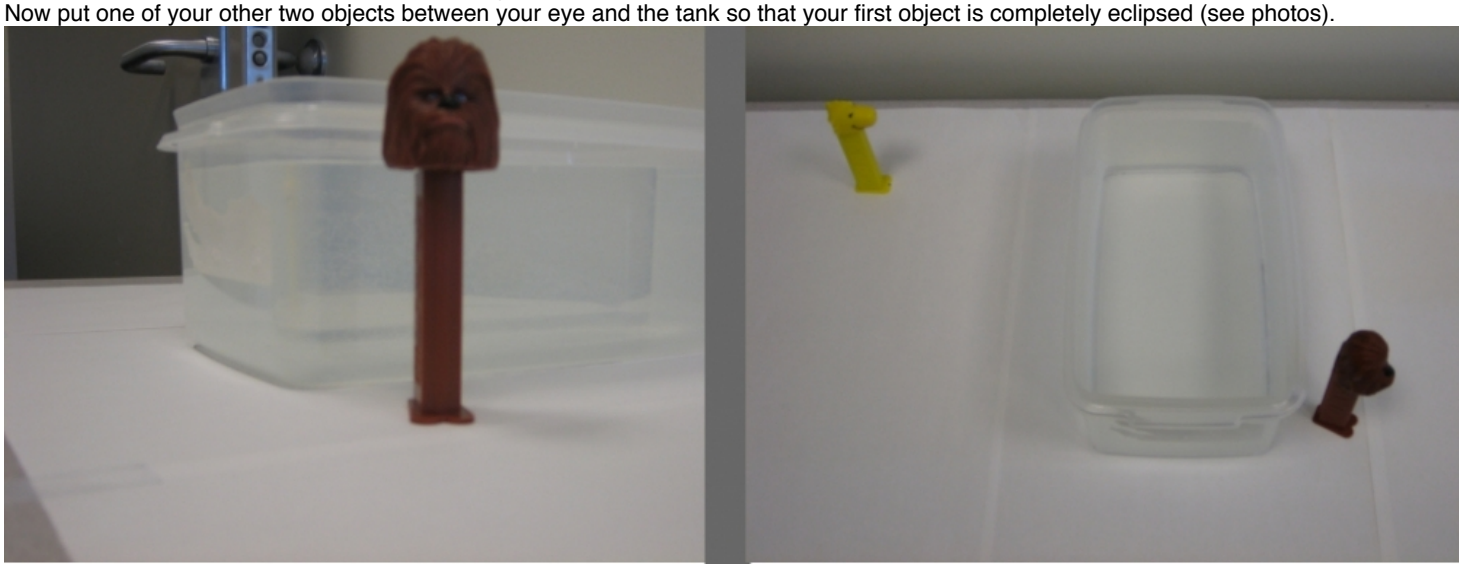


Illustration of step 5, eye view (left) and plan view (right). Chewbacca eclipses Woodstock.

6. Now put your third object between your eye and your second object so that the second object is completely eclipsed (see photos).

