ANALYSIS OF INSTRUMENTS

SECTION SPECTROSCOPY

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Spectroscopy :

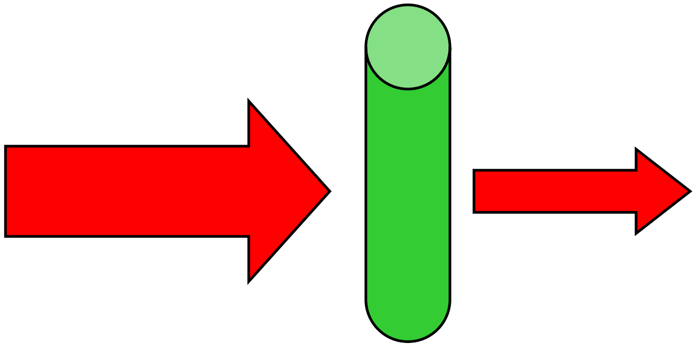
The study of the interaction between light and matter

Types of Spectroscopy :

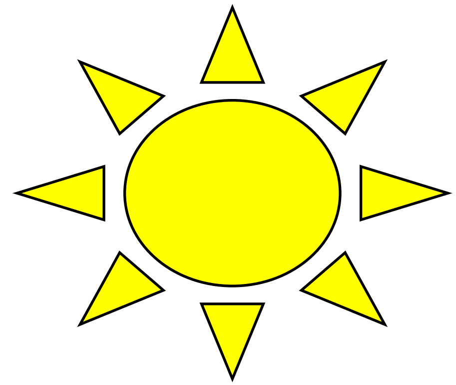
- Absorption
- Emission
- Reflection
- Scattering
- Fluorescence and phosphorescence

Electromagnetic radiation (light):
have the nature of dualism, as WAVE and PARTICLE (called photons or quanta)

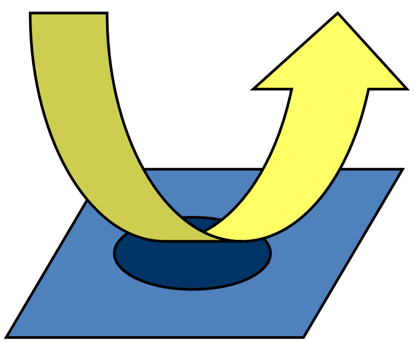
Types of Spectroscopy :



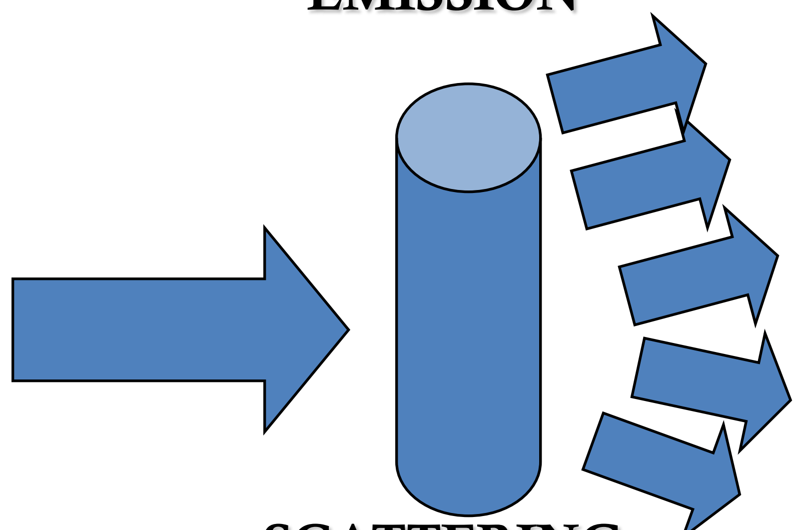
ABSORPTION



EMISSION

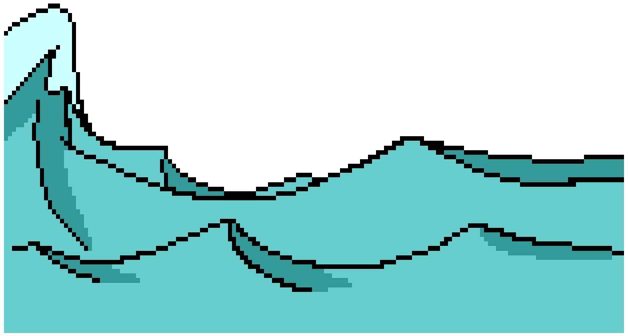


REFLECTION



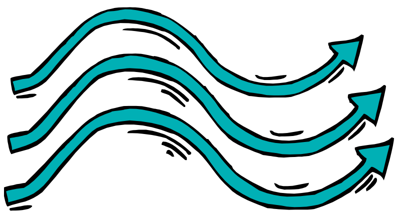
SCATTERING

A. ELECTROMAGNETIC RADIATION WAVE

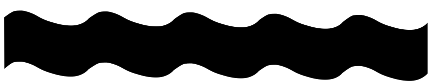


Wavelength (amplitude): wave height

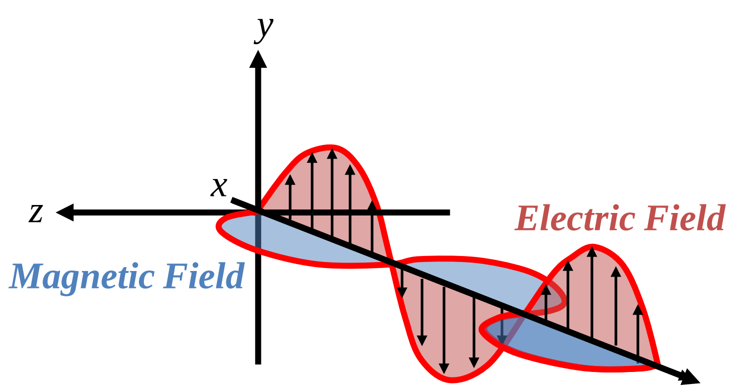
Frequency: the number of waves per second



