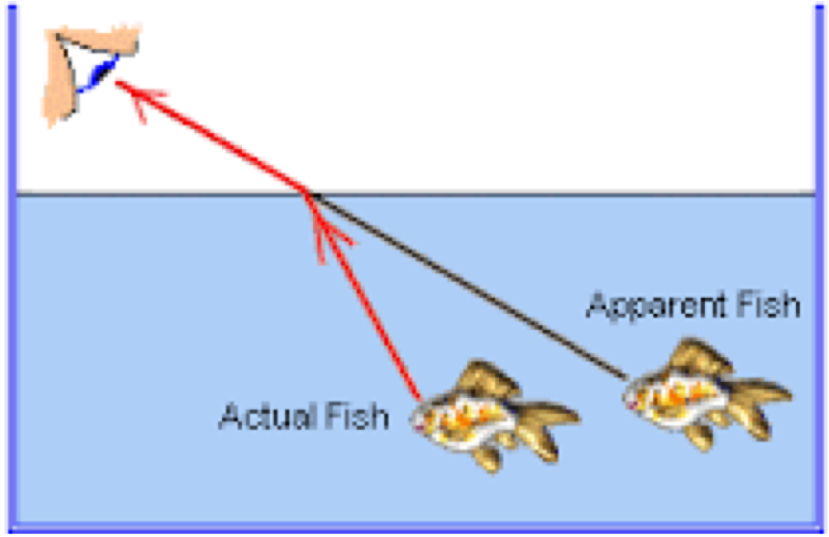
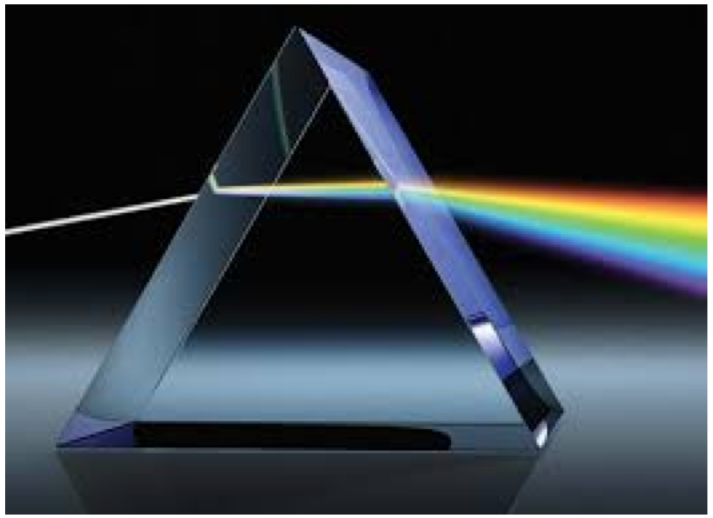


Refraction



Refraction

When a beam of light moves from one medium to another, its SPEED changes. This change in speed causes the beam to change direction, or BEND.

- Refraction is the change in the SPEED of light as it speeds up or slows down when moving from one medium to another.

