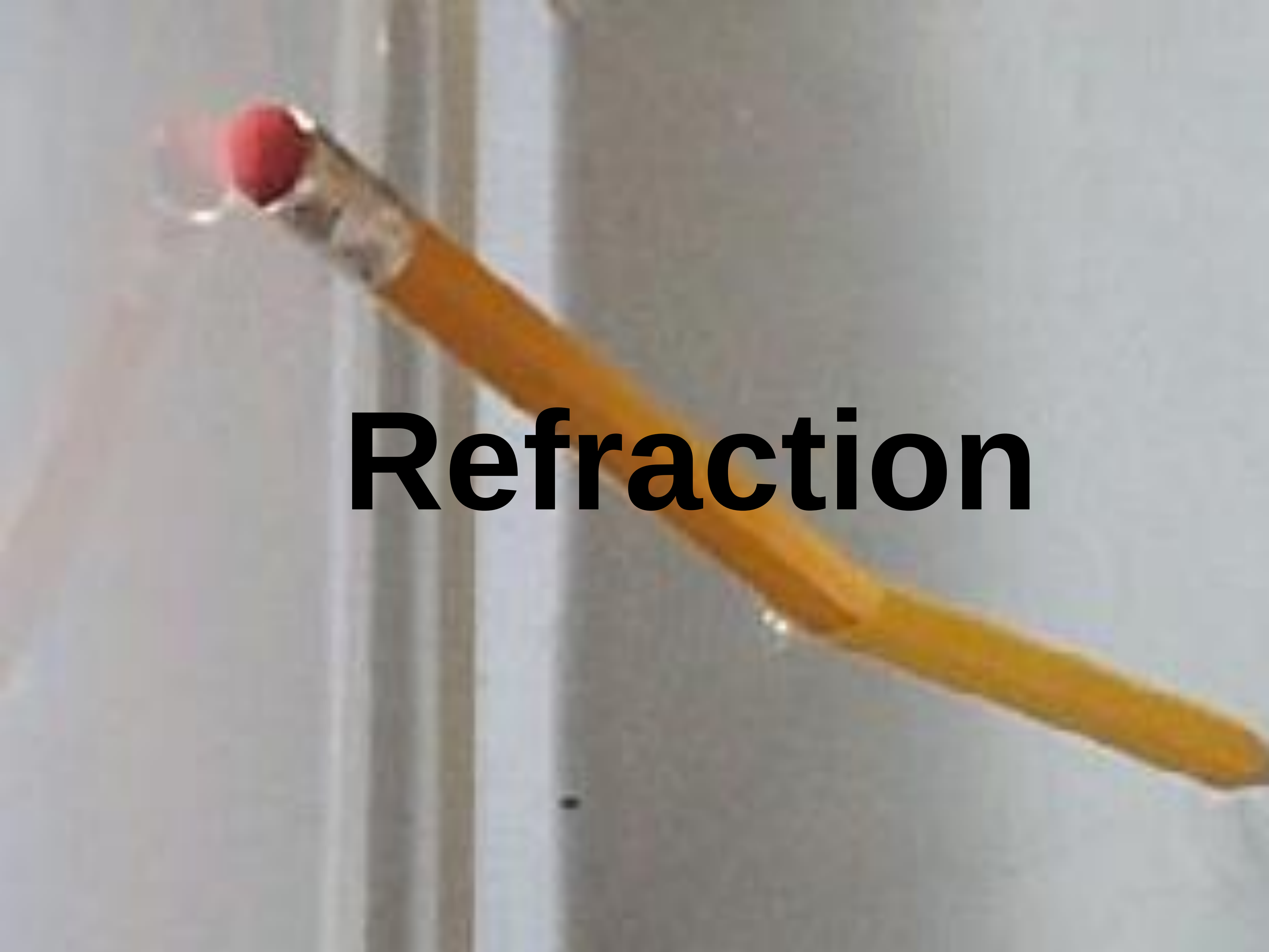
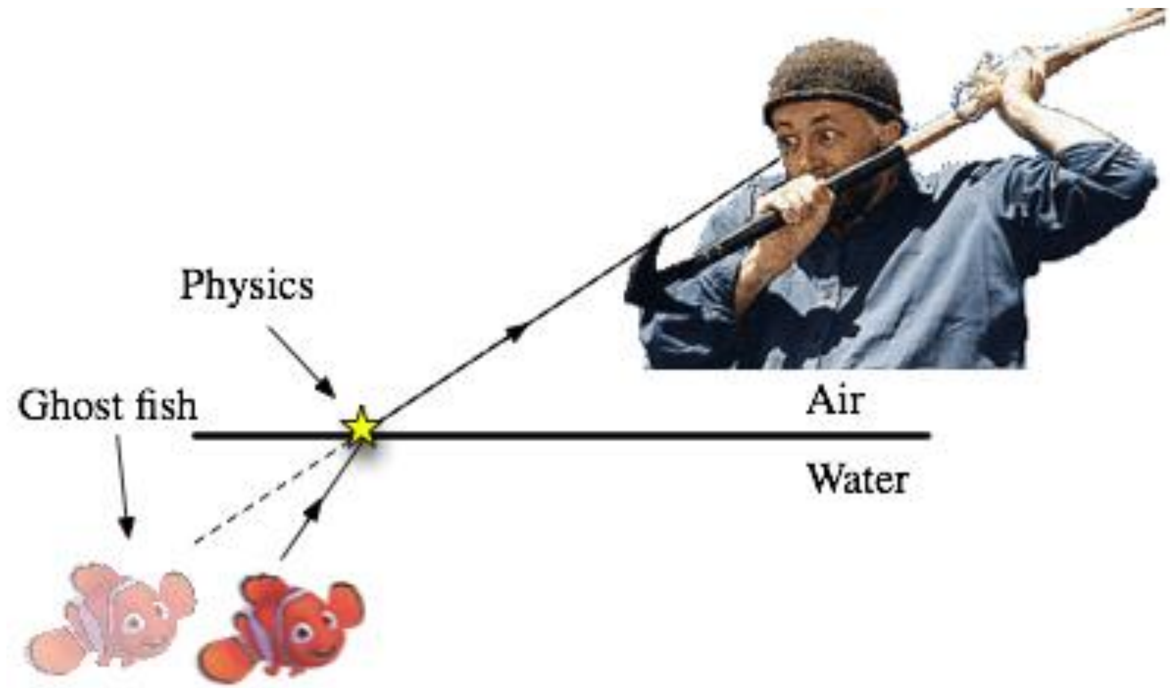
Refraction