Long waves = low frequency, low energy

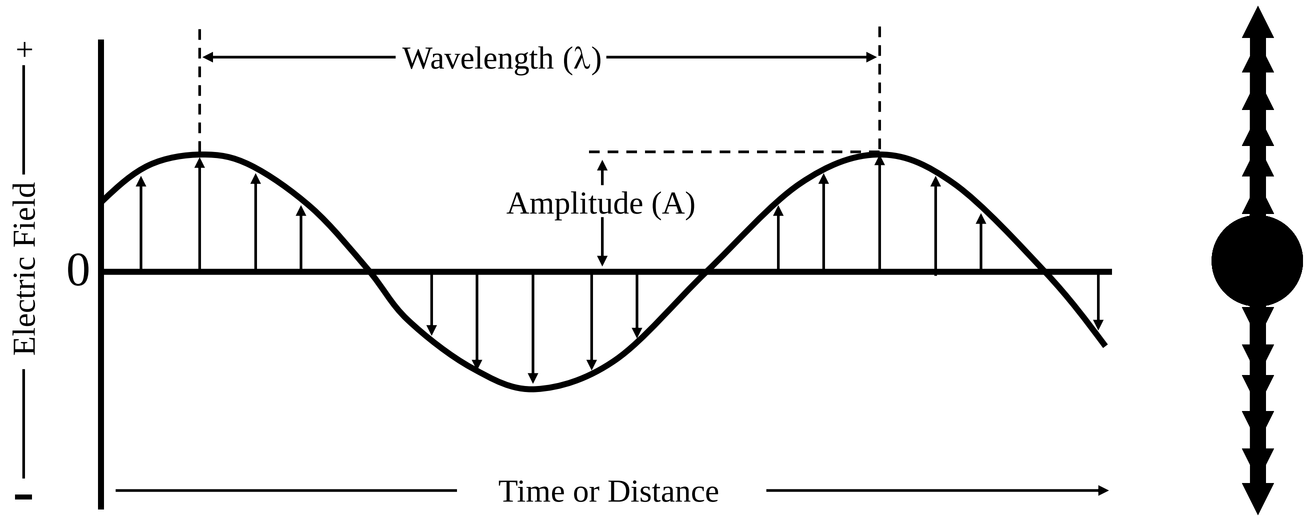


Short waves = high frequency and high energy



A. ELECTROMAGNETIC RADIATION WAVE

1. Parameter wave



Period (p) - the time required for the single wave.

Frequency (n) - the number of waves per second.

