## 

**University of Al-Mustaqbal**

**College of Science**

**Department of Medical Physics**

## Optics

## Lecture 1: Nature and propagation of light

## Second stage

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## Lecture 1: Nature and propagation of light

* **Optics**, the study of light, is conveniently divided into three fields are geometrical optics, physical optics and quantum optics.
* **Geometrical optics,** which includes the study of light propagation in straight lines, speed of light, properties of light, reflection, refraction, desperation, lenses and mirrors.
* **Physical optics,** which is concerned with the nature of light and involves primarily the theory of waves. This includes interference and diffraction.
* **Quantum optics,** which deals with the interaction of light with the atomic entities of matter and which for an exact treatment requires the methods of quantum mechanics.

# Light and vision

* + **Light or visible light** is [electromagnetic radiation](http://en.wikipedia.org/wiki/Electromagnetic_radiation) that is [visible](http://en.wikipedia.org/wiki/Visual_perception) to the [human eye](http://en.wikipedia.org/wiki/Human_eye), and is responsible for the sense of vision. It has a [wavelength](http://en.wikipedia.org/wiki/Wavelength) in a range from (400 - 700 nm).
* Light travels in straight lines and has the primary properties such as [intensity](http://en.wikipedia.org/wiki/Intensity_(physics)), propagation direction, [frequency](http://en.wikipedia.org/wiki/Frequency) or [wavelength](http://en.wikipedia.org/wiki/Wavelength) and [polarization](http://en.wikipedia.org/wiki/Polarization_(waves)).
* Light is a form of energy, which is emitted and absorbed in tiny "packets" called [photons](http://en.wikipedia.org/wiki/Photons), the smallest unit of light. Photons are emitted when electrons in an atom jump from one orbit to another, exhibits properties of both [waves](http://en.wikipedia.org/wiki/Wave) and [particles](http://en.wikipedia.org/wiki/Particle_physics). This property is referred to as the [wave–particle](http://en.wikipedia.org/wiki/Wave%E2%80%93particle_duality) [duality](http://en.wikipedia.org/wiki/Wave%E2%80%93particle_duality).
* For a given frequency *f* of the radiation, each photon has a fixed amount of energy *E* which is

***E*** = ***hf*** (1)

Where *h* is **Planck’s constant**, equal to (**6.63×10 −34 joul.sec**)

* The wavelength (λ) is the distance between 2 peaks of the wave.
* Frequency (ƒ) is the number of wave/second.
* The relationship between wavelength and frequency is given by:

# Speed of light = wavelength × frequency

**c = λ × ƒ**............ (2) where **c** = **3×108 m.s-1**

* Light is faster than sound and can travel through a vacuum.

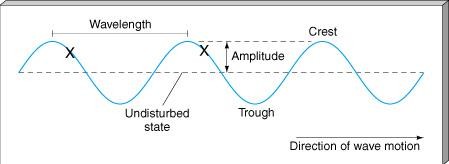
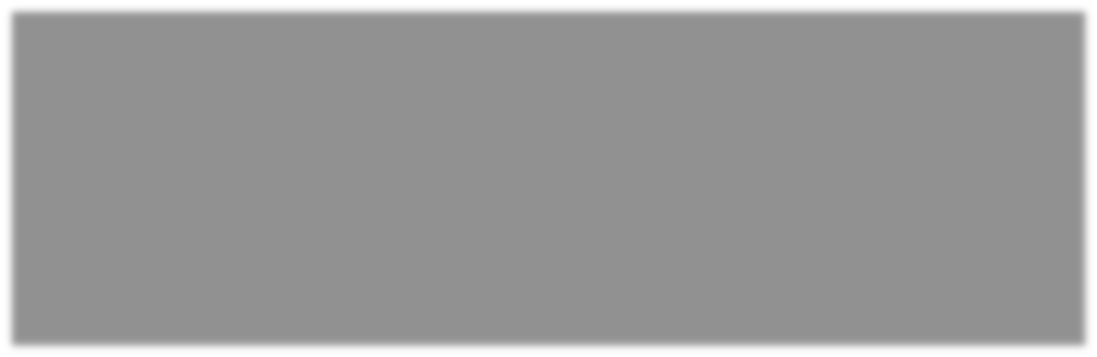


