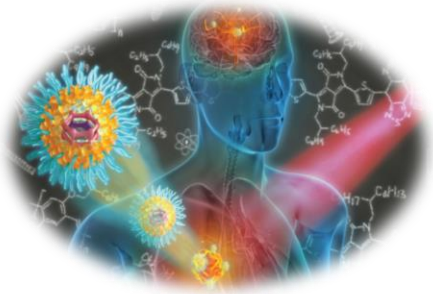
Salahaddin University-
Erbil College of Science
Physics Department



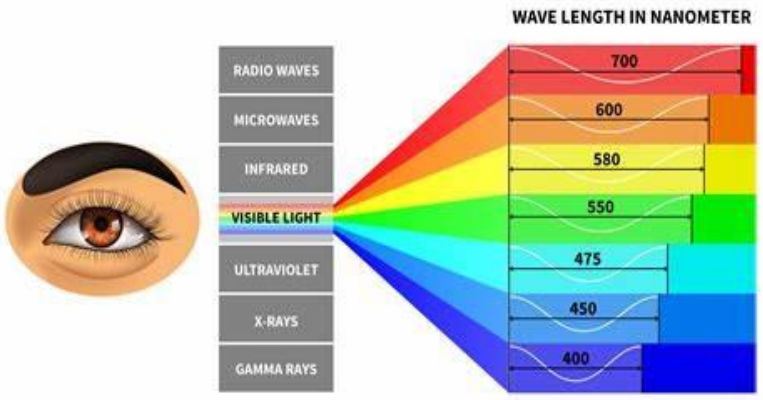
Medical Optics. 3rd stage
Medical branch

1st Lecture after course book

1st Weak

Date 24-1-2024

Chapter one
1-An Introduction
2- Nature of Light



Dr. Shaida Anwer Kakil

24/1/2024

Learning Outcomes

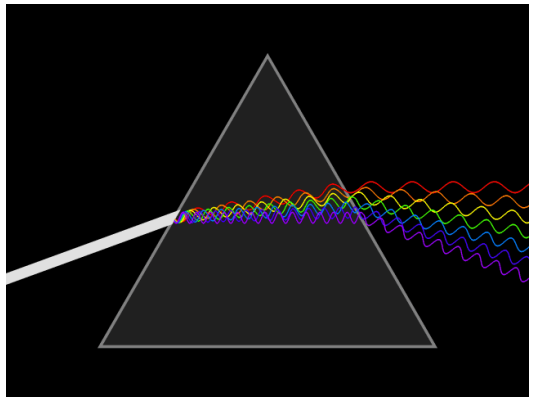
At the end of todays lecture you would be able to:

- **Understand the following terminologies: Optics , Photonics, Medical Optics .**
- **Understand the Physical meaning of Light and the properties of light**
- **Explain :Electromagnetic spectrum and Why Optics in Medicine**
- Explain the difference between Biomedical Optics & Biomedical Photonics

Physical meaning of Optics ,Photonic and Medical Optics

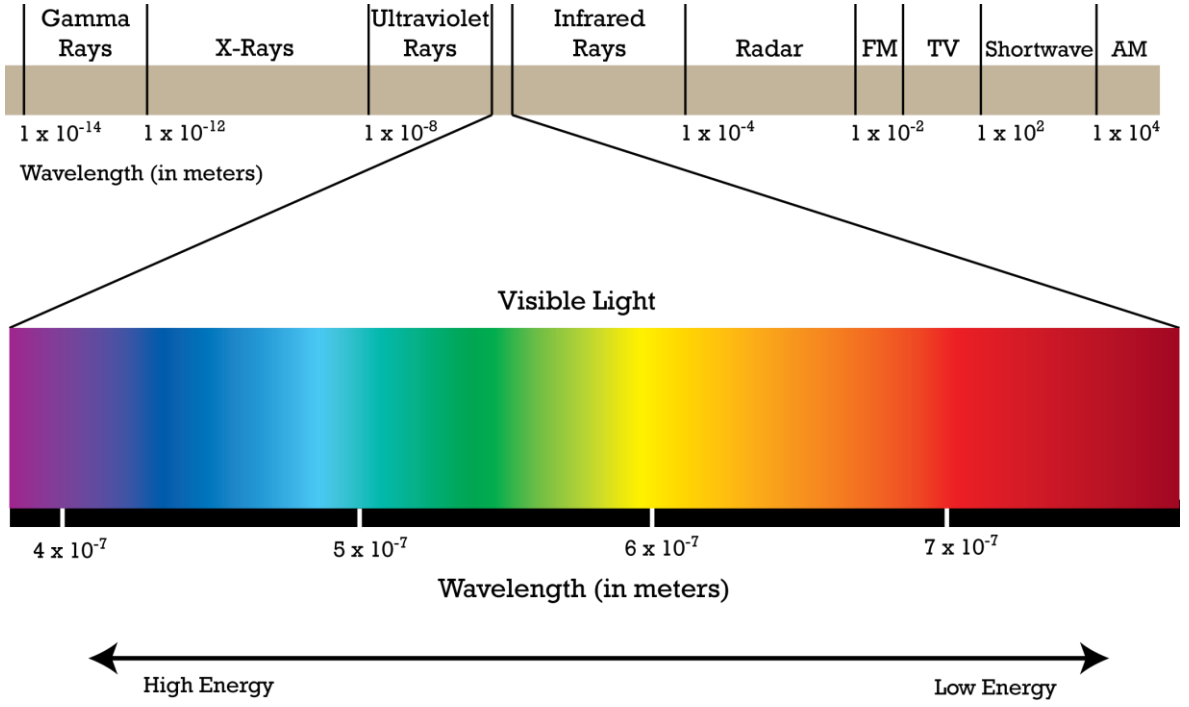
Optics

- Optics: the scientific study of sight and the behavior of light, or the properties of transmission and deflection of other forms of radiation.
- Optics is a branch of physics that deals with the determination of behaviour and the properties of light, **along with its interactions with matter** and also with the instruments which are used to detect it. Optics, in a simple manner, is used to describe the behavior of **visible light, infrared light, and ultraviolet.**



Light and Its Properties

- Light is a form of energy that is in the form of an electromagnetic wave and is almost everywhere around us. The visible light has wavelengths measuring between 400–700 nanometres.
- The Sun is the primary source of light by which plants utilize this to produce their energy.
- In physics, the term light also refers to electromagnetic radiation of different kinds of wavelengths, whether it is visible to the naked eye or not.
- Hence, by this, the gamma rays, microwaves, X-rays, and radio waves are also types of light.



