Early milestones in the history of optics

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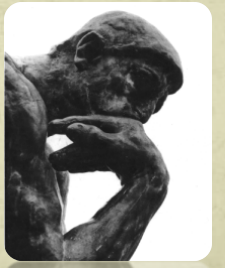
Why is it important?

- A proper study of historical experiments can give crucial context and understanding

- Many important and enlightening experiments have been "forgotten" by science

- A comprehension of such experiments can provide inspiration and a better understanding of the philosophy of science



Periods of optical history

Prehistory: initial studies of optics and vision

- ✓ Aristotle, Ptolemy, Ibn al-Haytham

Particle: light treated as a stream of particles

- ✓ Newton published Optiks in 1704

Wave: light treated as a continuous wave

- ✓ Young published double slit experiment in 1803

Quantum: light has wave/particle duality

- ✓ Einstein published photoelectric effect in 1905

Modern: light even weirder than we imagined!

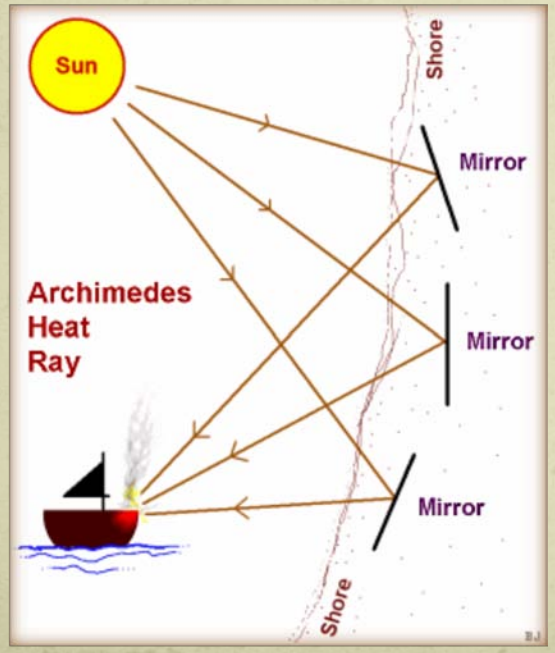
- ✓ Maiman builds first laser in 1960

Myth or Reality?

The earliest manufactured mirrors: pieces of polished stone

(obsidian, a naturally occurring volcanic glass)

10th century BC - plane mirror



Archimedes (c. 214–212 BC)
may have used mirrors acting collectively as a parabolic reflector to burn ships attacking Syracuse.

The beginning of geometrical optics

Euclid (300 B.C.)

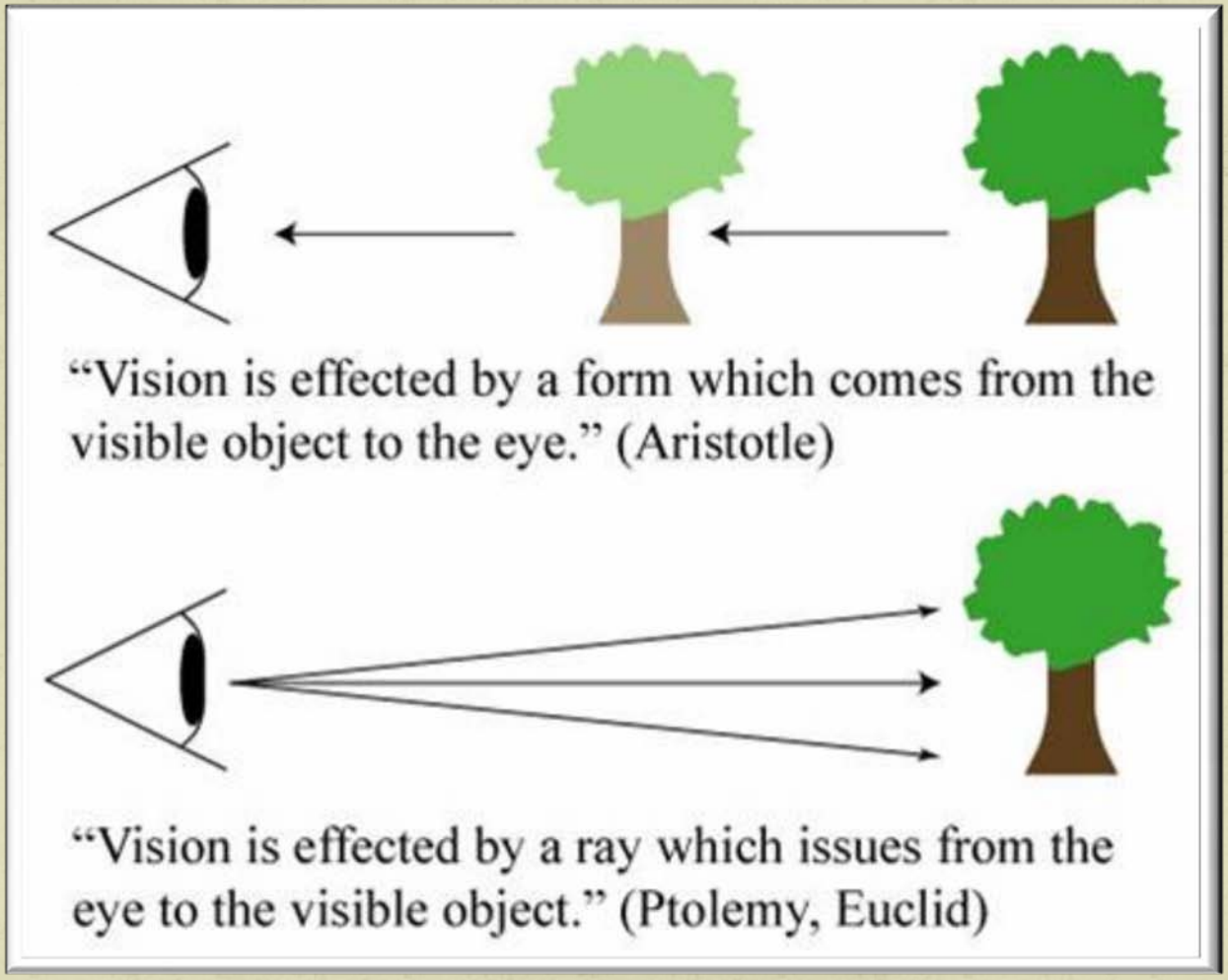
'Optica':

