THE DUAL NATURE OF LIGHT

LIGHT AS A WAVE

LIGHT AS A PARTICLE

BY –

ARIJIT PAUL
Dept. Of Physics, Midnapore college(autonomous)

KEY POINTS

- INTRODUCTION
- CONTRIBUTION & HISTORY
  - BY NEWTON (1680)
  - BY HUYGENS (1690)
- PHOTOELECTRIC EFFECT
- PLANK RESOLUTION
- EINSTEIN PHOTOELECTRIC EQUATION
- THE COMPTON EFFECT
- CONCLUSION

INTRODUCTION

Dual nature of light means light has two different nature, sometimes it behaves like a particle sometimes it behaves like a wave.

I discuss a few of the famous experiments which establishes the nature of light i.e. light is a wave or a particle.

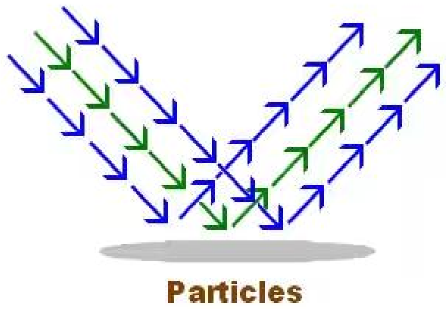
CONTRIBUTIONS & HISTORY

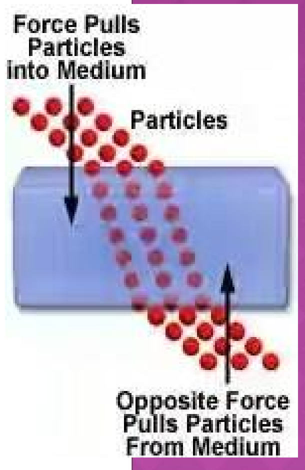
NEWTON CORPUSCULAR THEORY :-

Newton's corpuscular theory based on following points

i. Light consists of very tiny particles known as corpuscular.
ii. These corpuscles on emission from the source of light travel in straight line with high velocity.
iii. When these particle enter the eyes, they produce image of the object or sensation of vision.
iv. Corpuscles of different colours have different size.

Newton corpuscular theory explain law of reflection & refraction phenomena

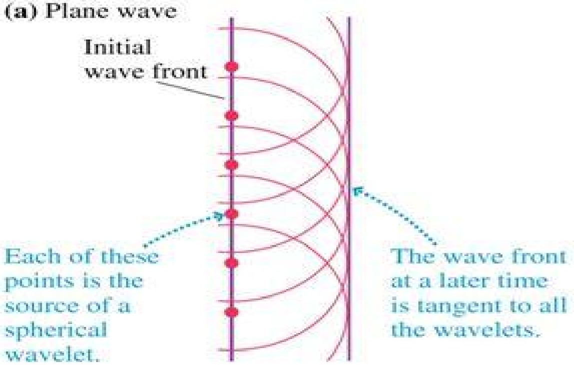


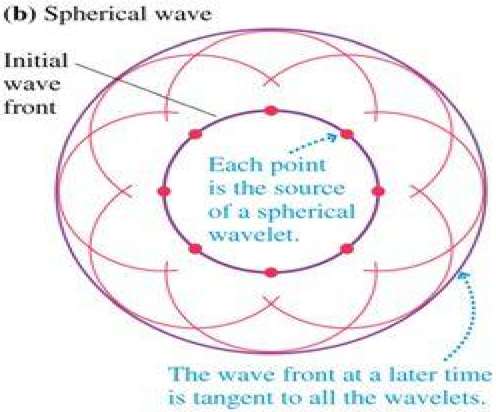


Huygens' Principle

Christian Huygens
(1629 - 1695)

