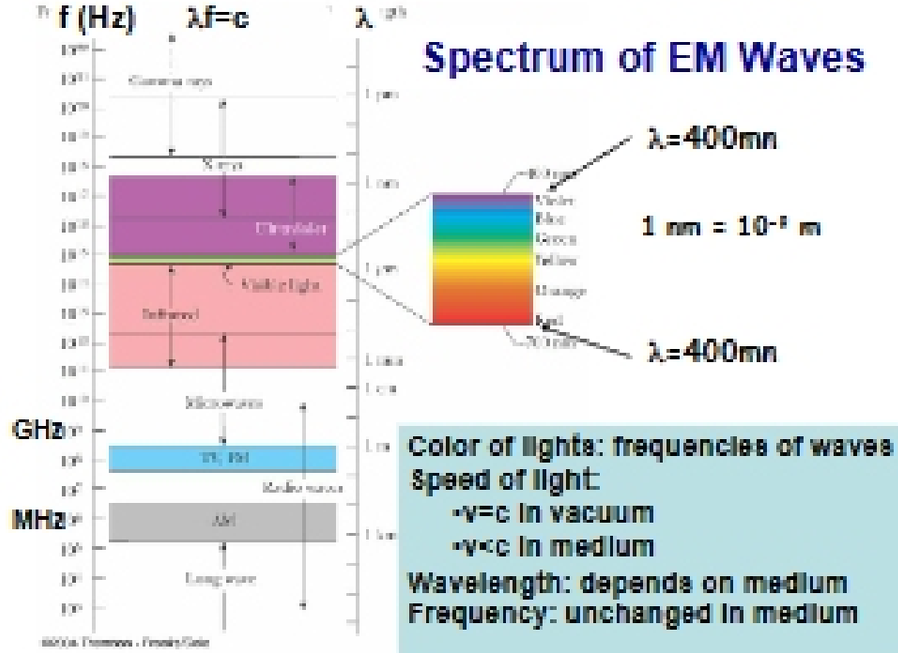
Physics 202, Lecture 23

Today's Topics

- Lights and Laws of Geometric Optics
  - Nature of Lights
  - 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

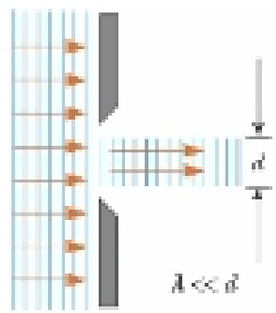
Light And Optics

- Nature of Lights
  - Lights as rays
  - Lights as EM waves: f, λ, ϕ, v, A, interference ...
  - Lights as group of photons (Quantum Theory)

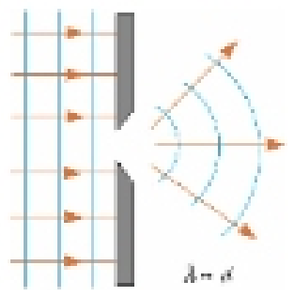
- Optics: Physics of lights
  - Geometric Optics: Treat light as rays. (Ch. 35,36)
    → Ray approximation.
  - Wave Optics: Wave properties becomes important
    Interferences, diffraction...(Ch. 37,38.)

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



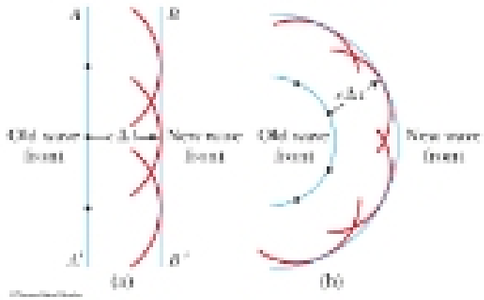
Ray approximation is not valid near the gap when λ~d. OK elsewhere

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.

The Huygen's Principle

- All points on a given wave front are taken as point sources for the production of spherical secondary waves, called wavelets, that propagate outward through a medium with speeds characteristic of waves in that medium. After some time interval has passed, the new position of the wave front is the surface tangent to the wavelets



