Welcome

to

The Lecture Notes

on

Applied Physics
(AS-1002)

- Dr. Shyam

Asstt. Professor

Syllabus Outline

- **Section-A:**

  Physical optics
  Relativity
  Electromagnetic wave theory

- **Section-B:**

  Introduction to Elementary **Quantum Mechanics**

- **Section-C:**

  Quantum Theory of Free Electrons
  Band Theory of Solids
  Super conductivity

- **Section-D:**

  Lasers and Fiber optics

Examination Pattern and Marks distribution

Total Marks for this paper: 150

1. External Examination (100 Marks)

A total **Nine (09)** questions will be asked

Two (02) **long answer** type questions from each section and one compulsory section consisting of **short answer type** questions from entire syllabus

You need to attempt Five (05) questions only, selecting one from each section and all questions of compulsory section

➡ **Answer Sheet will be of 40 pages only**

2. Internal Assessment (50 Marks)

To be awarded by **Subject Teacher** on the basis of performance in Periodical Examinations, Assignment tasks and Attendance in the class

Minimum total passing marks for this subject is **60 with** compulsorily **40** marks in **External Exams** and there is no minimum limit in internal assessment marks

Practical Exams (100 marks)

1. **External Practical Examination (50 Marks)**
2. **Internal Assessment (50 Marks)**

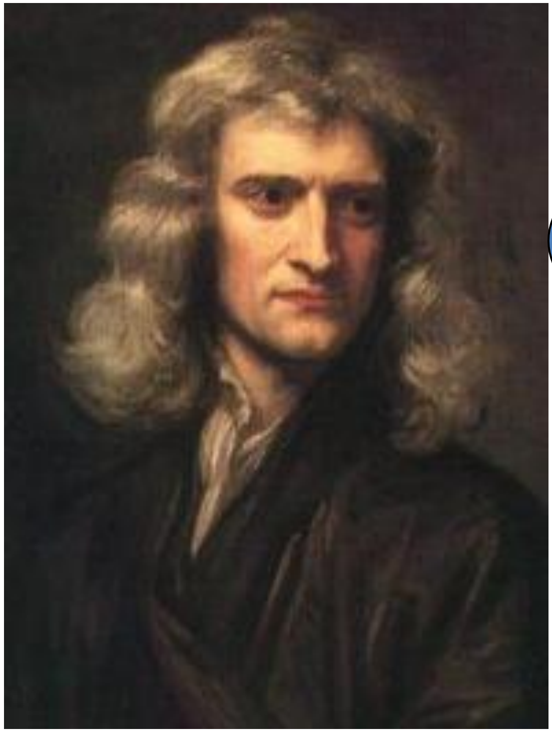
Minimum passing marks is **25** in each part

Section-A
(Physical Optics)

Aristotle (384 - 322 B.C.), an ancient Greek thinker, thought that **we saw the world by sending "something" out of our eye** and that reflected from the object.

Theories Related to Light

In the 17th century, two scientists had different views about the nature of light ……



Light is particles

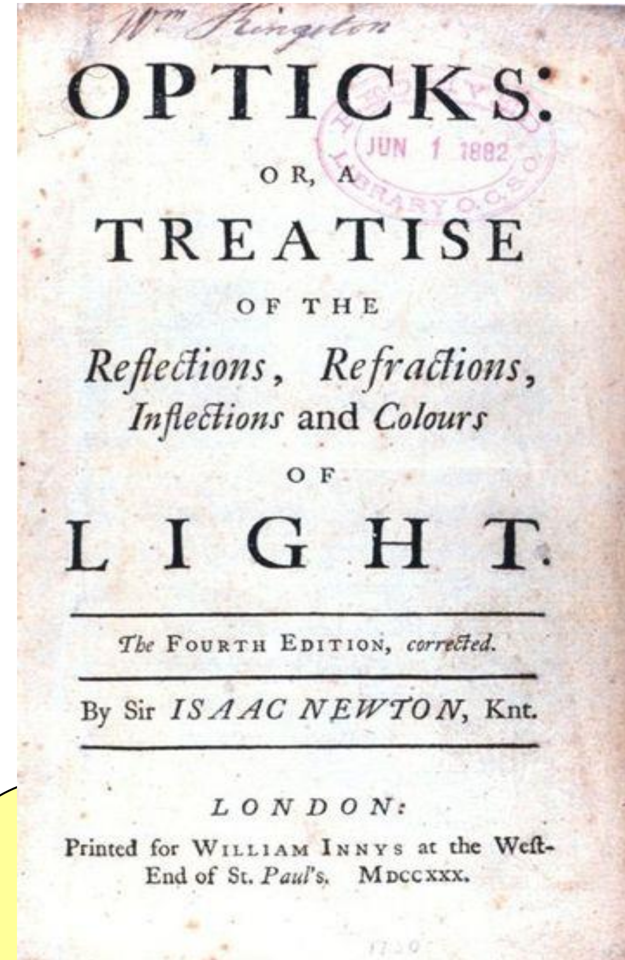
No! Light is waves

Isaac Newton
1643 - 1727

Christian Huygens
1629 - 1695

Newton proposed his **"particle theory of light"** (or "corpuscular theory of light") to explain the characteristics of light.

(**Source**: "*Opticks*", *published by Isaac Newton in 1704)*


OPTICKS:

OR, A

TREATISE

OF THE

Reflections, *Refractions*, *Inflections* and *Colours*

OF

LIGHT.

The FOURTH EDITION, *corrected.*

By Sir *ISAAC NEWTON*, Knt.

LONDON:

Printed for WILLIAM INNYS at the West-End of St. *Paul's*. MDCCXXX.

JUN 1 1882

I think light is a stream of tiny particles, called *Corpuscles* …

Let's see how Huygens used his "wave theory" to explain the characteristics of light

(**Sourc**e: *Treatise on light*, published by Huygens in 1690)

I think light is emitted as a series of waves in a medium he called *"aether"*

("aether" commonly also called "ether")

If you were one of the scientists in the 17th century, would you believe the **"particle theory of light"** or the **"wave theory of light"**? Why?

Hint: Which theory has a greater ability to explain the characteristics of light?

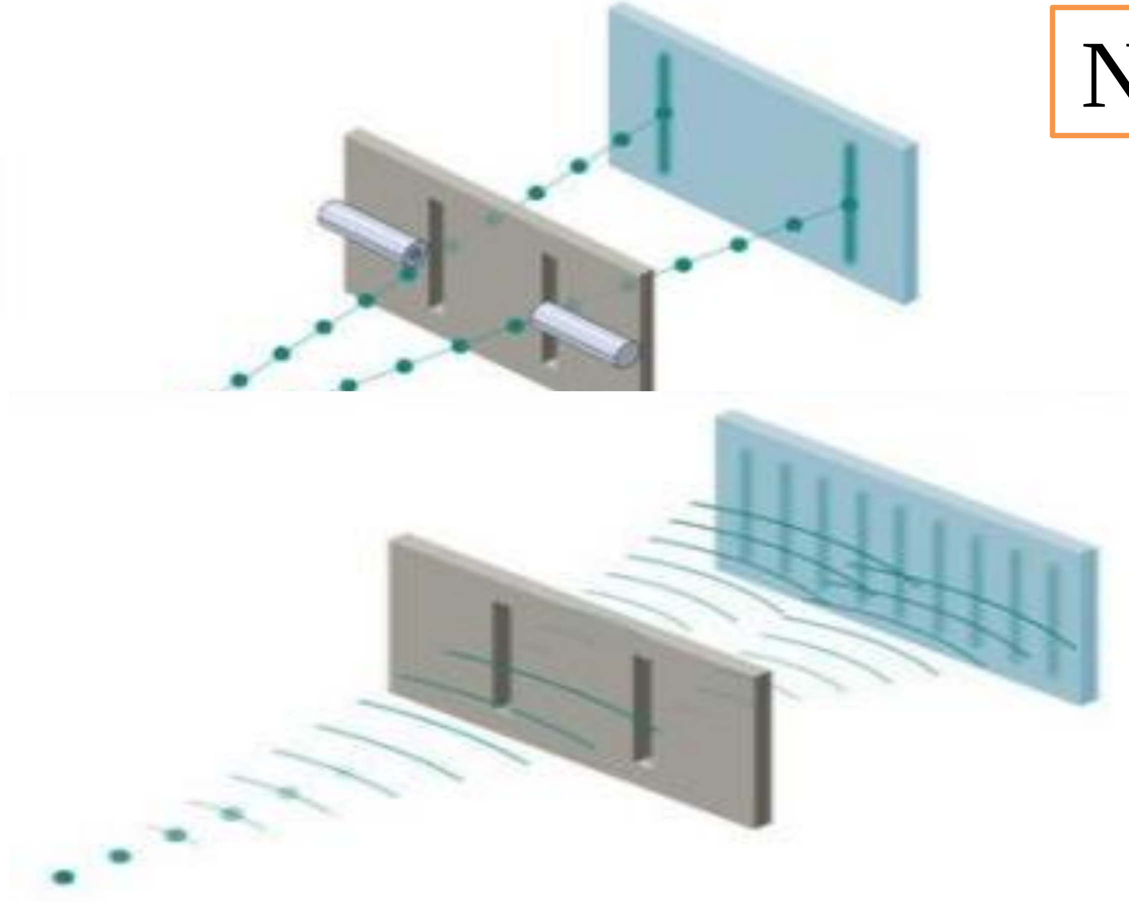
Newton was the "winner"….. (at that time!)

