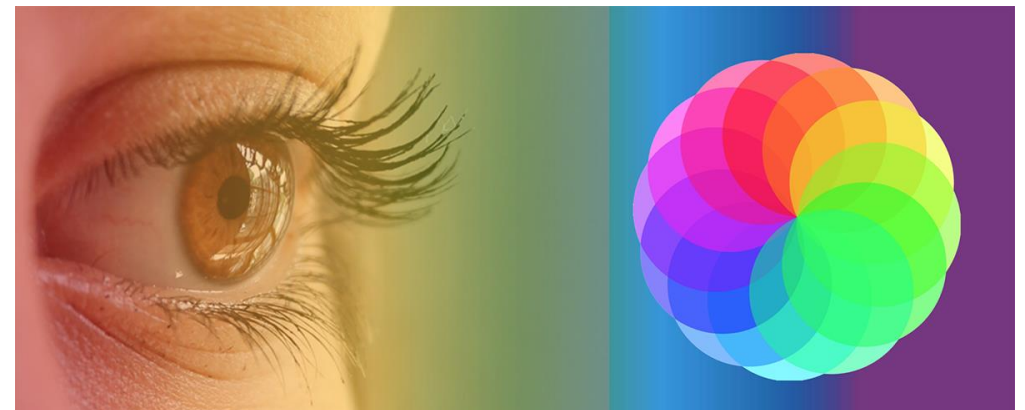


# Molecular Spectroscopy: The spectrum of electromagnetic radiation, the laws of Lambert and Beer

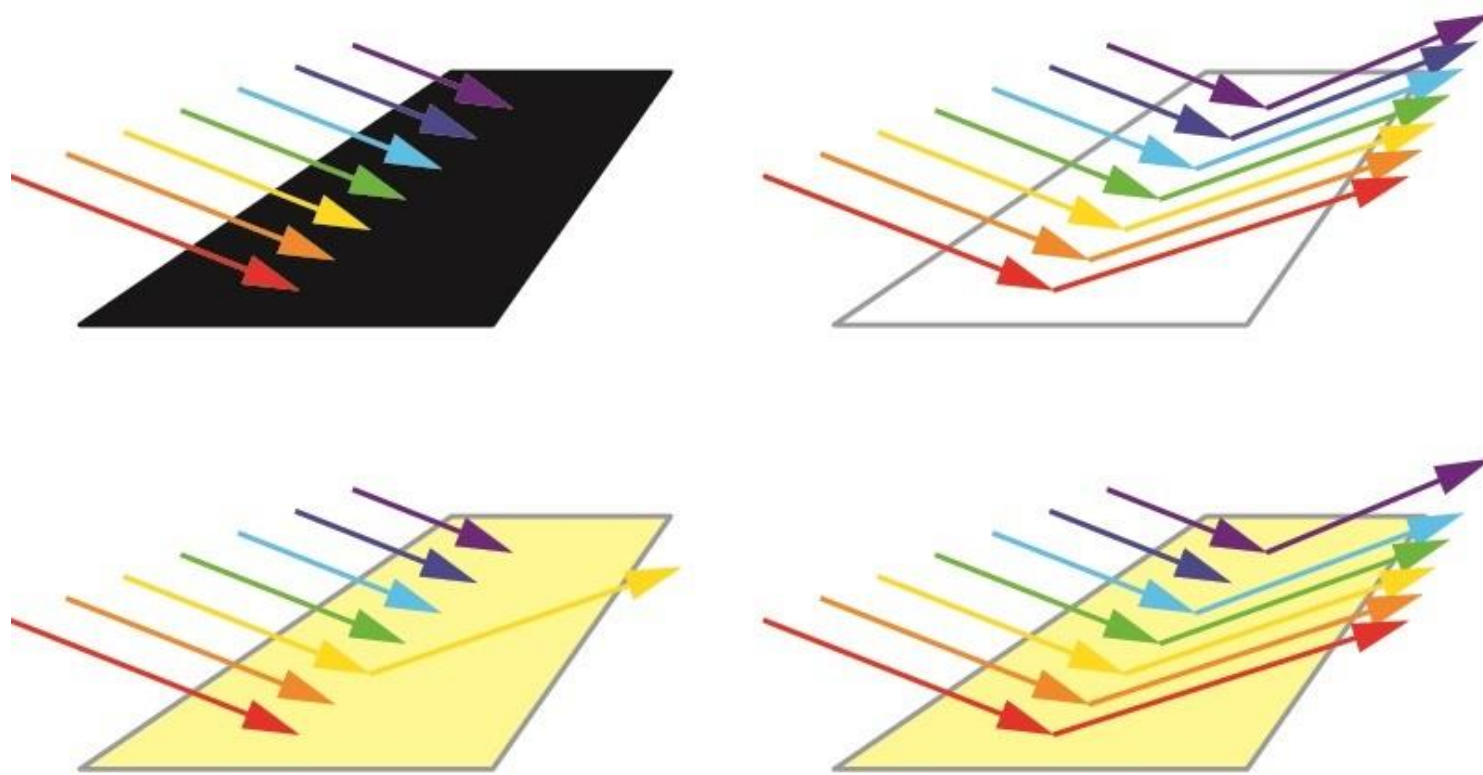
Dr. Soma Maji

# INTRODUCTION

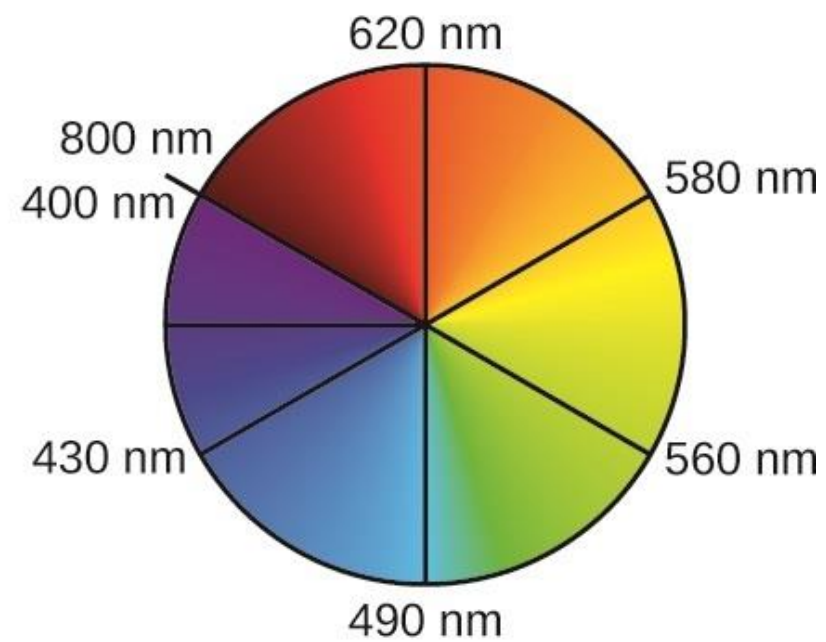
- Human eye perceives the difference in the colour of various compounds and things around them
- e.g. quinone is yellow; chlorophyll is green; 2,4-dinitrophenylhydrazone derivatives of aldehydes and ketones range in color from bright yellow to deep red, aspirin is colourless.
- So human eye is functioning like a spectrophotometer analysing the light reflected from the surface of solid or passing through a liquid.
- Sunlight seen as single white colour is in fact composed of a wide range of radiation with different wavelengths in the ultraviolet, visible and infrared portions of the spectrum.
- The electromagnetic spectrum of an object is the characteristic distribution of electromagnetic radiation emitted or absorbed by that particular object.
- In principle this spectrum is infinite and is continuous.