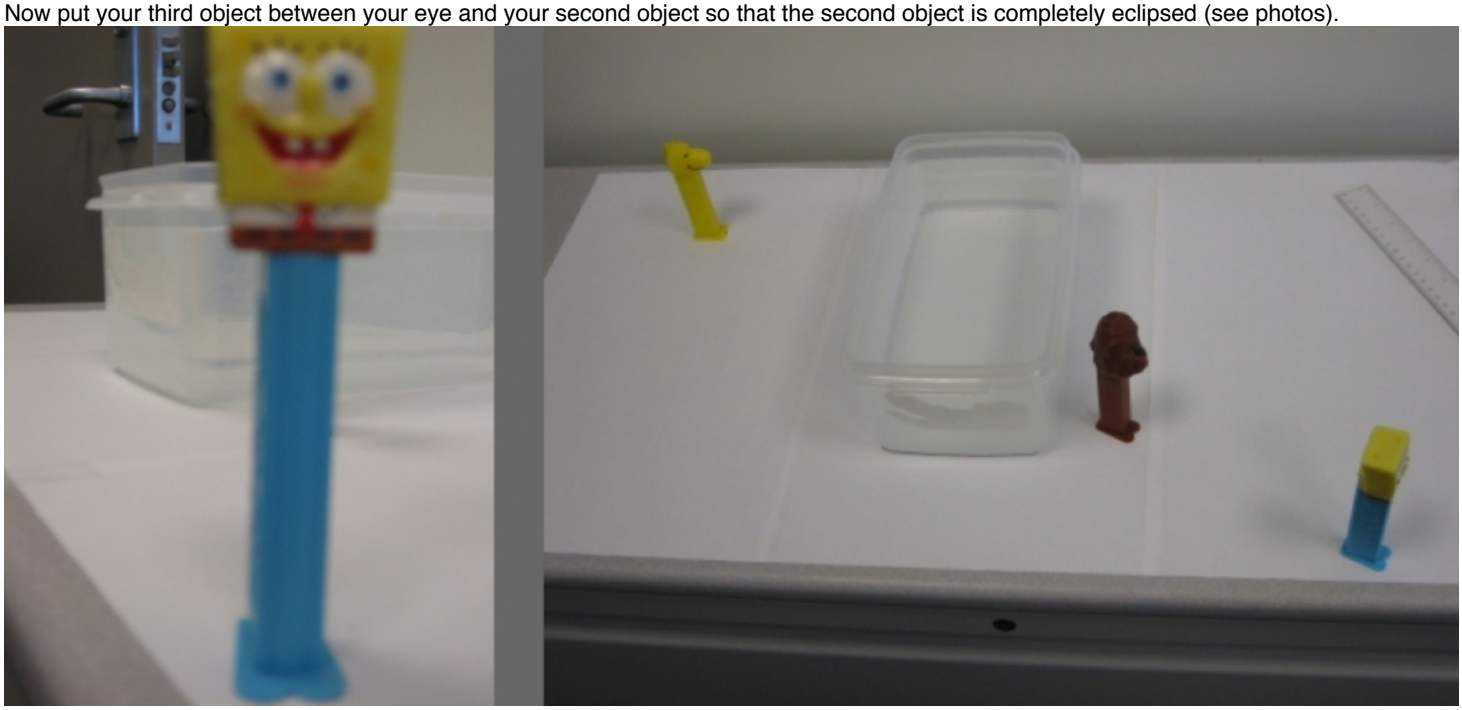


Illustration of step 6, eye view (left) and plan view (right). SpongeBob eclipses both Chewbacca and Woodstock.

7. Now take a pen and mark the location of your objects. I made a mark in the little divot right between their feet.
8. Now you can take your objects and the tank of water away from the paper. You should have an outline of your tank and three dots drawn on your paper.

