

AL- Mustaqbal University  
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Medical physics  
Third Stage

Lec 1

Properties of Light

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## Properties of Light

- Travels in straight lines in a homogeneous medium
- Interaction with matter
- Absorption
- Reflection, refraction and scattering
- Polarization and diffraction

## Electromagnetic wave ( EM Wave )

- EM waves are generated by vibrating electrons
- Composed of two perpendicular oscillating fields
- Can be characterized by its frequency, which is inversely related to wavelength

$$( f = c / \lambda )$$

- Shares with sound the properties of spreading loss, attenuation, reflection, refraction, and diffraction, **but** can travel in vacuum

**Light** is defined as an electromagnetic wave with a wavelength in the visible part of the electromagnetic spectrum (380 to 700 nanometres). That is, light is any electromagnetic wave that we can see with our eyes.

## Absorption vs propagation of light

- If light wave frequency = molecules resonant frequency
  - Light is absorbed (propagation is stopped)
  - Medium is opaque
- If light wave frequency  $\neq$  molecules resonant frequency
  - Light is reradiated and propagated forward through medium
  - Medium is transparent
- In a solid or liquid, propagation is in straight line
- In a gas, propagation is less organized and scatter increases

## speed of light

All travelling waves can essentially be thought of as energy-carrying oscillations in motion. This means that light waves should be no different, and if light is in motion, it must have a speed. It turns out that light not only has a speed but that its speed is the fastest in the universe.

The **speed of light** in free space,  **$c$** , is **300 million metres per second** ( $3.00 \times 10^8$  m/s), which is a constant and is essentially the speed limit of the universe that cannot be exceeded by any other object.

### Speed of light depends on media

<u>Medium</u>	<u>Speed (m/s)</u>	<u>Refractive index</u>
Vacuum	$3 \times 10^8$	1
Air	$2.99 \times 10^8$	1.00028
Water	$2.25 \times 10^8$	1.33
Glass	$1.99 \times 10^8$	1.5
Diamond	$1.25 \times 10^8$	2.4

Speed of light is slower in water than in air (opposite to sound)

**Light** waves can have different wavelengths, which determine the colour of visible light that is observed. This means that every time you view a beautiful red rose on a sunny day, your eyes perceive a **reflection** of red light from the rose, which has a wavelength of about 650 nm.

**Example:**

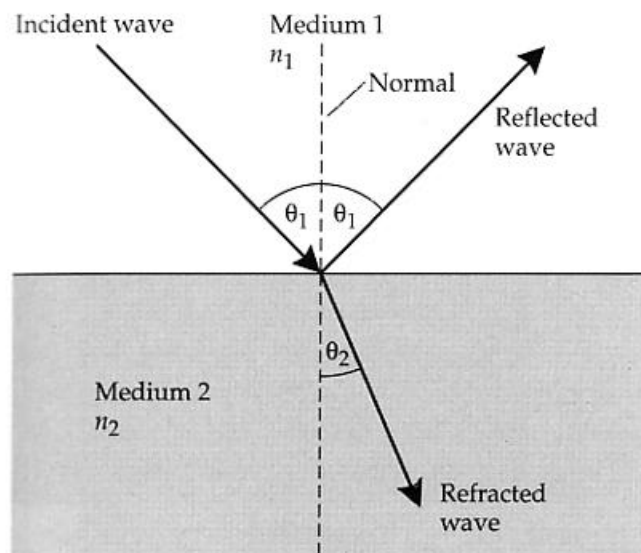
What is the wavelength of the red light that is emitted from a  $4.6 \times 10^{14}$  Hz laser ?

**We** know the frequency of the laser light and that the speed of light is  $3.00 \times 10^8$  m/s so we can apply the wave equation:

$$\begin{aligned}\lambda &= c / f \\ &= \frac{3 \times 10^8}{4.6 \times 10^{14}} \\ &= 6.5 \times 10^{-7} \text{ m} = 650 \text{ nm}\end{aligned}$$

This wavelength corresponds to the colour red .

**Light reflects and refracts**



When 2nd medium has slower speed, light refracts towards normal

When 2nd medium has faster speed, light refracts away from the normal

**Reflection** and **Refraction** These are two of the more important properties of light, which can be used to make observations of distant objects in the universe.

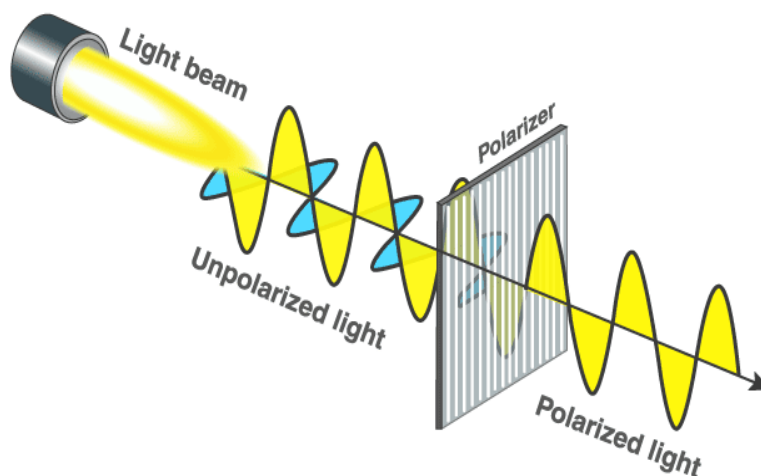
**Reflection** occurs when light that is travelling through a certain medium is incident onto a boundary between two media, and the light 'bounces' off the boundary or changes direction upon striking this boundary and moves on in the original medium. For an illustration of this, see the diagram above.