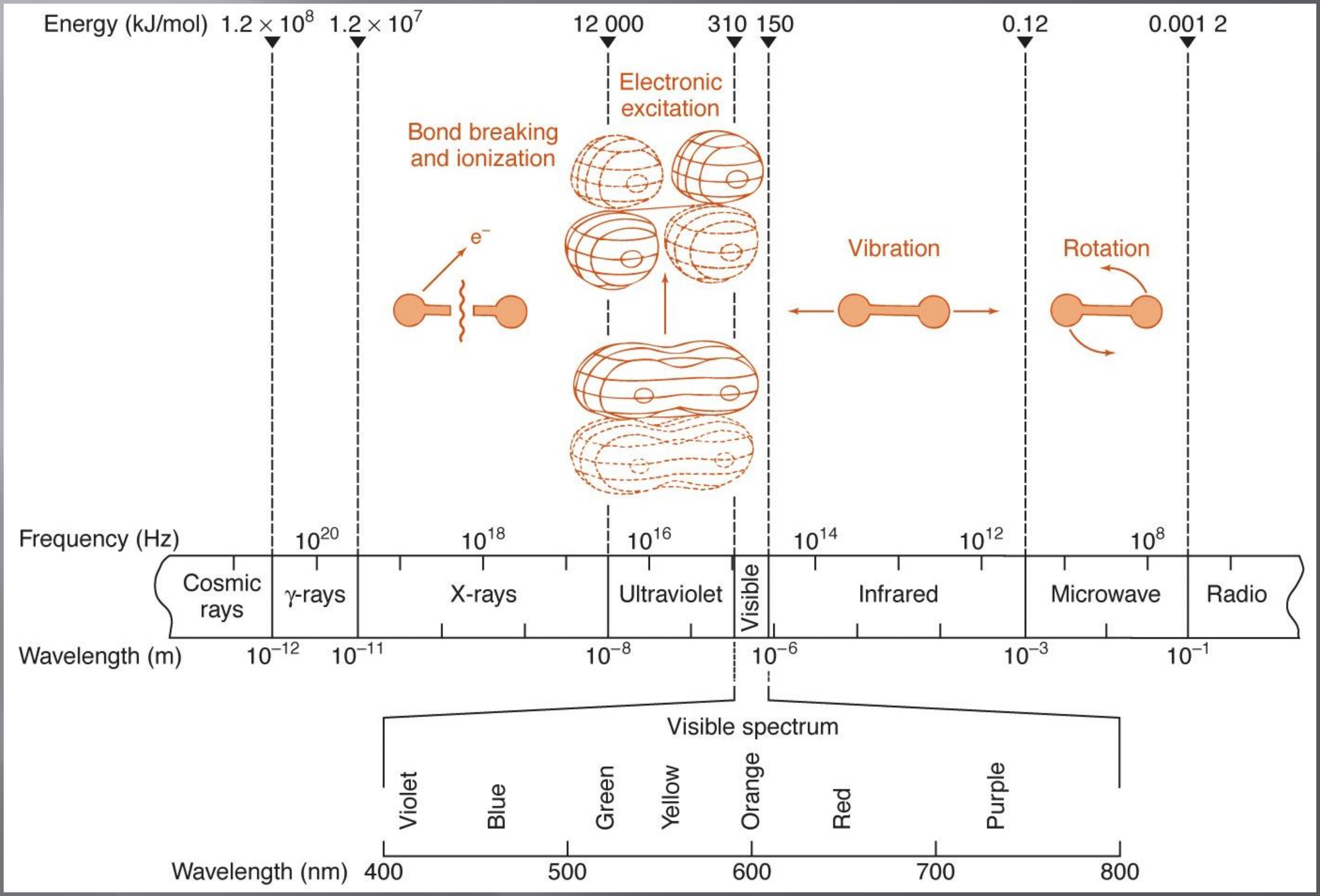
$\nu = 1/p \; (s^{-1} = Hz)$

Amplitude (A) - the maximum wave height.

Wavelength (l) - the distance between two identical points in one wave.

A. ELECTROMAGNETIC RADIATION WAVE

2. Electromagnetic Spectrum (EM)



A. ELECTROMAGNETIC RADIATION WAVE

2. Electromagnetic Spectrum (EM)

Types of spectroscopic methods based on EM radiation :

Type Spectroscopy	Usual Wavelength Range*	Usual Wavenumber Range, cm^{-1}	Type of Quantum Transition
Gamma-ray emission	0.005–1.4 Å	—	Nuclear
X-Ray absorption, emission, fluorescence, and diffraction	0.1–100 Å	—	Inner electron
Vacuum ultraviolet absorption	10–180 nm	1×10^6 to 5×10^4	Bonding electrons
Ultraviolet visible absorption, emission, and fluorescence	180–780 nm	5×10^4 to 1.3×10^4	Bonding electrons
Infrared absorption and Raman scattering	0.78–300 μm	1.3×10^4 to 3.3×10^1	Rotation/vibration of molecules
Microwave absorption	0.75–3.75 mm	13–27	Rotation of molecules
Electron spin resonance	3 cm	0.33	Spin of electrons in a magnetic field
Nuclear magnetic resonance	0.6–10 m	1.7×10^{-2} to 1×10^3	Spin of nuclei in a magnetic field

*1 Å = 10^{-10} nm = 10^{-8} cm
1 nm = 10^{-9} m = 10^{-7} cm
1 μm = 10^{-6} m = 10^{-4} cm

