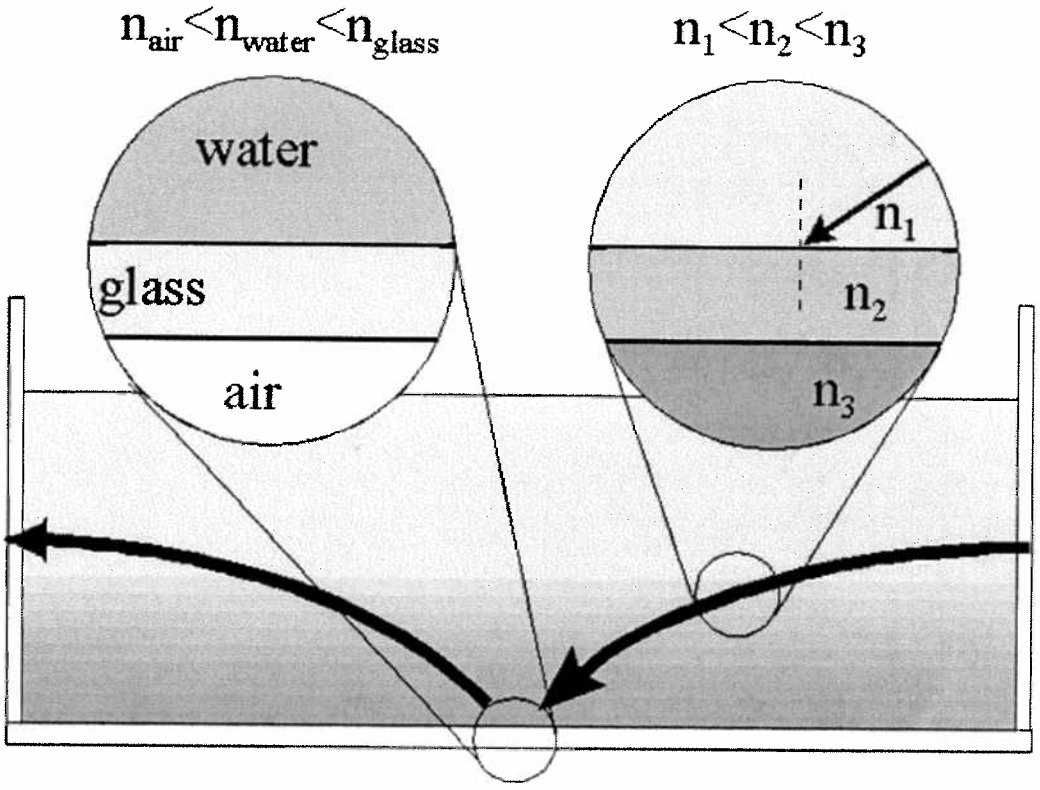
Bending Light / Atmospheric Mirages

Shine a laser pointer into an aquarium filled with a variable sugar solution. If you point the beam slightly below the horizontal it bends toward the bottom, then "bounces" off the bottom. This demonstrates total internal reflection at the bottom of the aquarium.



The sugar solution is made by dissolving 1.6 kg of sugar in 1 litre of water in a beaker. Warming the solution to 40-50^{o} C helps dissolve the sugar.

Add a pinch of coffee creamer or calcium hydroxide to both the aquarium water and sugar solution, to make the beam visible by the Tyndall effect.

Place the aquarium on blocks before you fill it, so you can show that no light is refracted below it. Fill the aquarium with water, and add the sugar solution to it by pouring the solution through a large funnel, which reaches to about 10 cm from the bottom of the aquarium. I just use a 2 Litre pop bottle that I've cut the bottom out of. This prevents the solution from mixing with the upper layer of water. A vertical gradient of the index of refraction is set up from the pure water at the top of the aquarium to the highest concentration of sugar solution at the bottom. The gradient lasts for a week or more.

The laser pointer can be aimed into the aquarium at many angles causing a multiplex of reflected, refracted rays that show up on the ceiling and walls around a darkened room. Ask the students which surfaces a particular spot must have reflected off or refracted through.