Photonics

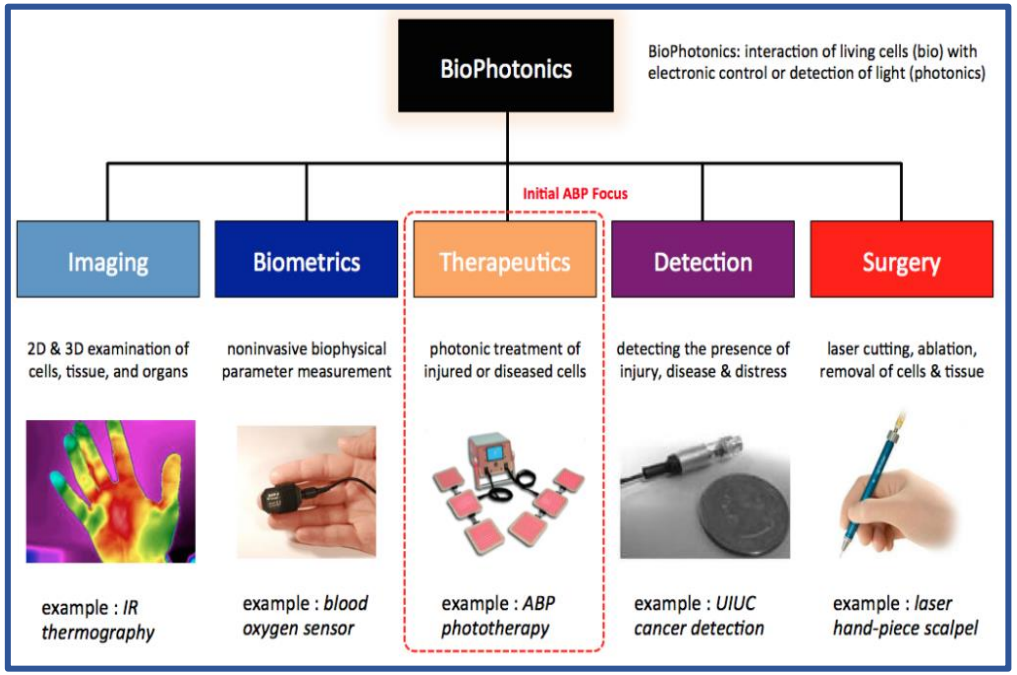
Photonics is the physical science and application of light (photon) generation, detection, and manipulation through emission, transmission, modulation, signal processing, switching, amplification, and sensing. Though covering all light's technical applications over the whole spectrum, most photonic applications are in the range of visible and near-infrared light.

Why Optics in Medicine?

- Nowadays, it is not only optics but also photonics that are used extensively in a myriad(great number) of medical applications, from diagnostics, to therapeutics, to surgical procedures. Hence, when we use the term medical optics, we are referring to **biomedical optics and biophotonics** as well. But it is in reality light and its interaction with living tissues that is at the center of what makes optics in medicine possible. Light possesses energy and is capable of interacting with biological cells, tissues, and organs.
- Such interaction can be used to probe the state of such living matter for diagnostics and analytical purposes or, it could be used to induce changes on the same living systems and be exploited for therapeutic purposes.

Q1) Explain the difference between Biomedical Optics & Biomedical Photonics

- Biomedical Optics and Biomedical Photonics are two fields that are closely related to each other. Biomedical Optics is the study of light-matter interactions in biological systems, while Biomedical Photonics is the application of photonics to the study of biological systems.
- In other words, Biomedical Optics is a fundamental science that studies the interaction of light with biological tissues, while Biomedical Photonics is an applied science that uses optical techniques to solve problems in biology and medicine



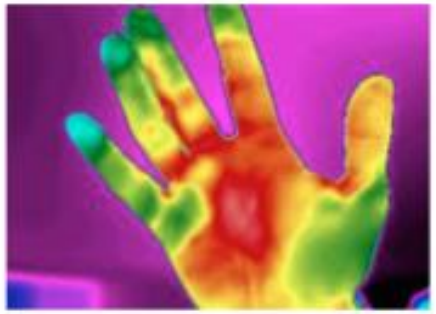
BioPhotonics

BioPhotonics: interaction of living cells (bio) with electronic control or detection of light (photonics)

Initial ABP Focus

Imaging

2D & 3D examination of cells, tissue, and organs



example : *IR thermography*

Biometrics

noninvasive biophysical parameter measurement

example : *blood oxygen sensor*

Therapeutics

photonic treatment of injured or diseased cells

example : *ABP phototherapy*

Detection

detecting the presence of injury, disease & distress

example : *UIUC cancer detection*

Surgery

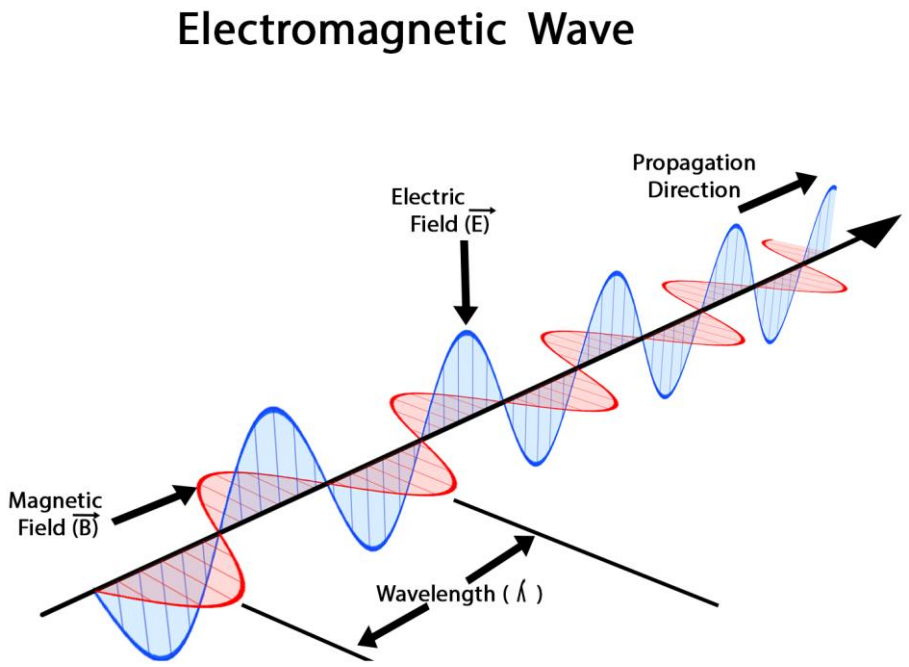
laser cutting, ablation, removal of cells & tissue

example : *laser hand-piece scalpel*

Chapter one “Nature of Light”

Chapter one Nature of Light

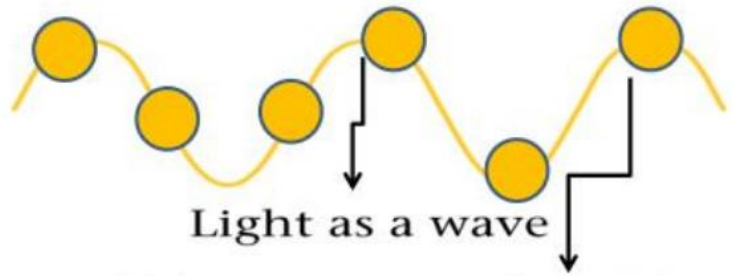
- Light is **electromagnetic radiation** that can be detected by the human eye. Electromagnetic radiation occurs over an extremely wide range of wavelengths, from gamma rays with wavelengths less than about 1×10^{-11} metres to radio waves measured in metres.



Albert Einstein proposed that light not only behaves as a wave, but as a particle too.

Light is a particle in addition to a wave-Dual nature of light.