Refraction

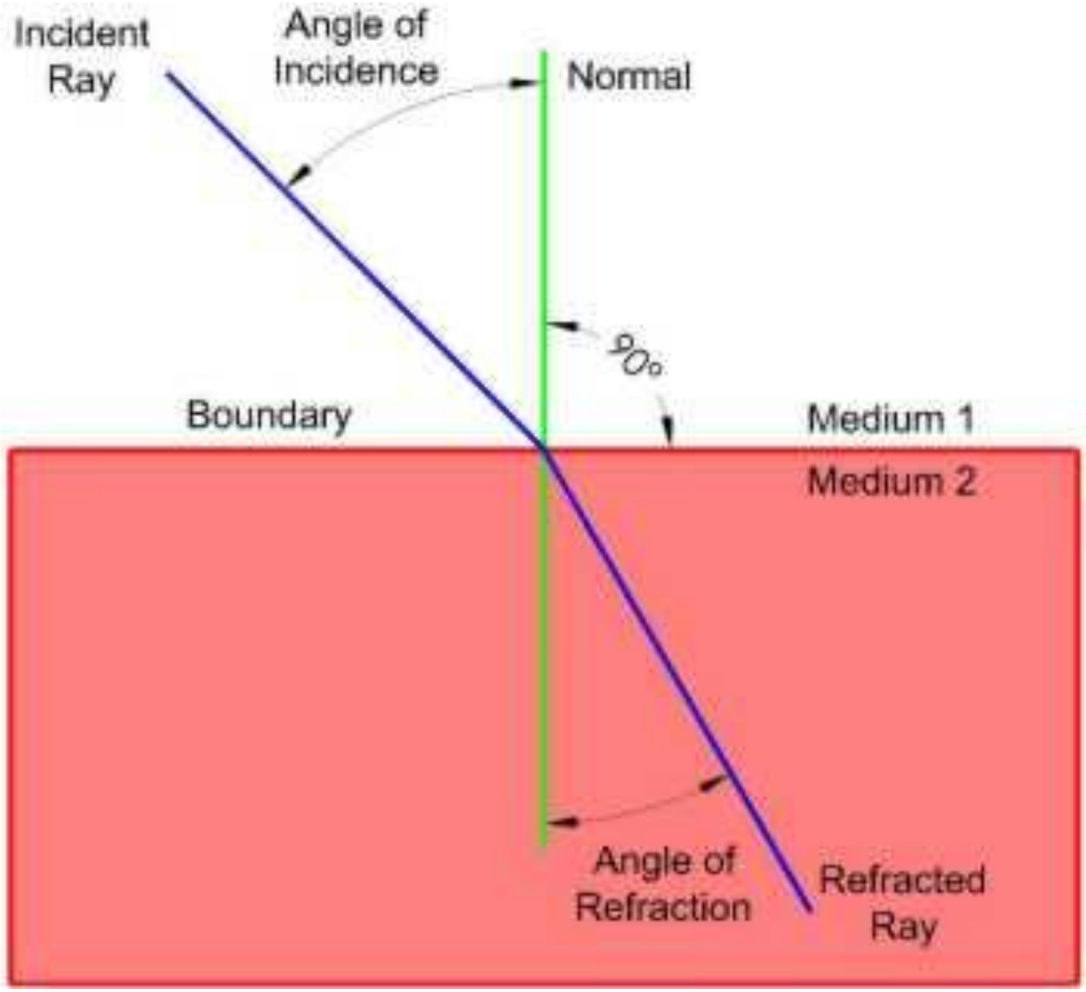
Suppose you decide to go spear fishing, but unfortunately you aren't having much luck catching any fish.



