Biomedical Engineering Department

Third Stage

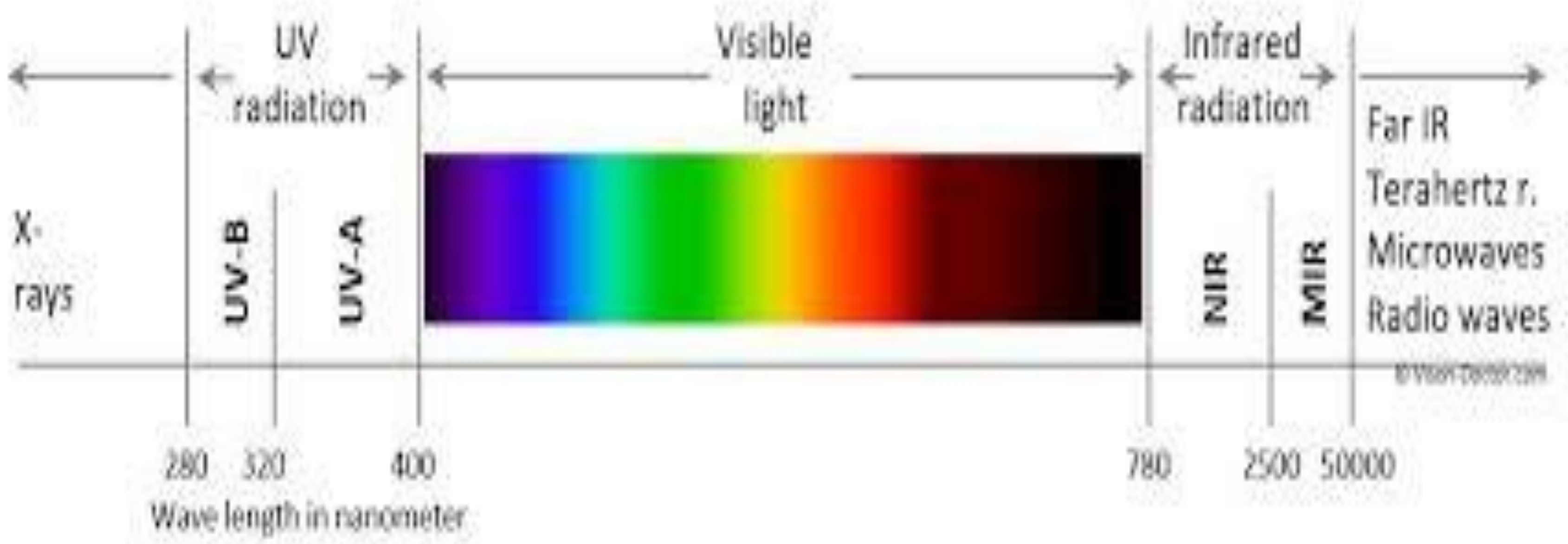
Medical Optics

Lecture 2

Properties of Light

Asst.lec.Hiba Diaa Alrubaie

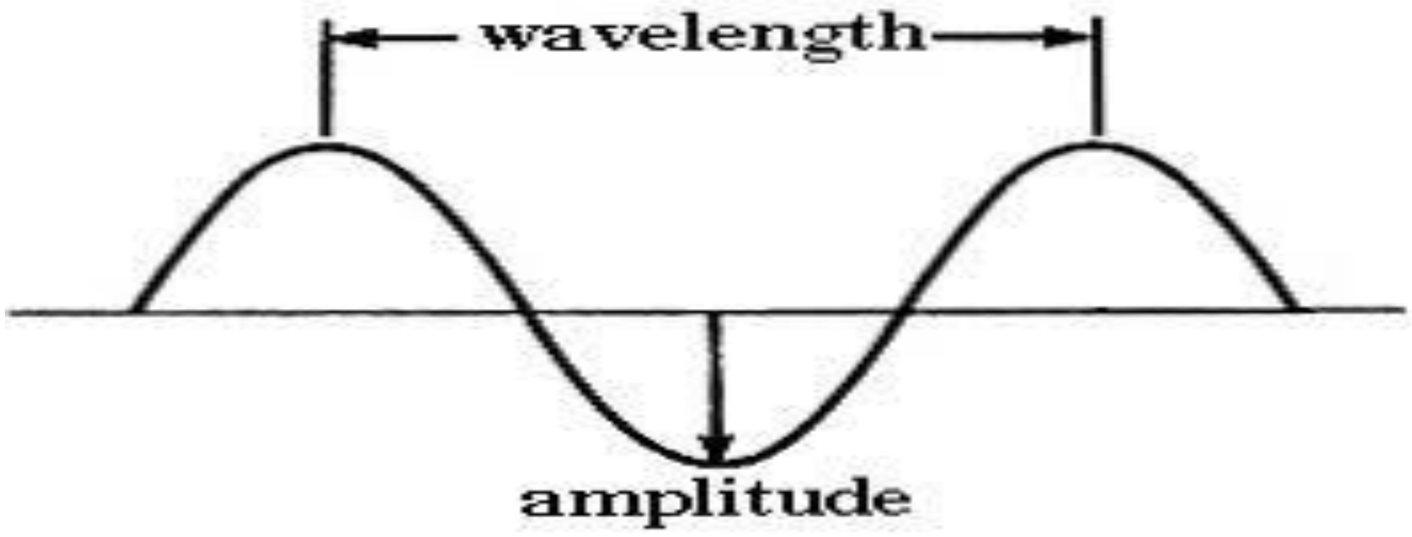
Light is a form of electromagnetic radiation that is visible to the human eye, typically ranging from wavelengths of about 400 to 700 nanometers (nm). It behaves both as a **particle** (photon) and a **wave**, a duality that is one of the key concepts in quantum mechanics.



Properties of Light

Wavelength (λ):

The distance between two successive crests or troughs of a wave. Wavelength is inversely related to energy—the shorter the wavelength, the higher the energy. Visible light has wavelengths in the range of 400-700 nm, where 400 nm corresponds to violet light, and 700 nm corresponds to red light.



Frequency (ν):

The number of wave cycles that pass a given point per second, measured in Hertz (Hz). It is inversely proportional to wavelength ($\nu = c/\lambda$, where c is the speed of light). Higher-frequency light has more energy.

Speed (c):

In a vacuum, light travels at about 299,792,458 meters per second (approximately 300,000 km/s). When it passes through a medium (like air, water, or glass), it slows down depending on the medium's refractive index.

Amplitude:

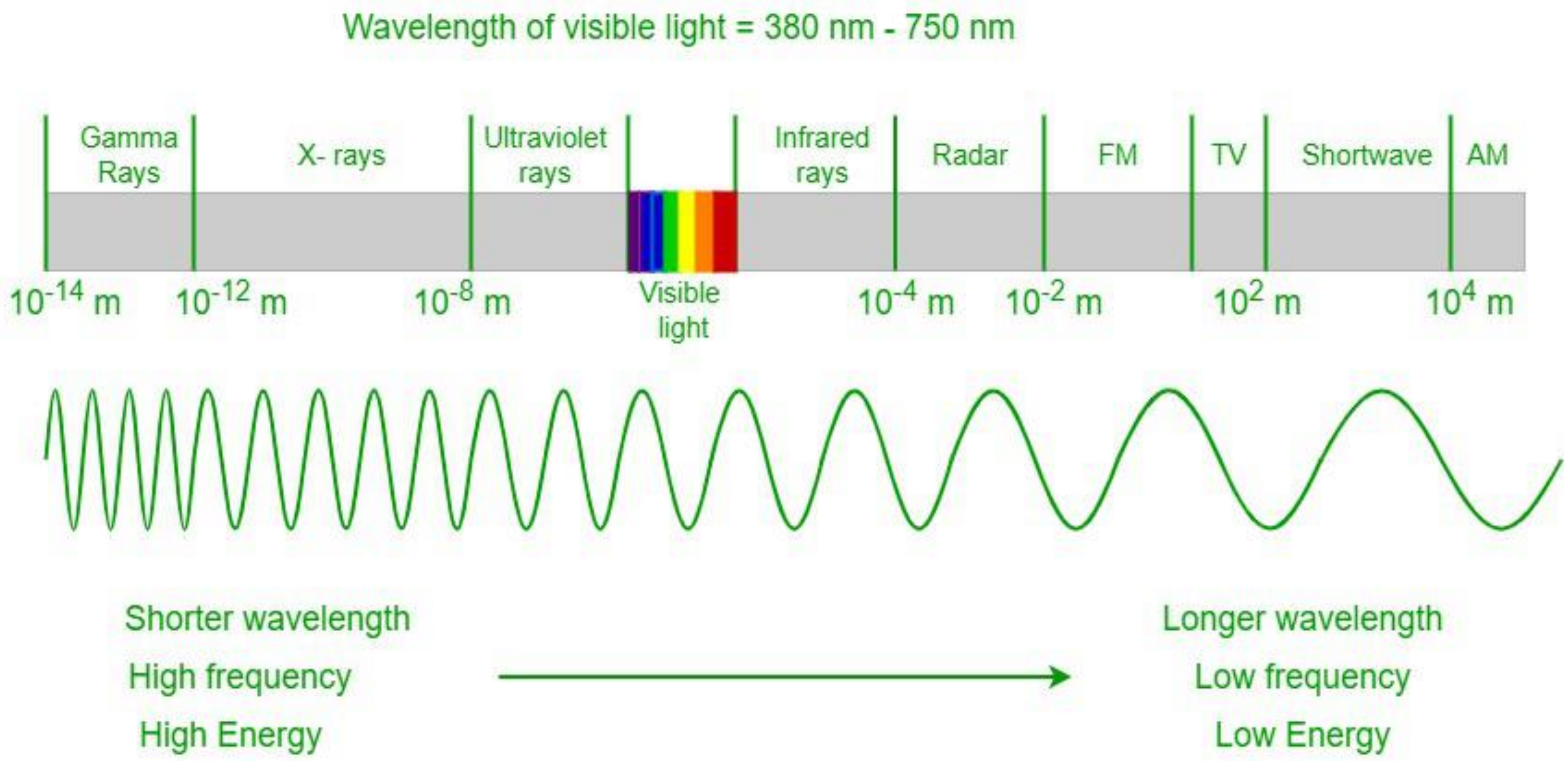
The height of the wave, which determines the brightness or intensity of the light. A higher amplitude means a brighter light.

Energy (E):

Light carries energy, which is related to its frequency. The energy of a photon is given by the equation E=hν, where h is Planck's constant. Higher frequency