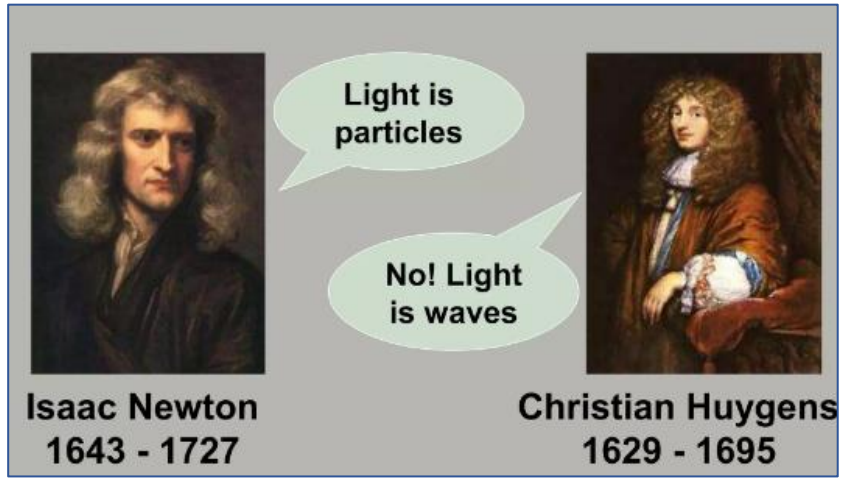
Dual nature of light - treated as
1) a wave or
2) as a particle



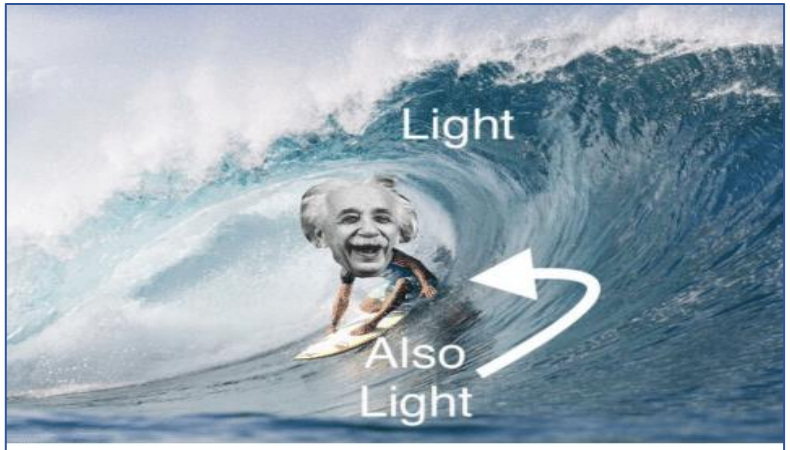
Dual nature of light successfully explains all the phenomena connected with light.

Is a light a wave or particle?

- Light is both a particle and a wave. Light has properties of both a particle and an electromagnetic wave but not all the properties of either. It consists of photons that travel in a wave-like pattern. The debate has raged for generations amongst the giants of the physics community regarding the nature of light, namely whether it is a particle or an electromagnetic wave.

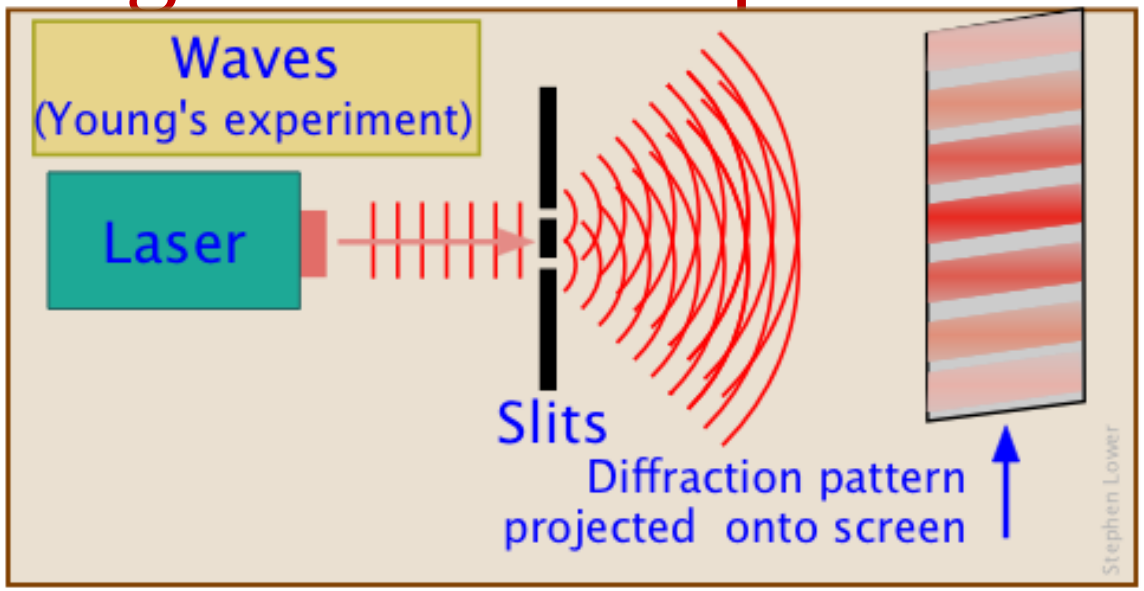


- Light has a dual nature.
- Depending on the phenomenon or behavior in question, light can be treated either as a wave or as a particle.
- To examine this wave-particle duality, we will examine two experimental proofs.



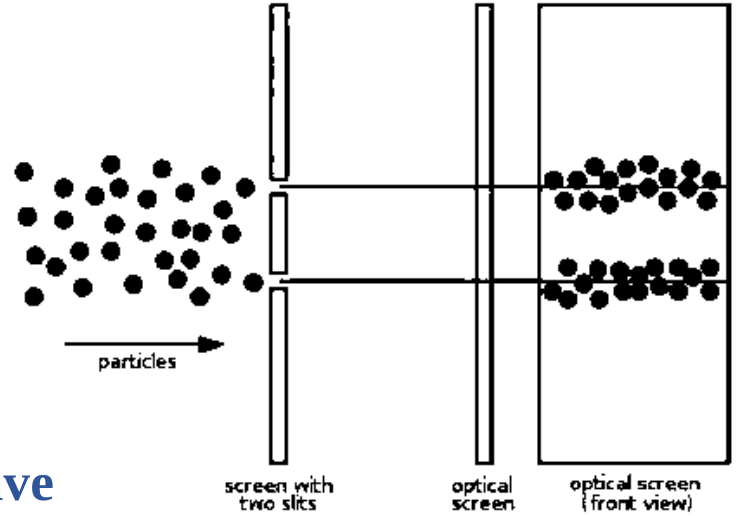
Einstein illustrates how light is both a wave and a particle (1905)

Is a light a wave or particle?