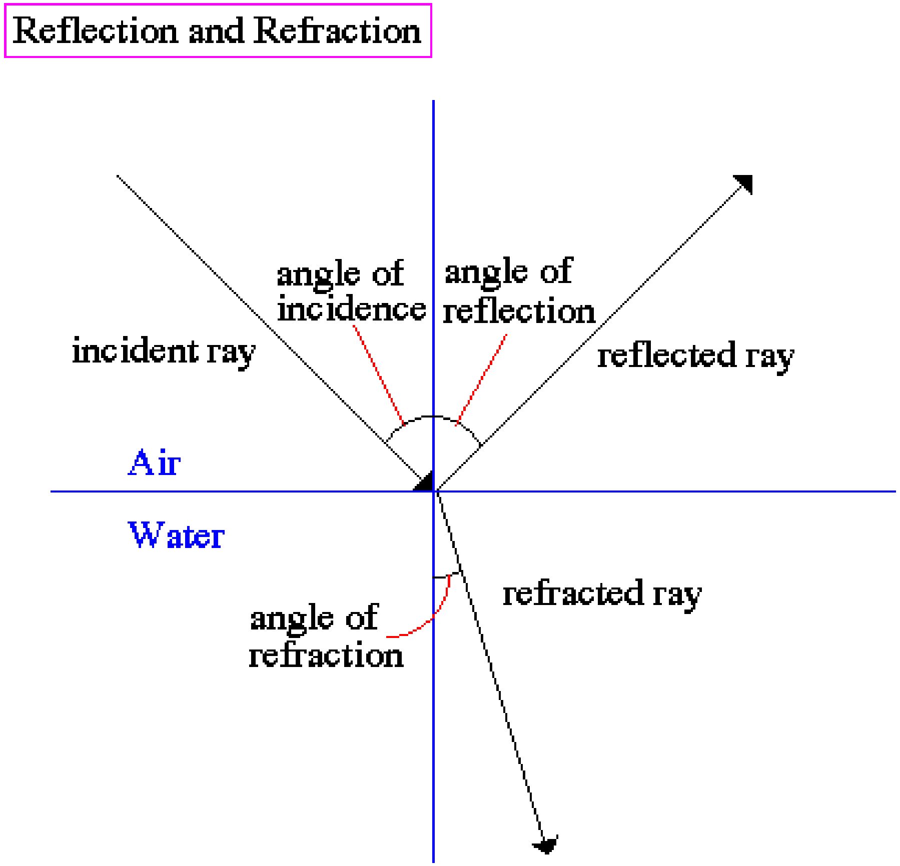
The cause of this is due to the fact that light BENDS when it reaches a new medium. The object is NOT directly in a straight line path, but rather it's image appears that way. The actual object is on either side of the image you are viewing.

Refraction

- The change in direction of a wave as it crosses the boundary between two media in which the wave travels at different speeds.



What EXACTLY is light doing when it reaches a new medium? We don’t want you to think ALL of the light refracts.



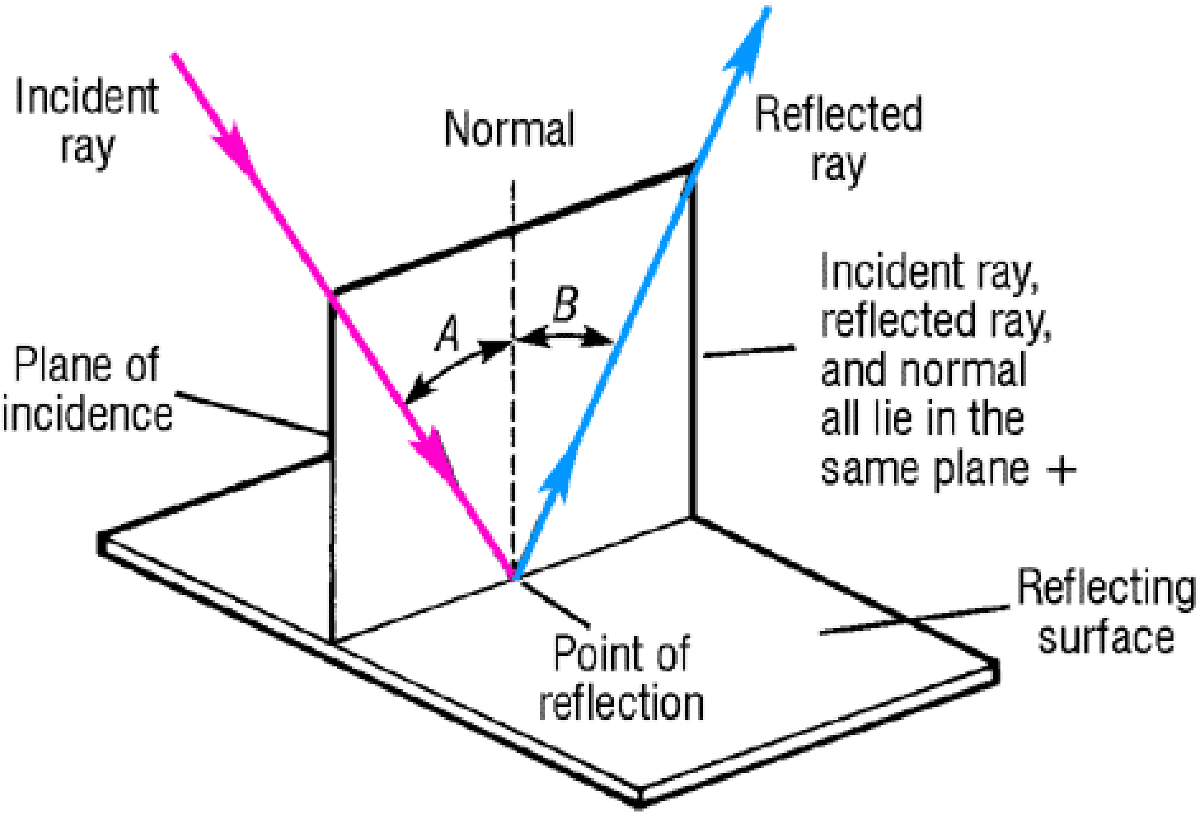
Some of the light REFLECTS off the boundary and some of the light REFRACTS through the boundary.