People tend to **submit to authority** when there is not enough evidence to make judgment.

*(People believed Newton's theory due to his **reputation** in science.)*

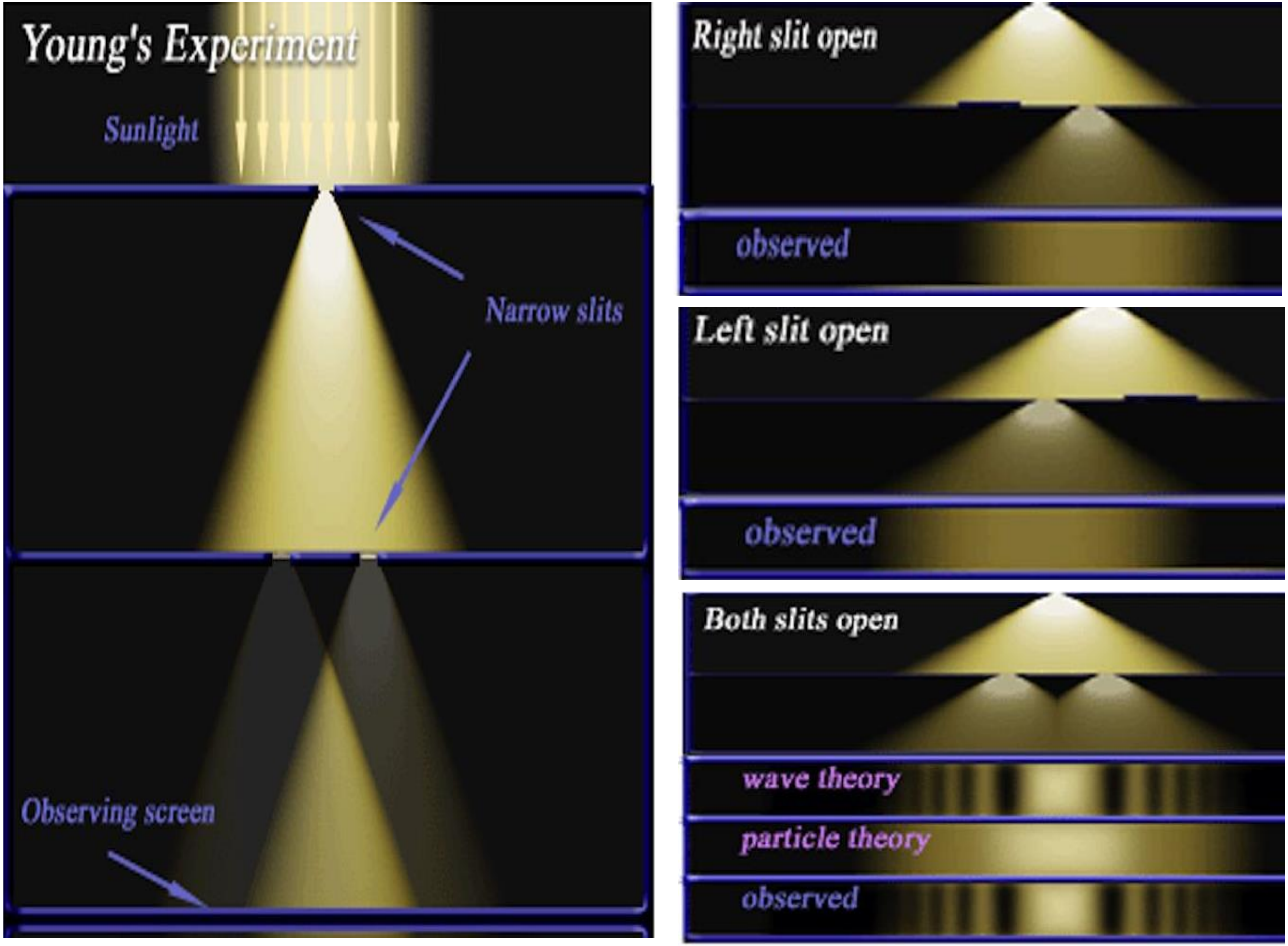
However, the wave theory of light was re-examined 100 years after Newton's particle theory of light had been accepted……

