Reflection, Refraction, and Total Internal Reflection

Purpose:
To investigate the effect of the angle of incidence upon the brightness of a reflected ray and refracted ray at a boundary and to identify the two requirements for total internal reflection.

Getting Ready:
Navigate to the **Refraction** Interactive at The Physics Classroom website:
http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Refraction

Navigational Path:
www.physicsclassroom.com ==> Physics Interactives ==> Refraction and Lenses ==> Refraction

Getting Acquainted:
Once you've launched the Interactive and resized it, experiment with the interface to become familiar with it. Observe how the laser can be dragged about the workspace, how it can be turned On (**Go** button) and Cleared, how the substance on the top and the bottom of the boundary can be changed, and how the protractor can be *toggled* on and off and repositioned. Also observe that there is an incident ray, a reflected ray and a refracted ray; the angle for each of these rays can be measured.

Part 1: Reflection and Refraction
Set the top substance to Air and the bottom substance to Water. Drag the laser under the water so that you can shoot it upward through the water at the boundary with air (don't do this at home ... nor in the physics lab). Toggle the protractor to **On**. Then collect data for light rays approaching the boundary with the following angles of incidence ($\Theta_{incidence}$). If there is no refracted ray, then put "--" in the table cell for the angle of refraction ($\Theta_{refraction}$). Finally, rank the brightness of the reflected rays using a "1" for brightest and a "6" for dimmest. Do the same for the brightness/dimness of the refracted rays, using a "1" for the brightest. Collect the data and answer the follow-up questions.

$\Theta_{incidence}$ (°)	$\Theta_{reflection}$ (°)	$\Theta_{refraction}$ (°)	Reflected Ray Brightness (1 = brightest, etc.)	Refracted Ray Brightness (1 = brightest, etc.)
10				
20				
30				
35				
40				
45				
50				
60				
80				

1. Use the patterns in the data table to complete the following paragraph.
   As the angle of incidence increases, the angle of refraction ______________________ (increases, decreases) and the refracted ray becomes ____________________________ (brighter, dimmer). As this occurs, the reflected ray becomes ____________________ (brighter, dimmer). For light passing across the boundary from water to air, the angle of refraction is always __________________________ (greater than, less than) the angle of incidence. Because of this, the refracted ray will reach 90° _______________ (before, after) the incident ray reaches 90°.
2. There are certain angles of incidence for which incident light in water does not refract into the air; instead the light undergoes **total internal reflection**. Is it possible for an incident light ray present in the air to approach the boundary with water and undergo total internal reflection? Use the simulation to study this question; explain your answer below.

Part 2: The Critical Angle

You observed in Part 1 that there is a range of angles for which the incident light in water does not refract into the air but instead undergoes total internal reflection. For light passing from water to air, this occurs for angles of about 49° and higher. The incident angle of 49° is the so-called **critical angle**. By definition, the critical angle is the angle of incidence for which the angle of refraction is 90.0°. Any incident light approaching the boundary at angles greater than the critical angle will undergo total internal reflection. Use the simulation to find the critical angle for the following situations. Get as close as you can to finding the critical angle. If there is no such critical angle (i.e., no total internal reflection), then indicate "--" for the critical angle.

Incident Medium	Refractive Medium	Critical Angle (°)
Water (n = 1.33)	Air (n = 1.00)	
Oil (n = 1.47)	Air (n = 1.00)	
Diamond (n = 2.42)	Air (n = 1.00)	
Water (n = 1.33)	Oil (n = 1.47)	
Oil (n = 1.47)	Water (n = 1.33)	
Diamond (n = 2.42)	Water (n = 1.33)	
Diamond (n = 2.42)	Oil (n = 1.47)	
Oil (n = 1.47)	Diamond (n = 2.42)	

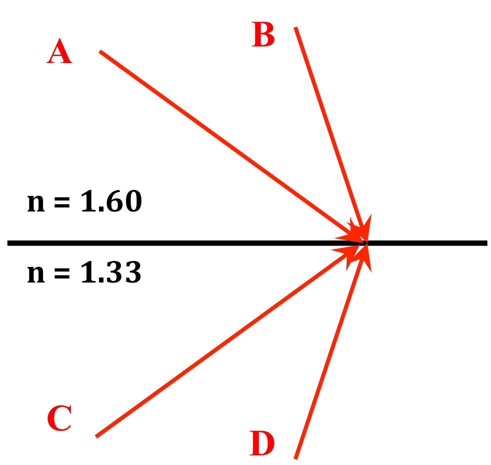
3. Analyze the Part 2 data. Observe that there are two situations in which there was no critical angle and no total internal reflection. What do these situations have in common that make them different than situations in which there was a critical angle? Explain.

4. Complete the following paragraph:

   Light approaching a boundary will undergo total internal reflection (**TIR**) if the **n** value of the incident medium is ________________________ (greater, less) than the **n** value of the refractive medium. That is, TIR occurs for light traveling from a _________________ (more, less) dense medium to a _________________ (more, less) dense medium. The second requirement for total internal reflection is that the angle of incidence is ___________________ (greater, less) than the critical angle.

5. Use your observations of the patterns to predict which light ray - **A**, **B**, **C**, or **D** - would be more likely to undergo total internal reflection for the following situations.

Situation 1



Situation 2