Angle of incidence = Angle of Reflection

Angle of Incidence > or < the Angle of refraction depending on the direction of the light

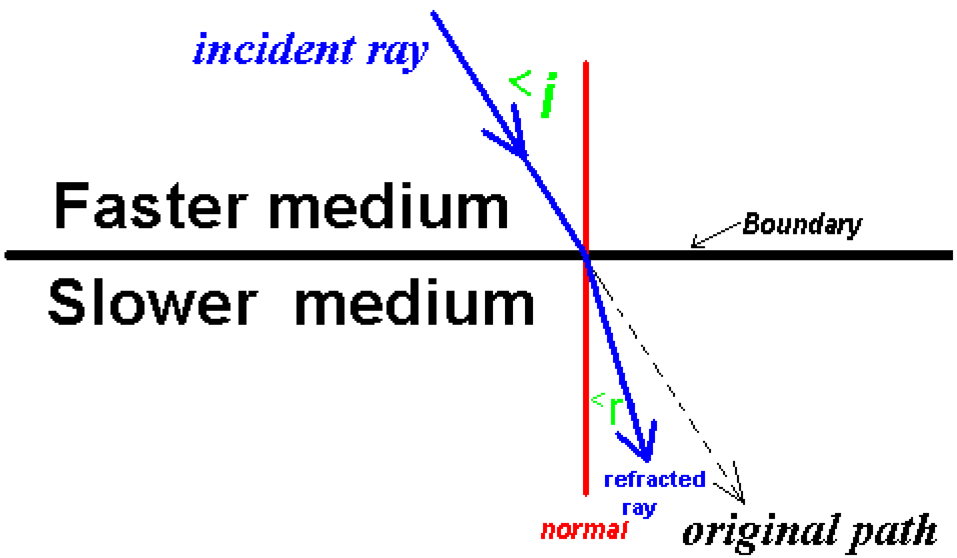
Rules for Refraction

- 1. The incident ray, refracted ray and the normal **all lie in the same plane.**

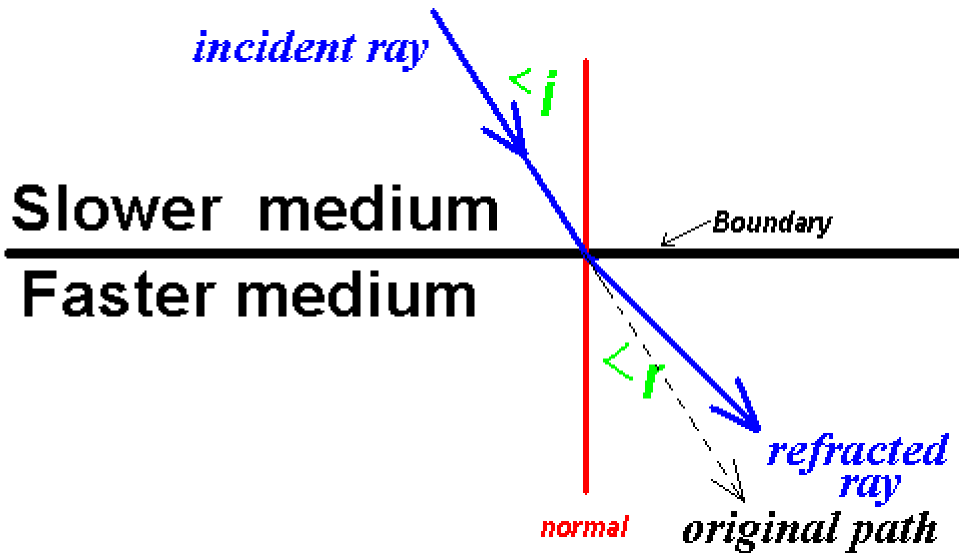


Rules for Refraction

- 2. Light bends **toward the normal** when the speed of light in the 2nd medium is **less** than the speed of light in the first medium



- Light bends **away from the normal** when the speed of light in the 2nd medium is **greater**.



- <u>Partial Reflection and Refraction</u>

- Some light that is travelling from one medium into another is reflected and some is refracted at the boundary between the different mediums