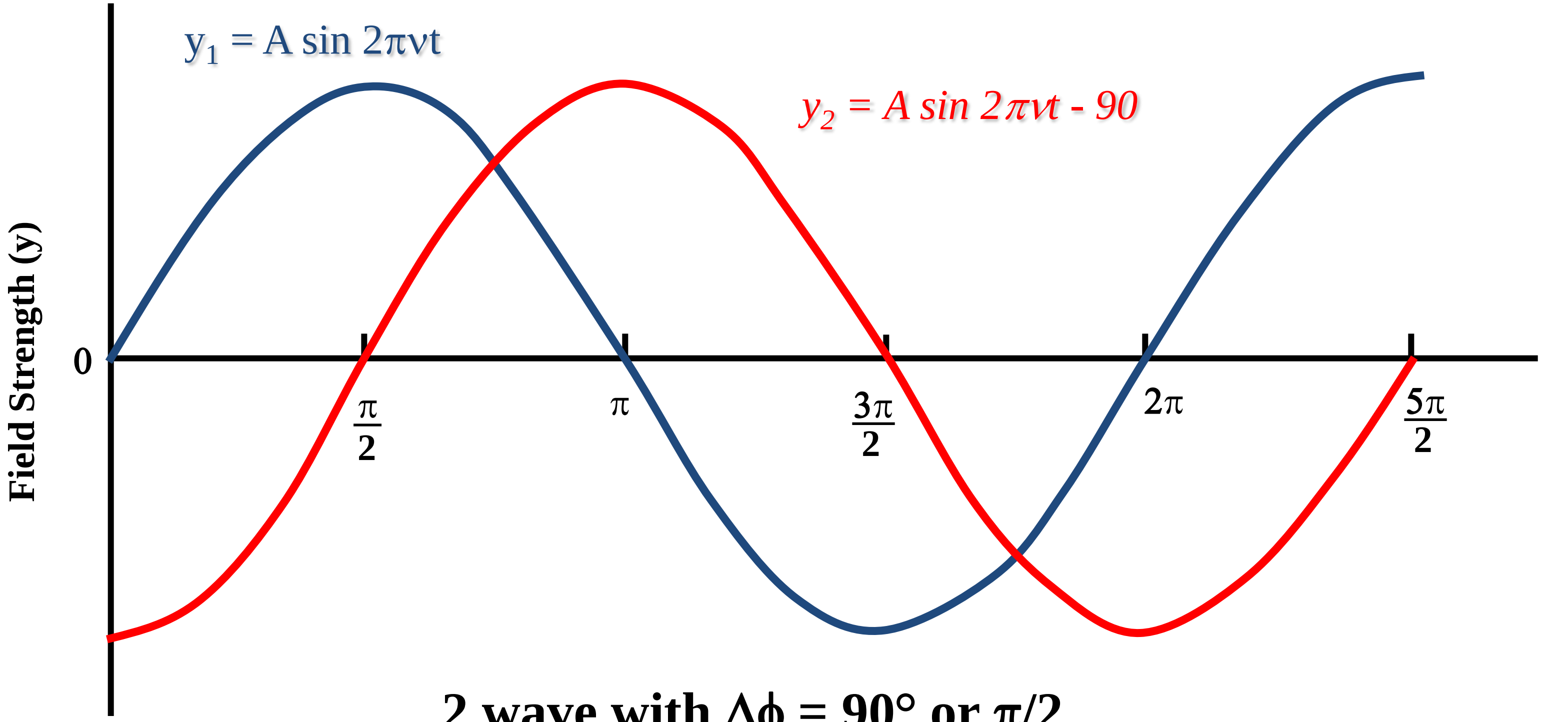
A. ELECTROMAGNETIC RADIATION WAVE

3. Mathematical Description EM Wave

Electromagnetic waves are sine functions, are additive.

$$y = A \sin (2\pi\nu t + \phi)$$

y = electrical or magnetic field strength
A = amplitude
n = frequency
t = time
f = phase angle (0° - 360° or 0 - 2π radians)



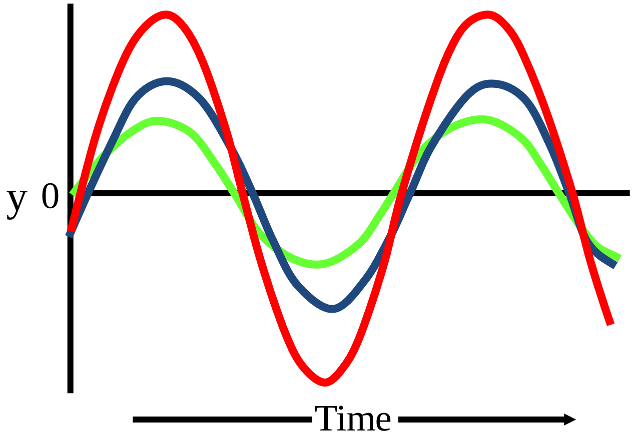
2 wave with Δϕ = 90° or π/2

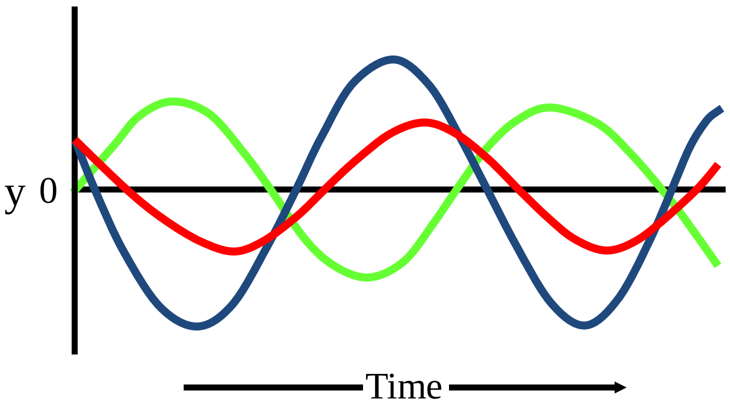
A. ELECTROMAGNETIC RADIATION WAVE

4. Superposition of Waves

- ***Principle of superposition*** *– if more than 2 wave passing through the same space, there will be interference that are additive.*

- *2 pieces of the wave at the same frequency, but different in phase and amplitude.*