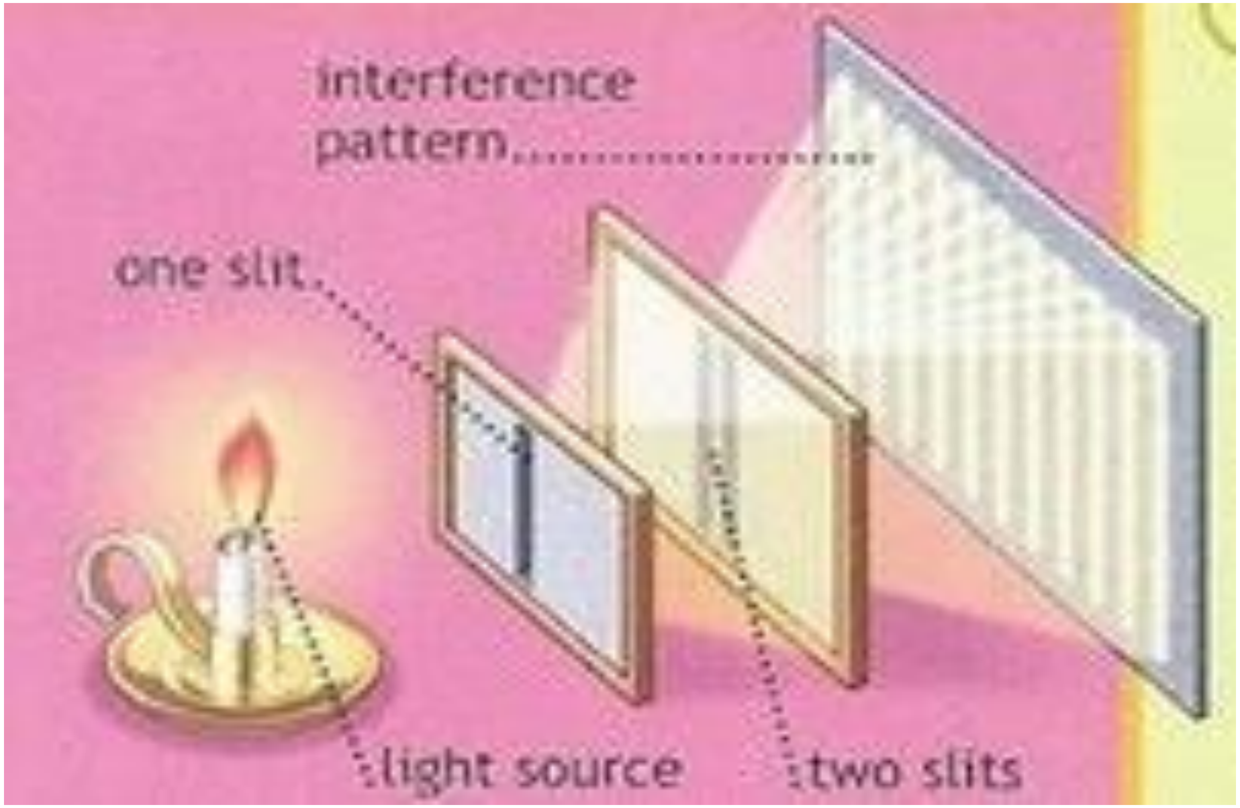
New observations

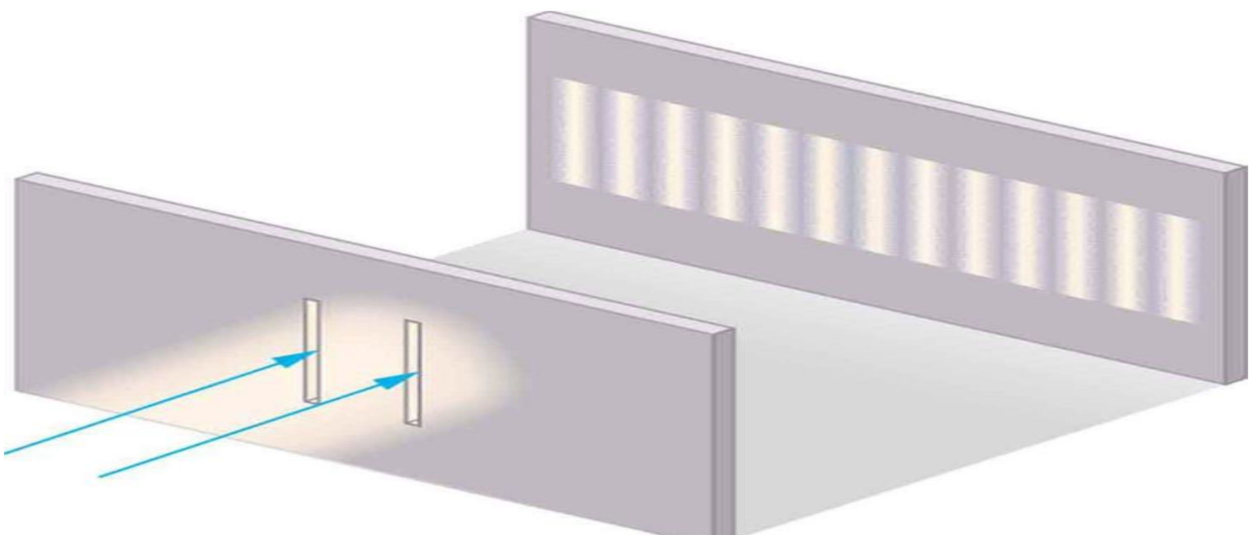


Thomas Young (1773-1829)

English, Could read at age 2. At 7, learnt Latin, Greek & maths. At 12, spoke Hebrew, Persian & could handle optical instruments. At 14, he spoke Arabic, French, Italian, Spanish, & Chaldean Syriac. PhD at 20. Gentleman, accomplished flute player. He is reported dancing above a rope. Worked for an insurance company, continuing research into the structure of the retina, astigmatism.

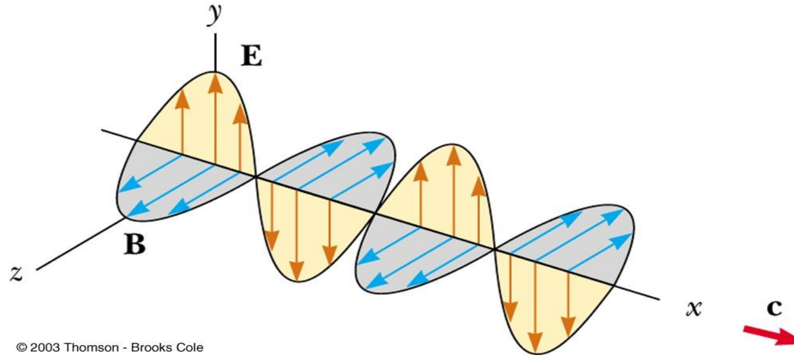

Young's Experiment
Sunlight
Narrow slits
Observing screen
Right slit open
observed
Left slit open
observed
Both slits open
wave theory
particle theory
observed

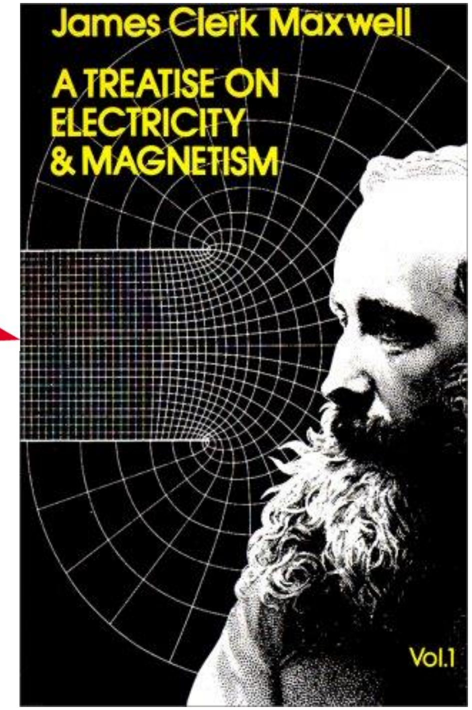




Light is not particles!

What kind of wave?





$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_o}$$

$$\nabla \cdot \mathbf{B} = 0$$

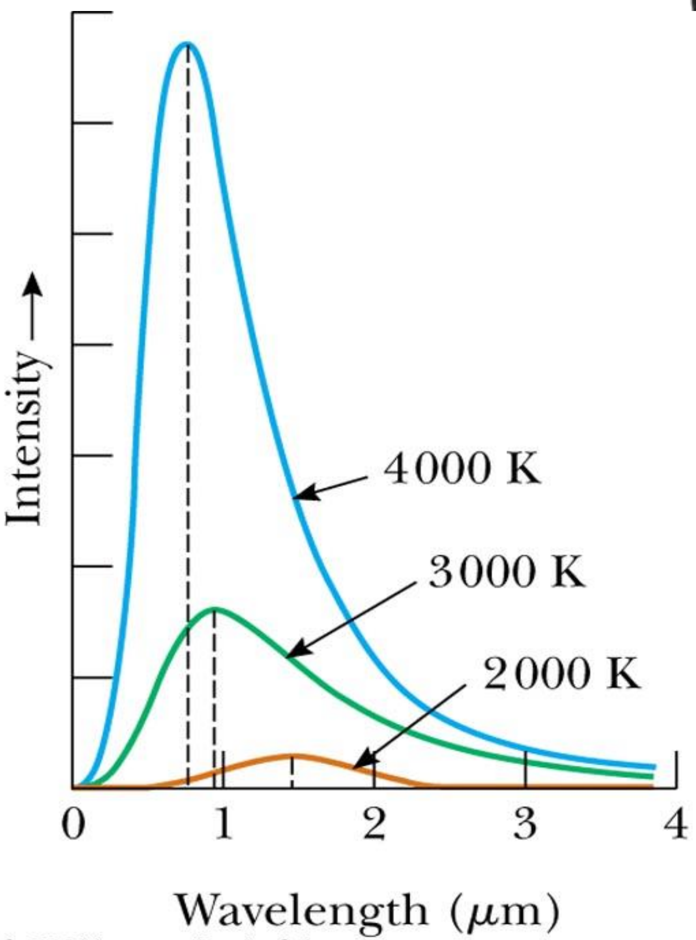
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_o \mathbf{j} + \mu_o \varepsilon_o \frac{\partial \mathbf{E}}{\partial t}$$

Light is an electromagnetic wave

“The velocity of EM waves is so nearly that of light, that it seems we have strong reason to conclude that **light itself** (including radiant heat, and other radiations if any) **is an electromagnetic** disturbance in the form of waves propagated through the electromagnetic field according to electromagnetic laws.”