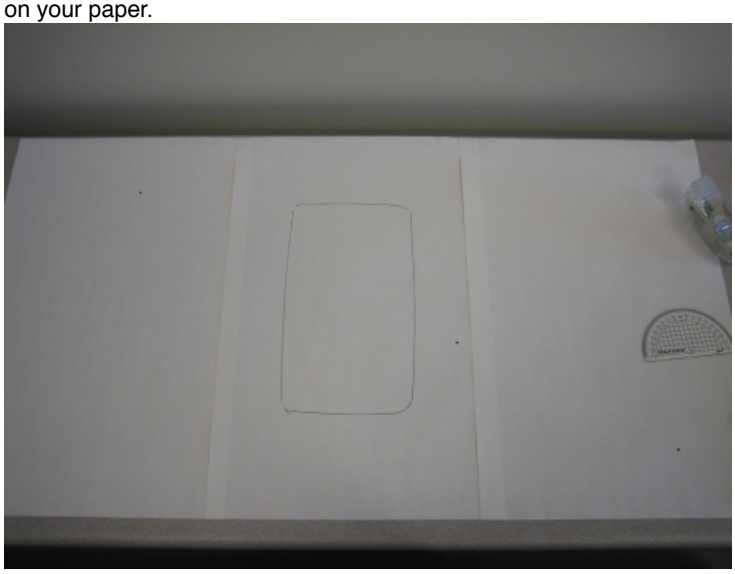


Illustration of step 8. There's the outline of the tank plus three dots showing the former locations of Woodstock, Chewbacca, and SpongeBob.

9. Connect the Chewbacca and SpongeBob dots with a line that extends to the outline of the tank.

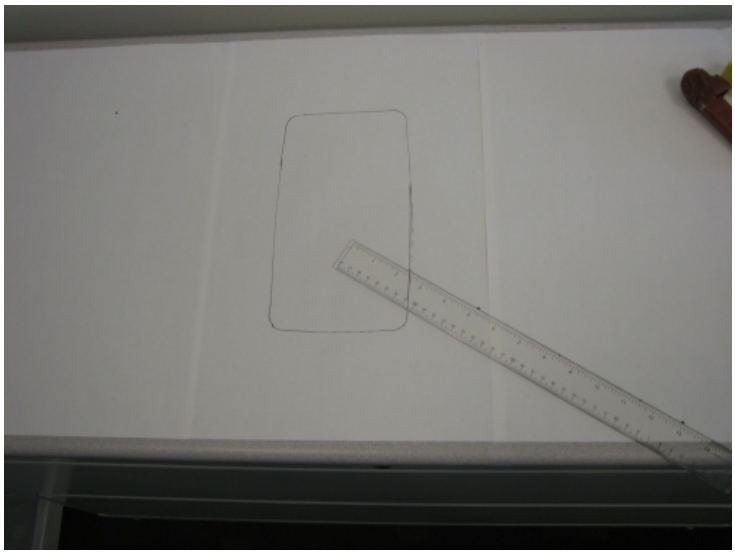


Illustration of step 9. Construct the incident ray with a straightedge.

10. Draw a line parallel to the Chewbacca-SpongeBob line that goes through the Woodstock point and connects to the outline of the tank on Woodstock's side of the tank. You can use a compass and straightedge to construct a parallel line. There is a Web site that gives a good tutorial showing how to do this: Math Open Reference [2]
11. Use the straightedge to connect the two points on each side of the outline of the tank. Now you should have three line segments that show how light traveled from Woodstock through the air, through water, through air again, and to your eye.

Nitpicker Alert!

It is true that light was bent as it traveled from the air, through the wall of the tank and then through the water, then the wall on the other side of the tank, then the air again. Unless your tank has really thick walls, like, for example, the underwater viewing area of polar bear exhibits at zoos that have glass several inches thick, we should be able to ignore the effects of the thickness of the tank walls.

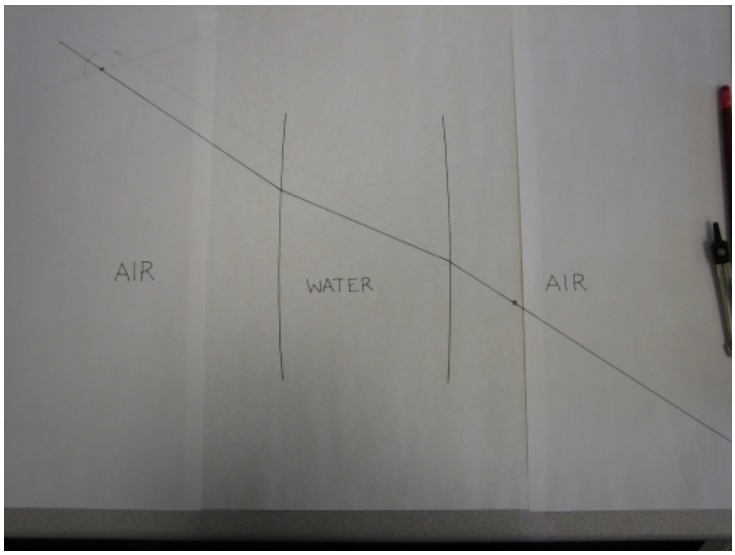


Illustration of step 11. There's the outline of the tank plus three line segments connecting the former locations of Woodstock, Chewbacca, and SpongeBob to the tank outline