# Wavelengths



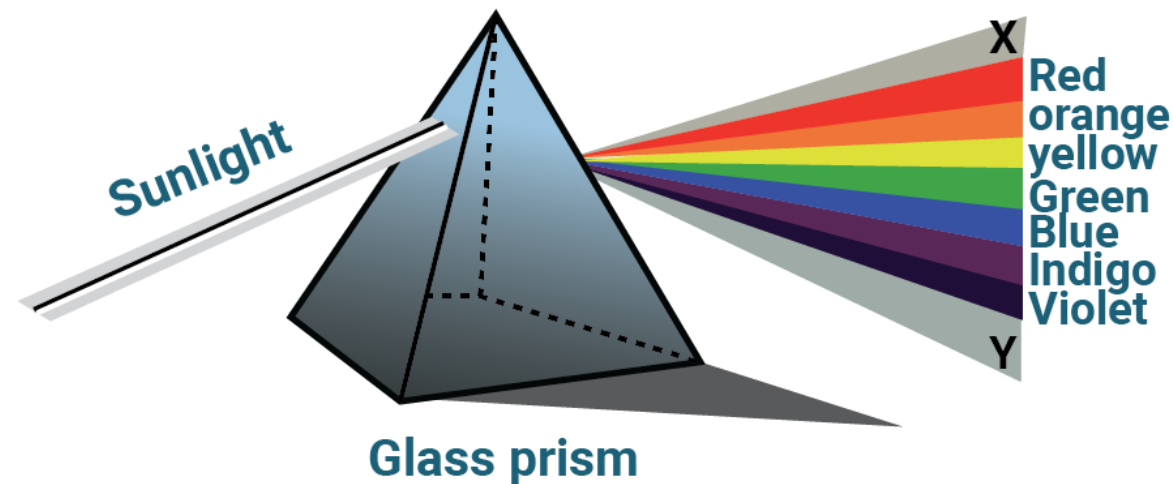
(a)

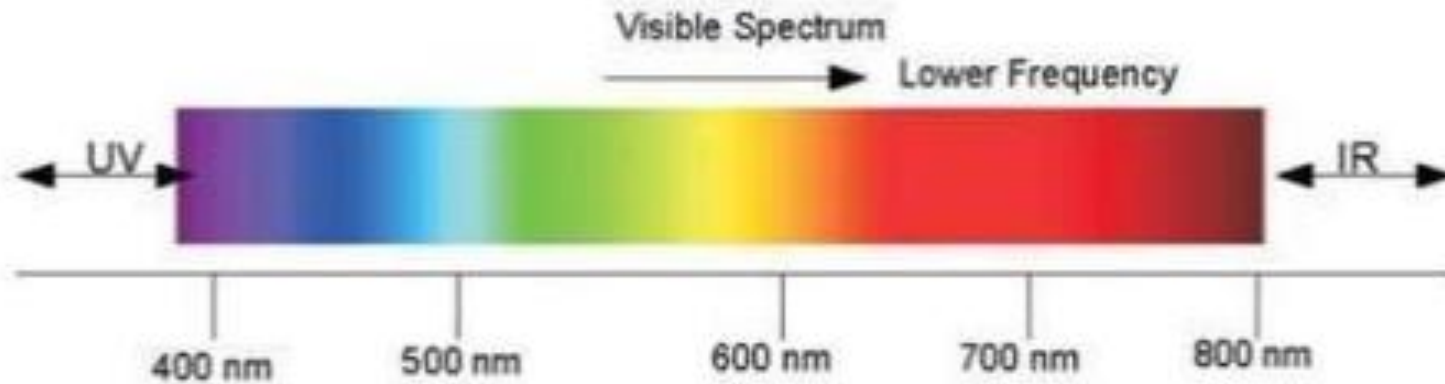


(b)

# CLASSIFICATION OF ELECTROMAGNETIC RADIATION

- When sunrays are passed through a prism, the rays bend in accordance to their wave lengths.
- Electromagnetic radiation such as visible light is commonly treated as a wave phenomenon, characterized by a wavelength or frequency.
- Wavelength is defined as distance between adjacent peaks (or troughs), and may be designated in meters, centimeters or nanometers ( $10^{-9}$  meters).
- Frequency is the number of wave cycles that travel past a fixed point per unit of time, and is usually given in cycles per second, or hertz (Hz).
- Generally electromagnetic radiation is classified on basis of its wave length. Visible wavelengths cover a range from approximately 400 to 800 nm.