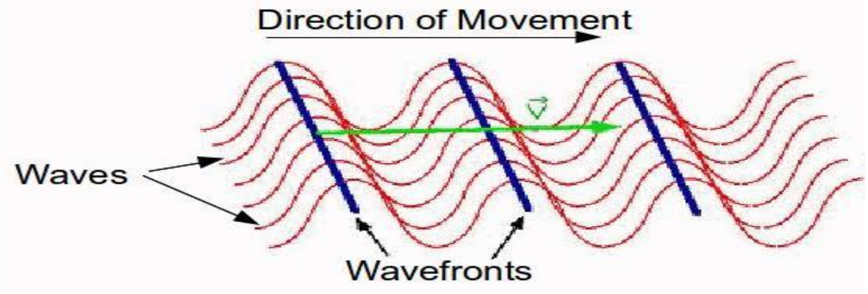
The Dutch scientist Christian Huygens, a contemporary of Newton, proposed *Huygens' Principle*, a geometrical way of understanding the behavior of light waves.





Huygens Principle: Consider a wave front of light:

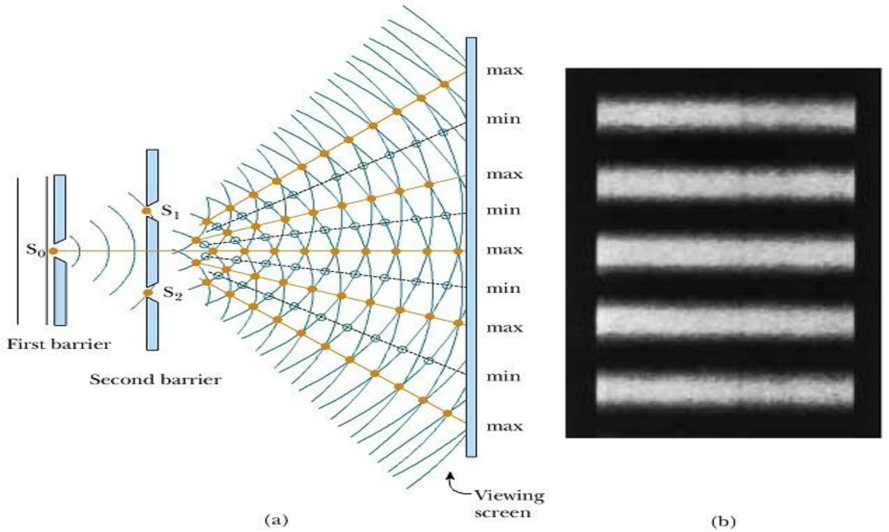
1. Each point on the wave front is a new source of a spherical wavelet that spreads out spherically at wave speed.
2. At some later time, the new wave front is the surface that is tangent to all of the wavelets.