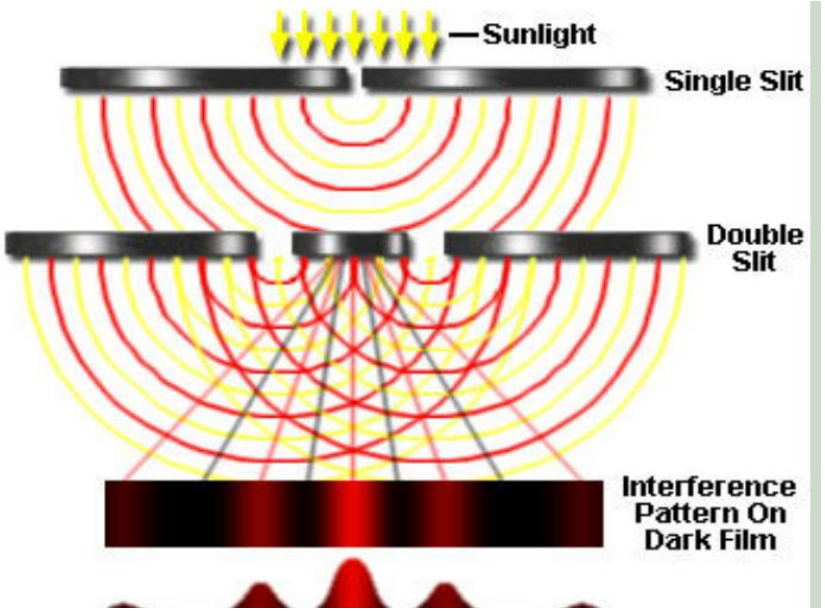
Particle

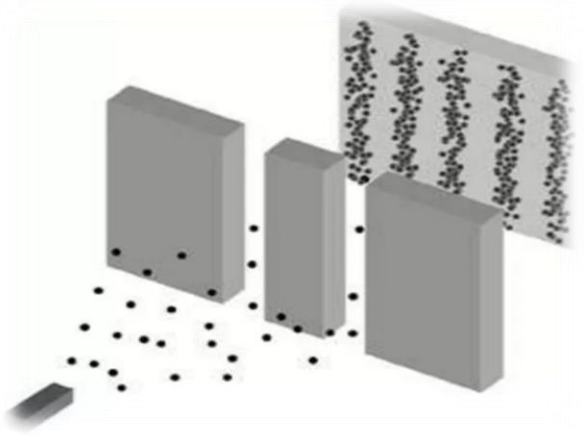
If light acts as a particle,only two slits will appear on the screen



Wave

The light will diffract and interfere making many fringes



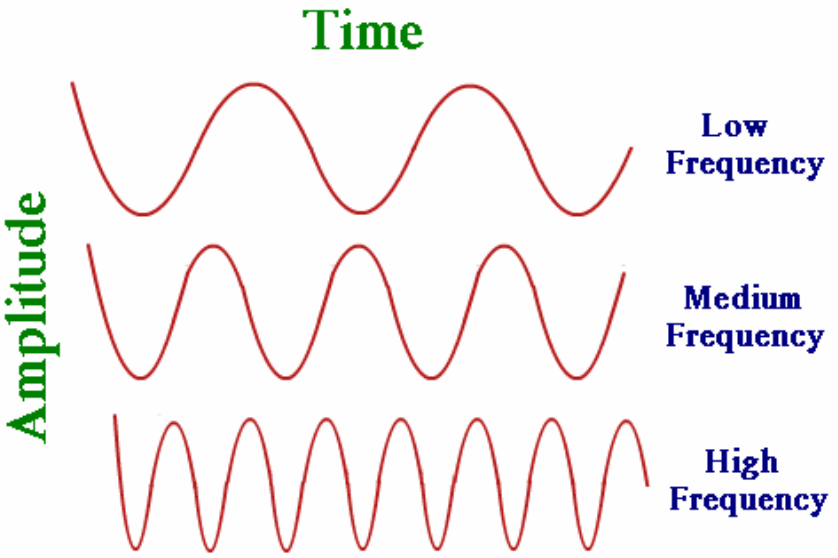


Nature of Light”

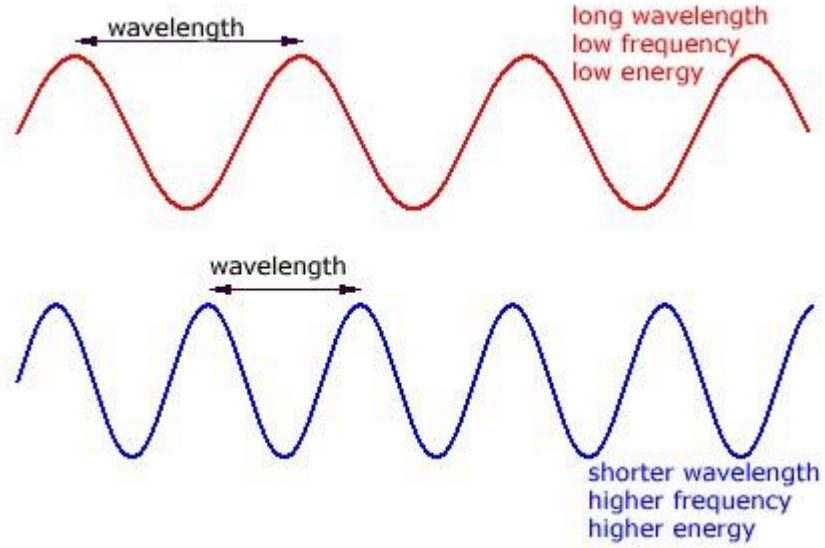
Waves are characterized by **frequency**, **wavelength**, **speed and phase**.

$$\lambda \nu = c$$

C is speed of light in a vacuum (≈air) = 2.997×10^8 m/s



- **all types of electromagnetic radiation travel at the speed of light, so the short wavelength radiation must have a high frequency**
- **-The speed of light and wavelength, which change as electromagnetic energy is propagated through media of different densities, the frequency remains constant and is therefore a more fundamental property.**
- Light behaves like waves in its propagation and in the phenomena of **interference and diffraction**



Particulate nature of radiation:

- The radiation can be described in terms of particles of energy called **photons**
- Planck was used the idea that black bodies emit light (and other electromagnetic radiation) only as discrete packets of energy called photons.
- The Photon has energy, but it has no mass and no charge
- Energy of photon is given by:

$$E_{\text{photon}} = h\nu$$

$$E = h\frac{c}{\lambda}$$

where h is Plank's constant ($h = 6.6256 \times 10^{-34}$ J s).

The quantized nature of light is most important when considering absorption and emission of electromagnetic radiation.

Light exhibits particle-like behaviour when exchanging energy with matter**, as in the Compton and photoelectric effects**

What are the Characteristics of Light?

- Light is an **electromagnetic wave**.
- Light travels in a straight line.
- Light is a transverse wave, and does not need any medium to travel. Light can travel through vaccum.
- Its speed through vaccum 3×10^{8} m/s.
- The velocity of light changises when it travels from one medium to another.

Effects of Materials on Light

Materials can be classified based on how it responds to light incident on them:

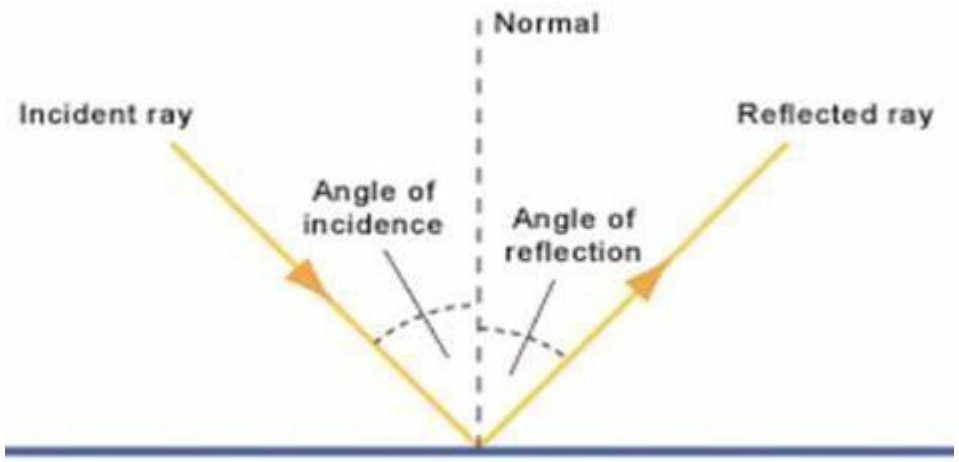
1. **Opaque materials** – absorb light; do not let light to pass through
2. **Transparent materials** – allow light to easily pass through them
3. **Translucent materials** – allow light to pass through but distorts the light during the passage

