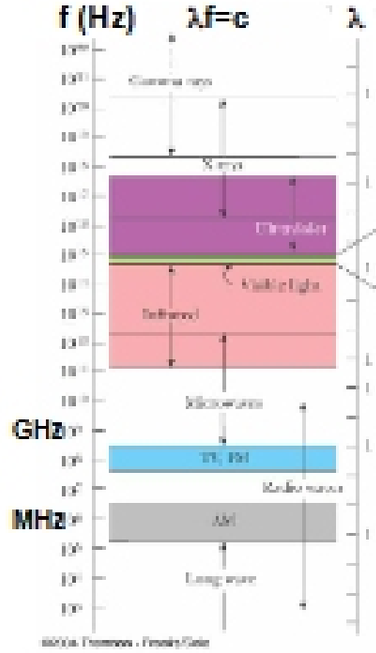
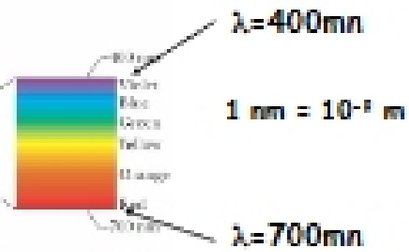
Physics 202, Lecture 23

Today's Topics

- Lights and Laws of Geometric Optics
  - Nature of Light
  - Reflection and Refraction
  - Law of Reflection
  - Law of Refraction
  - Index of Reflection, Snell's Law
  - Total Internal Reflection
  - Dispersion and Prisms



Spectrum of EM Waves



Color of lights: frequencies of waves
Speed of light:
- v=c in vacuum
- v<c in medium

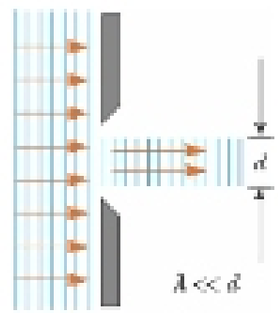
Wavelength: depends on medium
Frequency: unchanged in medium

Light And Optics

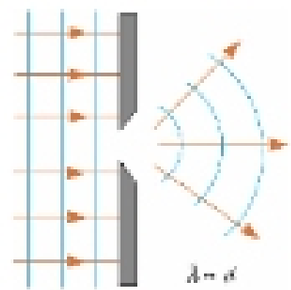
- Nature of Light
  - Light as rays
  - Light as EM waves: f, λ, ϕ, v, A, interference ...
  - Light as group of photons (Quantum Theory)
- Propagation of Light
  - Geometric Optics: Treat light as rays. (Ch. 31,32)
    → Ray approximation.
  - Wave Optics: Wave properties become important
    Interference, diffraction...(Ch. 33.)

Ray Approximation (1)

- When the wavelength of the light is much smaller than the size of the optical objects it encounters, it can be treated as (colored) rays.



Ray approximation is valid when λ<<d



Ray approximation is not valid near the gap when λ≈d. OK elsewhere

Ray Approximation (2)

- Basic features of ray approximation
  - Light rays travel in straight lines in a uniform medium
  - Light rays change direction at the boundary of media
    →Reflection and refraction
  - Light rays travel at speed of light in the medium
  - Trace of rays are reversible
  - Frequency (color) remains the same along the path.
  - Wavelength changes as light enters a different medium
  - When two set of light rays meet, they pass through each other, interference is not considered.
  - Phases are usually not a concern.

Light rays at a boundary

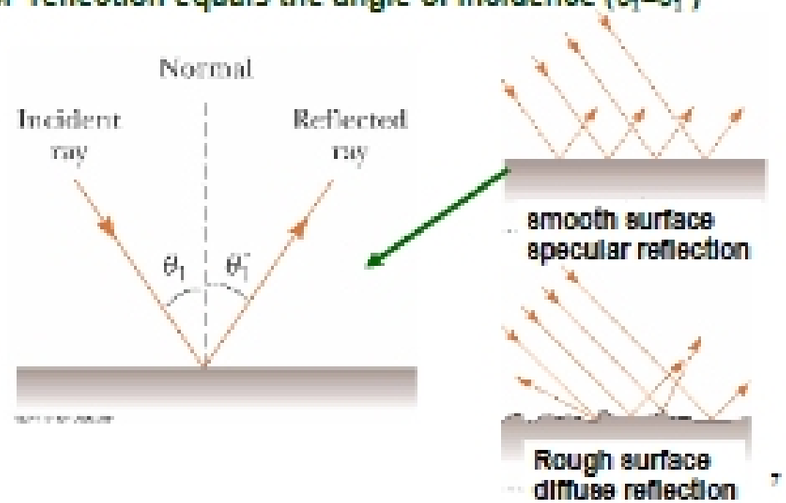
- At a boundary, three things may happen:
  - Rays are reflected. (Reflection)
  - Rays are refracted. (Refraction)
  - Rays are absorbed. (Absorption)