light (e.g., ultraviolet) carries more energy than lower frequency light (e.g., infrared).

where:

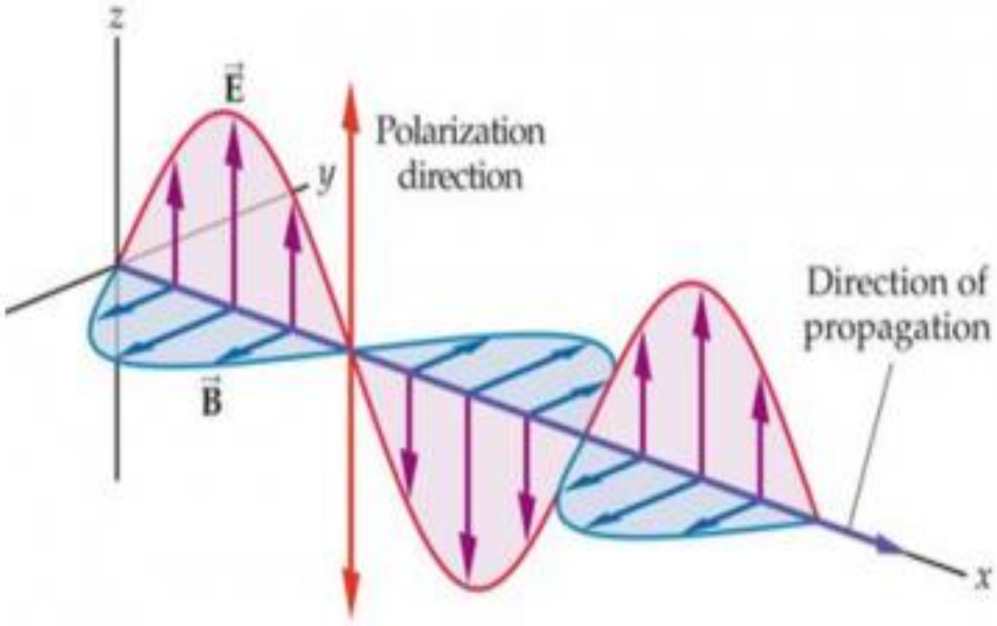
- E is the energy of the photon,
- h is Planck’s constant ($h \approx 6.626 \times 10^{-34} J$)
- ν (Greek letter "nu") is the frequency of the electromagnetic wave associated with the photon.