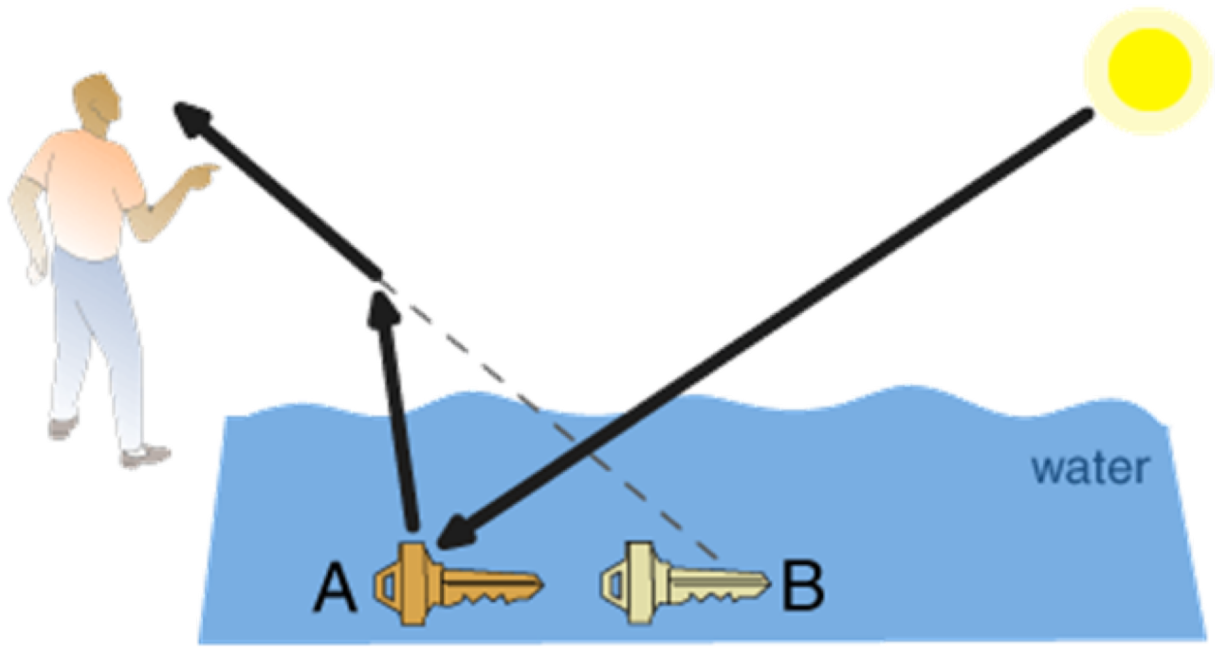
The Index of Refraction is a value used to indicate how much light bends as it pass through a substance

Table 1. Index of Refraction Ranges for Several Types of Glasses

Glass	Index of Refraction
Headlight glass	1.47-1.49
Television glass	1.49-1.51
Window glass	1.51-1.52
Bottles	1.51-1.52
Ophthalmic lenses	1.52-1.53

Table taken from Saferstein, R., Criminalistics Lab Manual, p. 30 (reference above).

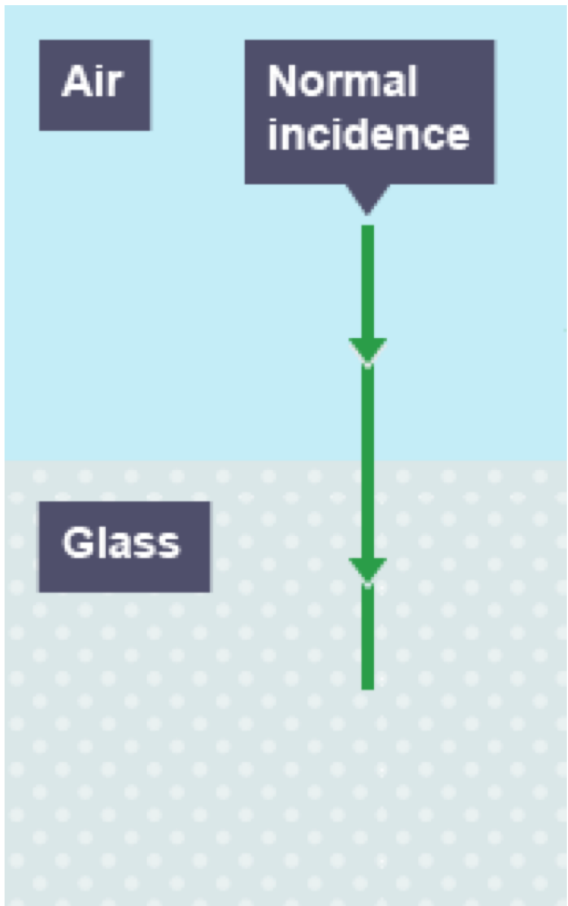
If light travels from a less-dense medium (air) to a denser medium (water), the beam of light will slow down and bend away from the normal, as shown below.