- light travels in straight lines
- the law of reflection
- study on the relationship between the apparent sizes of objects and the angles that they subtend at the eye

Ptolemy (90-168 C.E.)

- study of refraction, including atmospheric refraction
- the angle of refraction is proportional to the angle of incidence

Vision Models



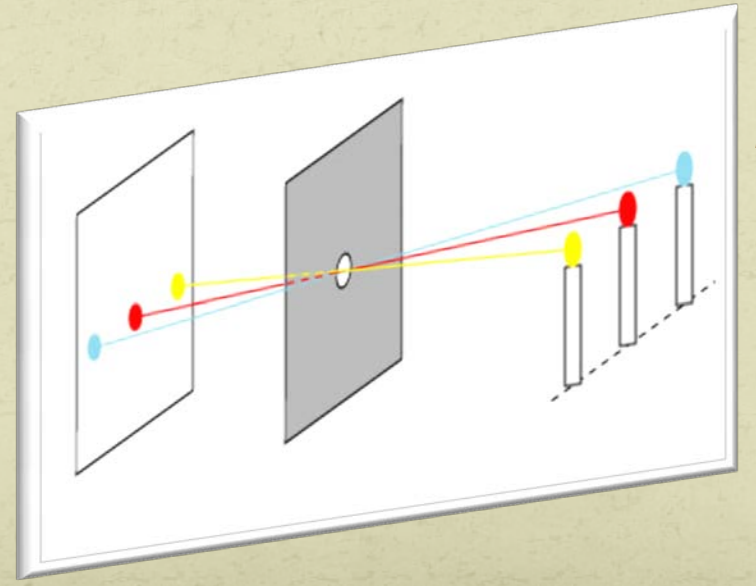
Bradley Steffens, Ibn al-Haytham, First Scientist

Ibn al- Haytham's Camera obscura

Ibn-al-Haitham (965-1020)

- *spherical and parabolic mirrors, spherical aberration*
- *magnification produced by lenses and atmospheric refraction.*

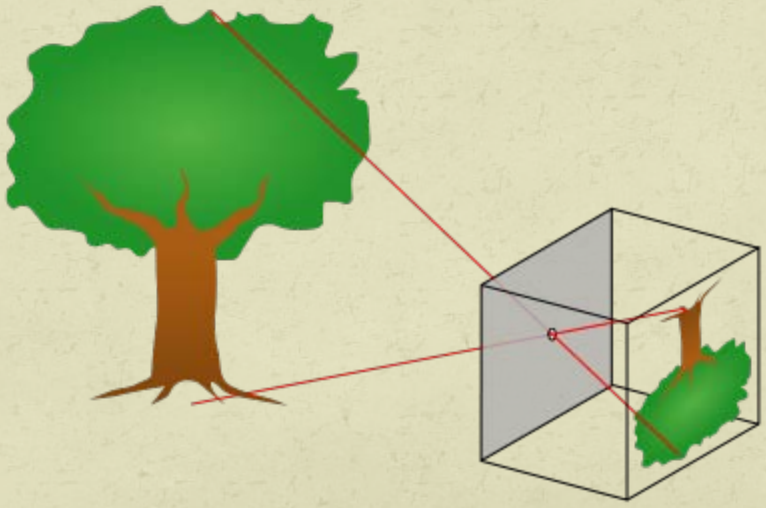
Ibn al-Haytham used multiple light sources to demonstrate that light followed straight line paths through the holes:



By screening one light source or another, was able to demonstrate that the "image" was inverted on passing through the hole!

