INDEX OF REFRACTION

- Light travels slower the more optically dense the medium it is traveling through
- As light changes speed it changes path (refraction)
  - If light moves from a less optically dense medium to a more optically dense medium it will slow down.
  - If light moves from a more optically dense medium to a less optically dense medium it will speed up.
- The ratio of the speed of light in a vacuum (3 E 8 m / s) to the speed of light in a transparent substance is known as the index of refraction. The larger the index of refraction the slower light travels.

INDEX OF REFRACTION

- n = c / v
- n = index of refraction (no units)
- c = speed of light (3 E 8 m / s)
- v = velocity of light in the transparent substance (m / s)
- n_{air} = 1 (you should memorize this!!!!)

SAMPLE PROBLEM

The hardest mineral is diamond which has an index of refraction of 2.42. At what speed does light travel through a diamond?

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

n = 2.42

c = 3 E 8 m / s

v = ?

$$2.42 = \frac{3E8m/s}{v}$$

$$v = 1.24E8m/s$$

Practice

If light travels through the mineral calcite with a velocity of 2.02 E 8 m/s, what is the index of refraction for calcite?

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

n = ?

c = 3 E 8 m / s

v = 2.02 E 8 m/s

$$n = \frac{3E8m/s}{2.02E8m/s}$$

$$n = 1.485$$

Snell's Law (a.k.a. The Law of Refraction)

- As light passes from one transparent medium to another it's speed changes and therefore the path of the light changes (bends)
- Willebrord Snell determined the relationship between the angle of incidence and the angle of refraction as follows

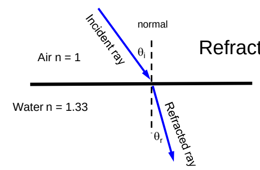
Snell's Law

$$n_1 \sin\theta_i = n_2 \sin\theta_r$$

- n_1 = index of refraction of the substance that the light is traveling from
- θ_i = angle of incidence (measured from the normal to the incident ray)
- n_2 = index of refraction of the substance that the light is traveling into
- θ_r = angle of refraction (measured from the normal to the refracted ray)

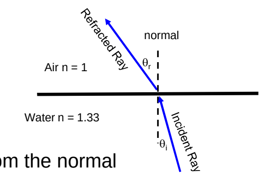
Snell's Law

- As light moves from a **less** optically **dense** medium **to** a **more** optically **dense** medium it will slow down and bend **toward the normal.** ($n_1 < n_2$)
- As light moves from a **more** optically dense medium **to** a **less** optically **dense** medium it will speed up and bend **away from the normal.** ($n_1 > n_2$)



$n_1 < n_2$

Refracted Ray bends toward the normal



$n_1 > n_2$

Refracted Ray bends away from the normal

SAMPLE PROBLEM

Light strikes water (n = 1.33) from air at an angle of 36 degrees to the vertical. What is the angle of refraction?

$n_1 = 1$
$n_2 = 1.33$
$\theta_i = 36°$
$\theta_r = ?$

$n_1 \sin\theta_i = n_2 \sin\theta_r$
$1 \sin 36° = 1.33 \sin\theta_r$
$\sin \theta_r = (1 \sin 36°) / 1.33$
$\sin \theta_r = 0.442$
$\theta_r = 26.23°$

Practice

Light strikes air from ice (n = 1.31) at an angle of 25 degrees to the vertical. What is the angle of refraction?

$n_1 = 1.30$
$n_2 = 1.00$
$\theta_i = 25°$
$\theta_r = ?$

$n_1 \sin\theta_i = n_2 \sin\theta_r$
$1.30 \sin 25° = 1.00 \sin\theta_r$
$\sin \theta_r = (1.30 \sin 25°) / 1.00$
$\sin \theta_r = 0.554$
$\theta_r = 33.62°$

Critical Angle

- As a ray of light emerges from a more optically dense medium into a less optically dense medium it speeds up and bends away from the normal.
- As the angle of incidence increases the angle of refraction gets closer and closer to 90 degrees.
- The angle of incidence that produces a 90 degree angle of refraction is called the **critical angle**.
- If a light ray strikes the surface at an angle **greater** than the critical angle then a phenomenon known as **total internal reflection** occurs. This is how fiber optics transfer information along a glass fiber.

Critical Angle

Using Snell's Law:

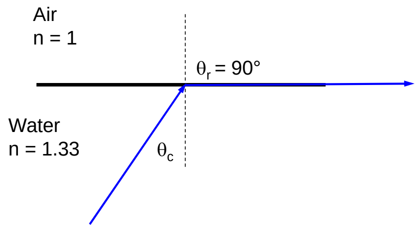
$n_1 \sin \theta_c = n_2 \sin 90°$

since sin 90° = 1 you will get

$n_1 \sin \theta_c = n_2$ therefore:

$$\sin \theta_c = n_2 / n_1$$

Critical Angle



SAMPLE PROBLEM

What is the critical angle for light emerging from a diamond (n = 2.42) into air?

θ_c = ?
$n_2 = 1$
$n_1 = 2.42$

$\sin \theta_c = n_2 / n_1$
$\sin \theta_c = 1 / 2.42$
$\sin \theta_c = 0.413$
$\theta_c = 24.4°$

Practice

What is the critical angle for light emerging from flourite (n = 1.433) into air?

θ_c = ?
$n_2 = 1$
$n_1 = 1.433$

$\sin \theta_c = n_2 / n_1$
$\sin \theta_c = 1 / 1.433$
$\sin \theta_c = 0.698$
$\theta_c = 40.25°$