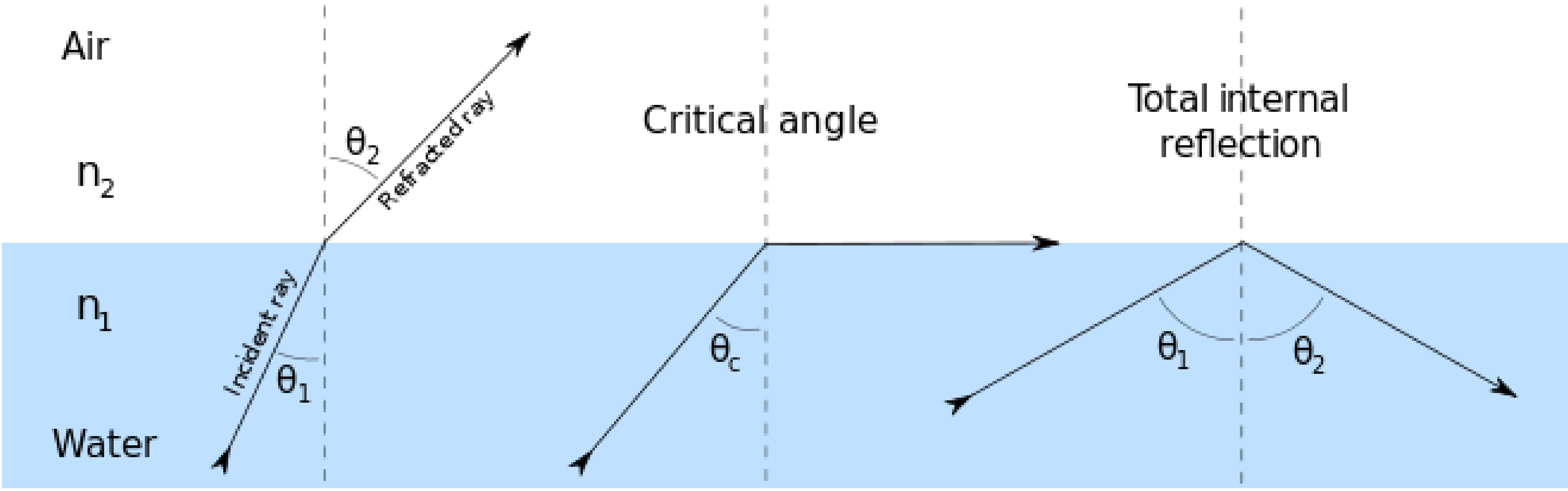
- Critical Angle

- The angle of incidence that produces an angle of refraction of 90 degrees.

- Total internal Reflection

- Incident light is not refracted but is entirely reflected back from the boundary between the 2 mediums.

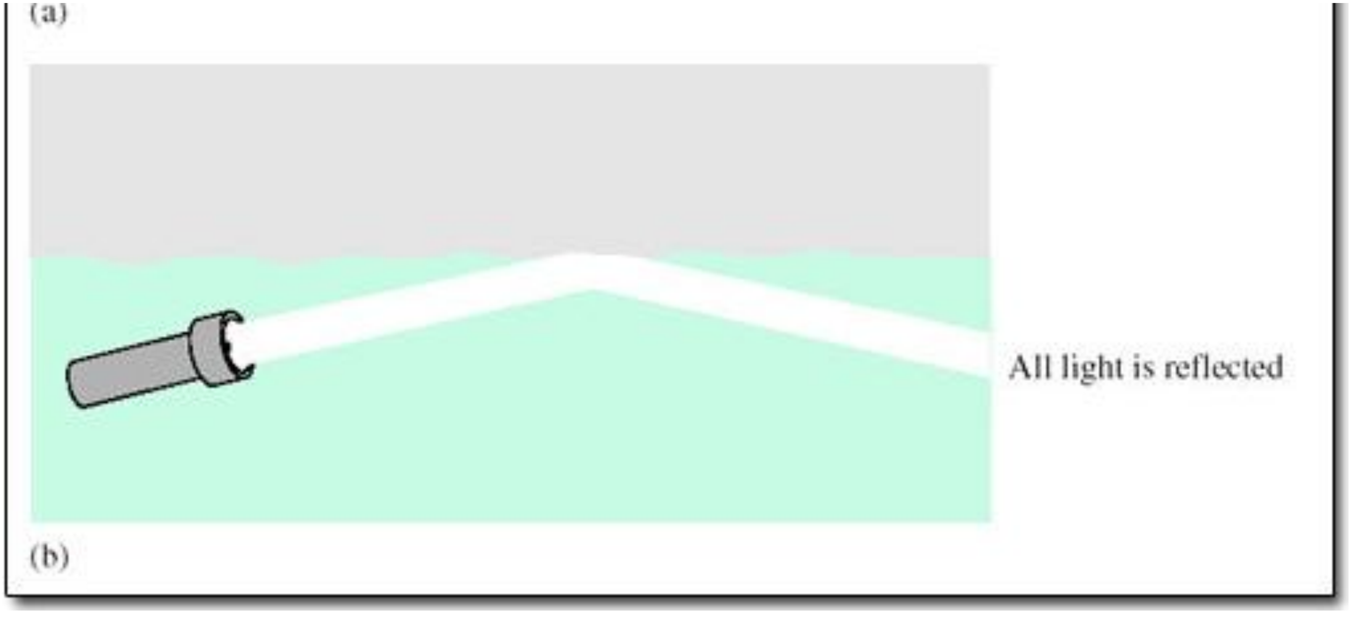
- This occurs when light travels from a medium in which its speed is lower to a medium in which its speed is higher.

