Name ________________________ Date ________________ Hour __________

Refraction Activity

Big Idea: Light travels in straight lines except when it reaches a boundary between different mediums. At the boundary, light both bounces off and passes through the surface, changing direction.

Goal: You will conduct a series of inquiries about the behavior of light rays when they meet a surface between two different materials.

Computer Setup: Access the URL http://phet.colorado.edu/en/simulation/bending-light and start the "Bending Light" simulation by clicking on the green "Run Now!" button. http://bit.ly/1zn2qu5

Phase I: Exploration

1. If you have played with the simulation at all, click on the yellow "Reset All" button at bottom right.
2. Click once on the red button on the laser at upper left. Do not move the laser. You should see a red ray of light from the laser that strikes the boundary between the white and blue areas. This segment, from the laser to the boundary, is called the *incident ray.*
3. Click and drag the round protractor from the Toolbox and place it in the middle of your screen. Adjust its position to accurately measure the angle between the normal (vertical dashed line) and the incident ray that comes out of the laser.
   This angle should be 45°. If you are not seeing that, or you are not sure, ask your teacher to check the position of your protractor.
4. Also measure the angle of the *reflected ray* (the ray headed up and to the right, also in the white part of the area). Record that angle in the following table.
   Click and drag the laser to change the angle at which its ray hits the boundary of the blue and white areas. Record the angle of both the incident ray and the reflected ray. Do this for several laser positions.
5. Consider the research question, "**Is the reflected ray angle related to the incident ray angle?**" It has been said that the reflected angle is equal to the incident angle. Which of your observations confirm or contradict this statement?

Incident Ray Angle	45°				
Reflected Ray Angle					

Phase II: Does the Evidence Match the Conclusion?

Consider the research question, "**How is the index of refraction (*n*) of a material related to the speed of light in that material?**"

6. Select the tab "More Tools" at the top of the simulator, and click on the yellow "Reset All" button in the lower right. Press the red button to turn on the laser.
7. Click and drag the "Speed" meter from the Toolbox, placing its point on the incident ray. Move the speed meter to different points on the incident ray (make sure to keep it on the incident ray, between the laser and the horizontal boundary).
   How fast is the incident ray? If there is a single speed, state that; if the speed varies, state the range (minimum and maximum) of speeds.
8. Move the speed meter to the reflected ray, and measure the speed at various points along that section. How fast is the reflected ray? Again, answer as a single speed if possible, or a range if necessary.
9. Now move the speedometer to the ray that is below the boundary, in the bluish area. Measure and record its speed, again as a single number or as a range.
10. In the gray "Material" boxes on the right side, there is a text box labeled "Index of Refraction (n)" where you may enter numbers. In the lower one, choose "Custom" from the drop down menu, then enter a

value from 1.00 to 1.60, and measure the speed of the refracted ray. Record the results in the following table, and repeat for other values of *n*.

11. If a student proposed the general rule, **"The speed of light is a constant in all materials, regardless of *n*,"** would you agree, or disagree? Explain your answer, and quote evidence you have collected in the preceding work, or evidence you generate on your own using the "Bending Light" simulation. If you disagree, describe precisely how *n* is related to the speed of light.

Index of Refraction	1.500				
Speed of Light					

Phase III: What Conclusions Can You Draw from the Evidence?

Consider the following research question, **"When light passes into a medium where it slows down, does it bend toward the normal or away from the normal?"**

Suppose a student gathers the following data using the "Bending Light" simulation. (*You may want to follow what they did by using the simulation to reproduce these results yourself.*)

Incident Angle = 45°

Incident ray passing through Index of Refraction n = 1.20

Incident ray speed = 0.83 c

I set the Index of Refraction for the bottom area to various values, and measured the angle of the refracted ray, with these results:

n = 1.00 1.10 1.20 1.30 1.40 1.60

v= 1.00c 0.91c 0.83c 0.77c 0.71c 0.62c

angle = 58° 50° 45° 40° 37° 32°

12. What conclusions and generalizations can you make from the data gathered above? Explain your reasoning and provide specific evidence, with sketches if necessary, to support your reasoning.

Phase IV: Summary

Create a summary (conclusion), in your own words, that describes the path(s) taken by light that strikes a boundary between two different materials. You should cite specific evidence you have collected here. Feel free to create and label sketches to illustrate your response. When light passes from one medium to another, it doesn't stay in a straight line, why does this happen? Be as specific as possible in stating what you learned!