Black body Radiations



© 2003 Thomson - Brooks Cole

Max Planck (1901)
Göttingen

Photons

Electromagnetic radiation has a frequency and a wavelength:

$$\nu = \frac{c}{\lambda}$$

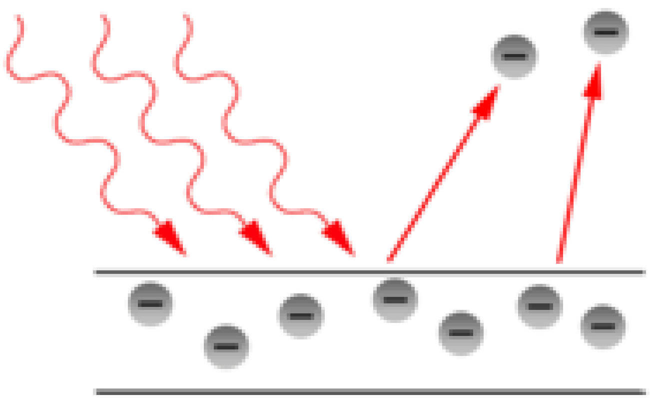
Frequency is related to the energy of a photon:

$$E = h\nu = \frac{hc}{\lambda}$$

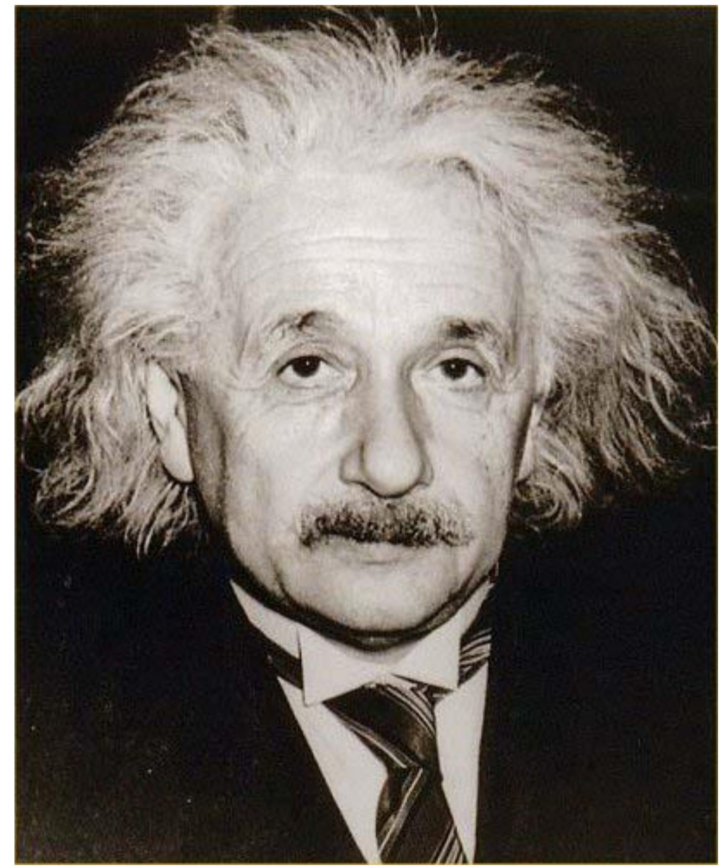
$$E_{tot} = n\,h\nu$$

The wave theory of light was widely accepted until 1905……

Wave theory of light? “No way!”



Photoelectric effect



Albert Einstein

1879 - 1955

Let's *COMPROMISE*
Dual Nature of Radiations

Albert Einstein provided a piece of convincing evidence for the particle nature of light ……

Has the story ended yet?

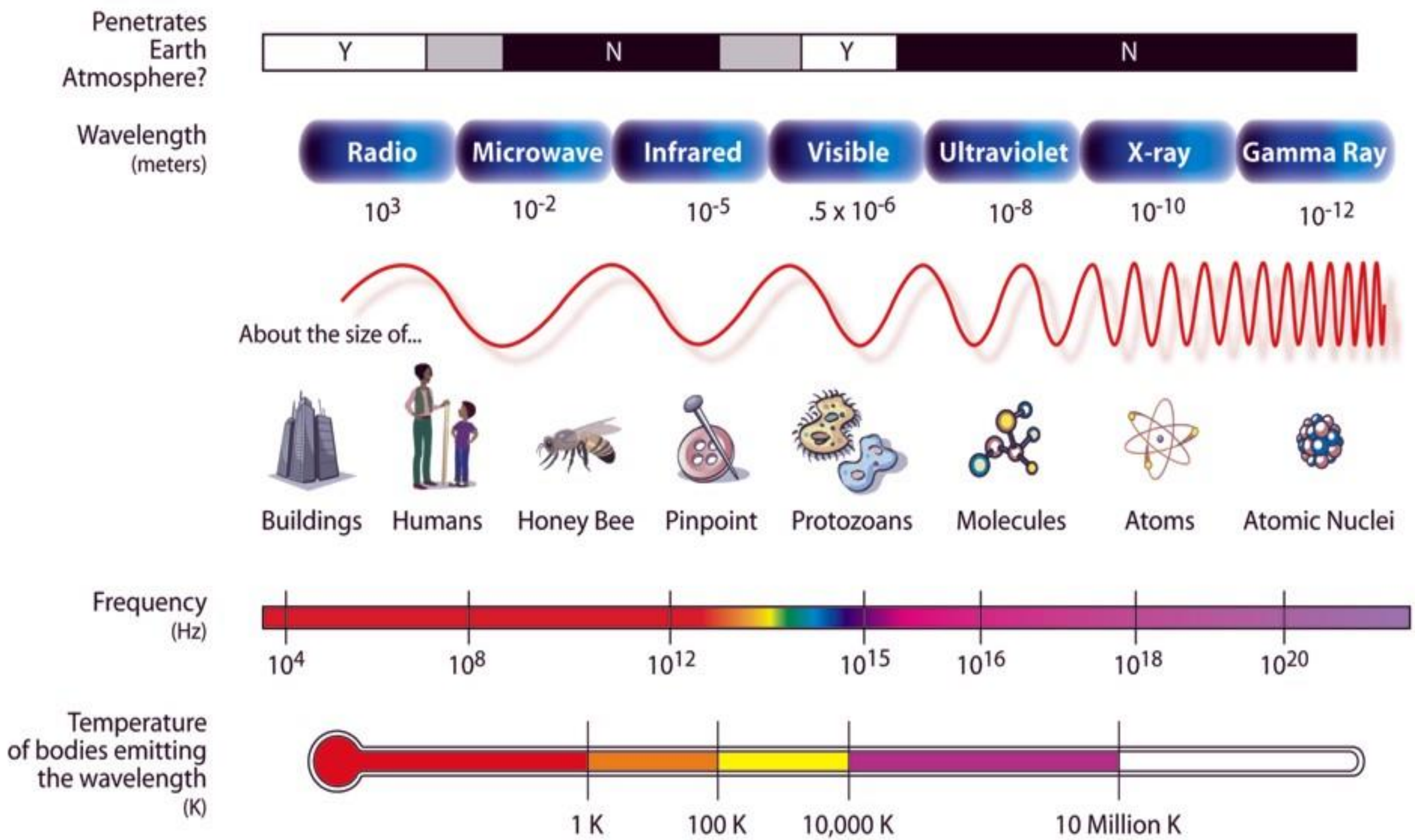
Is light particles or waves?

Light is not particles, not waves, but BOTH!