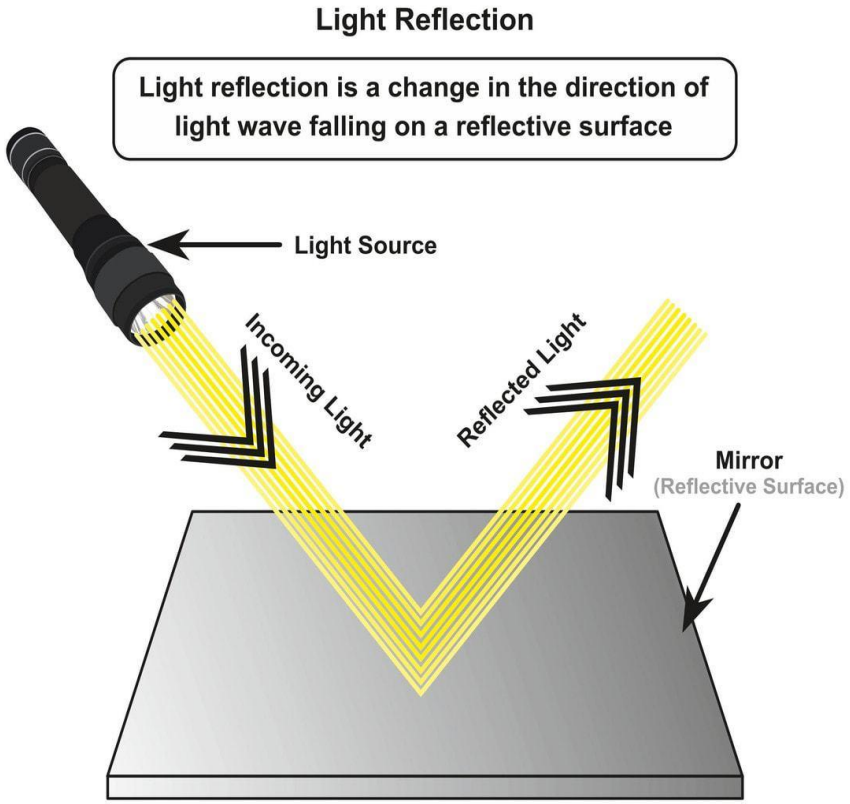
Basic properties of light

There are 5 basic properties of light :

1-Reflection of light

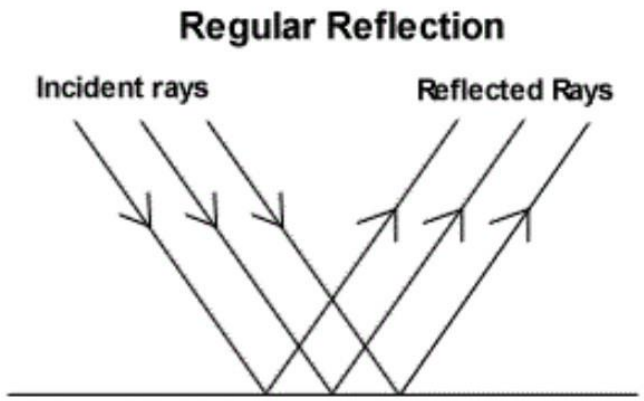
The reflection of light **occurs whenever a ray of light falls on a smooth polished surface and bounces back**. In other words, the ray of light approaching any surface results in the reflection of the light.

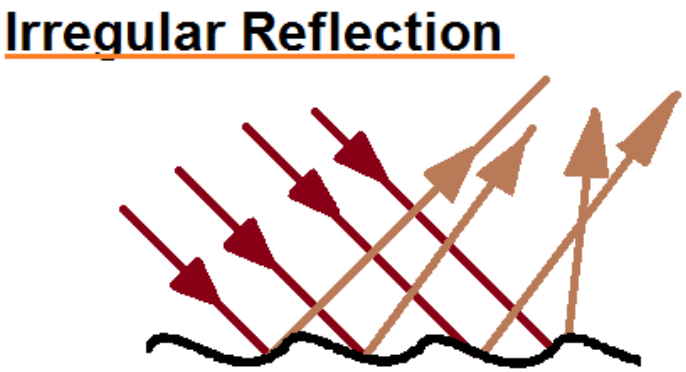




1-Reflection of light

- **Reflection can be of two types:**
- Regular reflection: Regular reflection is also termed as specular reflection, which occurs when the beam of light falls on a regular, polished, and smooth plane.
- Irregular reflection: Irregular reflection also termed as diffuse reflection, which occurs when the beam of light falls on the rough surface and reflects light in various directions.



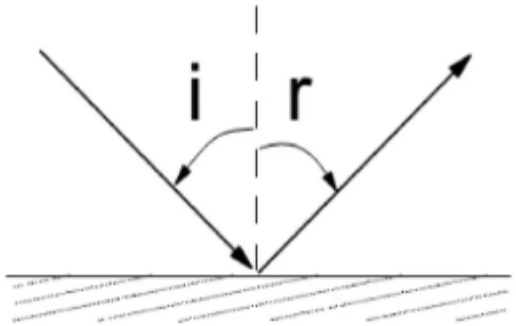


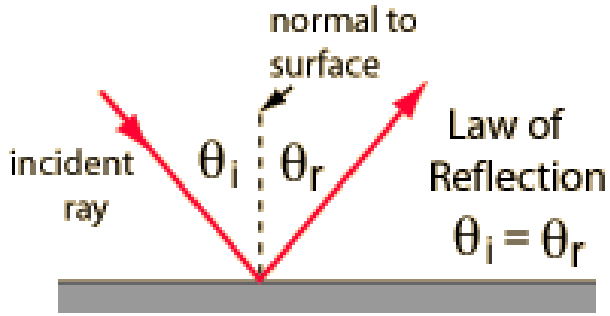
1-Reflection of light

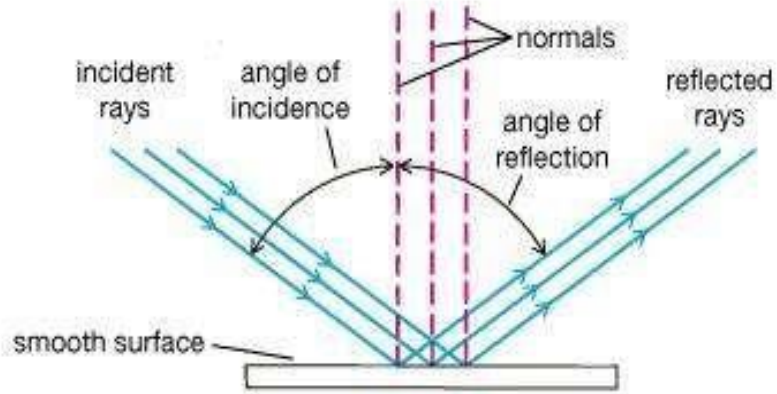
Laws of Reflection

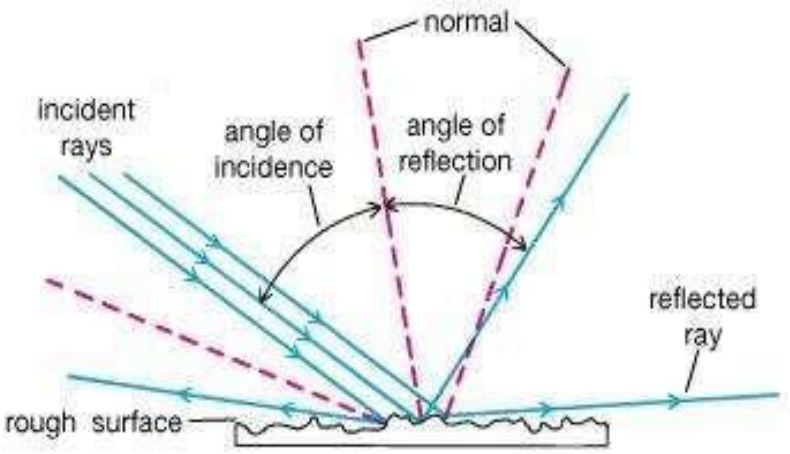
- **Two laws which govern reflection of light**