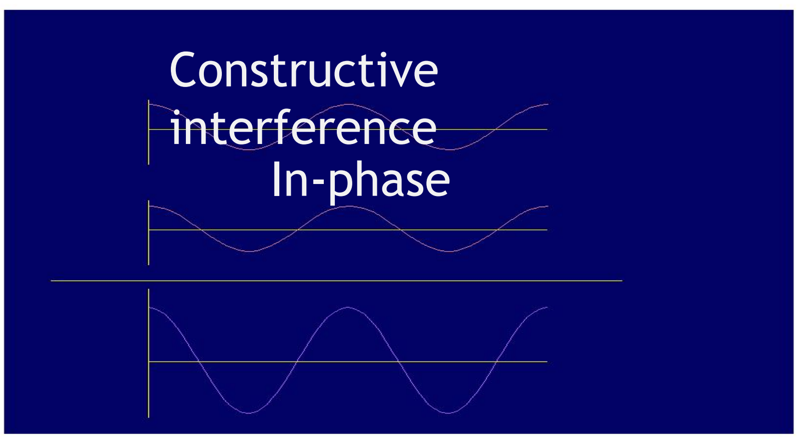


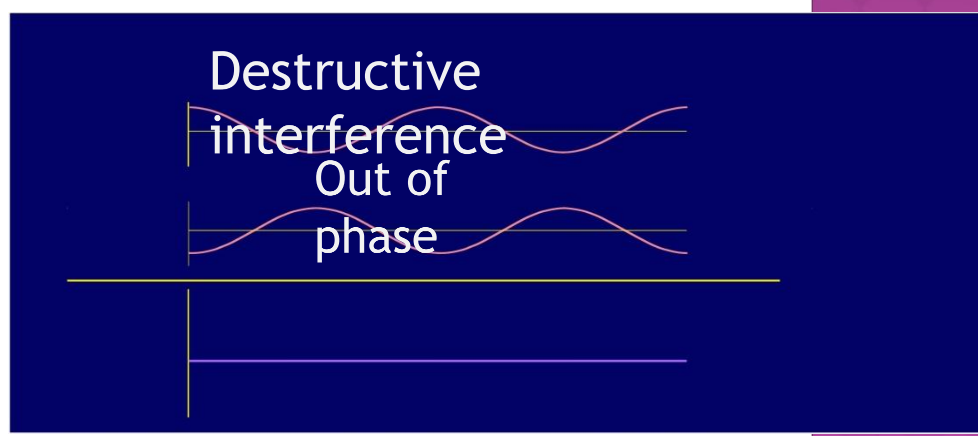
YOUNG'S EXPERIMENT

The phenomenon of interference was first demonstrated by Thomas Young in 1801 with a simple experiment.

This phenomenon requires for its explanation that light must have a wave nature.

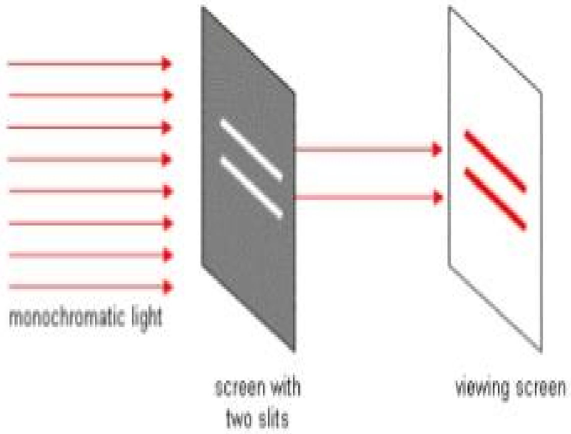






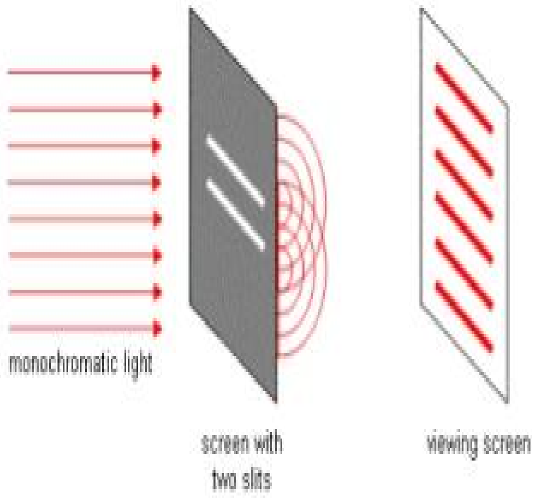
What if light were only particles?

If light were particles (did not exhibit properties of waves), then we would see two maximas that correspond to only rays that hit directly where the slits are located.



What if light had wave properties?

