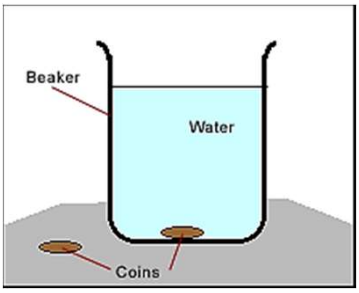
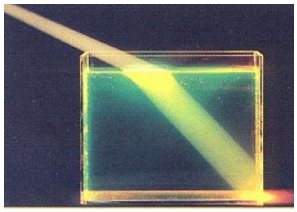
Refraction

Quick Activity

- Fill a beaker with water
- Drop a coin into the beaker
- While looking from the top of the beaker, try to poke the coin with the pencil
- Keep the pencil in the beaker and look at the pencil from the side of the beaker



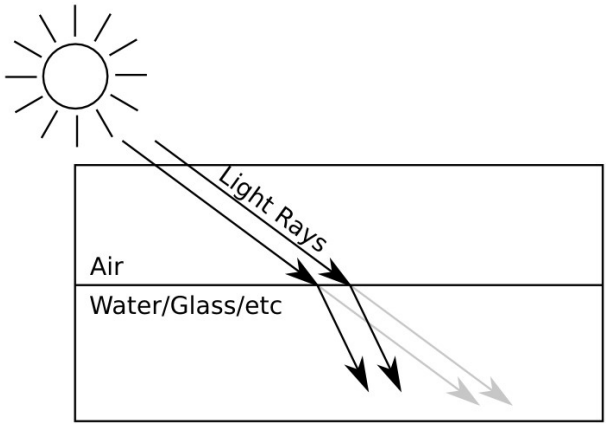
Speed of Light



- In space: 3.0 x 10^8 m/s
- In air: a bit slower
- In glass: even slower
- The more DENSE a material is, the slower the light will travel
- This is why light BENDS when travelling from one material to another

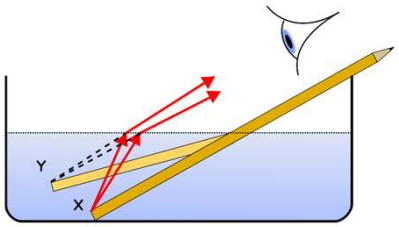
Refraction

- The bending of light when it moves from one material into another



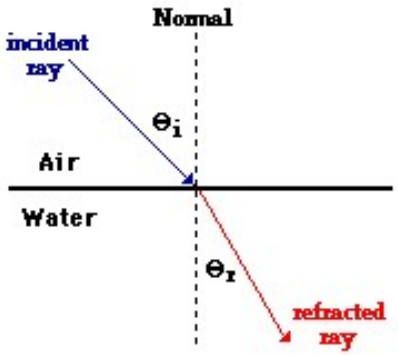
Tricking the Brain!

- Our brain thinks that light travels in straight lines
- That's why when we look at the pencil from the top, it isn't where we think it is



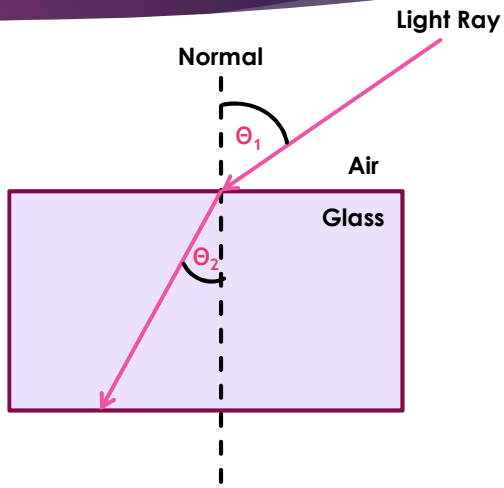
Angles

- Angle of incidence, Θ_1
  - Angle from the normal to the incident ray
- Angle of refraction, Θ_2
  - Angle from the normal to the refracted ray