Figure 1: Motion of the light wave

# Electromagnetic spectrum

* Electromagnetic (EM) radiation is classified by wavelength into [radio](http://en.wikipedia.org/wiki/Radio), [microwave](http://en.wikipedia.org/wiki/Microwave), [infrared](http://en.wikipedia.org/wiki/Infrared), the [visible region](http://en.wikipedia.org/wiki/Visible_region) we perceive as light, [ultraviolet](http://en.wikipedia.org/wiki/Ultraviolet), [X-ray](http://en.wikipedia.org/wiki/X-ray) and [gamma (γ) ray](http://en.wikipedia.org/wiki/Gamma_rays).
* The behavior of EM radiation depends on its wavelength. Higher frequencies have shorter wavelengths, and lower frequencies have longer wavelengths as shown in Fig 1.
* Light is a form of electromagnetic waves- travels through space, each colour is associated with a different wavelength as shown in Table 1.
* White light is a mixture of the colors of the rainbow; a prism splits white light into the various colors.

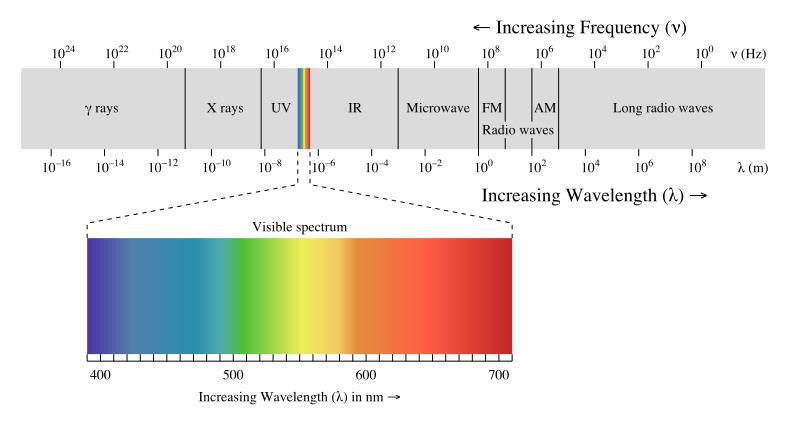
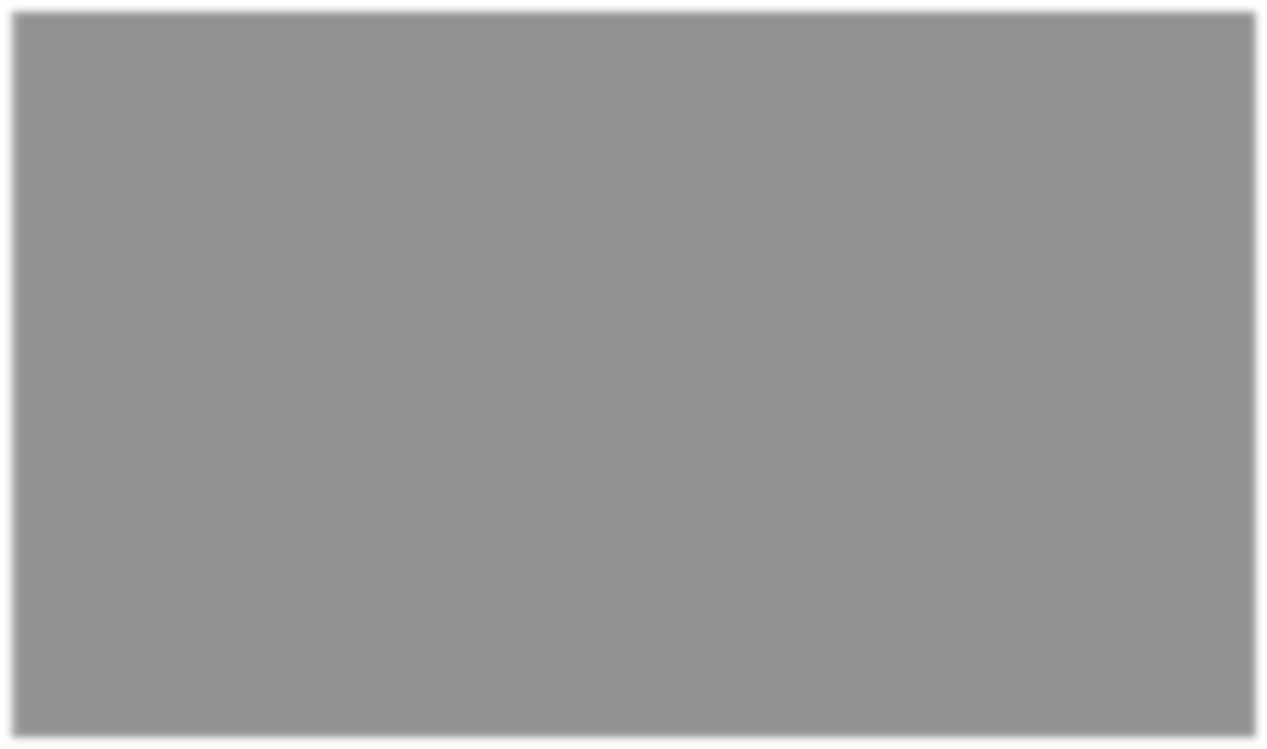