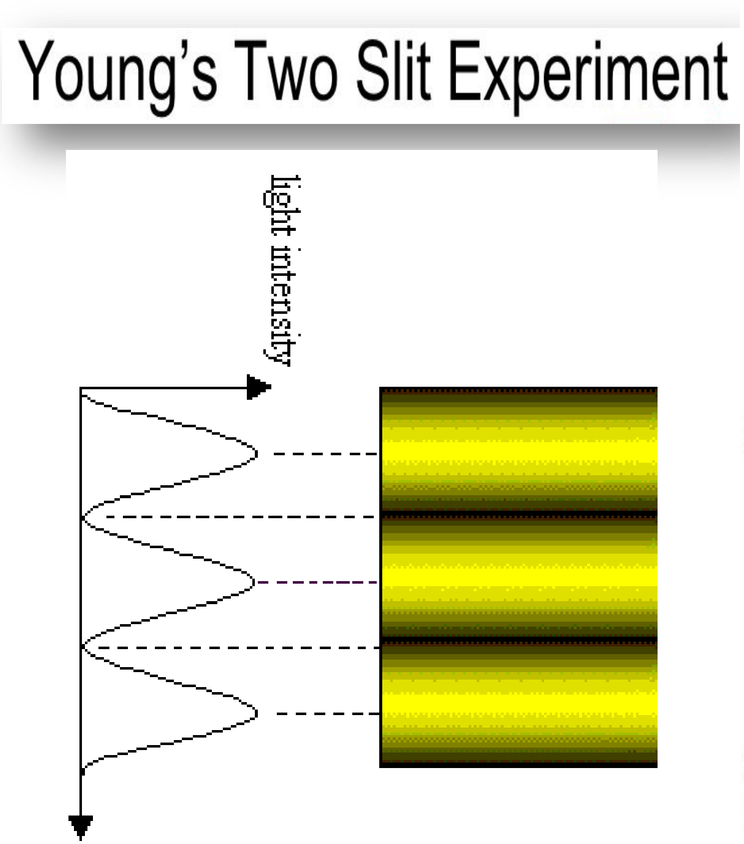
Louis de Broglie

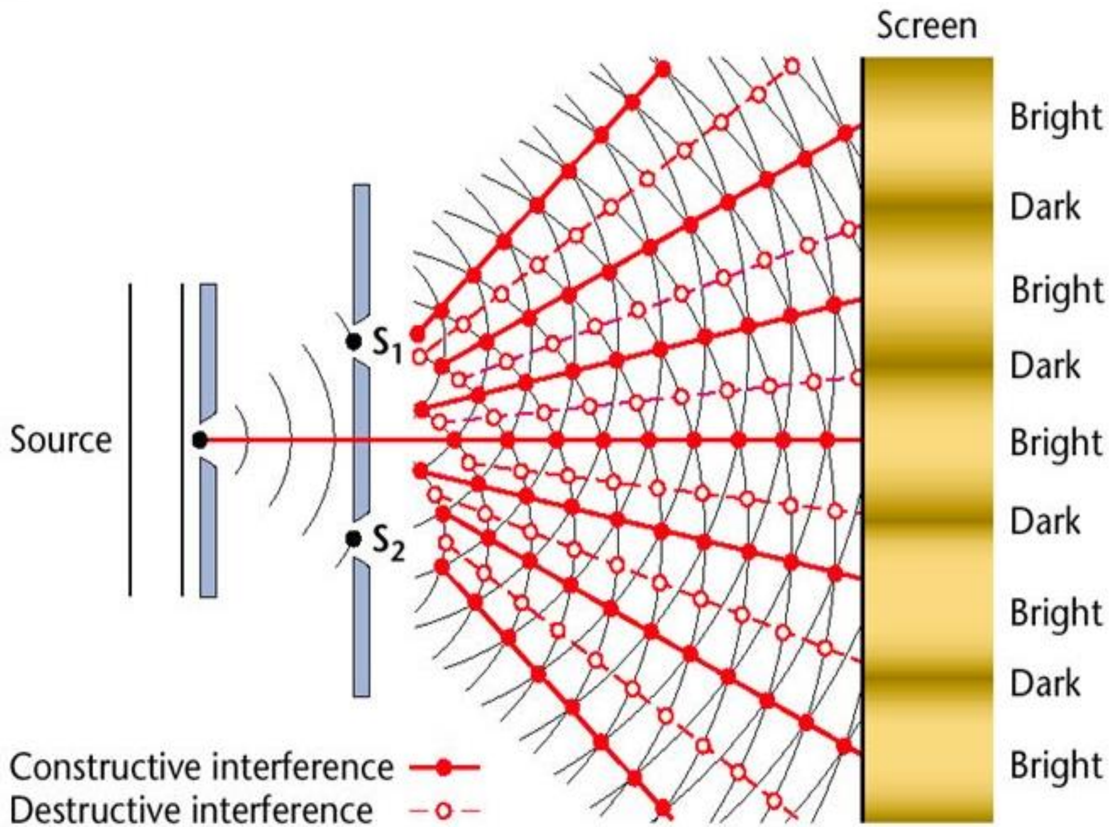
1892 - 1987

THE ELECTROMAGNETIC SPECTRUM

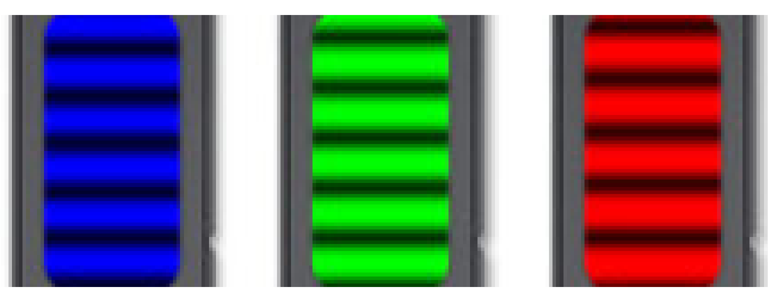


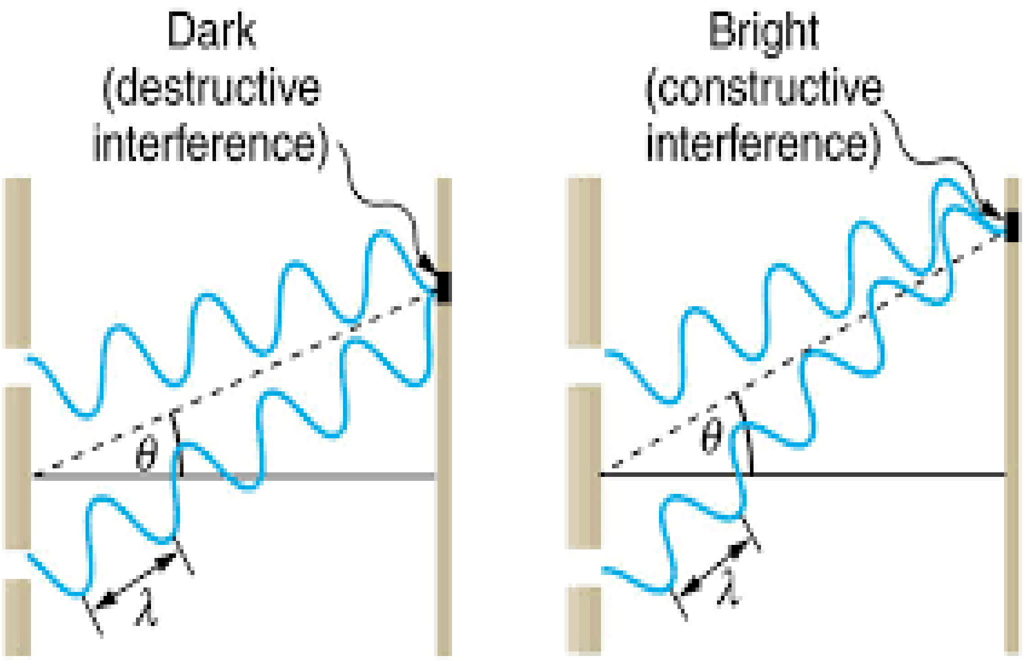
Interference of Light

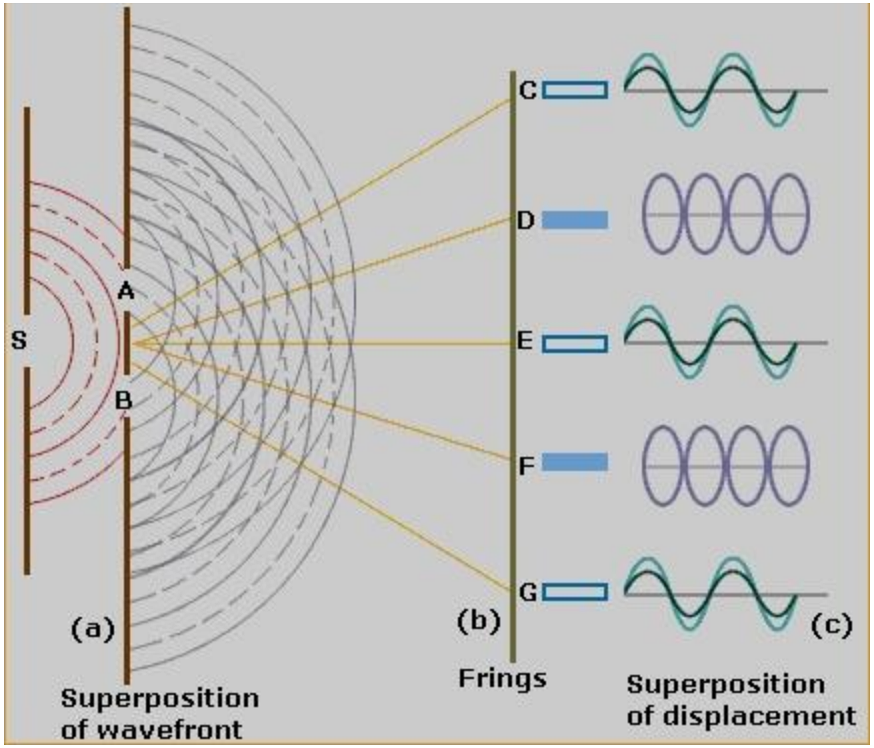




Non-uniform distribution of light due to superposition of light waves







Essential Condition: Coherent Sources

Sources which emit light of **same Wave length** and with constant **Phase difference**