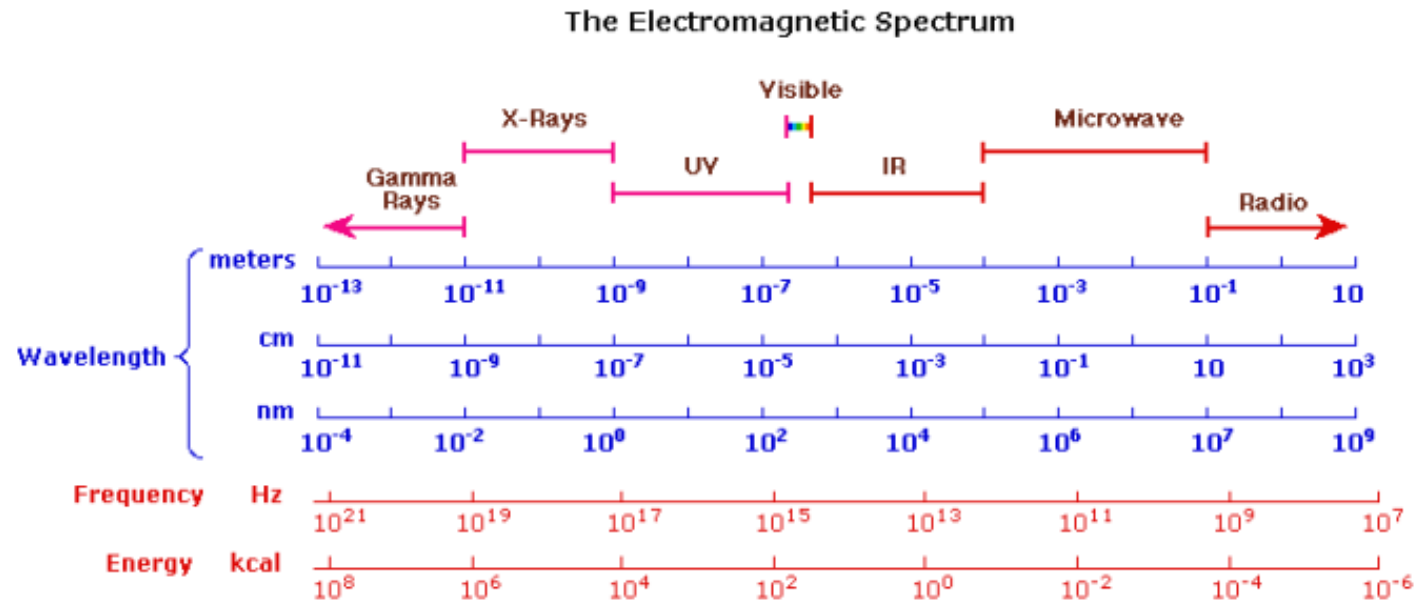




### Wavelength in nm -visible spectrum

- Red colour has the longest wavelength while violet has the shortest wavelength,
- The remaining colours are in decreasing order of wavelengths.
- People perceive this radiation as the visible light, ultraviolet (UV) rays, x-rays and gamma rays.
- The behaviour of electromagnetic radiation depends on its wavelength and on the amount of energy it carries with when it interacts with single atoms and molecules.
- This energy is measured per quantum (photon).