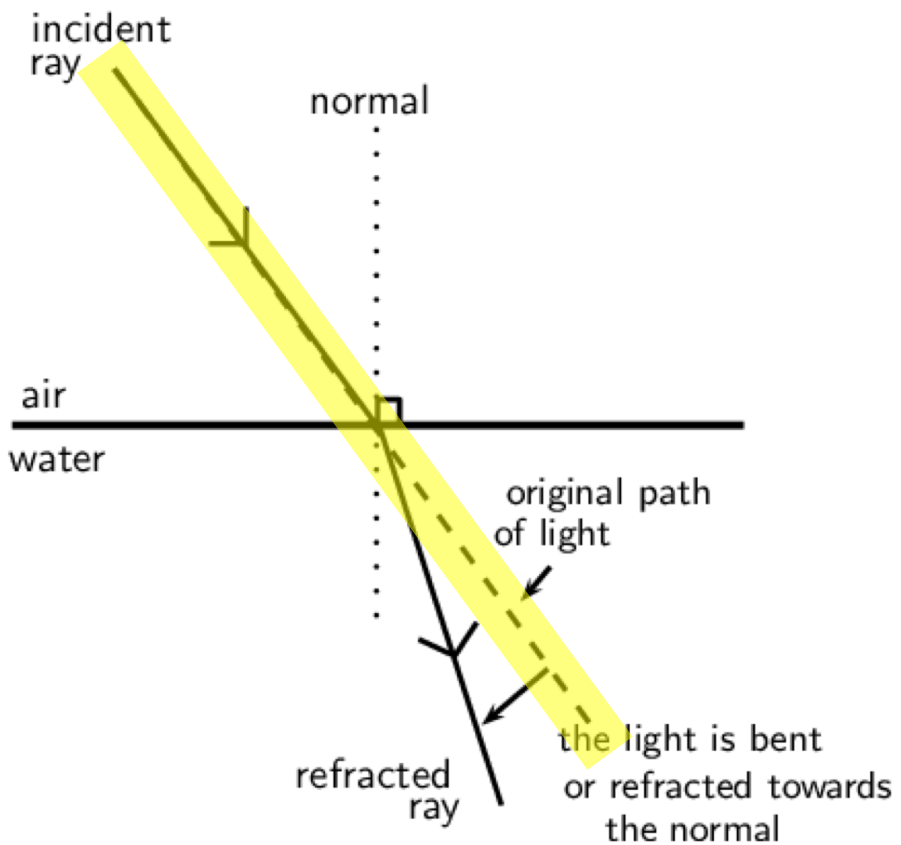
Refraction of light makes key appear to be in position B

How do you calculate Index of Refraction?

The normal is a line perpendicular to the surface where the two different mediums meet.