Wavelength of visible light = 380 nm - 750 nm
Gamma Rays
X- rays
Ultraviolet rays
Infrared rays
Radar
FM
TV
Shortwave
AM
10^-14 m
10^-12 m
10^-8 m
Visible light
10^-4 m
10^-2 m
10^2 m
10^4 m
Shorter wavelength
High frequency
High Energy
Longer wavelength
Low frequency
Low Energy

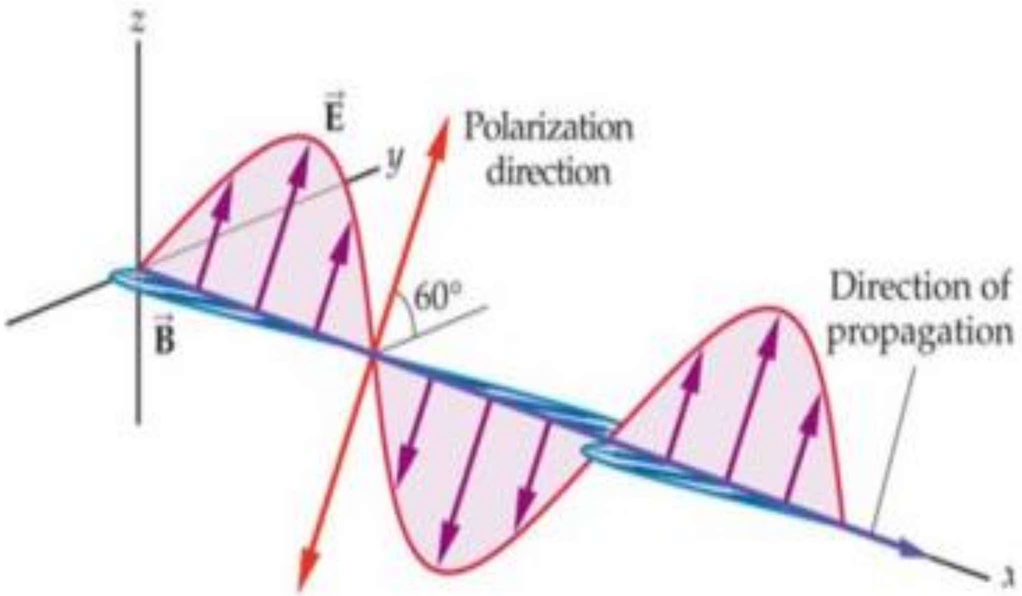
Polarization:

Polarization is a property applying to transverse waves that specifies the geometrical orientation of the oscillations, In a transverse wave, the direction of the oscillation is perpendicular to the direction of motion of the wave. Transverse waves that exhibit polarization include **electromagnetic waves** such as **light** and radio waves, gravitational waves, and transverse sound waves (shear waves) in solids.

An electromagnetic wave such as light consists of a coupled oscillating **electric field** and **magnetic field** which are always perpendicular; by convention, the “polarization” of electromagnetic waves refers to the direction of the electric field. In **linear polarization**, the fields oscillate in a single direction. In **circular** or **elliptical polarization**, the fields rotate at a constant rate in a plane as the wave travels. The rotation can have two possible directions; if the fields rotate in a right hand sense with respect to the direction of wave travel, it is called right circular polarization, while if the fields rotate in a left hand sense, it is called left circular polarization.