Safety

Safety concerns of using laser pointers are well discussed at
http://www.hc-sc.gc.ca/english/iyh/products/laser.html and
http://www.optometry.uwaterloo.ca/patients/laser/safety.htm

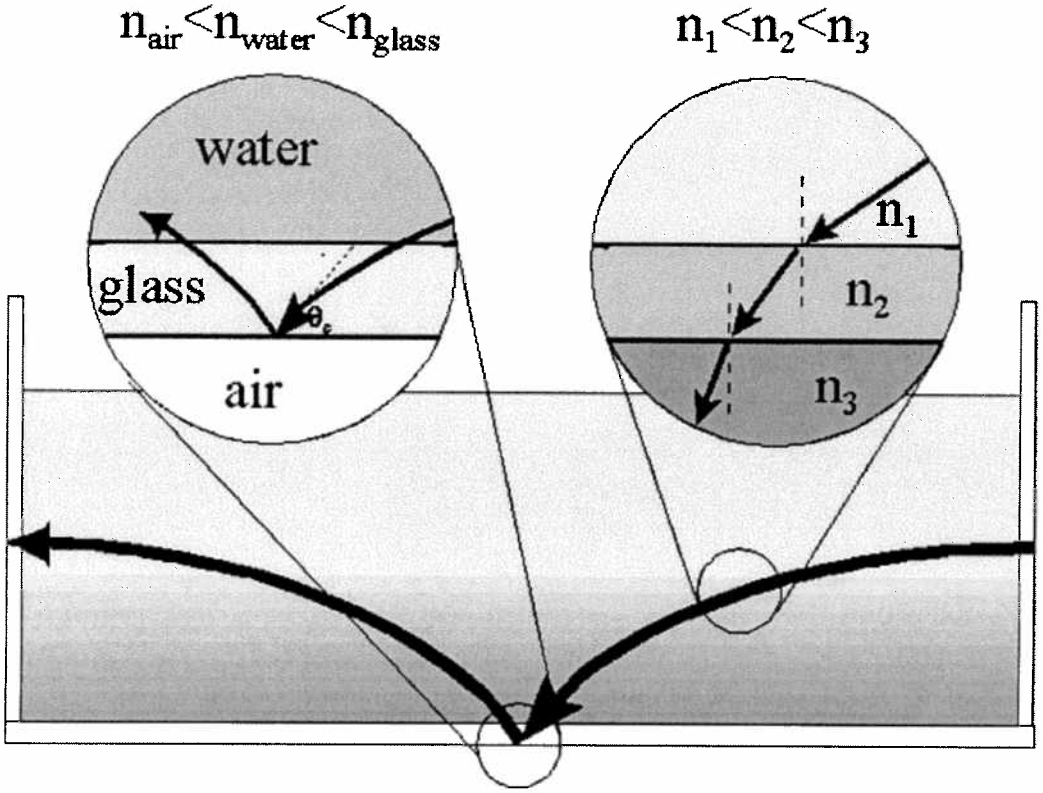
Questions for the student

1) At which boundary, water/glass or glass/air, does Total Internal Reflection occur? Explain why

ANSWER: Total Internal Reflection occurs at the glass/air boundary because the light must be moving from an optically more dense to a less dense medium.

2) Why does the ray get steeper when going down then flatter when going up?

ANSWER: The ray gets steeper as it moves down because it bends toward the normal as it moves from optically less dense to a more dense medium. It gets flatter as it moves up because it bends away from the normal as it moves from optically more dense to a less dense medium. See Diagram below



Application To Atmospheric Mirages

This gradient of the index of refraction, is similar to the gradient in the earth's atmosphere due to temperature variation. You can use this demo as an introduction to atmospheric (superior) mirages See http://www.islandnet.com/~see/weather/elements/mirage1.htm

Reference

Berry, D.A. "A Potpourri of Physics Teaching Ideas" (Bouncing Laser Beam - pg 174)