Obscura Camera

Using geometrical optics, we can demonstrate that light passing through a small pinhole into a darkened room forms a "reversed" image of the object:



The colorful side of the subject

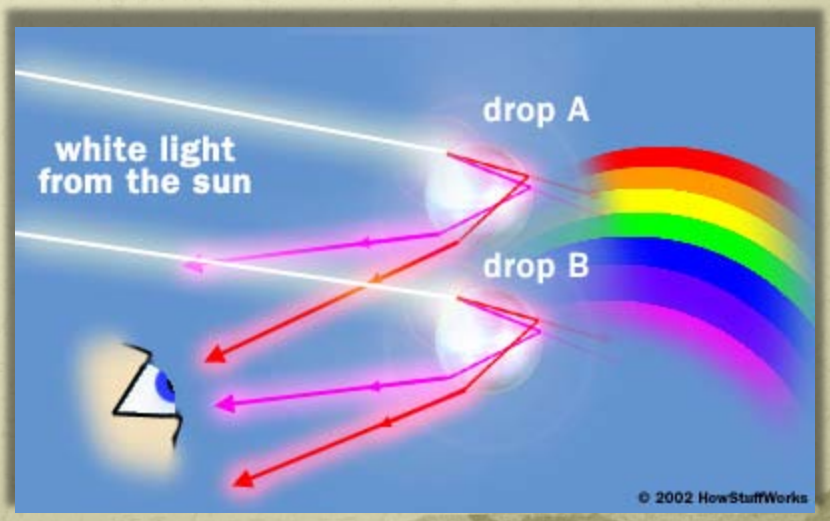
Roger Bacon (1267), follower of Grosseteste at Oxford

- The speed of light is finite
- Light is propagated through a medium in a manner analogous to the propagation of sound.

- 'Opus Maius', the magnification of small objects using convex lenses

Application: in the correction of defective eyesight

He attributed the phenomenon of the rainbow to the reflection of sunlight from individual raindrops



Eye and Lenses function

Johannes Kepler (1571-1630)

'Pars optica' correct description of how the eye functions

- basic investigations of the optical properties of lenses
- how they function together with the eye to correct defects in vision.

Before:

Convex lenses had been used in spectacles since 1260 and concave ones since at least 1450

But:

Kepler's optical analysis was the first ever published scientific investigation of how lenses function

Profound Understanding of Optics

Jensen, Kepler, Galileo, Snelius, Cavalieri, Fermat, Newton and others

Till the Middle of the 17th Century

Telescopes

Microscopes

Wave Theory

Francesco Grimaldi (1618,1663)

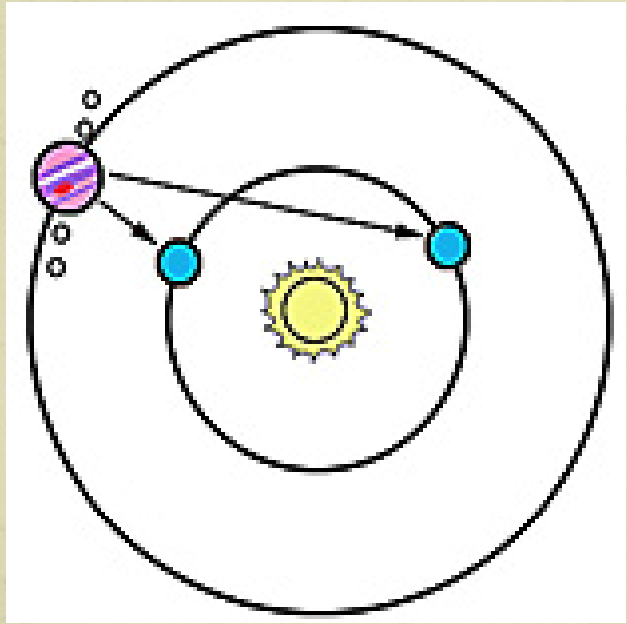
1st reference to the wave-theory of light(1665): certain diffraction pattern behind the aperture, which led him to interpret a fluid-like behavior for light