$$y = y_1 + y_2 = a_1 sin\omega t + a_2 \sin(\omega t + \varphi)$$

$$y = A\sin(\omega t + \tau)$$

$$I = A^2$$

$$I = a_1^2 + a_2^2 + 2a_1a_2\cos\varphi$$

Condition for *Constructive Interference*

For I to be maximum $\quad \cos\phi = +1$

Phase difference $\quad \phi = 2n\pi$

Path difference $\quad x = n\lambda$

Condition for *Destructive Interference*

For I to be minimum $\quad \cos\phi = -1$

Phase difference $\quad \phi = (2n+1)\pi$

Path difference $\quad x = \left(\frac{2n+1}{2}\right)\lambda$

$n = 0, 1, 2, 3, 4, \ldots\ldots$

$$\boxed{I_{max} = (a_1 + a_2)^2 = \left(\sqrt{I_1} + \sqrt{I_2}\,\right)^2}$$

$$\boxed{I_{min} = (a_1 - a_2)^2 = \left(\sqrt{I_1} - \sqrt{I_2}\,\right)^2}$$

If $a_1 = a_2 = a\ (say)$ **then**

$$\boxed{\begin{aligned} I_{max} &= 4a^2 = 4\,I \\ I_{min} &= 0 \end{aligned}}$$

Fringe Contrast: $$f = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

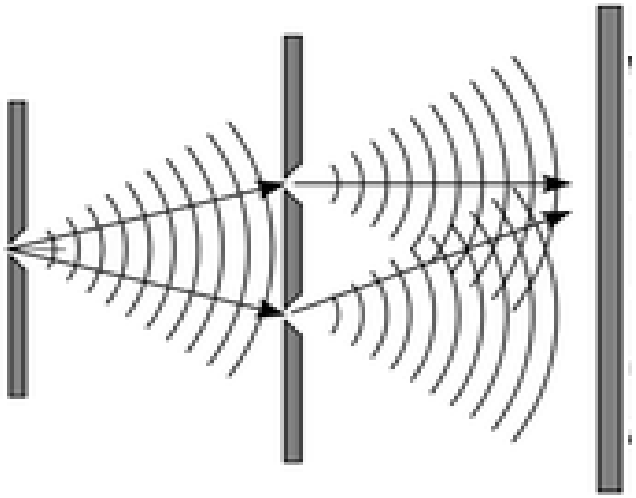
Note:

If n number of light sources each of intensity *I* interfere coherently then $I_{max} = n^2 I$

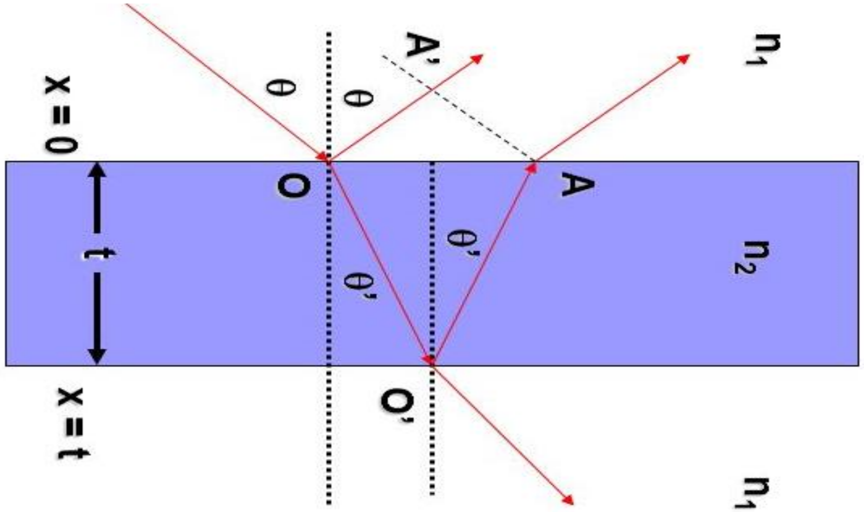
and if incoherently then $I_{max} = nI$

Methods to obtain Interference pattern

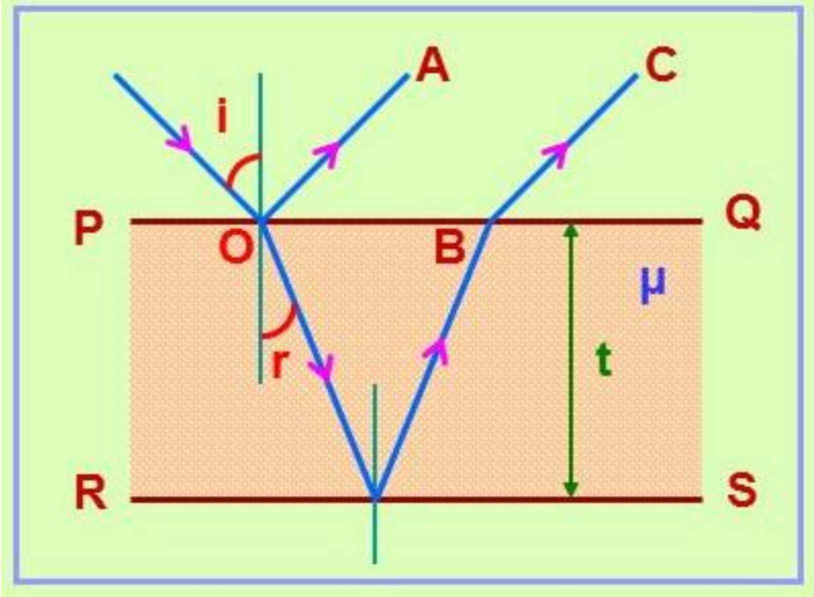
1. **Division of Wave front:**
E.g. YDSE, Fresenel's biprism, Llyod's mirror etc.

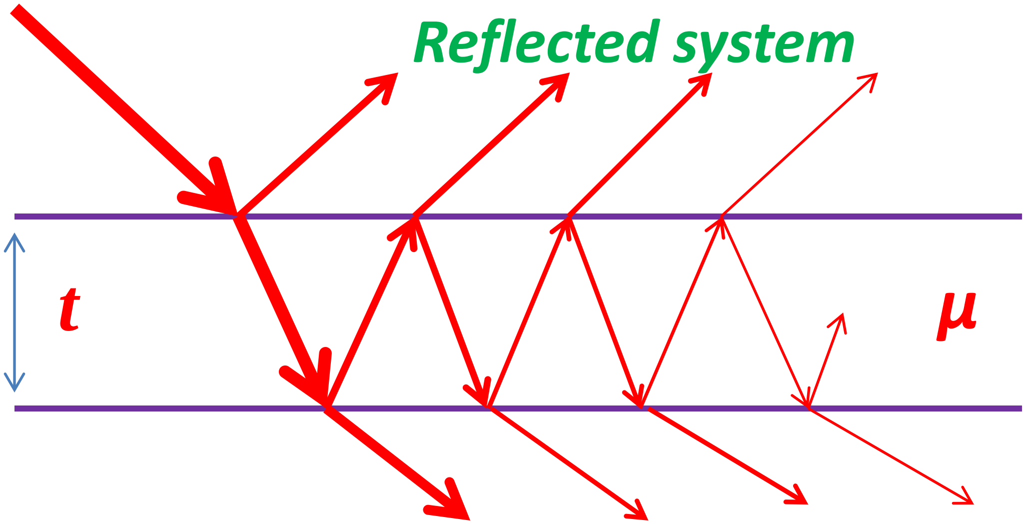


2. **Division of Amplitude:**
E.g. Interference in thin films, Newton rings, Michelson's interferrometer etc.