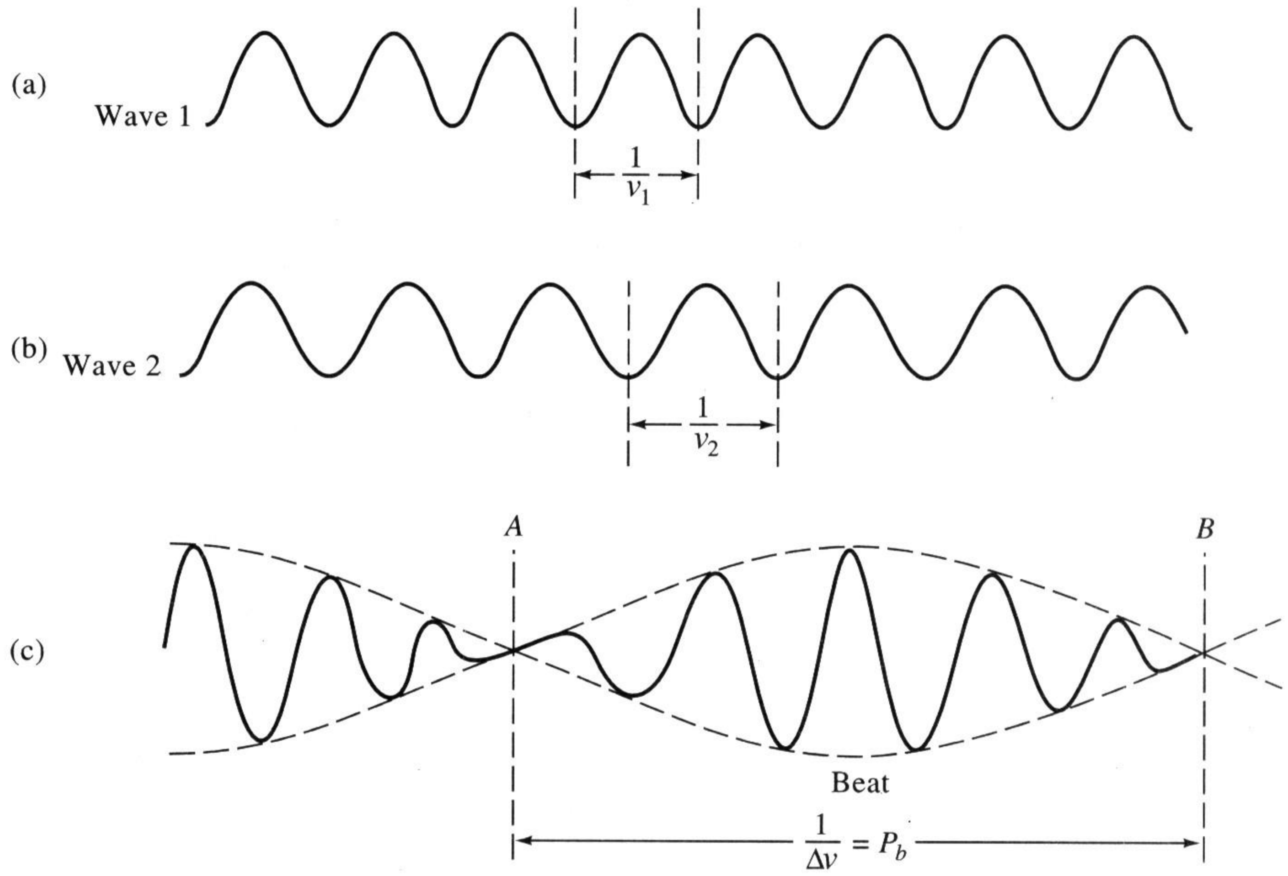
✓ ***Constructive Interference*** - *occurs when two waves of the same phase* $[(f_2 - f_1) = 0° \text{ or } 360°]$

✓ ***Destructive Interference*** - *occurs when two waves have different phase* $[(f_2 - f_1) \text{ is } 180°]$

A. ELECTROMAGNETIC RADIATION WAVE

4. Superposition of Waves

- *2 EM wave with different freqency*



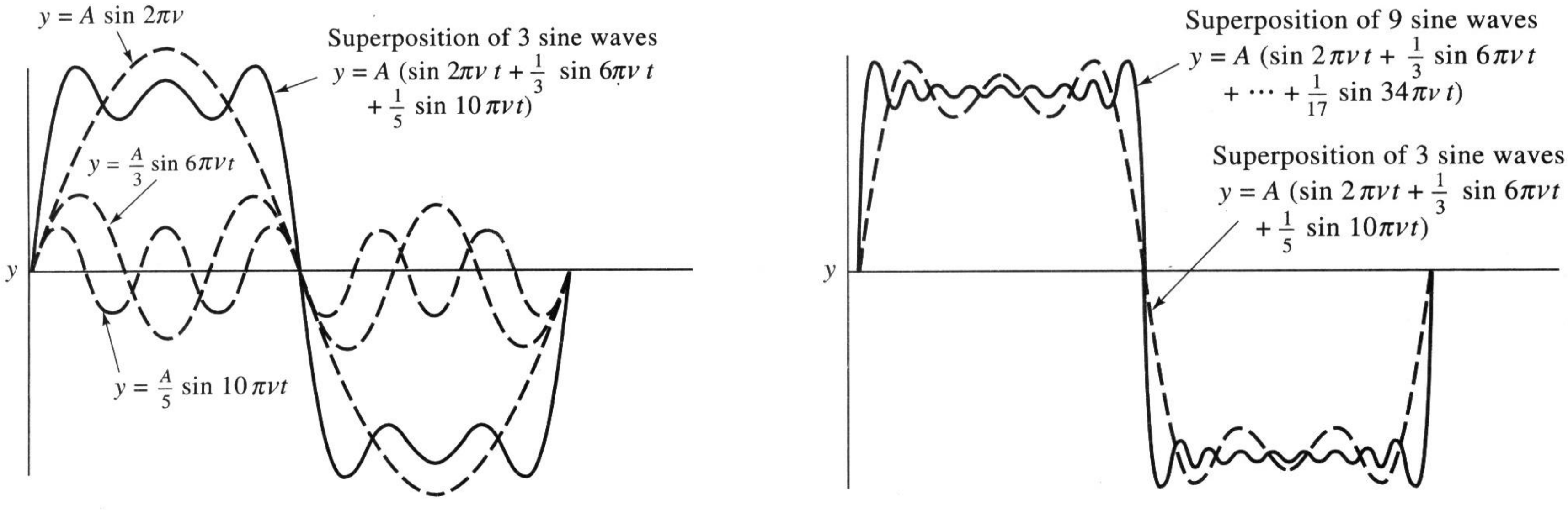
The beat period (P) is dependent upon the difference in wavelengths (1/Δυ).