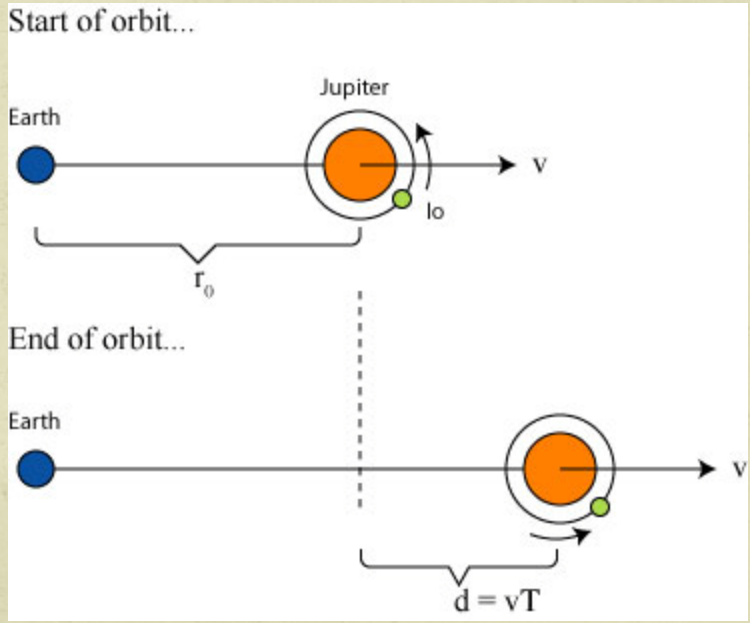
Earlier Studies:

Newton: the corpuscular interpretation of light.
The light particles interacted with the medium - a very volatile all-pervading substance (ether), which would cause waves

Speed of Light

Measurements of the speed of light had first been made by Römer in 1676:





Essentially the Doppler effect!

Ether

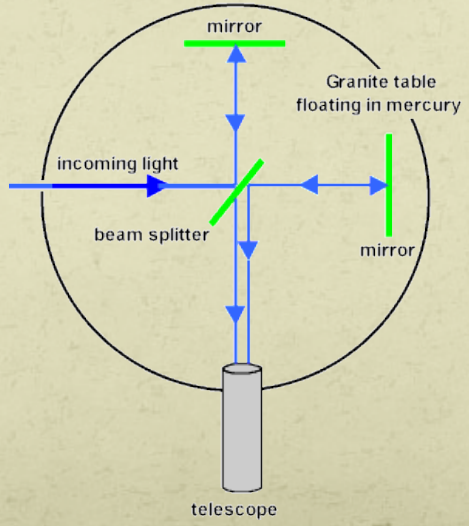
Christian Huygens (1629 - 1695)

Wave theory

light is transmitted through an all-filling ether that is made up of small elastic particles, which in their turn can act as a secondary source of wavelets

Albert Michelson and Edward Morley (1887):

One beam traveling with the "ether wind" as the earth orbited the sun, and the other at 90º to the ether wind. If light was a mechanical wave, then the speed of light should vary with the earth's motion through the ether



The earth is in motion relative to a "luminiferous ether" through which light propagates. The speed of light is a constant, independent of its direction of propagation

Wave/Particle nature of light

(1704) Newton
light itself is corpuscular, but that the corpuscles are able to excite waves in the ether

(1801) Thomas Young
wave theory by demonstrating the interference of light in a typical wave-phenomenon

(1811) Fresnel
diffraction and interference phenomena, wave theory of light

(1845) Michael Faraday
rotation of the plane of polarized light that passes through glass in a magnetic field

(1865) James Clerk Maxwell
light is a electromagnetic wave

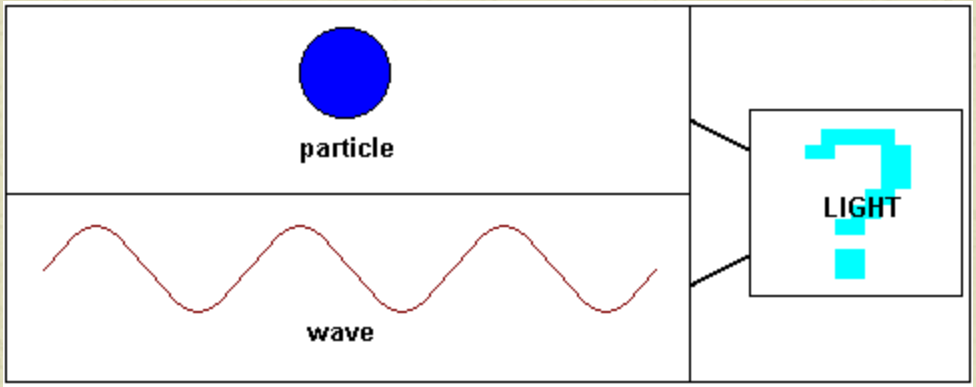
(1905) Einstein
photoelectric effect. He showed that light has momentum, a typical particle thing

(1905) Gustav Mie
light scattering from particles that are big compared to the wavelength of light

Last but not least…

Nowadays, we know that:

The light is neither wave nor particle.
It behaves like both.



How to imagine the wave-particle duality.

A strange dualism inherent to all matter, especially on the sub-atomic scale called the wave-particle duality.