This wave **is polarized** in z -direction



This wave **is polarized** in a direction at an angle of 60° with y-axis

- Reflection: When light strikes a surface, it can bounce back. The angle of incidence (the angle at which light strikes a surface) is equal to the angle of reflection.

- Refraction: When light passes from one medium to another, it changes speed, causing the light to bend. The amount of bending depends on the refractive index of the two media and is described by Snell’s Law.

In the context of Snell's Law and optics, n is the refractive index of a material, and it is defined as the ratio of the speed of light in a vacuum to the speed of light in the medium. The formula is:

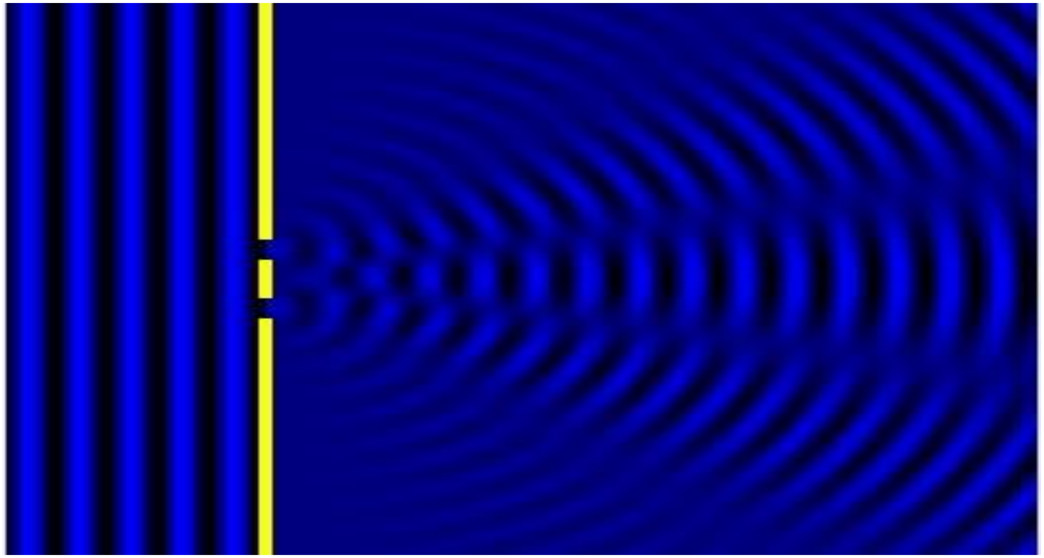
$$n = \frac{co}{c}$$

Where:

- n is the refractive index,
- c0 is the speed of light in a vacuum (≈3×108\approx 3 \times 10^8≈3×108 m/s),
- c is the speed of light in the medium.

Diffraction:

Light can bend around obstacles or spread out after passing through small openings, a property of its wave nature. This bending leads to interference patterns under certain conditions.



Interference:

When two or more light waves overlap, they can interfere constructively (amplitudes add up) or destructively (amplitudes cancel out). This can create patterns of bright and dark regions.