1. **The incident ray, the reflected ray and the normal to the reflecting surface all lie in the same plane.**
2. **The angle of incidence *i* equals the angle of reflection *r*.**









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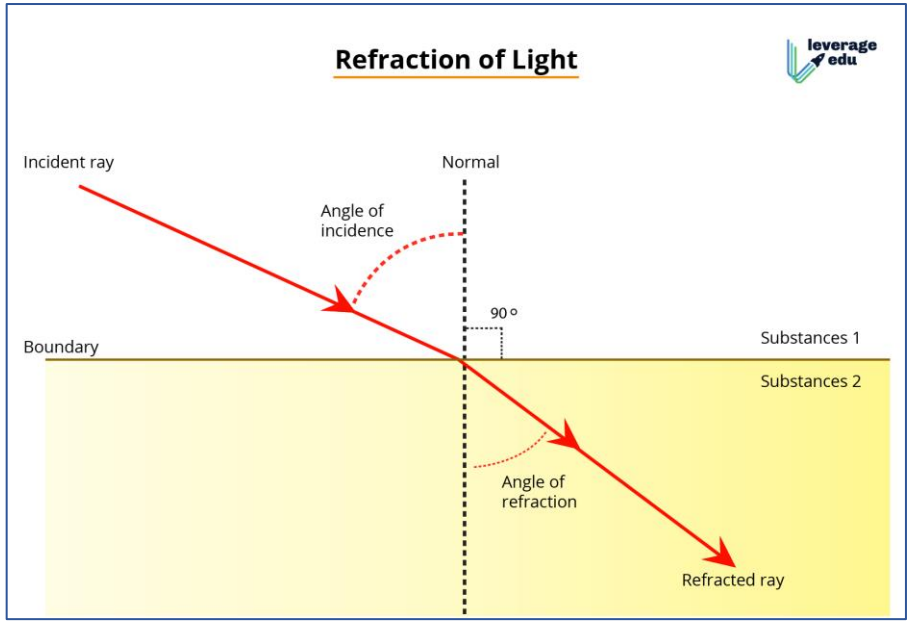
2-Refraction of light

- This bending of light is caused by the difference in the speed of light in the two media
- Refraction of light can be seen in many places in our everyday life. It makes objects under a water surface appear closer than they really are. It is what optical lenses are based on, allowing for instruments such as glasses, cameras, binoculars, microscopes, and the human eye. Refraction is also responsible for some natural optical phenomena including rainbows and mirages.



Light travels faster in air, slow in water and slower still in glass.

The slower light is in a medium, the more it refracts/bends in it.

The measure of how much light refracts in a medium is called **index of refraction.**

Medium	Index of Refraction (n)
air	1.000293
water	1.3330
glass	1.490
diamond	2.419

Light bends/refracts when it changes speed.

This usually happens when the light travels from one medium to the next.

Simple rule of thumb in refraction:

- If light slows down, it will refract towards the normal line.
- If light speeds up, it will refract away from the normal line.

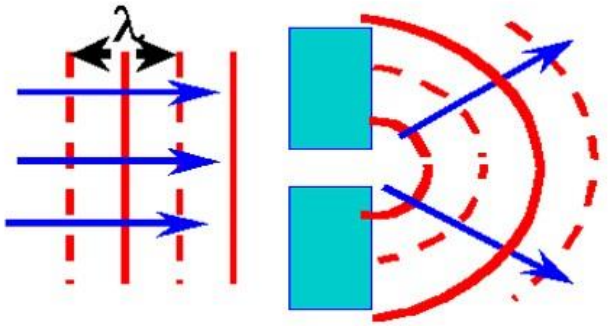
We here define ***refractive index***, n, of a material or substance as the ratio of the speed of light in a vacuum, C, to the speed of light in a material through which it passes, C_m.

$n = C/C_m$

The important difference between reflection and refraction:

Parameters	Reflection	Refraction
Description	Reflection is the bouncing back of light when it strikes a smooth surface.	Refraction is the bending of light rays when it travels from one medium to another.
Nature Of Surface	Generally occurs on shinny surfaces that only allow rebounding of light without permitting penetration through it.	This occurs in transparent surfaces that allow bending of the ray to a different medium.
Types	There are two forms of reflection, they are, Regular reflection (Specular reflection) and Diffused reflection.	There is a single form of refraction.
Occurrence	Occurs in mirrors.	Occurs in lenses.
Behaviour Of Light	In this process, light bounces back and returns back in the same direction.	In this process, light changes path i.e travels from one medium to another.
Speed Of Light	When a light ray strikes the boundary of a shiny surface the speed of light ray does not vary.	The speed of light varies with the medium in which the ray undergoes bending.
Medium Of Light Propagation	The medium in which light propagates remains the same •	The medium of propagation gets changed.
The angle of Reflection And Angle of Incidence	The angle of reflection and angle of incidence is the same in the case of reflection.	In refraction, the angle of reflection and angle of incidence are not the same.

3-Diffraction of light



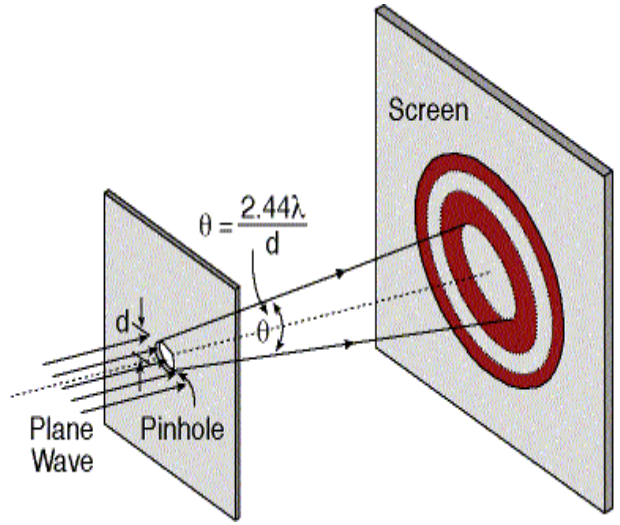
Why does light diffraction occur?

- More specifically when applied to **light**, **diffraction** of **light** occurs when a **light** wave passes by a corner or through an opening or slit that is physically th approximate size of, or even smaller than that **light**'s wavelength.
- **Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening**.