Interference in Thin films





Path difference between the rays A and C

$$\Delta = 2\mu t \cos r$$

Additional path difference due to reflection of ray A from denser medium is λ/2. Hence total path difference

$$\boxed{x = 2\mu t \cos r + \frac{\lambda}{2}}$$

For constructive interference

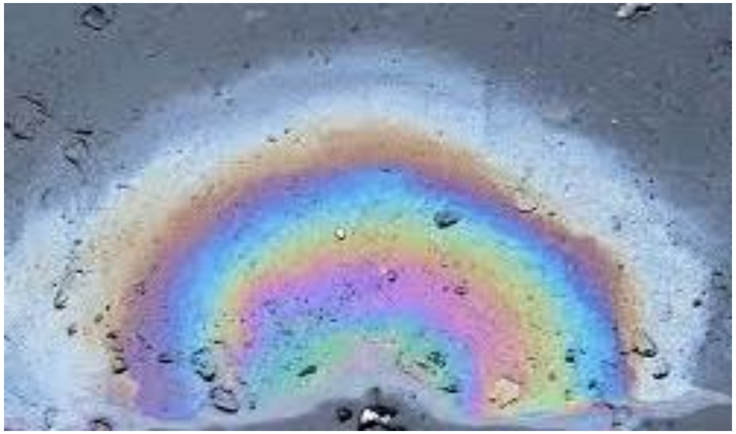
$$2\mu t \cos r + \frac{\lambda}{2} = n\,\lambda \quad \Longrightarrow \quad \boxed{2\mu t \cos r = \left(n - \frac{1}{2}\right)\lambda}$$

For destructive interference

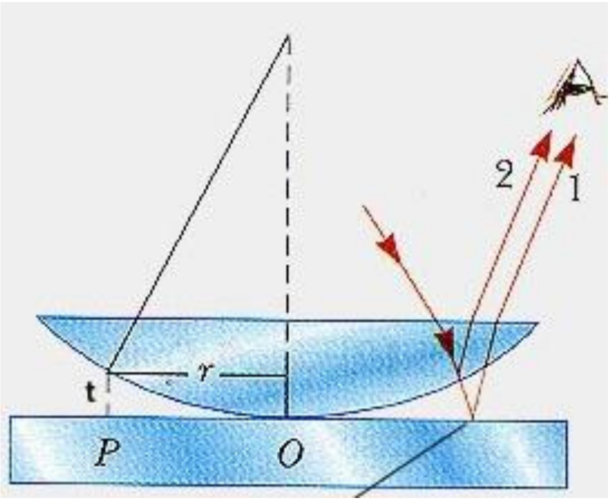
$$2\mu t \cos r + \frac{\lambda}{2} = \frac{(2n+1)}{2}\lambda \quad \Longrightarrow \quad \boxed{2\mu t \cos r = n\lambda}$$

Transmitted system is **complementary interference** pattern of the reflected system, hence **conditions** for constructive and destructive systems are **interchanged**

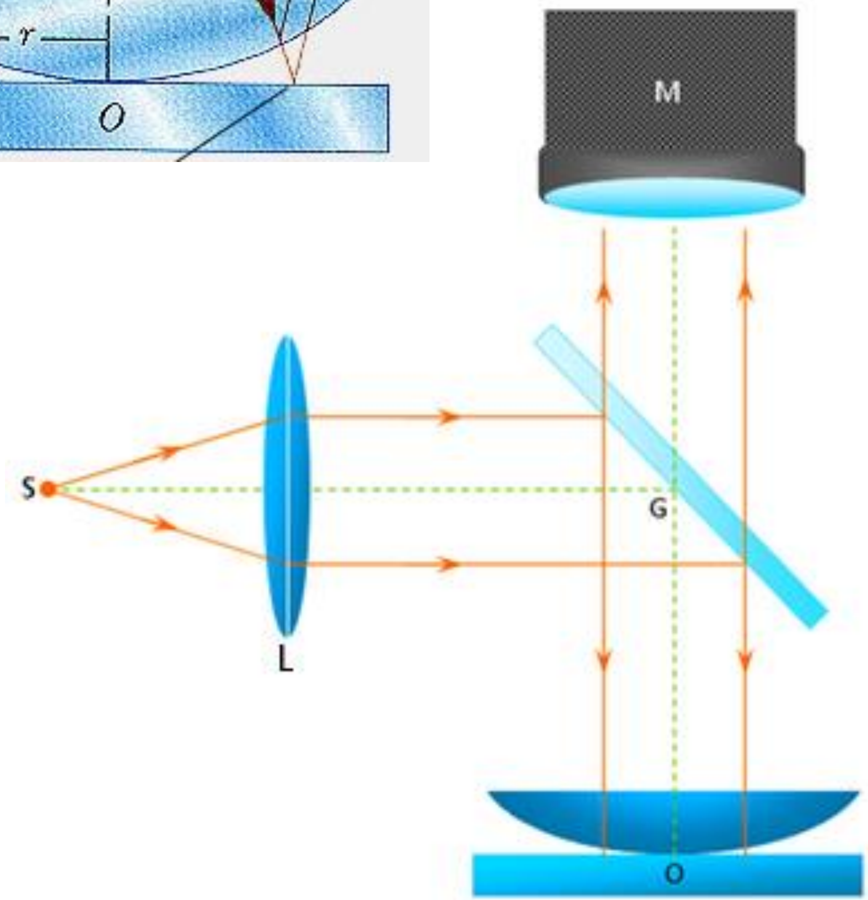
Multiple colours on thin films in white light