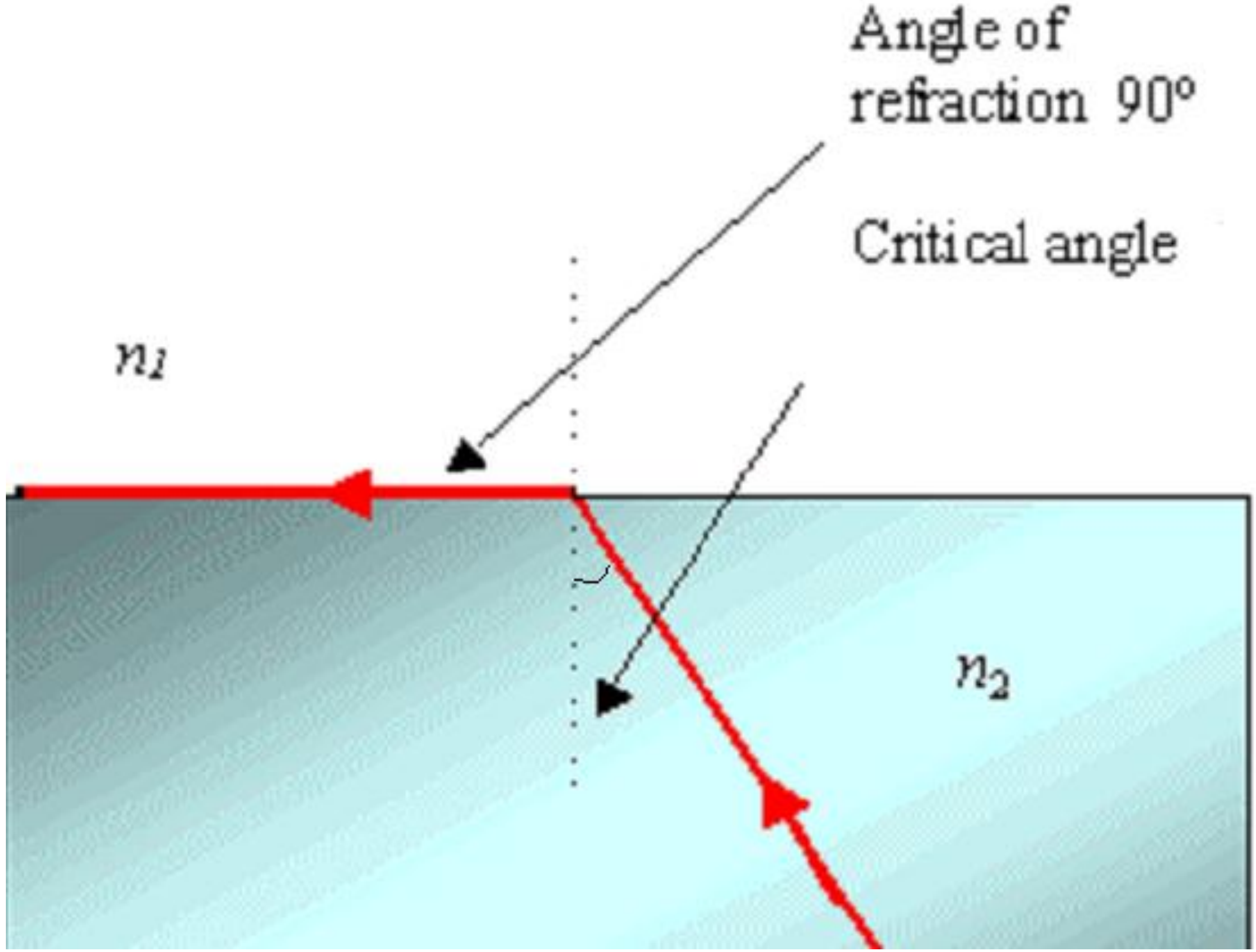


Air
n_2
n_1
Water
θ_2
Refracted ray
Incident ray
θ_1
Critical angle
θ_c
Total internal reflection
θ_1
θ_2

TIR

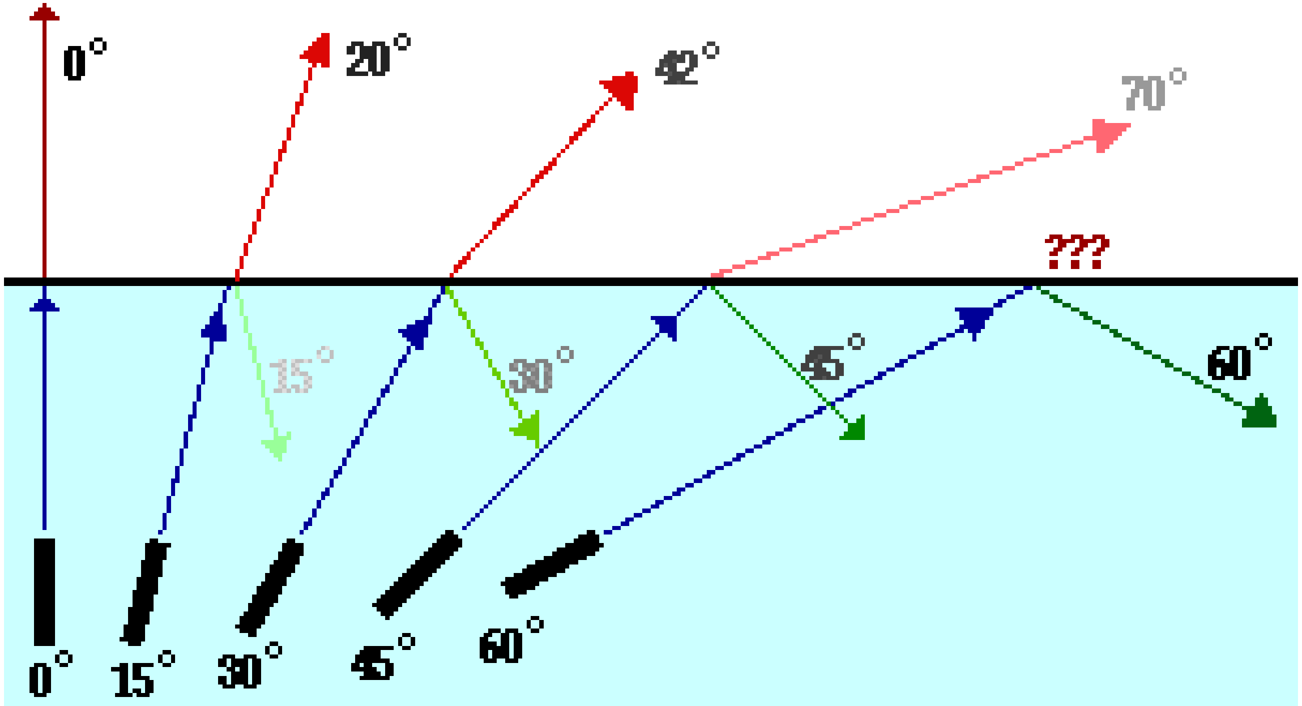
- The reflection of the total amount of incident light at the boundary between two medium.