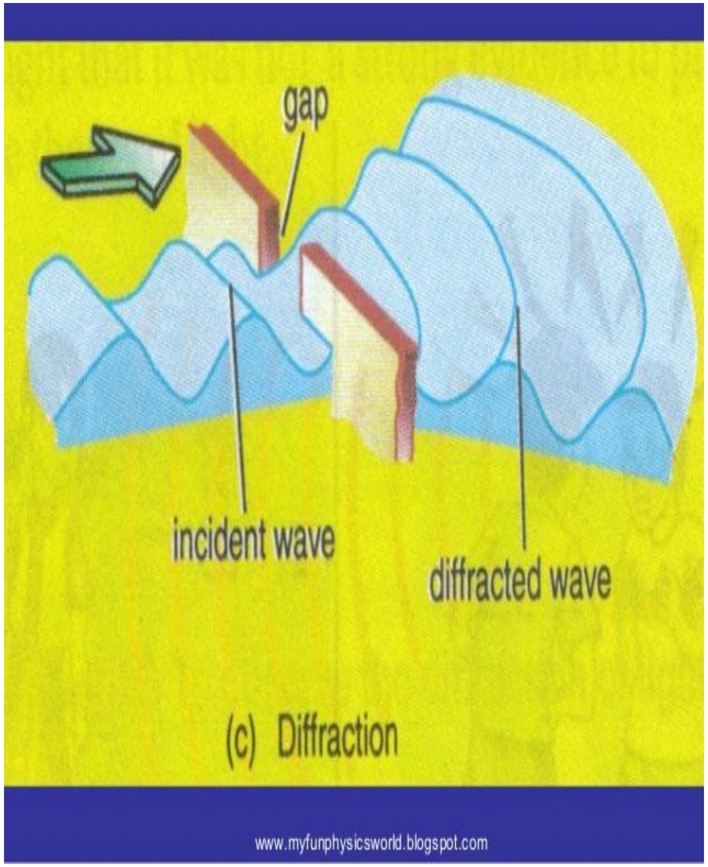
If light had wave properties, then we would observe diffraction as we pass through the slits. We would then be able to see an interference patterns (constructive and destructive) from the waves as they meet each other. An image of alternating dark and light bands (interference fringes) would then appear on the screen.