Light Rays at the Boundary

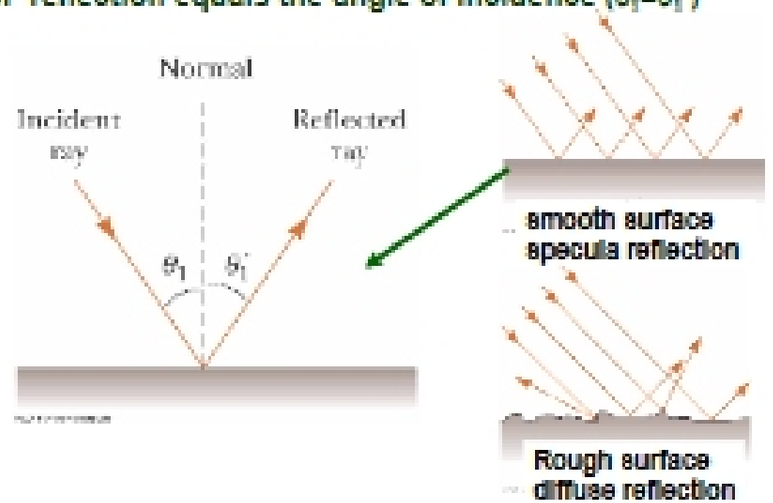
- At a boundary, three things may happen:
  - Rays are reflected. (Reflection)
  - Rays are refracted. (Refraction)
  - Rays are absorbed. (Absorption)

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

Note: Frequency is unchanged in reflection and refraction

Reflection

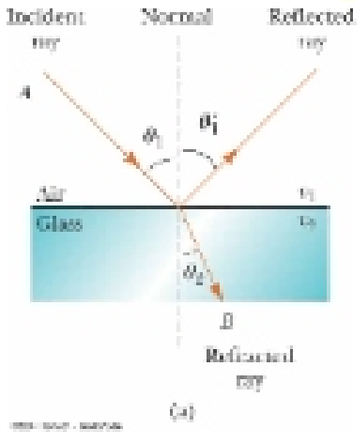
- Law of reflection: On a smooth boundary, the angle of reflection equals the angle of incidence ($\theta_1 = \theta_1'$)



Refraction

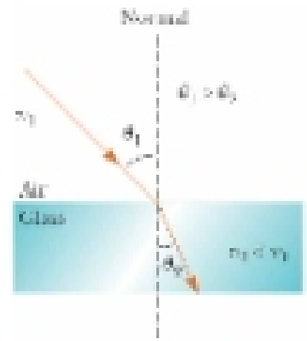
☐ Law of refraction: $\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \frac{v_2}{c}$

if v_1=c (in vacuum)



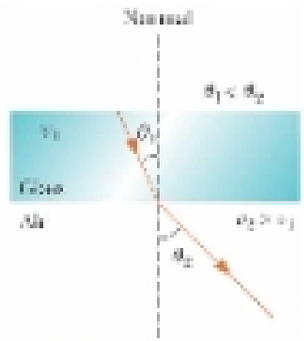
Note: $\theta_1 > \theta_2$ if $v_1 > v_2$

Demo: From Air to Glass and From Glass to Air



$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \frac{v_2}{c}$

$\theta_2 < \theta_1$



$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \frac{c}{v_1}$

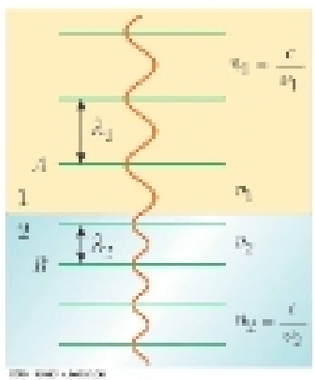
$\theta_2 > \theta_1$

Index of Refraction

☐ Index of refraction n ≡ c/v
- vacuum → n=1
- low v → high n
- all media have n>1
- $\lambda_1 n_1 = \lambda_2 n_2$

☐ Snell's law of refraction

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



Frequency is unchanged when light enters into a different medium

Index of Refraction For Various Material

Table 35.1

Indexes of Refraction*

Substance	Index of Refraction	Substance	Index of Refraction
Solids at 20°C		*Liquids at 20°C*	
Cubic zirconia	2.20	Benzene	1.501
Diamond (C)	2.419	Carbon disulfide	1.628
Fluorite (CaF_2)	1.434	Carbon tetrachloride	1.461
Fused quartz (SiO_2)	1.458	Ethyl alcohol	1.361
Gallium phosphide	3.50	Glycerin	1.473
Glass, crown	1.52	Water	1.333
Glass, flint	1.66		
Ice (H2O)	1.309		
Polystyrene	1.49	*Gases at 0°C, 1 atm*	
Sodium chloride (NaCl)	1.544	Air	1.000293
		Carbon dioxide	1.000451

* All values are for light having a wavelength of 589 nm in vacuum.