Constructive Interference

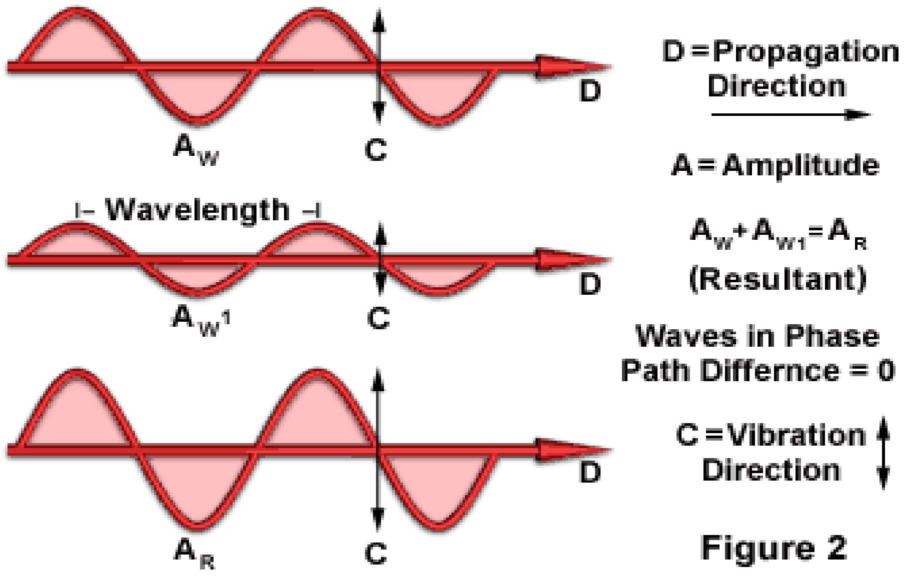
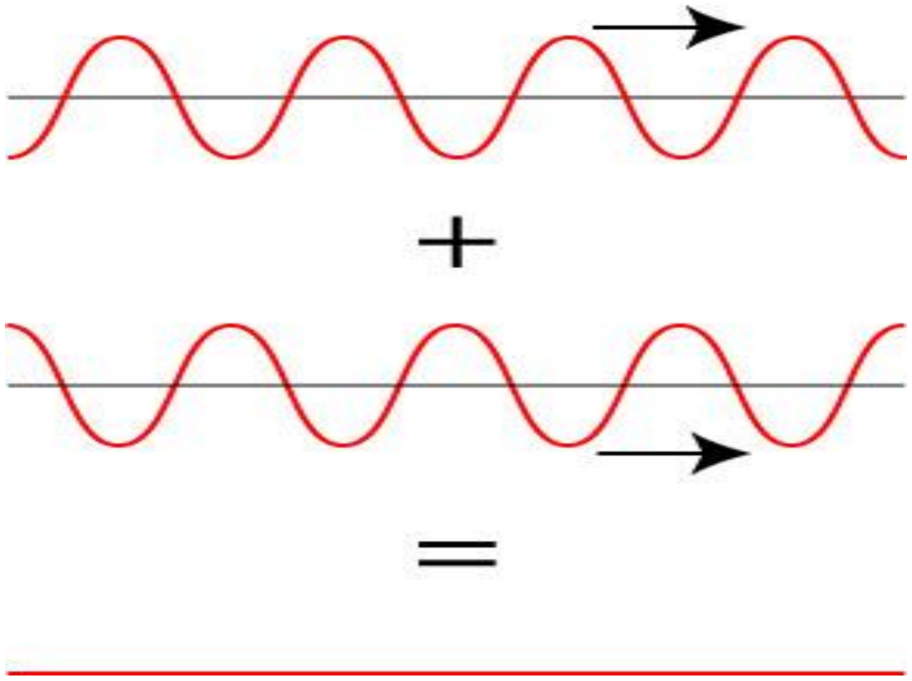
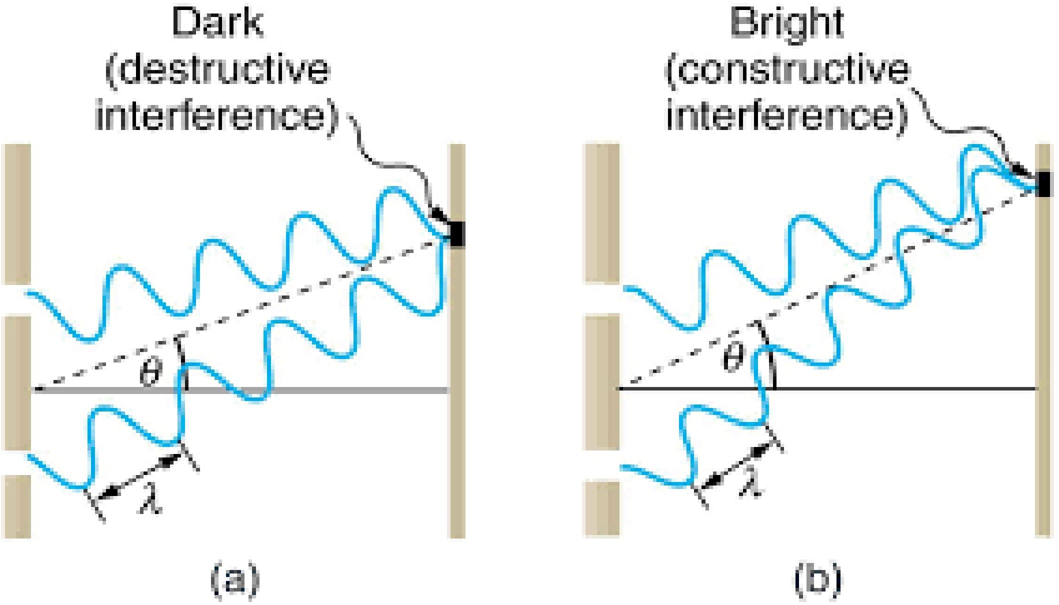