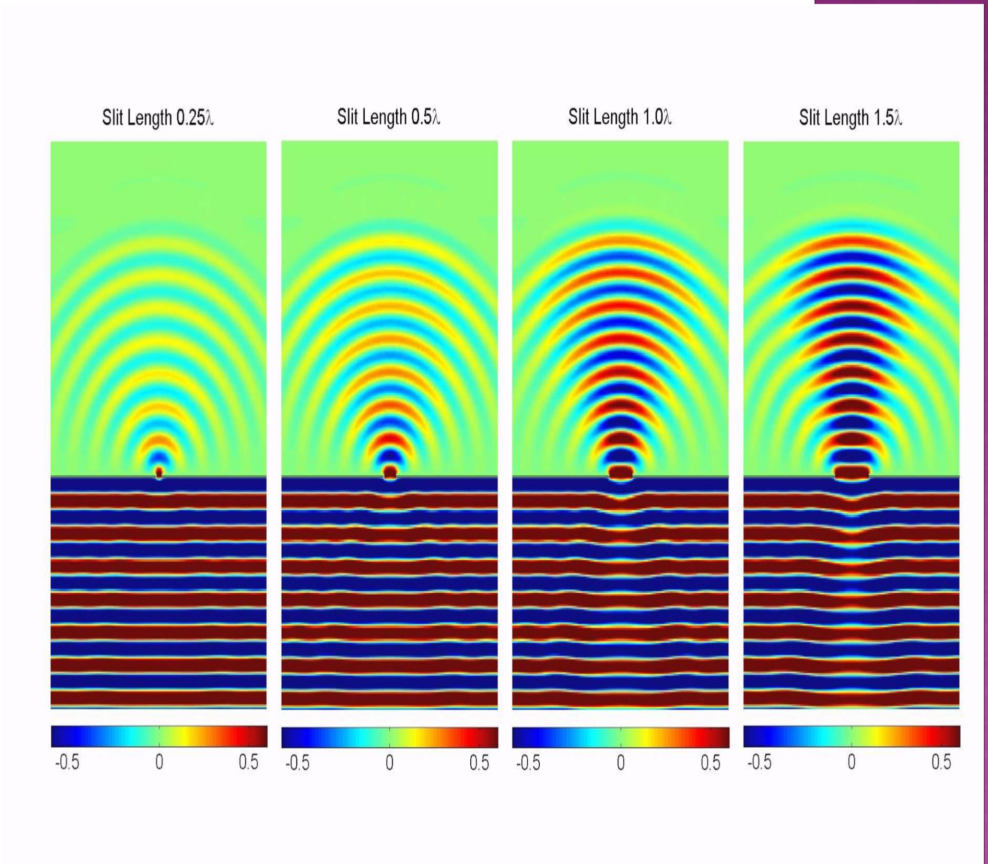


In fact, Young did observe an image of alternating dark and light bands, which confirms that light has wave properties.

DIFFRACTION OF LIGHT

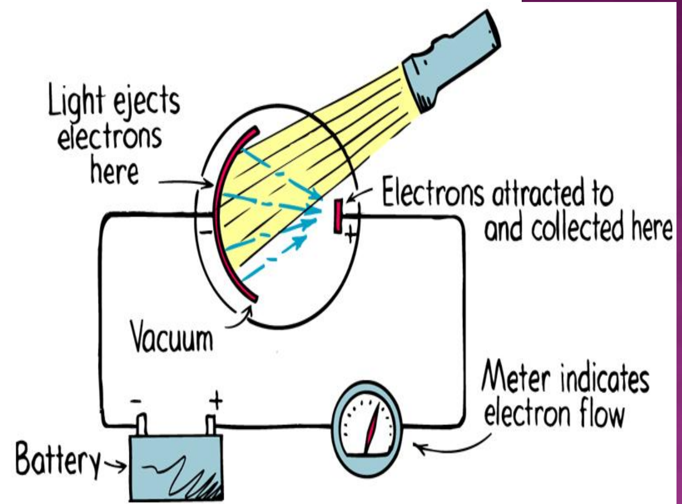
Augustin Fresnel used Huygens wave theory gave a explanation of the phenomenon of diffraction of light (bending of light around sharp obstacles).The effect is found to be significant when the dimension of the diffracting element becomes comparable with the wavelength of light.





PHOTOELECTRIC EFFECT

The phenomenon of emission of electrons from the surface of a metal by the action of a beam of electromagnetic radiation (light) is known as photoelectric effect. The well-known photosensitive metals are Na, K,Cs etc. The phenomenon was discovered in 1887 by Hertz.



Copyright © 2006 Paul G. Hewitt, printed courtesy of Pearson Education Inc., publishing as Addison Wesley.

Main observed facts :-

i. The strength of photocurrents is directly proportional to the intensity of incident light.
ii. For a given emitter light of frequency smaller than a critical frequency ν_0 (called threshold frequency) can not emit photoelectrons
iii. Photoemission is an instantaneous phenomenon.
iv. The maximum kinetic energy of emitted electrons is a linear function of the frequency but independent of the intensity of incident light.

PLANCK'S RESOLUTION

- Planck hypothesized that the blackbody radiation was produced by resonators.
  - Resonators were submicroscopic charged oscillators.
- The resonators could have discrete energies.
  - $E_n = nhf$
    - n is called the quantum number
    - f is the frequency of vibration
    - h is Planck's constant
- Key point is quantized energy states

EINSTEIN'S PHOTOELECTRIC EQUATION

According to Einstein light is not only emitted or absorbed inn quanta but also pr
individual quantum is known as photon.
An electron absorbs the energy hν of a photon when it collides with a photon.
So the Einstein's equation is -

$$h\nu = \frac{1}{2}mv^2 + W_0$$

Explanation of photoelectric effect on the basis of quantum theory :-

i. If the frequency ν of the incident light is such that $h\nu < W_0$ then $\frac{1}{2}mv^2 < 0$. T
photoemission is possible in this case. So give the idea of threshold frequenc

ii. Increase in intensity of light means increase in the number of photons incide
Each collision produces a photoelectron. So the photocurrent will increase w
frequency.