12. Draw a line perpendicular to the tank outline at the point at which the incident ray from Woodstock to the tank intersects the tank outline.
13. Measure the angle of incidence. This is the angle between the Woodstock-tank line segment and the perpendicular line.
14. Measure the angle of refraction. This is the angle between the perpendicular line and the ray path inside the tank. See photo below.

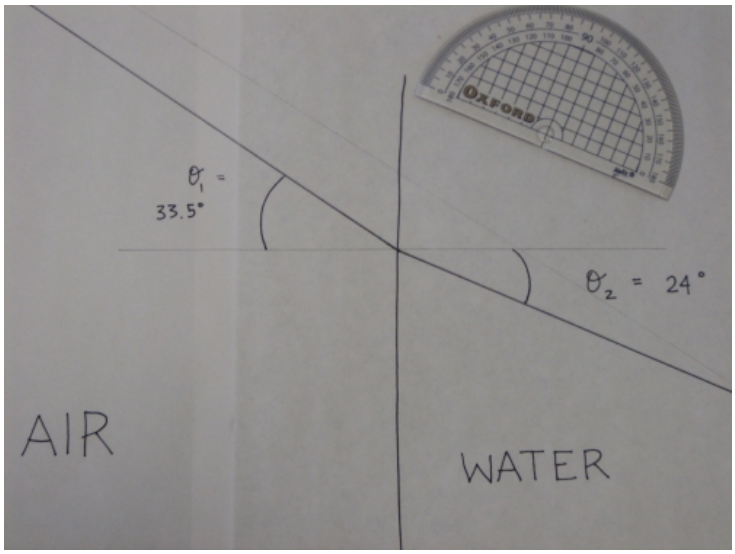


Illustration of steps 12, 13, and 14. The angle of incidence (θ_1) = 33.5° and the angle of refraction (θ_2) = 24°. Note that the protractor is just sitting there as a prop. I obviously did not measure the angles from way over there!

15. Replace the tank, put Woodstock in a different place and repeat the above procedure. You may also leave Woodstock in the same place and move your eye to a different place. Either way, repeat several times with either or both of the above variations.
16. Using the worksheet for *Lesson 4 Activity: Optics Lab*, fill out Table 1 with your angle measurements.
17. Eat all the Pez. This will ensure that your blood sugar is sufficiently high to carry out the next set of calculations.
18. Continue completing the *Lesson 4 Activity: Optics Lab* worksheet.

Submitting your work

Submit your Lesson 4 Activity: *Optics Lab* worksheet. It should contain the plots you made and the answers to the questions at the end of this lab experiment. Please save your worksheet in the following format:

L4_Optics_AccessAccountID_LastName.doc (or whatever your file extension is).

For example, former Cardinals pitcher and hall of famer Bob Gibson would name his file "L4_Optics_rxg45_gibson.doc"

Then, upload your worksheet to the Optics Lab assignment in Canvas by the due date specified on the first page of this lesson.

Grading criteria

I will use my general grading rubric for problem sets [3] to grade this activity.

Links
[1] https://www.e-education.psu.edu/earth520/sites/www.e-education.psu.edu.earth520/files/textFiles/interior/L4_opticsFall2015.doc
[2] http://www.mathopenref.com/constparallel.html
[3] https://www.e-education.psu.edu/earth520/node/1686