**Refraction** is another property of wave motion that is displayed by visible light. It occurs when light rays move from one medium to another and, upon doing so, change direction and speed. This is illustrated by the arrow in the diagram above .

### Polarisation of light

Polarized light is a transverse wave whose electric field vibrates in one direction perpendicular to its line of propagation.

Polarisation of light is a property shown by transverse waves. The light waves which travel only in a single plane are known as polarized light waves. The process of transforming unpolarized light waves to polarized light waves is called the polarisation of light .



# Discussion

## 1. Light in a homogeneous medium travels:

- a) In curves
  - b) Randomly
  - c) In straight lines ☒
  - d) In zigzag motion
  - e) Only in gases
- 

## 2. Which of the following is *not* an interaction of light with matter?

- a) Absorption
  - b) Reflection
  - c) Refraction
  - d) Nuclear fission ☒
  - e) Scattering
- 

## 3. When light is absorbed by a medium, it means:

- a) Frequency  $\neq$  molecules' resonant frequency
  - b) Frequency = molecules' resonant frequency ☒
  - c) Speed of light increases
  - d) Medium becomes transparent
  - e) Light propagates forward
- 

## 4. If light frequency does not match molecular resonance, the medium is:

- a) Opaque
- b) Transparent ☒
- c) Metallic
- d) Non-polarized
- e) Non-reflective

**5. Electromagnetic waves are generated by:**

- a) Vibrating nuclei
  - b) Vibrating electrons ☒
  - c) Vibrating protons
  - d) Vibrating neutrons
  - e) Static charges
- 

**6. In an EM wave, the electric and magnetic fields are:**

- a) Parallel to each other
  - b) Perpendicular to each other ☒
  - c) At  $45^\circ$  to each other
  - d) Randomly oriented
  - e) Aligned with propagation
- 

**7. The relation between frequency and wavelength of light is:**

- a)  $f = \lambda / c$
  - b)  $f = c / \lambda$  ☒
  - c)  $\lambda = f / c$
  - d)  $c = \lambda / f$
  - e)  $f = \lambda \times c$
- 

**8. The speed of light in vacuum is:**

- a)  $3.0 \times 10^6$  m/s
  - b)  $3.0 \times 10^8$  m/s ☒
  - c)  $3.0 \times 10^5$  m/s
  - d)  $2.99 \times 10^7$  m/s
  - e)  $1.0 \times 10^9$  m/s
-

**9. The speed of light is fastest in:**

- a) Air
  - b) Glass
  - c) Vacuum ☒
  - d) Water
  - e) Diamond
- 

**10. The refractive index of water is approximately:**

- a) 1.5
  - b) 1.0
  - c) 2.4
  - d) 1.33 ☒
  - e) 1.25
- 

**11. Which medium has the highest refractive index?**

- a) Glass
  - b) Water
  - c) Diamond ☒
  - d) Air
  - e) Vacuum
- 

**12. Speed of light is slower in water than in air. This behavior is:**

- a) Same as sound
  - b) Opposite to sound ☒
  - c) Identical to sound in solids
  - d) Same as in gases
  - e) Faster in liquids
-



**13. Visible light wavelength range is approximately:**

- a) 100–300 nm
  - b) 200–500 nm
  - c) 380–700 nm ☒
  - d) 700–1200 nm
  - e) 1–10  $\mu\text{m}$
- 

**14. Red light has an approximate wavelength of:**

- a) 400 nm
  - b) 500 nm
  - c) 650 nm ☒
  - d) 700 nm
  - e) 800 nm
- 

**15. For a laser of frequency  $4.6 \times 10^{14}$  Hz, the wavelength is:**

- a) 450 nm
  - b) 550 nm
  - c) 650 nm ☒
  - d) 750 nm
  - e) 850 nm
- 

**16. When light enters a slower medium, it refracts:**

- a) Away from normal
  - b) Towards normal ☒
  - c) Parallel to normal
  - d) Without bending
  - e) In random directions
-

**17. Reflection of light occurs when:**

- a) Light changes speed
  - b) Light bounces back at boundary ☒
  - c) Light is absorbed
  - d) Light polarizes
  - e) Light scatters randomly
- 

**18. Refraction is caused by:**

- a) Change in frequency
  - b) Change in speed and direction ☒
  - c) Change in amplitude only
  - d) No change in velocity
  - e) Total internal reflection
- 

**19. Which of the following is true for EM waves but not sound waves?**

- a) Attenuation
  - b) Reflection
  - c) Refraction
  - d) Can travel in vacuum ☒
  - e) Diffraction
- 

**20. The fastest speed possible in the universe is:**

- a) Sound speed in steel
  - b) Speed of light in air
  - c) Speed of light in vacuum ☒
  - d) Speed of electrons in metal
  - e) Speed of sound in water
-

**21. In gases, propagation of light is:**

- a) Highly organized
  - b) Less organized with more scattering ☒
  - c) Faster than in liquids
  - d) Without diffraction
  - e) Only polarized
- 

**22. Polarization is a property of:**

- a) Longitudinal waves
  - b) Transverse waves ☒
  - c) Mechanical waves
  - d) Scalar waves
  - e) Random waves
- 

**23. Polarized light means:**

- a) Vibrates in many planes
  - b) Vibrates in one plane only ☒
  - c) No vibration
  - d) Travels in vacuum only
  - e) Has lower frequency
- 

**24. The process of converting unpolarized light into polarized light is called:**

- a) Reflection
  - b) Diffraction
  - c) Refraction
  - d) Polarisation ☒
  - e) Absorption
- 

**25. Which property of light is used to observe distant objects in the universe?**

- a) Absorption only
- b) Reflection and refraction ☒
- c) Diffraction only
- d) Polarisation
- e) Scattering