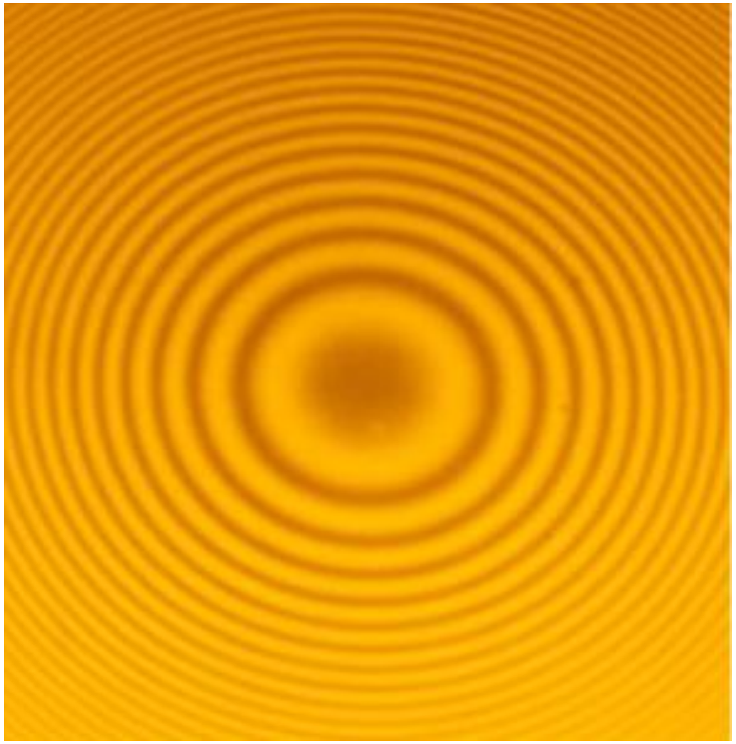
Newton Rings

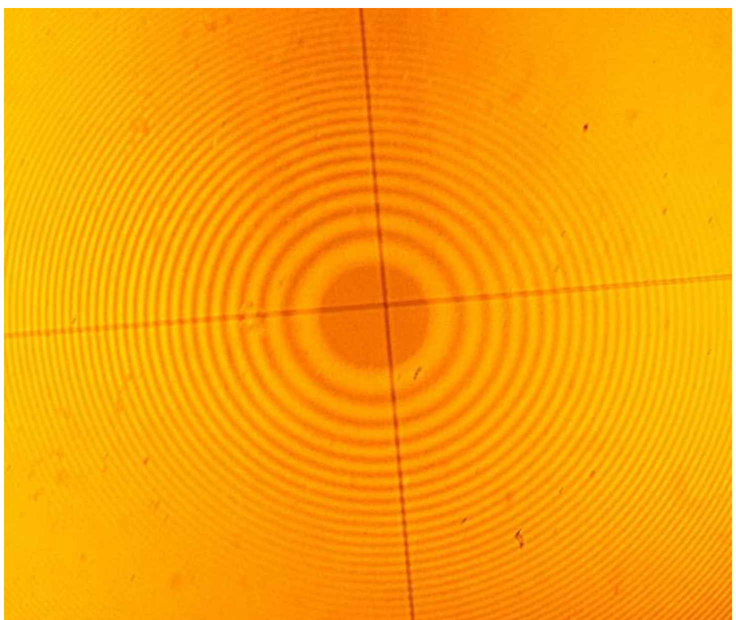


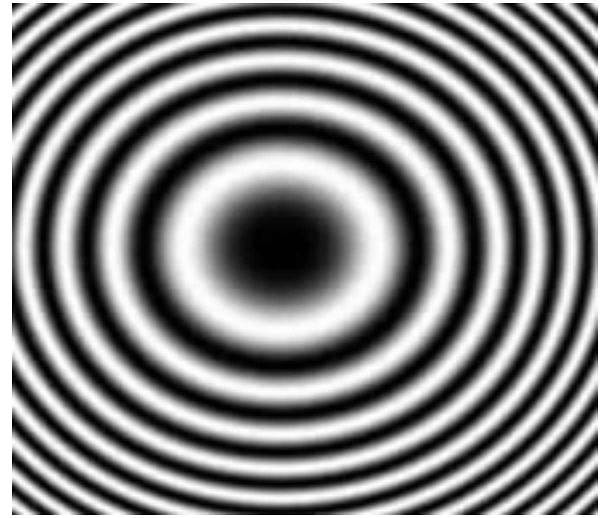
Circular fringes formed due to the interference of the rays partially reflected from the upper and lower surface of a thin air film enclosed between the curved surface of a plano-convex lens and plane glass sheet

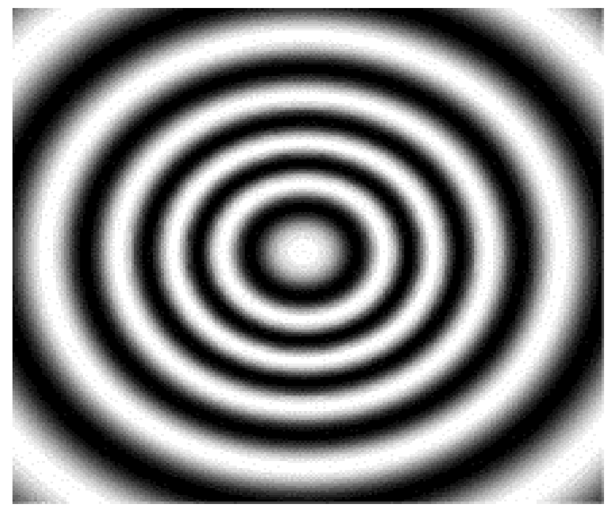


View of Newton rings



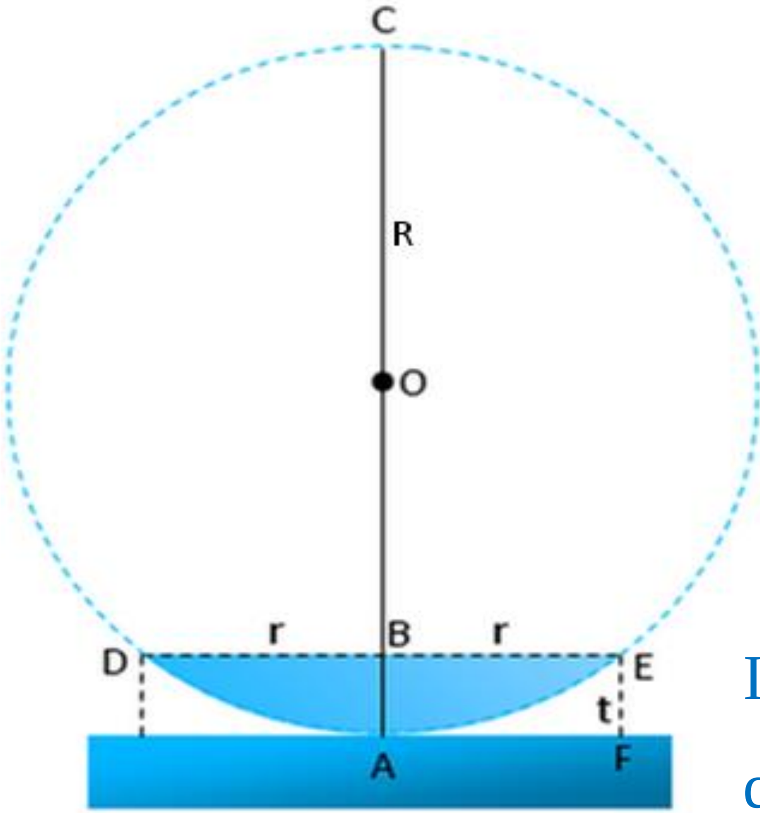






Reflected and transmitted systems are complementary to each other

Theory of Newton Rings



$$DB \times BE = AB \times BC$$

$$= AB \times (AC - AB)$$

$$= t \times (2R - t)$$

$$= (2tR - t^2)$$

$$\mathbf{DB \times BE \approx 2\,t\,R} \qquad \text{as } t <<< R$$

If thickness t results into an n^{th} ring of diameter D_n then $\mathbf{DB \times BE} = \frac{D_n{}^2}{4}$ hence

$$\frac{D_n{}^2}{4} = 2\,t\,R \quad \rightarrow \quad \boxed{\frac{D_n{}^2}{4R} = 2\,t}$$

The path difference between the two rays, one reflected from ***E*** and other from ***F***

$$x = 2\mu t \cos r + \lambda/2 \quad \rightarrow \quad \boxed{x = 2\mu t + \lambda/2}$$

for nearly normal incidence

For constructive interference

$$2\mu t + \frac{\lambda}{2} = n\,\lambda$$

$$\boxed{2t = \left(n - \frac{1}{2}\right)\lambda}$$

Taking μ=1 for air film

$$\frac{D_n{}^2}{4R} = \left(n - \frac{1}{2}\right)\lambda$$

$$\boxed{D_n{}^2 = \left(n - \frac{1}{2}\right)4R\lambda}$$

Diameters of various order bright rings

For destructive interference

$$2\mu t + \frac{\lambda}{2} = \frac{(2n+1)}{2}\lambda$$

$$\boxed{2t = n\lambda}$$

Taking μ=1 for air film

$$\frac{D_n{}^2}{4R} = n\lambda$$

$$\boxed{D_n{}^2 = 4nR\lambda}$$

Diameters of various order Dark rings

Determination of λ

Diameters of n^{th} and m^{th} order Dark rings are

$$D_n{}^2 = 4nR\lambda$$

$$D_m{}^2 = 4mR\lambda$$

$$D_n{}^2 - D_m{}^2 = 4R(n-m)\,\lambda \quad \Longrightarrow \quad \boxed{\lambda = \frac{D_n{}^2 - D_m{}^2}{4R(n-m)}}$$

Determination of μ of any transparent liquid

Diameter of any Dark ring with air film enlosed

$$D_{air}{}^2 = 4nR\lambda$$

Diameter of any Dark ring with liquid film enlosed

$$D_{liq}{}^2 = 4nR\,\frac{\lambda}{\mu}$$

$$\mu = \frac{D_{air}{}^2}{D_{liq}{}^2} \quad \Longrightarrow \quad \boxed{\mu = \left(\frac{D_{air}}{D_{liq}}\right)^2}$$