Figure 2: Electromagnetic spectrum

Table 1: The range of the wavelength for colours of visible light

|  |  |
| --- | --- |
| **Colour** | **Range of wavelength (λ) nm** |
| Violet | 400 – 450 |
| Blue | 450 – 520 |
| Green | 520 – 560 |
| Yellow | 560 – 600 |
| Orange | 600 – 625 |
| Red | 625 – 700 |

# Light rays and beams

* A ray of light is the direction along which the light energy travels, while the beam of light is a collection of rays.
* Substances like wood which do not allow light to pass through them are called opaque.
* Transparent substance, like glass, which allows some of light energy incident on it to pass through, the remainder of the energy being absorbed or reflected.

# Index of refraction (refractive index)

* Definition- is defined as a ratio of the speed of light in vacuum or air relative to the speed of light in a considered medium. This can be written as:

***n*=** 𝑣𝑒𝑙𝑜𝑐𝑖𝑡𝑦 𝑜𝑓 𝑙𝑖𝑔ℎ𝑡 𝑖𝑛 𝑣𝑎𝑐𝑢𝑚

𝑣𝑒𝑙𝑜𝑐𝑖𝑡𝑦 𝑜𝑓 𝑙𝑖𝑔ℎ𝑡 𝑖𝑛 𝑚𝑒𝑑𝑖𝑢𝑚

**=**𝑐 (3)

𝑣

* Refractive index describes how light or other radiation propagates through that medium and it has no units.
* Refractive index of air and [water](http://en.wikipedia.org/wiki/Water) is 1 and 1.33 respectively, meaning that light travels 1.33 times as fast in vacuum as it does in water.
* When light travels from one medium to another, its **wavelength (λ) changes** but its **frequency (ƒ) remains constant**.

**Example 1**: The wavelength of green light is *522 nm*, what is the frequency of this radiation?

# Solution:

λ = *522 nm* = *522 × 10-9 m*, c = *3×108 m.s-1*

*c* = λ × ƒ ƒ = *c* / λ

ƒ = *3×108 m.s-1* / *522 × 10-9 m* = *5.47 × 1014 Hz*.

**Example 2**: A light beam travels at *1.94 × 108 m.s-1*in quartz. Find the index of refraction of quartz at this wavelength?

# Solution:

*v = 1.94 × 108 m.s-1*, *c* = *3×108 m.s-1*

*n* = *c* / *v*

*n* = *3×108 m.s-1* / *1.94 × 108 m.s-1* = 1.55.

**Example 3:** The wavelength of green light is *522 nm*, what is the Energy of this radiation?

# Solution:

λ = *522 nm* = *522 × 10-9 m*, c = *3×108 m.s-1*

*c* = λ × ƒ ƒ = *c* / λ

ƒ = *3×108 m.s-1* / *522 × 10-9 m* = *5.47 × 1014 sec-1*

*E* = *hf*

*E = 6.6 × 10-34 joul.sec × 5.47 × 1014 sec-1* = *36.1 × 10-24 joul*

## Home works about lecture 1

**Q1:** Find the speed of light in the glass if the refractive index of the glass is 1.45?

(A) 4×108 m.s-1 (B) 3×108 m.s-1 (C) 2×108 m.s-1 (D) 1×108 m.s-1

**Q2:** The range of visible light in the electromagnetic filed is:

(A) 100 – 300 nm (B) 400 – 700 nm (C) (800 – 1100 nm) (D) (1200 – 1500 nm)

**Q3:** The range of weave length of violet colour is:

(A) (560 – 600 nm) (B) (520 – 560 nm) (C) (450 – 520 nm) (D) (400 – 450 nm)

Q4: Defined as a ratio of the speed of light in air relative to the speed of light in a considered medium?

(A) Refractive index (B) frequency (C) wave length (D) ray

**Q5**: The formula of frequency (f) expressed as:

(A) ƒ = λ / c (B) ƒ = *c* / λ (C) ƒ = *c* × λ (D) ƒ = λ × c