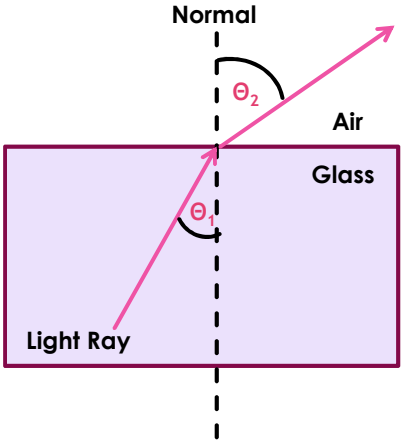
Less Dense to More Dense

- The Light Ray SLOWS down in the glass, so it bends TOWARDS the normal
- $\Theta_1 > \Theta_2$



More Dense to Less Dense

- The Light Ray SPEEDS up in air, so it bends AWAY from the normal
- $\Theta_2 > \Theta_1$



Index of Refraction in Material

MATERIAL	INDEX OF REFRACTION
vacuum	1.00
air	1.0003
water	1.33
ethyl alcohol	1.36
Pyrex glass	1.47
Glass	1.52
Diamond	2.42

- In a material with a higher index of refraction, the light slows down and bends towards the normal.
- In a material with a lower index of refraction, the light speeds up and bends away from the normal.

Index of Refraction

- A number that tells us how the speed of light in space compares with the speed of light in a given substance (medium)

Speed of light in space: always 3.0×10^8 m/s

Index of Refraction $n = \frac{c}{v}$

Speed of light in given substance

Solving Problems in Science

- We will use the GRASS method
  - G – Given
  - R – Required
  - A & S – Analysis and Solve
  - S – Statement

Example #1

- The speed of light in lead crystal is 1.34 x 10^8 m/s. Calculate the index of refraction of the crystal.
  - Given: v = 1.34 x 10^8 m/s, c = 3.00 x 10^8 m/s
  - Required: n = ?
  - Analyse & Solve: $n = \frac{c}{v} = \frac{3.00 \times 10^8}{1.34 \times 10^8} = 2.24$
  - Statement: The index of refraction is 2.24

All your equal signs should be under each other. Mine is done this way so I can fit the solution on one slide.

Another Equation

- The index of refraction can also be calculated using the angle of incidence and the angle of refraction.

$$n = \frac{sin\ \theta_1}{sin\ \theta_2}$$

Example #2

- What is the refractive index for a new material, where it is found that the angle of incidence is 30° and the angle of refraction is 18°?
  - Given: $\Theta_1 = 30^\circ, \Theta_2 = 18^\circ$
  - Required: $n = ?$
  - Analyse & Solve: $n = \frac{sin\ \theta_1}{sin\ \theta_2} = \frac{\sin 30}{\sin 18} = 1.62$
  - Statement: The index of refraction is 1.62

All your equal signs should be under each other. Mine is done this way so I can fit the solution on one slide.

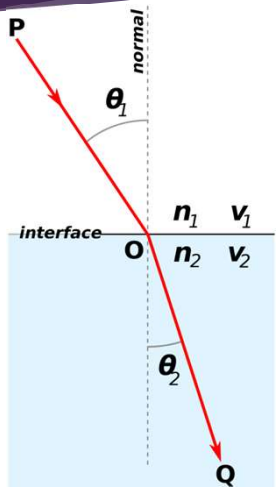
Snell's Law

- Used to calculate the angle of refraction when light is traveling from one material to another

Index of refraction for material #1 — Angle of refraction #2

$$n_1(\sin\Theta_1) = n_2(\sin\Theta_2)$$

Angle of incidence #1 — Index of refraction for material #2



Example #3

- A light wave travels from water (n = 1.33) into glass (n = 1.52) with an incident angle of 15°. What is the angle of refraction?
  - Given: $\Theta_1 = 15°$, $n_1 = 1.33$, $n_2 = 1.52$
  - Required: $\Theta_2 = ?$
  - Analyse & Solve: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$1.33 \sin 15 = 1.52 \sin\theta_2$$

Example #3

- A light wave travels from water (n = 1.33) into glass (n = 1.52) with an incident angle of 15°. What is the angle of refraction?
  - Analyse & Solve:

$$\sin\theta_2 = \frac{1.33\sin 15}{1.52} = 0.226$$

$$\theta_2 = \sin^{-1} 0.226$$
$$= 13.1°$$

All your equal signs should be under each other. Mine is done this way so I can fit the solution on one slide.

  - Statement: The angle of refraction is 13.1°

Homework

- Practice problems on p. 438 & p. 441