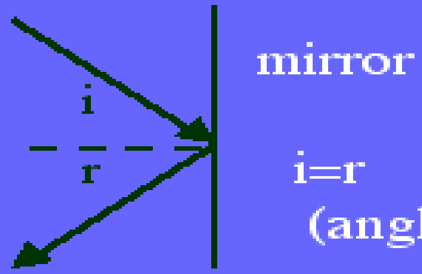
Figure 2





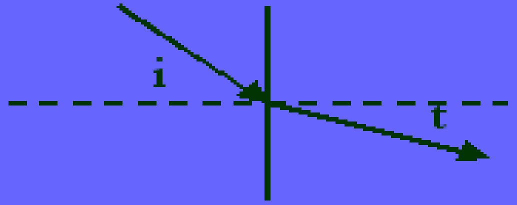
Wave Properties of Light

- Reflection



i=r
(angle of incidence = angle of reflection)

- Refraction

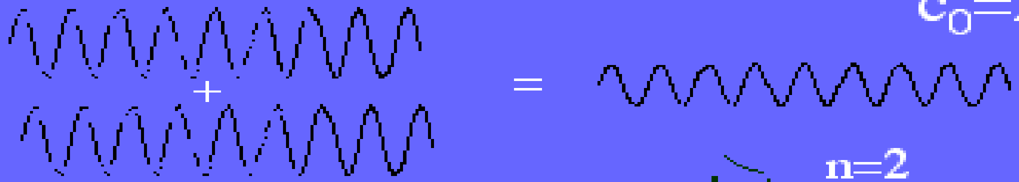


$n_i \sin i = n_t \sin t$

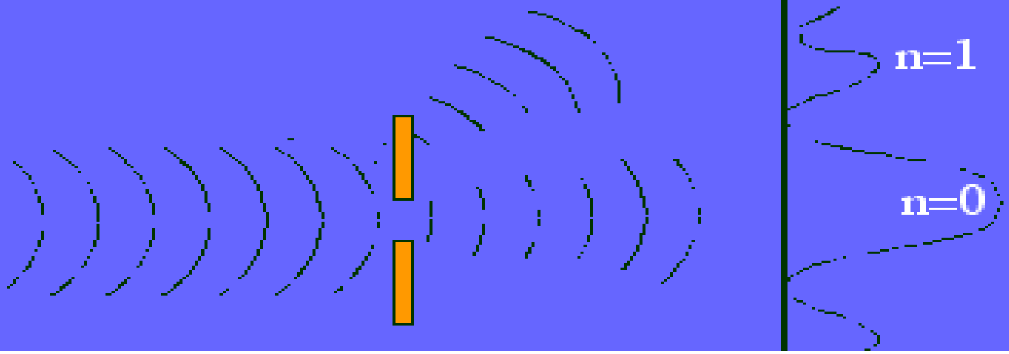
$n = c_0 / c$

$c_0 = 2.97 \times 10^8$ m/s

- Interference



- Diffraction



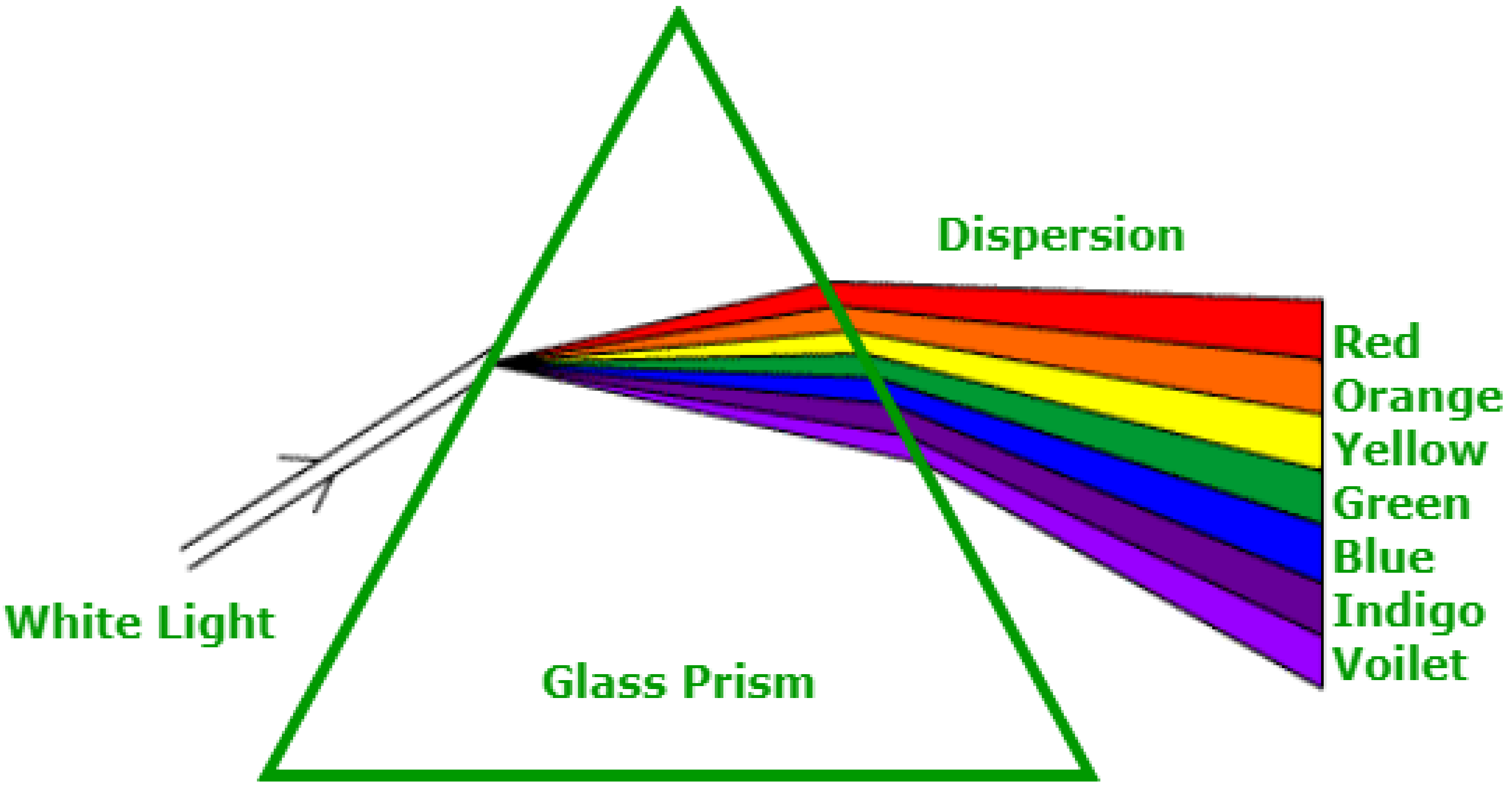
$n \lambda = d \sin \theta$

Absorption:

When light passes through a medium, it can be absorbed, converting its energy into heat or causing electronic transitions in the absorbing material (like chlorophyll in plants absorbing light for photosynthesis).

Dispersion:

Different wavelengths of light travel at different speeds when passing through a medium, causing light to spread out into its constituent colors, like when a prism separates white light into a rainbow.


Dispersion
Red
Orange
Yellow
Green
Blue
Indigo
Voilet
White Light
Glass Prism