$I_{in} = I_{reflection} + I_{refraction} (+ I_{absorption})$

Note: Frequency is unchanged in reflection and refraction

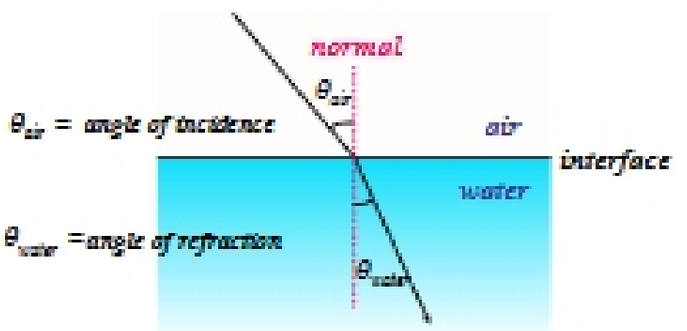
Reflection

- Law of reflection: On a smooth boundary, the angle of reflection equals the angle of incidence ($\theta_1=\theta_1'$)



Refraction

- what happens when light penetrates into a denser medium?
- the rays are kinked towards the normal



Refraction: Deflection of light ray depends on index of refraction n

- speed of light in medium is c/n
- n depends on the medium

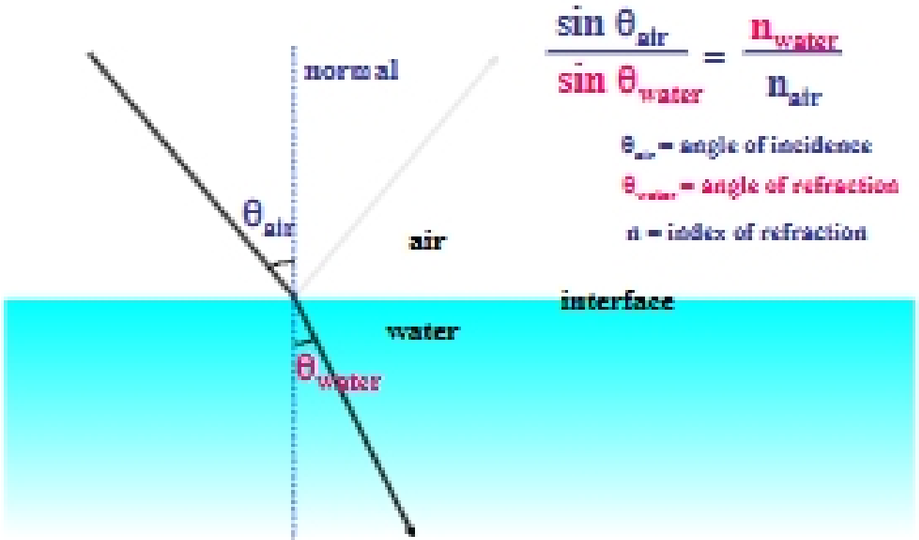
air $n = 1$

water $n = 1.33$

glass $n = 1.52$

(n also depends slightly on the color of the light: n for glass is 1.53 for blue light and 1.51 for red light)

Refraction : Snell's law



$$\frac{\sin\theta_{air}}{\sin\theta_{water}} = \frac{n_{water}}{n_{air}}$$

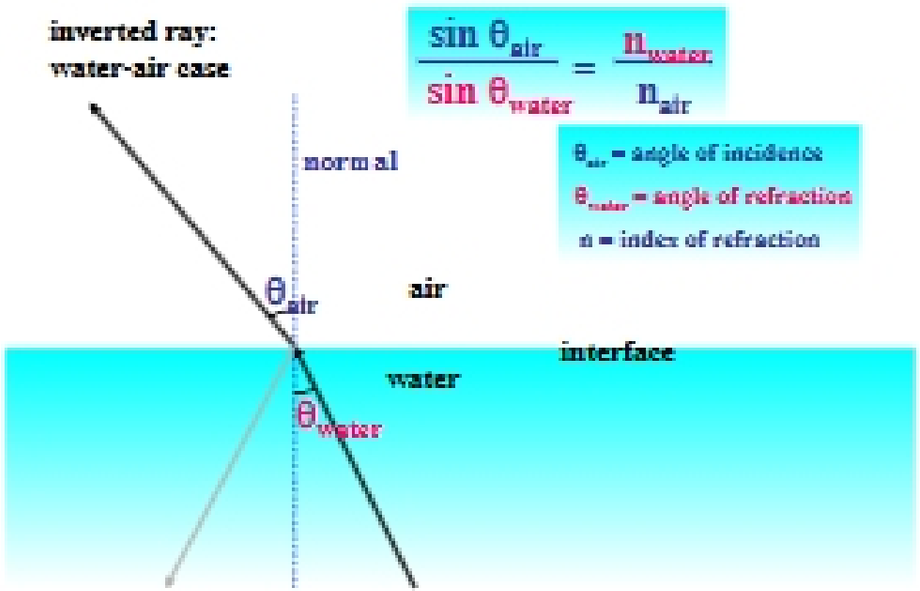
θ_{air} = angle of incidence

θ_{water} = angle of refraction

n = index of refraction

Refraction : Snell's law

inverted ray: water-air case



$$\frac{\sin\theta_{air}}{\sin\theta_{water}} = \frac{n_{water}}{n_{air}}$$

θ_{air} = angle of incidence

θ_{water} = angle of refraction

n = index of refraction

Light rays going from water to air are deflected so that they are *farther away* from the normal to the interface.