Angle of refraction 90°
Critical angle
n_1
n_2

As the angle of incidence increases from 0 to greater angles ...



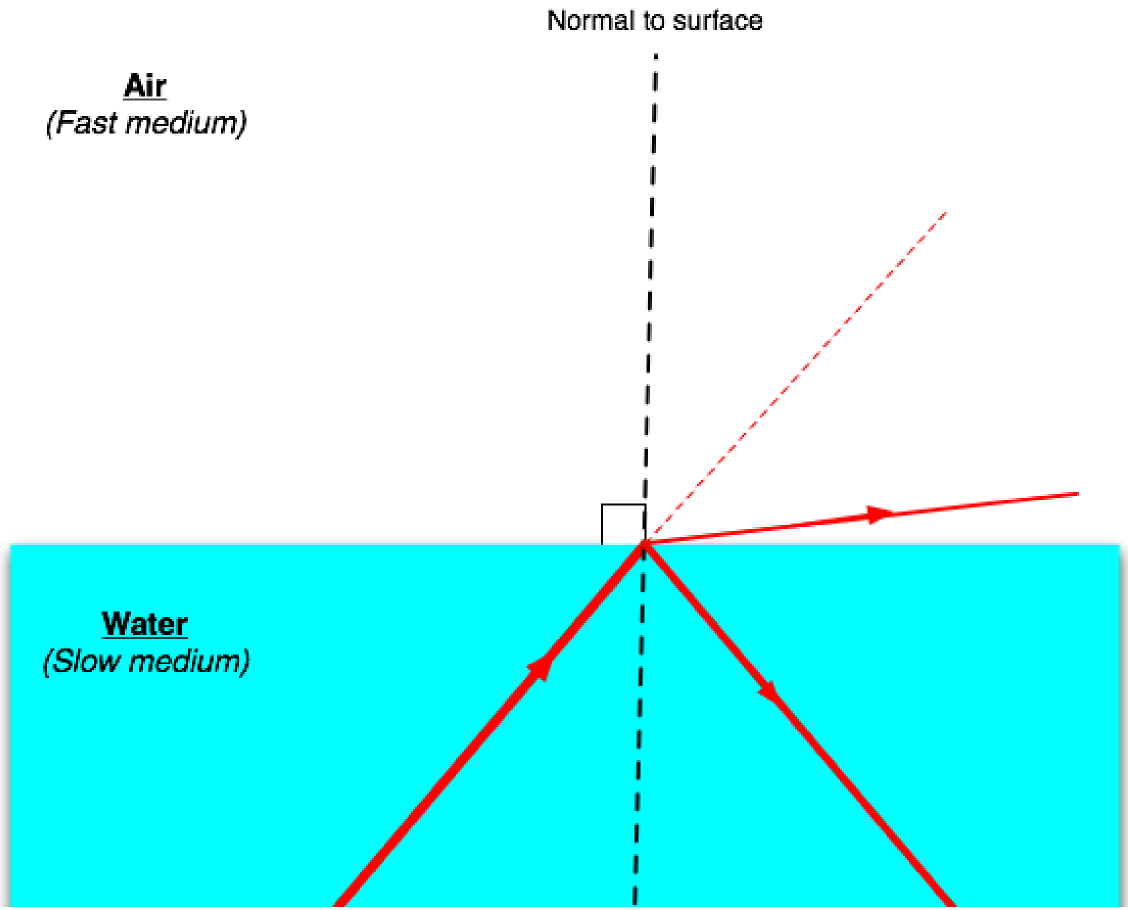
...the refracted ray becomes dimmer (there is less refraction)

...the reflected ray becomes brighter (there is more reflection)

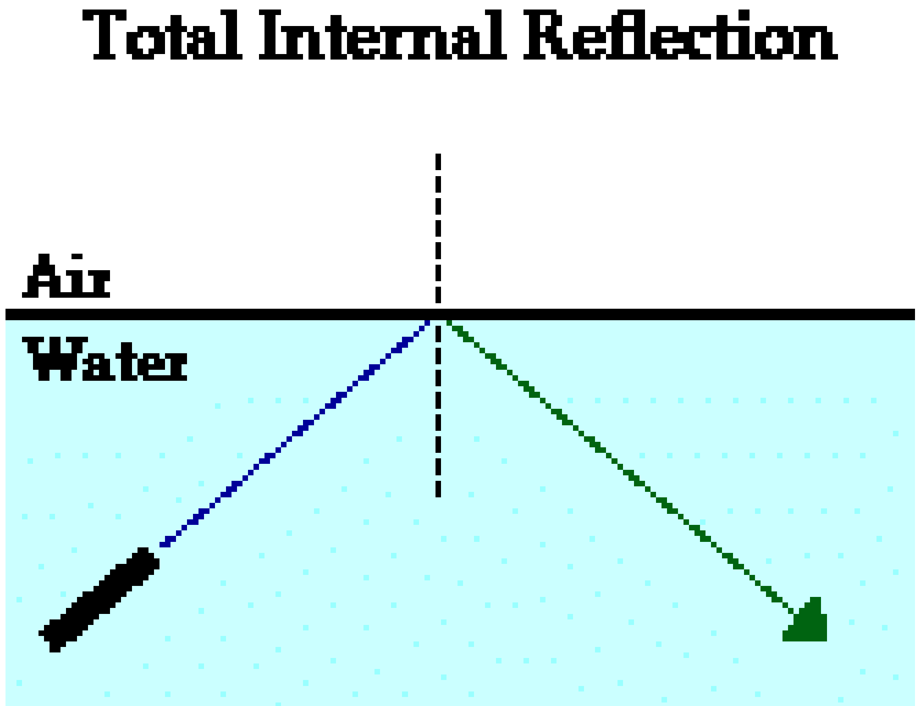
...the angle of refraction approaches 90 degrees until finally a refracted ray can no longer be seen.