A. ELECTROMAGNETIC RADIATION WAVE

4. Superposition of Waves

- *Jean Fourier (1768 –1830) suggest that some movement can be described as the sum wave of Sinus and cosinus wave*

Example: ***square wave***



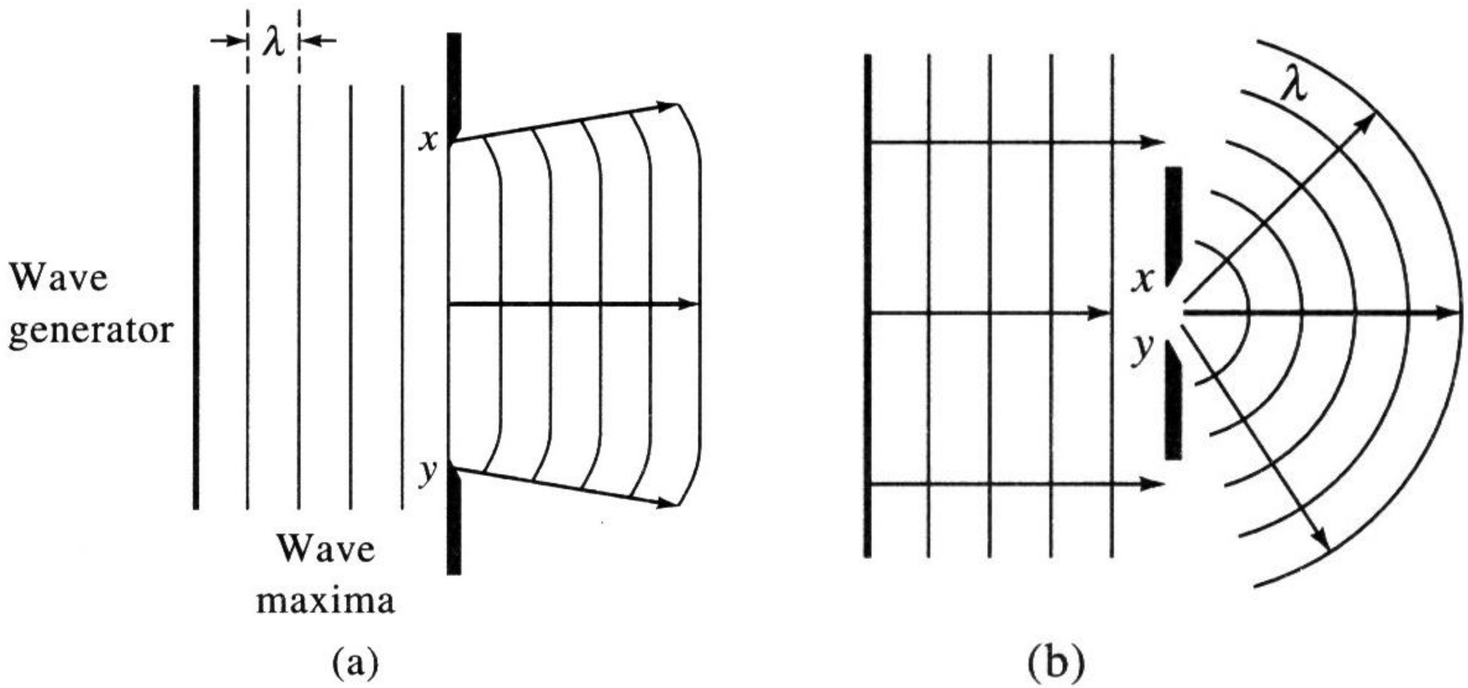
(a) (b)

➢ <u>Fourier Transform</u>

A. ELECTROMAGNETIC RADIATION WAVE

5. Diffraction of Radiation

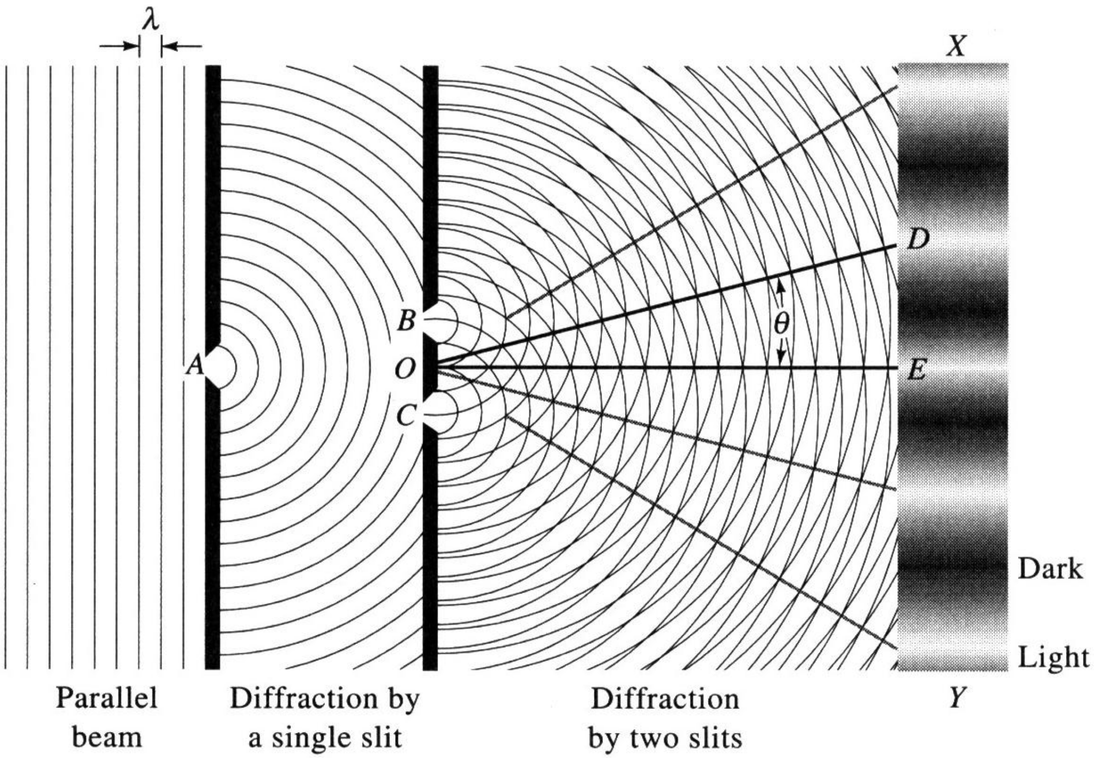
Diffraction - *when a wave passes through a narrow slit, the waves will be deflected.*