# ELECTROMAGNETIC SPECTRUM



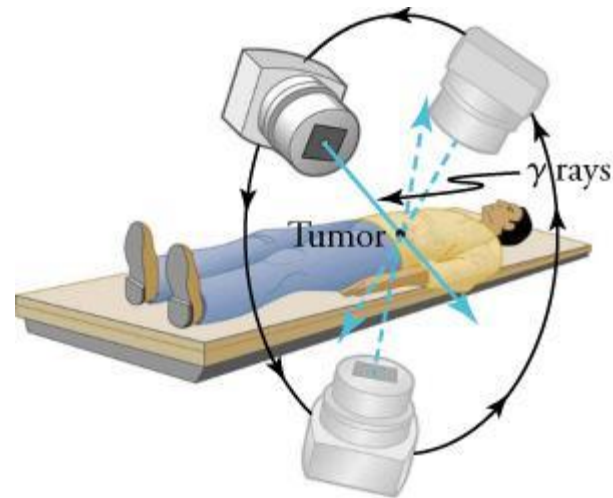
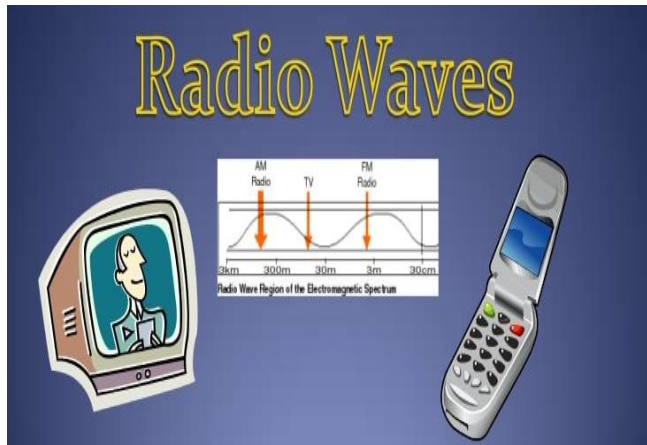
## Spectrum of electromagnetic radiation

**Electromagnetic spectrum** can broadly be grouped into non-ionizing and ionizing radiation. The non ionizing radiation when obtained by low induced current is non thermal while **high induced current generates heat which is effectively used in the microwave ovens.** **Photo electric excitation** is used for producing photochemical effect.

## Regions of the Electromagnetic Spectrum

<b>The Electromagnetic Spectrum</b>			
<b>Wave Type</b>	<b>Wavelength (m)</b>	<b>Frequency (Hz)</b>	<b>Energy (J)</b>
Radio waves	$> 0.1$	$< 3 \times 10^9$	$< 2 \times 10^{-24}$
Microwaves	$10^{-3} - 0.1$	$3 \times 10^9 - 3 \times 10^{11}$	$2 \times 10^{-24} - 2 \times 10^{-22}$
Terahertz waves	$10^{-3} - 10^{-4}$	$3 \times 10^{11} - 3 \times 10^{12}$	$2 \times 10^{-22} - 2 \times 10^{-21}$
Infrared	$7 \times 10^{-7} - 10^{-3}$	$3 \times 10^{11} - 4 \times 10^{14}$	$2 \times 10^{-22} - 3 \times 10^{-19}$
Optical(visible light)	$4 \times 10^{-7} - 7 \times 10^{-7}$	$4 \times 10^{14} - 7.5 \times 10^{14}$	$3 \times 10^{-19} - 5 \times 10^{-19}$
Ultraviolet	$10^{-8} - 4 \times 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{16}$	$5 \times 10^{-19} - 2 \times 10^{-17}$
X-rays	$10^{-11} - 10^{-8}$	$3 \times 10^{16} - 3 \times 10^{19}$	$2 \times 10^{-17} - 2 \times 10^{-14}$
Gamma rays	$< 10^{-11}$	$> 3 \times 10^{19}$	$> 2 \times 10^{-14}$

- The ionizing radiation is more useful in medical field.
- Rays generated during ionization produce several effects such as damage to the DNA and also breaking of the bonds which are of immense help in treatment of cancer, correcting birth defects and also causing mutation.
- In non-ionizing radiation, the extremely low frequency rays and very low frequency are included. These are generally referred as **radio waves**.
- The next range of frequency is categorized as **microwave**, which is followed by infra red rays.
- The visible range is forming the next group of rays. The ultra violet rays, Xrays and gama rays are considered under the category of ionizing radiation.