Two Requirements for Total Internal Reflection

1. The light is in the more dense medium and approaching the less dense medium.



- 2. The angle of incidence is greater than the critical angle.



Applications of TIR
Fiber Optics

Diamonds

Index of Refraction

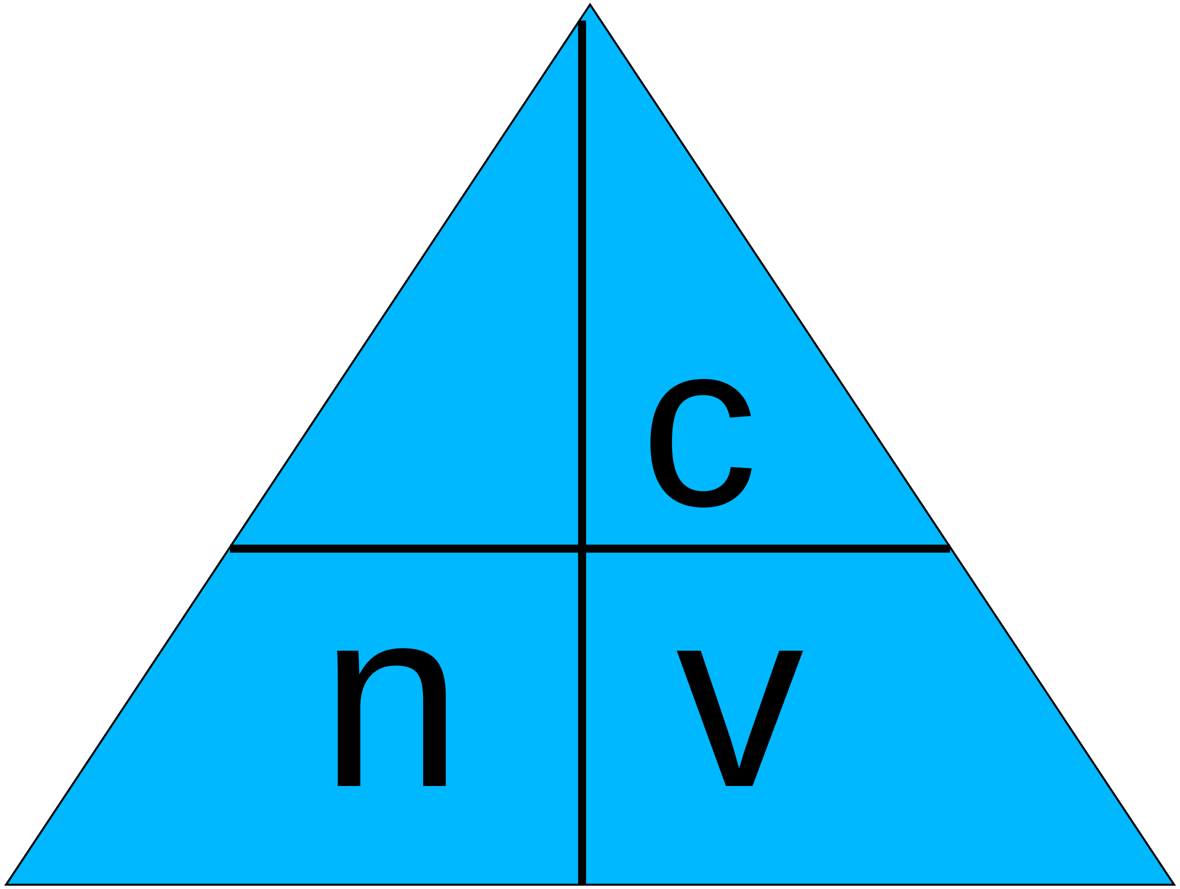
n = Index of Refraction

c = Speed of light in a vacuum

v = Speed of light in a substance

$$n = \frac{c}{v}$$

Re-arranging the formula



$n = \frac{c}{v}$ $c = n \times v$ $v = \frac{c}{n}$

Sample Problem 1

The speed of light in vegetable oil is 2.04×10^{8} m/s.

Calculate the index of refraction for vegetable oil.

Use the GRASS method

G (Given): $c = 3.00 \times 10^{8}$ m/s

$v_{vegetable\ oil} = 2.04 \times 10^{8}$ m/s

R (Required): $n = ?$

A (Analysis): $n = \frac{c}{v}$

$= \frac{3.00 \times 10^{8} \text{ m/s}}{2.04 \times 10^{8} \text{ m/s}}$

S (Solution): $= 1.47$

S (Statement): The index of refraction for vegetable oil is about 1.47.

Sample Problem 2

Calculate the speed of light in glass

Given: $c = 3.00 \times 10^8$ m/s

$n_{glassl} = 1.52$

R (Required): v = ?

A (Analysis): $v = \frac{c}{n}$

$= \frac{3.00 \times 10^8 \text{ m/s}}{1.52}$

S (Solution): $= 1.97 \times 10^8$ m/s

S (Statement): The speed of light in glass is 1.97×10^8 m/s