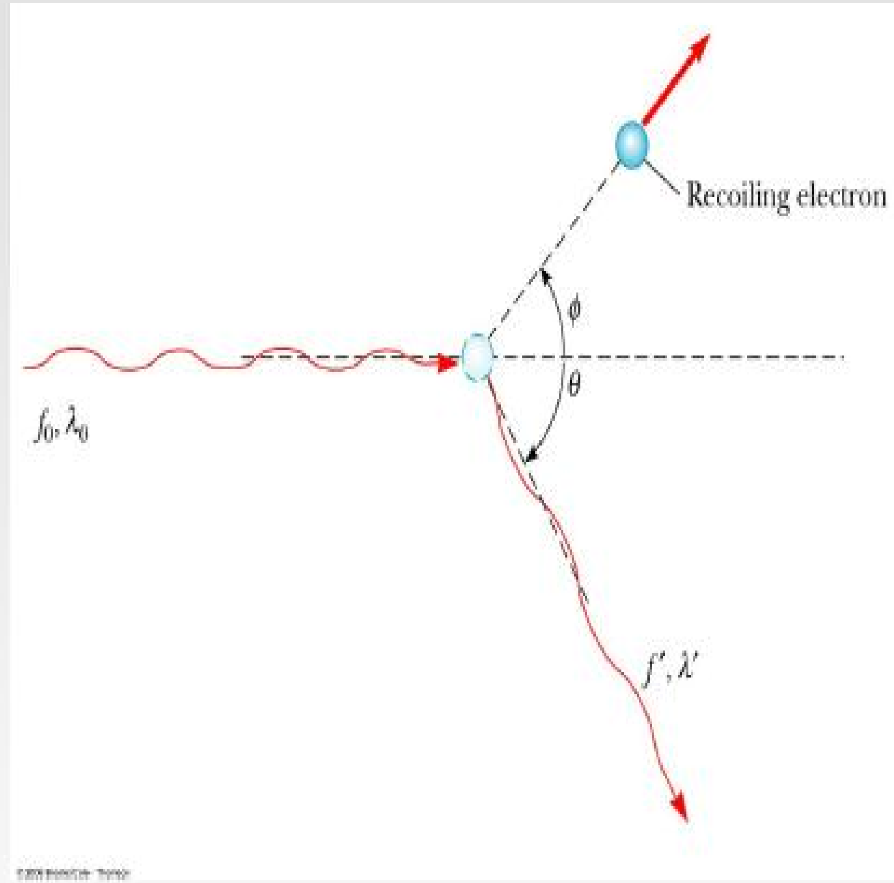
iii. As W_0 is constant for a particular emitter, equation shows that K.E off phot
linearly with frequency. Since the energy $h\nu$ of each photons remain same,
the maximum K.E of photoelectrons does not increase with intensity for a

iv. As the process is regarded as a collision between photon & electron, it shou
process.

COMPTON SCATTERING

- Compton assumed the photons acted like other particles in collisions
- Energy and momentum were conserved
- The shift in wavelength is

$$\Delta\lambda = \lambda - \lambda_o = \frac{h}{m_e c}(1 - \cos\theta)$$



CONCLUSION

Phenomenon	Can be explained in terms of waves.	Can be explained in terms of particles.
Reflection	✓	✓
Refraction	✓	✓
Interference	✓	⊗
Diffraction	✓	⊗
Polarization	✓	⊗
Photoelectric effect	⊗	✓

The phenomenon of interference , diffraction and polarization of light are well explained by considering the wave nature of light on the other hand , phenomena like photoelectric effect , Compton effect , Raman effect etc. require particle nature of light .

Bohr's complementary principle states that the wave and particle description are complementary ways.

According to uncertainty principle it is impossible to design an experiment which will show both the particle and wave nature at the same time.

Thank you