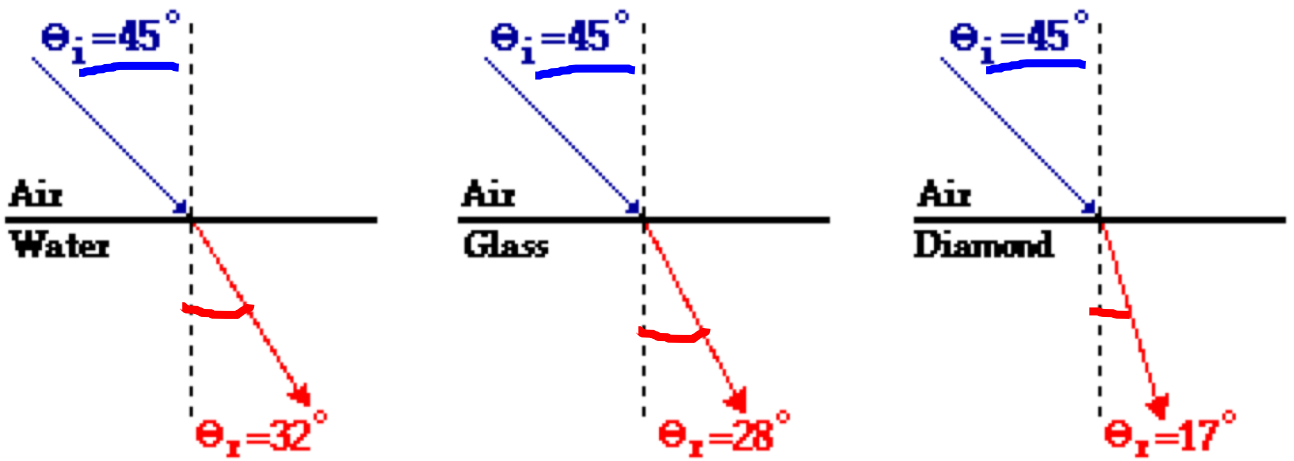


The incoming beam of light passing through the first medium (air) is called the INCIDENT ray, and the beam of light as it passes through the second medium (water, glass, etc) is called the REFRACTED ray.



The angle the incident ray forms with the normal is called the ANGLE OF INCIDENCE

The angle the refracted ray forms with the normal is called the ANGLE OF REFRACTION



- The more dense the material that light has to pass through, the more pronounced the bending of light.

Snell's Law – describes the behavior of light as it travels from one medium into a different medium

n1(sine angle 1) = n2(sine angle 2)

n1 = refractive index of medium 1
n2 = refractive index of medium 2

angle 1 = angle of incidence
angle 2 = angle of refraction

Table of sin (angle)

Angle	sin (a)	Angle	sin (a)	Angle	sin (a)	Angle	sin (a)
0.0	0.0	25.0	.4226	46.0	.7193	71.0	.9455
1.0	.0174	26.0	.4384	47.0	.7314	72.0	.9511
2.0	.0349	27.0	.4540	48.0	.7431	73.0	.9563
3.0	.0523	28.0	.4695	49.0	.7547	74.0	.9613
4.0	.0698	29.0	.4848	50.0	.7660	75.0	.9659
5.0	.0872	30.0	.5000	51.0	.7772	76.0	.9703
6.0	.1045	31.0	.5150	52.0	.7880	77.0	.9744
7.0	.1219	32.0	.5299	53.0	.7986	78.0	.9781
8.0	.1392	33.0	.5446	54.0	.8090	79.0	.9816
9.0	.1564	34.0	.5592	55.0	.8191	80.0	.9848
10.0	.1736	35.0	.5736	56.0	.8290	81.0	.9877
11.0	.1908	36.0	.5878	57.0	.8387	82.0	.9903
12.0	.2079	37.0	.6018	58.0	.8480	83.0	.9926
13.0	.2249	38.0	.6157	59.0	.8571	84.0	.9945
14.0	.2419	39.0	.6293	60.0	.8660	85.0	.9962
15.0	.2588	40.0	.6428	61.0	.8746	86.0	.9976
16.0	.2756	41.0	.6561	62.0	.8829	87.0	.9986
17.0	.2924	42.0	.6691	63.0	.8910	88.0	.9994
18.0	.3090	43.0	.6820	64.0	.8988	89.0	.9998
19.0	.3256	44.0	.6947	65.0	.9063	90.0	1.00
20.0	.3420	45.0	.7071	66.0	.9135		
21.0	.3584			67.0	.9205		
22.0	.3746			68.0	.9272		
23.0	.3907			69.0	.9336		
24.0	.4067			70.0	.9397		

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Example 1: A beam of light travels in air and then passes through a piece of glass. As the light passes from the air into the piece of glass, the light ray is bent.