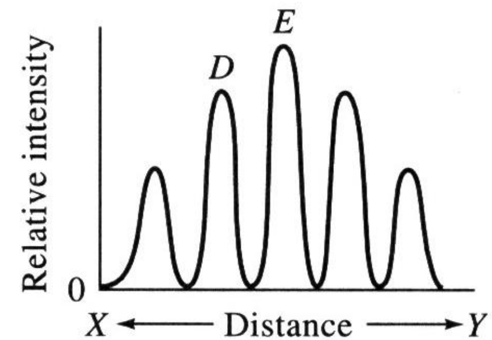


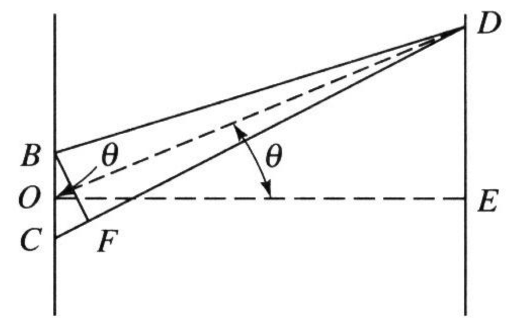
A. ELECTROMAGNETIC RADIATION WAVE

5. Diffraction of Radiation

- *Thomas Young demonstrating the wave nature of light using diffraction at 1880.*







$n\lambda = \overline{BC}\sin\theta$ atau $n\lambda = \dfrac{\overline{BC}\cdot\overline{DE}}{\overline{OE}}$

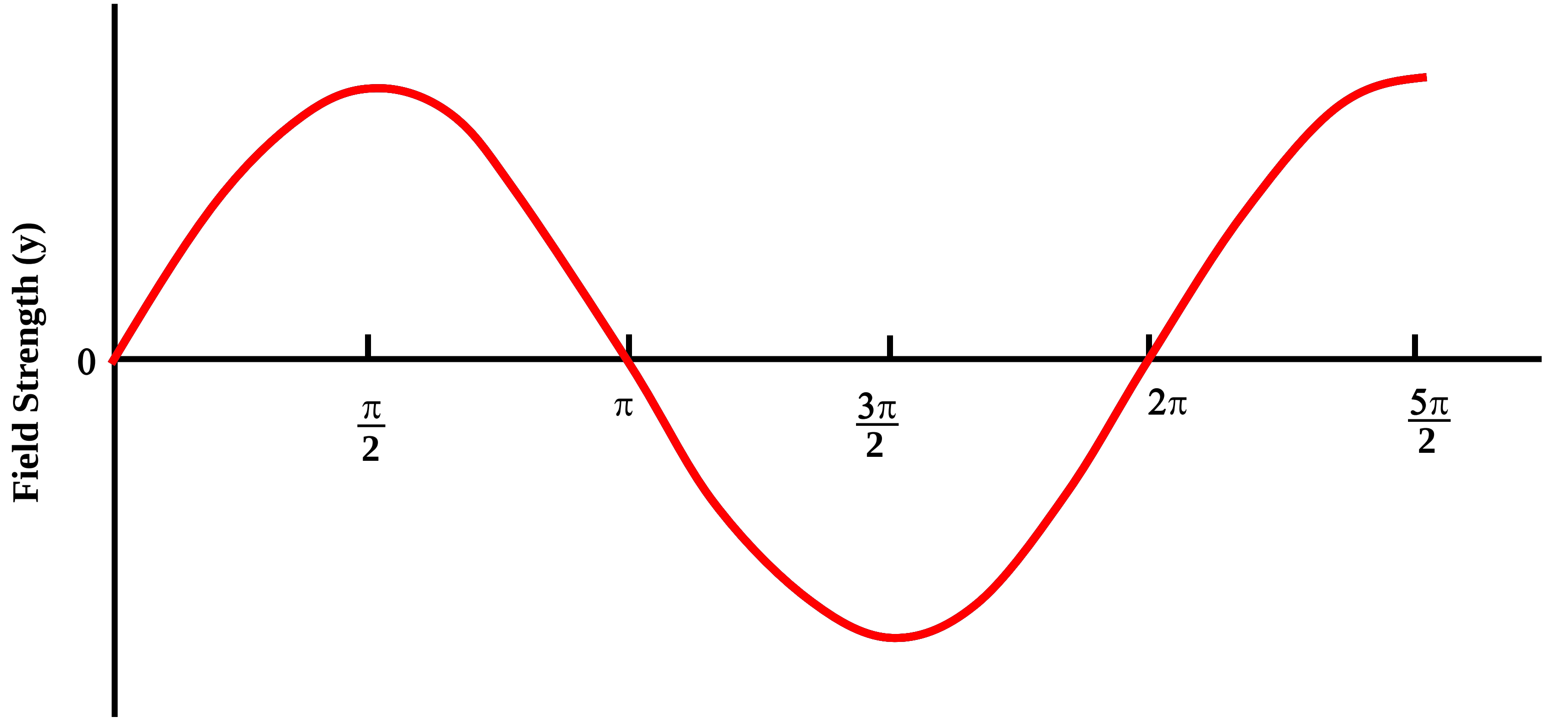
n = order of interference

A. ELECTROMAGNETIC RADIATION WAVE

6. Coherence of Radiation

Second beam called COHERENT, if:

1. **Have the same wavelength.**
2. **The same Phase.**



A. ELECTROMAGNETIC RADIATION WAVE

7. Transmission of Radiation

- When light waves into liquid or solid material, the speed will slow down.
- This is largely attributable due to oscillating electric fields interact with electrons of the medium, so that the waves slow down.
- Index of refraction (η_i) - a measure of the level of interaction between matter and radiation that is transmitted through the substance

$\eta_i = c/v_i$ (>1) the ratio between the speed in vacuum and media.

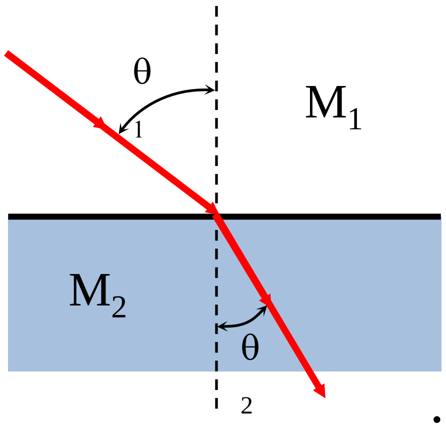
η_i = index of refraction
c = speed of light (3.00×10^8 m/s)
v_i = velocity in the medium

η frequency dependent

A. ELECTROMAGNETIC RADIATION WAVE

7. Refraction of Electromagnetic Radiation

- When EM radiation that crosses between different media refractive index (hi) file will change direction and speed.



Snell law

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\eta_2}{\eta_1} = \frac{v_1}{v_2}$$

- **If η_1 in vacuum =1, so:**

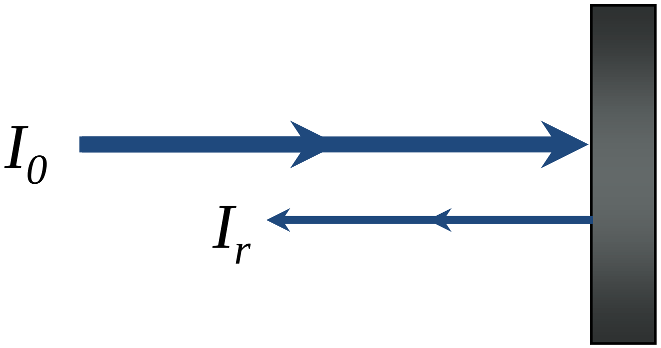
$$\frac{\sin\theta_1}{\sin\theta_2} = \eta_2$$

- applies also if η_1 is air, because $\eta_{vacuum} = 1.00027\eta_{air}$

A. ELECTROMAGNETIC RADIATION WAVE

8. Reflection of Radiation

- Occurs when EM radiation coming at the interface between two media of different refractive index which in the direction of 90 °, some light will be reflected.



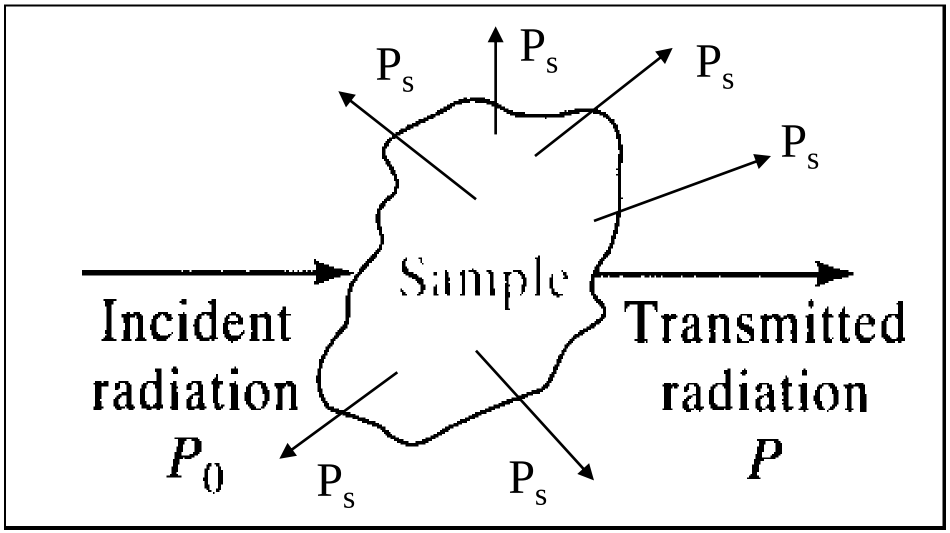
$$\frac{I_r}{I_0} = \frac{(\eta_2-\eta_1)^2}{(\eta_2+\eta_1)^2}$$

I0 = intensity of radiation that comes

Ir = intensity of radiation that is reflected

A. ELECTROMAGNETIC RADIATION WAVE

9. Scattering of Radiation



Tyndall Scattering	*- by colloids or very large molecules*
Rayleigh Scattering	*- by molecules or aggregates*
	- same frequency
	- proportional to 4th power of freq.
Raman Scattering	*- by molecules*
	- different frequencies
	- proportional to 4th power of freq.

B. ENERGY LEVELS