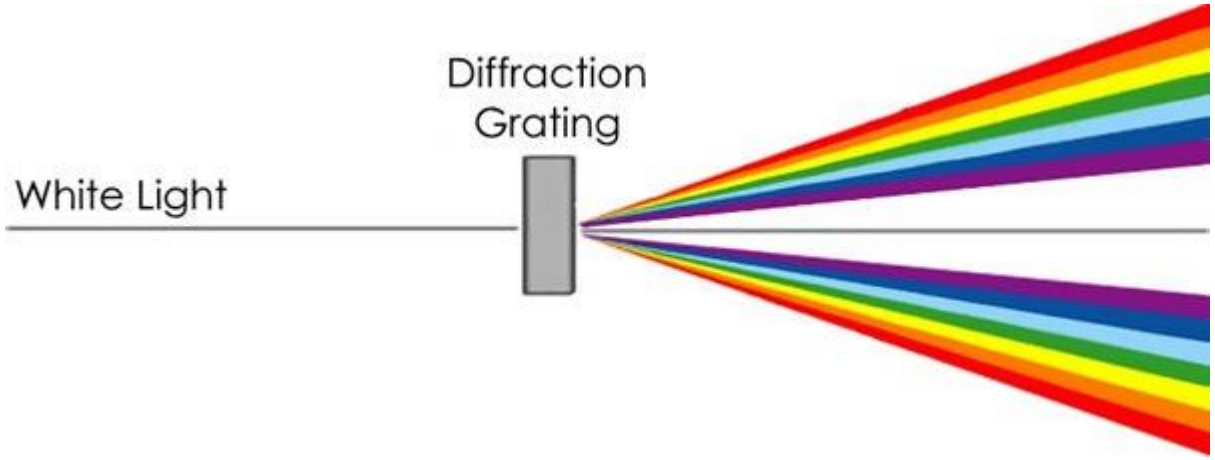
There are two conditions for the production of diffraction:

(1) In case of straight edge: The edge should be very sharp and its width is to be equal to or is of the order of the wavelength λ of light.

(2) In case of thin hole: The diameter of the hole should be extremely small such that it is equal to or is of the order of the wavelength λ of light.

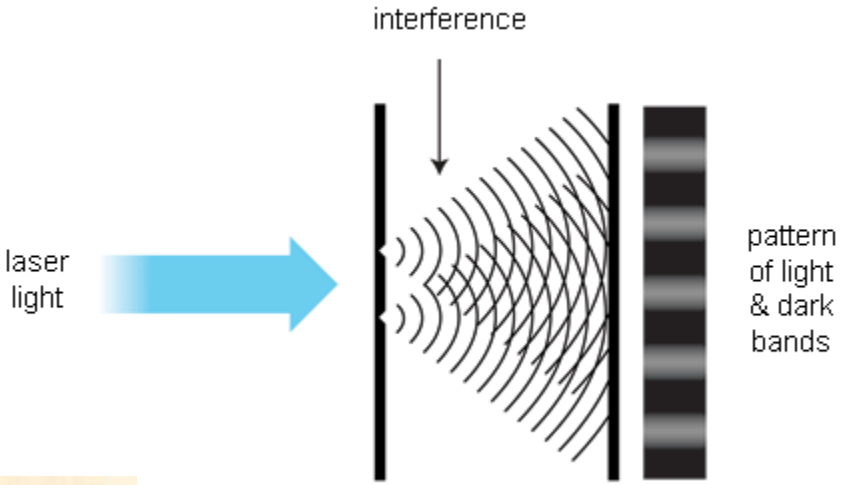


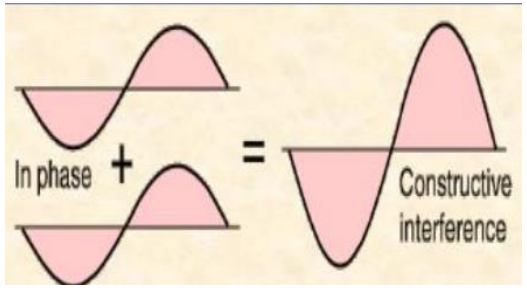
3-Diffraction of light

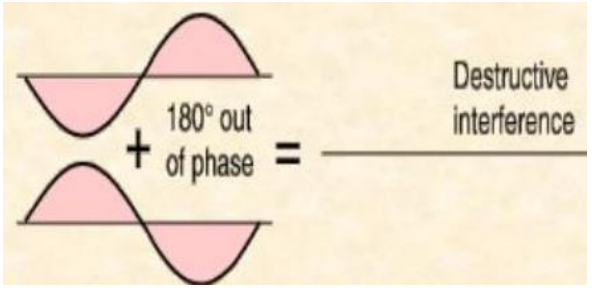


4-Interference of light

- interference of light is the phenomenon that occurs when **two waves of light meet and the crest of one wave cancels out the trough of the other wave**. One of the fundamental properties of light is its ability to interfere with itself.







CONSTRUCTIVE INTERFERENCE	DESTRUCTIVE INTERFERENCE
Two waves sum up each other	Two waves negate each other
Crest and crest meet one another	Crest and trough meet one another
The resultant wave has a larger amplitude	The resultant wave has a smaller amplitude

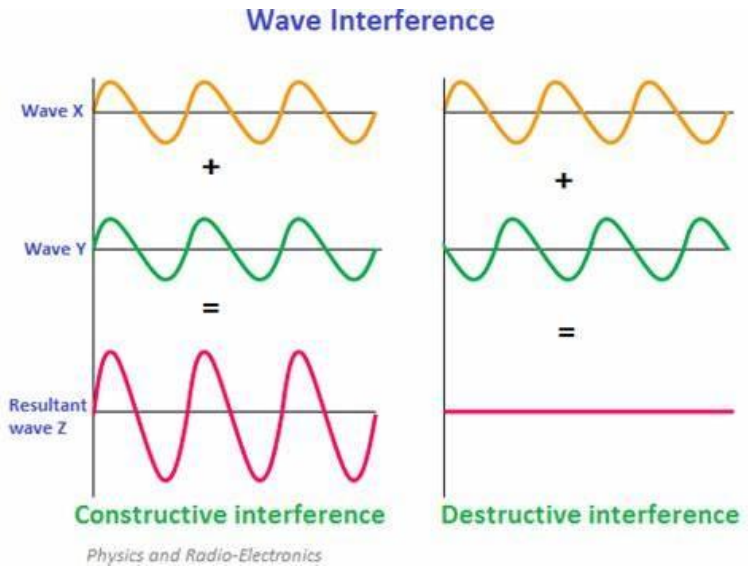
H.W

1. In constructive interference, the two waves' amplitudes are

1.added to produce a larger amplitude.
2.subtracted to produce a smaller amplitude.
3.added to produce a smaller amplitude.
4.cancelled out by each other.
5.in opposite directions.

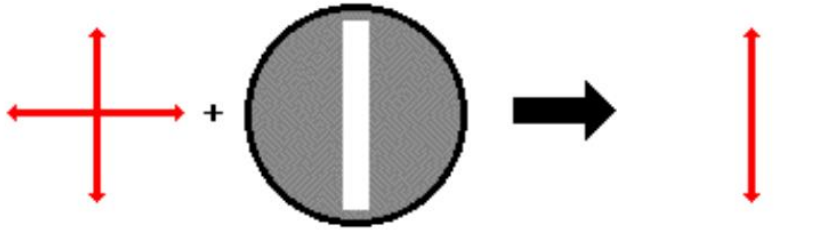
2. In observing two interfering waves, the amplitude of the resulting wave can be found at every point using the principle of