The refractive index of air is 1.00, the angle of the incidence of air is 45°. As light passes through the glass the angle of refraction is 29°. What is the refractive index of the glass?

$$n1(\text{sine angle } 1) = n2(\text{sine angle } 2)$$

$$(1.00)(\text{sine angle } 45°) = n2(\text{sine angle } 29°)$$

$$\frac{(1.00)(.7071)}{.4848} = \frac{n2(.4848)}{.4848}$$

$$1.459 = n2$$

Example 2: As light travels from air to water, it bends.

refractive index of air = 1.00 angle 1 = 30°
refractive index of water = ? angle 2 = 22°

Use Snell's Law to determine the angle of refraction.

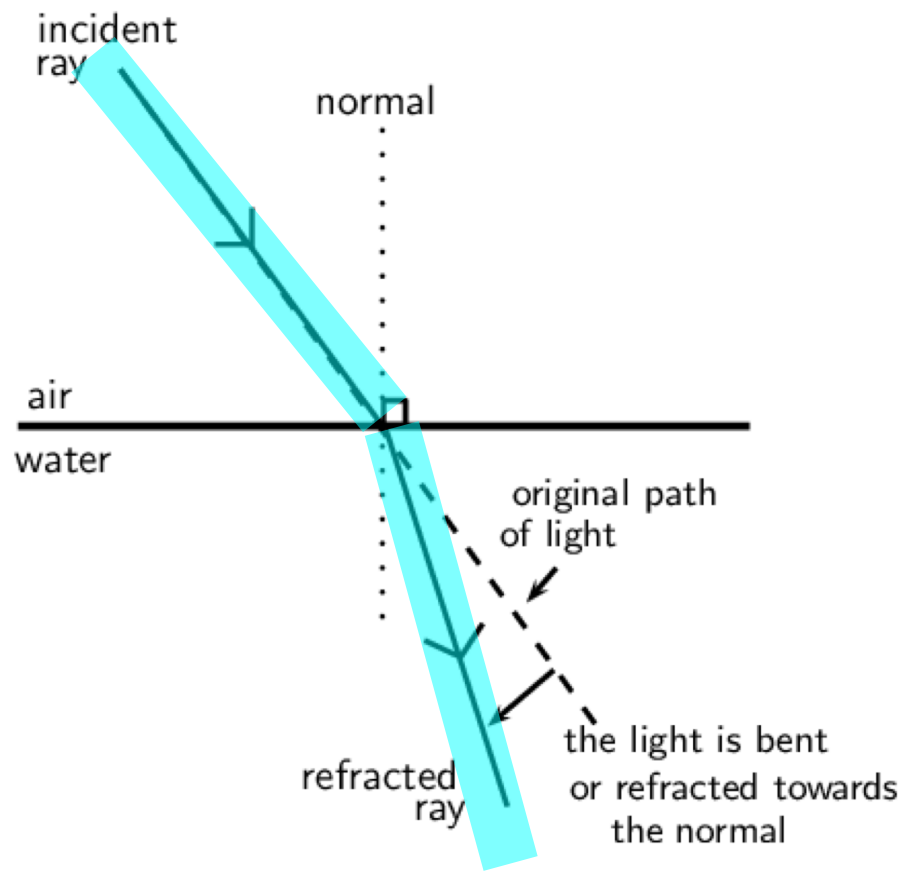
$$n1(\text{sine angle } 1) = n2(\text{sine angle } 2)$$

$$(1.00)(\text{sine angle } 30°) = n2(\text{sine angle } 22°)$$

$$\frac{(1.00)(.5000)}{.3746} = \frac{n2(.3746)}{.3746}$$

$$1.33 = n2$$

- As light passes from medium 1 to medium 2, light SLOWS DOWN
- Light bends TOWARDS the normal as it slows down!