# LAMBERT-BEER LAW

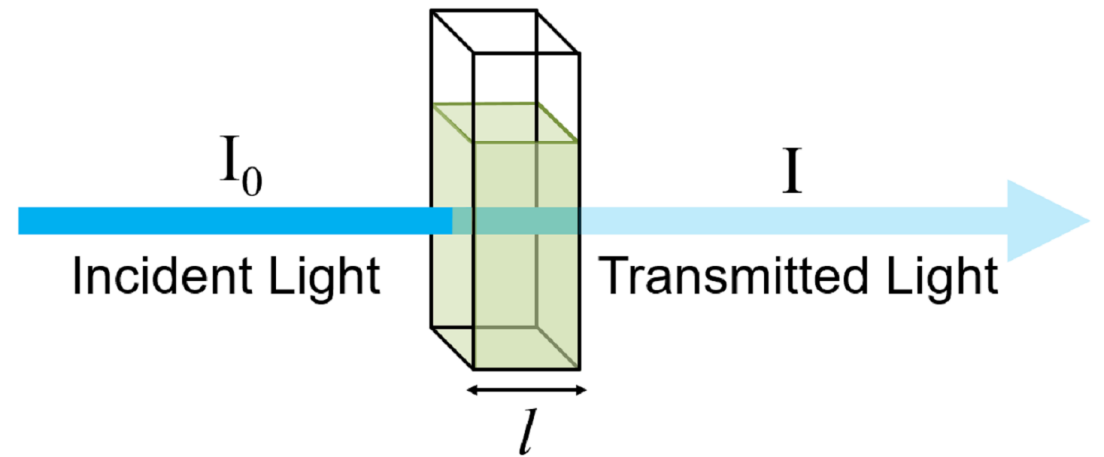
- This law relates to the absorption of light and to the properties of material through which the light travels.
- Transmittance is the term used to the amount of light penetrating a solution.
- It is expressed as the ratio between the intensity of transmitted light ( $I_t$ ) to the intensity of initial light of light beam ( $I_0$ )

$$T = I_t / I_0$$

Where:  $T$  - Transmittance

$I_t$  - Intensity of the transmitted light

$I_0$  - Intensity of the initial light beam



- The law states that there is a logarithmic dependence between transmission (or transmissivity) of light through a substance,  $T$ , and the product of absorption coefficient of substance,  $\alpha$ , and the distance the light travels through the material (i.e. the path length),  $\ell$ .
- The absorption coefficient can, in turn, be written as a product of either a molar absorptivity of the absorber,  $\varepsilon$ , and the concentration  $c$  of absorbing species in the material, or an absorption cross section,  $\sigma$ , and the (number) density  $N'$  of absorbers.
- For liquids, these relations are usually written as:

$$T = \frac{I}{I_0} = 10^{-\alpha \ell} = 10^{-\varepsilon \ell c}$$

The transmission (or transmissivity) is expressed in terms of an absorbance which, for liquids, is defined as

$$A = -\ln\left(\frac{I}{I_0}\right)$$

- Thus, if path length and molar absorptivity (or the absorption cross section) is known and if the absorbance is measured, then the concentration of the substance (or the number density of absorbers) can be deduced.
- If the concentration is expressed as a **mole fraction** i.e. a dimensionless fraction, **the molar absorptivity ( $\epsilon$ ) takes the same dimension as the absorption coefficient**, *i.e.* reciprocal length (e.g.  $\text{m}^{-1}$ ).
- However, if the concentration is expressed in moles per unit volume, the molar absorptivity ( $\epsilon$ ) is used in  $\text{L}\cdot\text{mol}^{-1}\cdot\text{cm}^{-1}$ , or sometimes converted in SI units of  $\text{m}^2\cdot\text{mol}^{-1}$ .
- The absorption coefficient  $\alpha'$  is one of many ways to describe the absorption of electromagnetic waves.