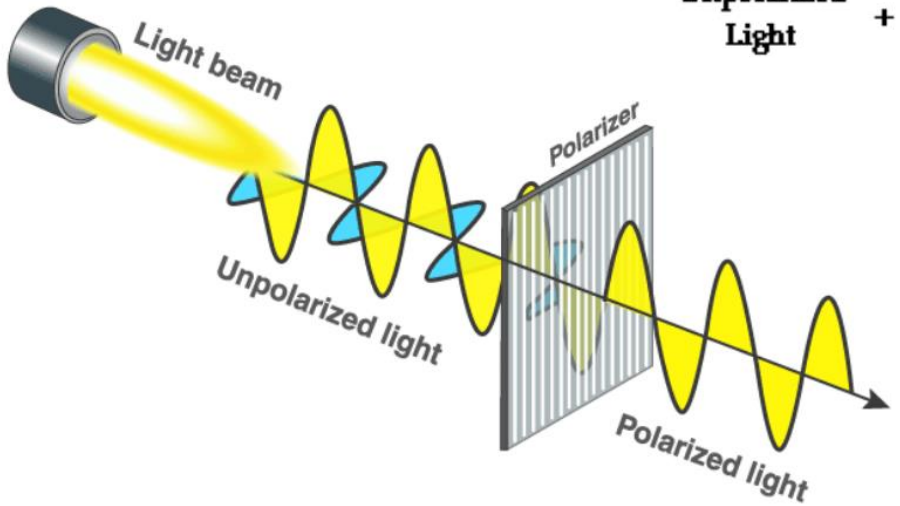
1.superposition.
2.supposition.
3.subversion.
4.subduction.
5.superstition

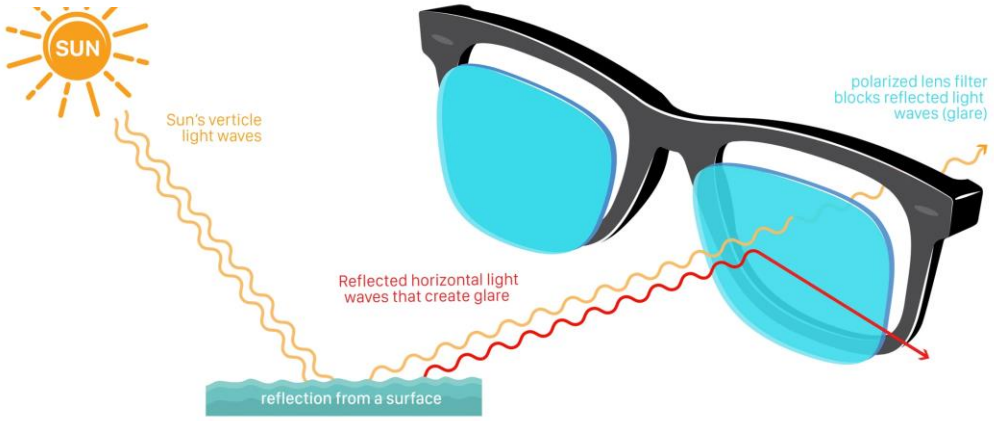


5-Polarization of light

- Normal light vibrates equally in all direction perpendicular to its path of propagation. If the light is constrained to vibrate in only on plane, however, we say that it is plane polarized light. The direction that the light vibrates is called the vibration direction, which for now will be perpendicular to the direction. There are two common ways that light can become polarized.







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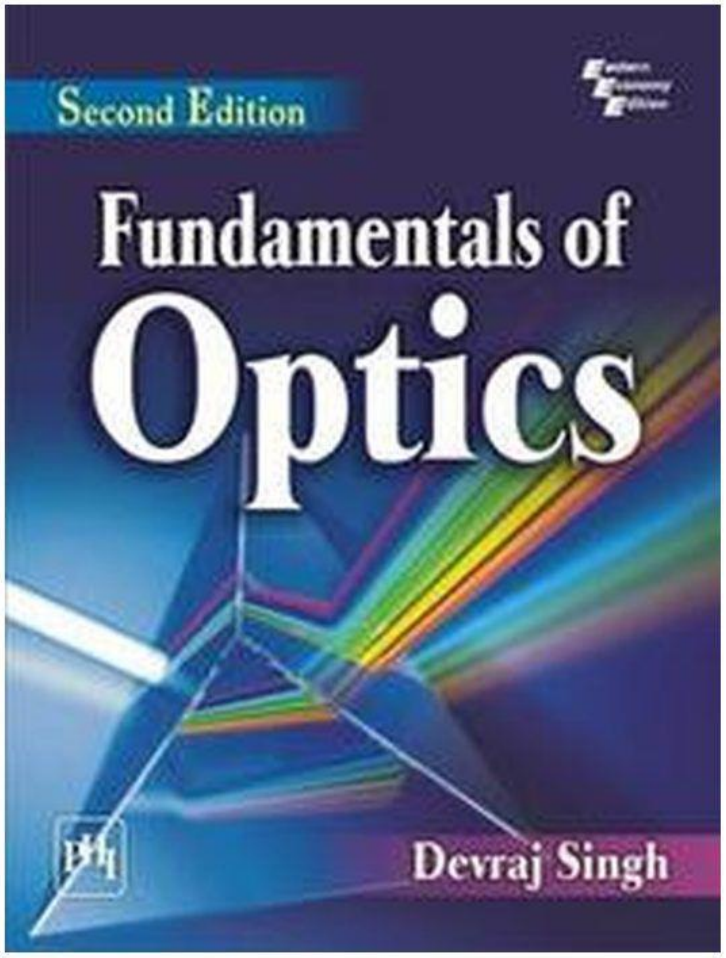

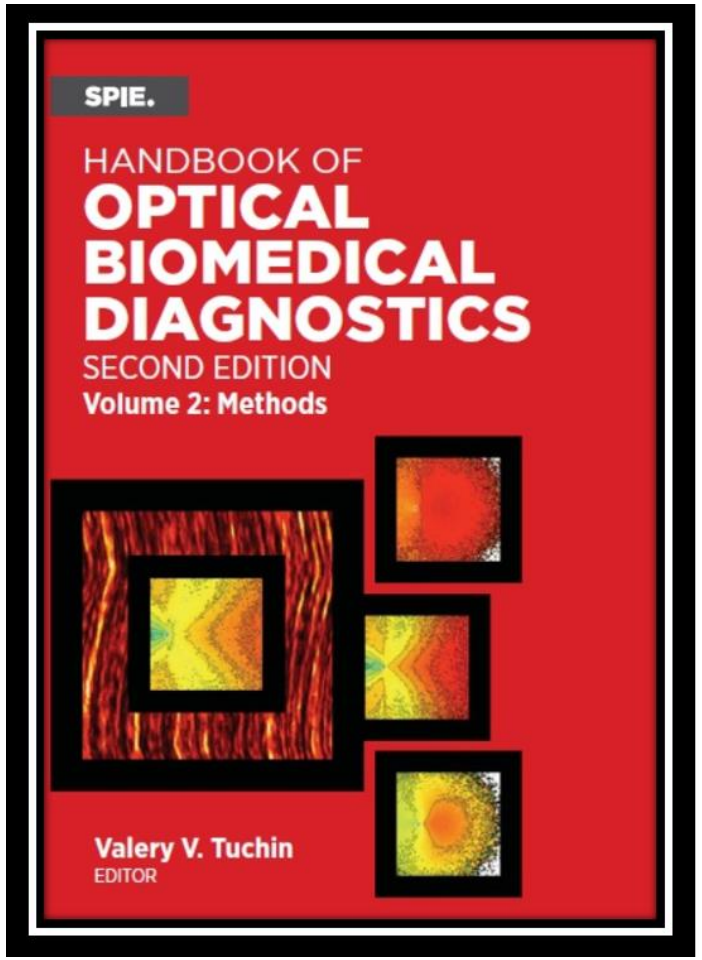

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