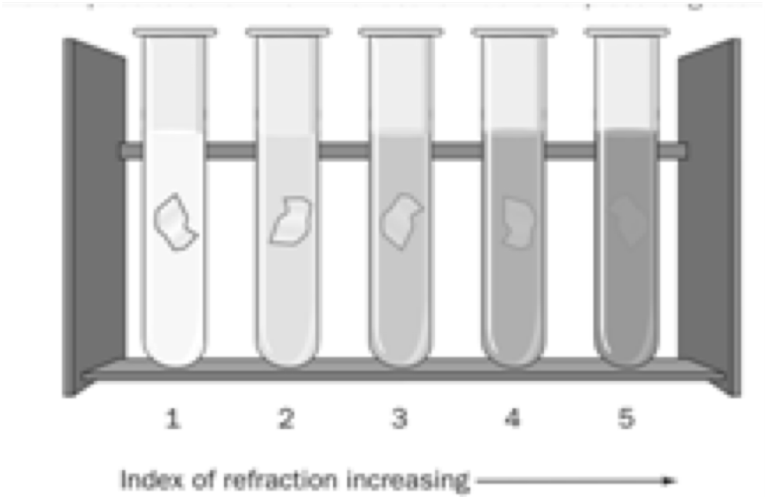
Application of Refractive Index to Forensics
- Match glass from a crime scene to glass collected as evidence

1) Compare the refractive index of the evidence glass to the refractive index of the glass from the crime scene

Submersion Method

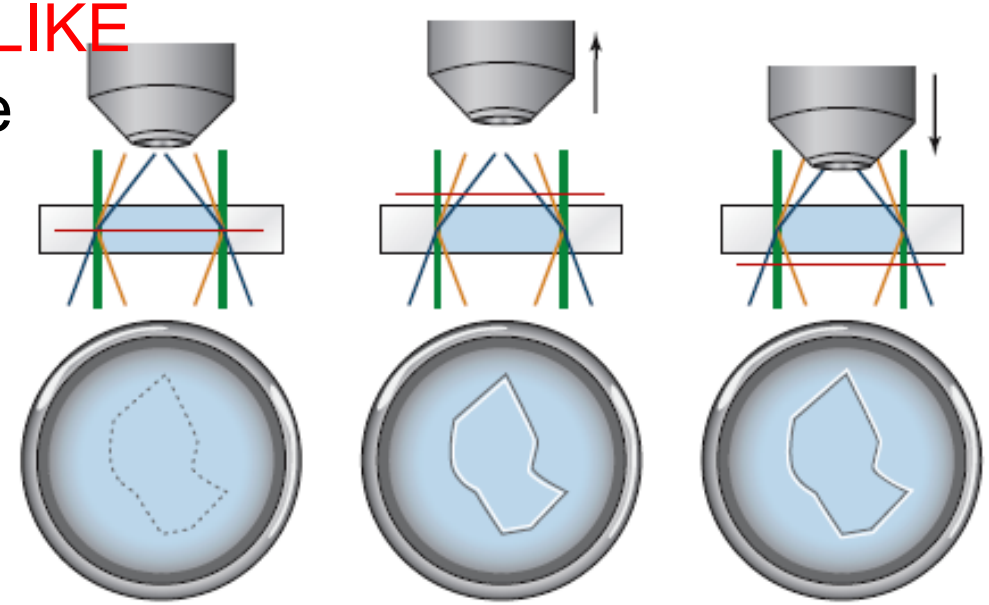
Placing the glass fragment into different LIQUIDS of known refractive indexes

- If the glass has the same refractive index, the glass fragment will seem to DISAPPEAR in the liquid



Looking for Becke Lines

Submerging the fragment of glass in a liquid and then viewing it under low power using a microscope
- if the refractive index of the liquid medium is different from the refractive index of the piece of glass, a HALO-LIKE ring appears around the edges of the glass
 – this effect is called a becke line



Match Point	Moved up	Moved down
No Becke line. Glass and liquid refractive indices match. Glass seems to disappear.	Becke line moves towards higher refractive index. Glass piece has a higher refractive index than the liquid.	Becke line moves towards lower refractive index. Glass piece has a lower refractive index than the liquid.