



QLI Lab 

Brief history of optics




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Quantitative Light Imaging Laboratory
<http://light.ece.uiuc.edu>

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Fire- primary light source



Prometheus stole fire from the god Zeus and gifted it to mankind

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First Known Lens


Nirumund Lens-Assyria 700 B.C.
On Display at the British Museum



Similar lenses are known to have existed in ancient Egypt, Greece and Babylon

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QLJ Lab **5th Century B.C Greece** UIUC



Belief is that Aphrodite lit a fire (one of the four elements) in the human eye which shines out of the eye making sight possible. Empedocles postulates an interaction between eye rays and source rays.

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QLJ Lab **Mo Zi** UIUC
-first optics writing 5th Century B.C, China



Described the basic optical knowledge, including the definition and creating of vision, propagation of light in straight line, pinhole imaging, the relationship between object and image in plane mirror, convex mirror and concave mirror.

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QLJ Lab **Euclid: 300 BC** UIUC

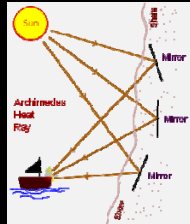


"Optica": beginning of geometrical optics: "things seen under a greater angle appear greater, and those under a lesser angle less, while those under equal angles appear equal".

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QLI Lab **Archimedes Heat Ray** UIUC

c. 214-212 BC- Siege of Syracuse




The diagram shows a sun in the upper left corner. Three rays of light originate from the sun and reflect off three mirrors positioned on a ship's hull. The rays converge on a small boat in the water below, labeled 'Archimedes Heat Ray'. The mirrors are labeled 'Mirror'.

*In October 2005 a group of students from the [Massachusetts Institute of Technology](#) carried out an experiment with 127 one-foot (30 cm) square mirror tiles, focused on a mock-up wooden ship at a range of around 100 feet (30 m). Flames broke out on a patch of the ship, but only after the sky had been cloudless and the ship had remained stationary for around ten minutes. It was concluded that the device was a possible weapon under these conditions.

*When *MythBusters* broadcast the result of the San Francisco experiment in January 2006, the claim was placed in the category of "busted" (or failed)

QLI Lab **Lucretius: 55 B.C.** UIUC



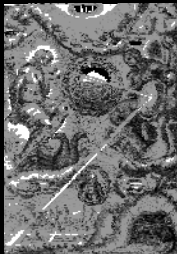
A black and white photograph of a classical marble bust of the Roman philosopher Lucretius. The bust is shown from the chest up, wearing a draped garment. The name 'LUCRETIUS' is inscribed on the base of the bust.

The light and heat of the sun; these are composed of minute atoms, which lose no time in shooting right across the interspace of air in the direction imparted by the shove.

—Lucretius, *On the nature of the Universe*

QLI Lab **Heron of Alexandria** UIUC


+ 40 C.E.



A diagram illustrating the principle of Catoptrica. It shows a complex arrangement of mirrors and light rays. A source of light on the left sends rays that reflect off multiple mirrors, eventually reaching an observer on the right. The diagram demonstrates that the actual path taken by the light is the shortest possible path between the source and the observer.

Catoptrica: The actual path taken by a ray of light reflected from a plane mirror is shorter than any other reflected path that might be drawn between the source and point of observation.



QLJ Lab **Claudius Ptolemaeus: 130 C.E** UIUC



Studies refraction and suggests that the angle of refraction is proportional to the angle of incidence.

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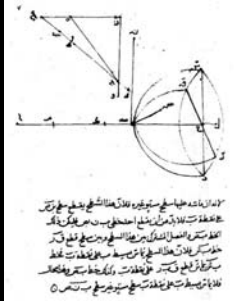
QLJ Lab **Al-Kindi (Alkindus)** UIUC
c. 801-973

-“everything emits rays in every direction which fills the world”
-introduced Indian numerals to the Muslim and Christian world


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QLJ Lab **Ibn Sahl: c. 940-1000** UIUC
-Persian mathematician in Bagdad



Treatise “On Burning Mirrors and Lenses”, Derives the laws of refraction (Snell’s Law), 600 years before Snell and Descartes.

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QLI Lab **Ibn al-Haytham (Alhazen)** UIUC 
The Father of Modern Optics: c. 965-1040



- Book of Optics: Studies lenses, vision, and Camera Obscura; finite speed of light
- Visual perception

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QLI Lab **Salvino D'Armato- 1284** UIUC 
-invents wearable eye glasses



Magnifying glasses had been used much earlier
(8th century BC in Egypt, Emperor Nero 1st century AD)

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QLI Lab **1595, Holland:** UIUC 
Earliest Microscopes



Credited to Hans and Zacharias Janssen
(spectacle makers)

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Earliest working Telescopes
Holland 1600's



•Maybe: Sacharias Jansen constructed the first telescope in 1604
•Isaac Newton - first functional reflecting telescope in 1668

Galileo's Telescope ~1609




Galileo Galilei: Portrait in crayon by Leoni.



Galileo's Telescopes
The marked line is assumed to center

Johannes Kepler: c. 1571-1630



•"Astronomiae Pars Optica": Described the inverse-square law governing the intensity of light, reflection by flat and curved mirrors, and principles of pinhole cameras, as well as the astronomical implications of optics such as parallax and the apparent sizes of heavenly bodies

•the first to recognize that images are projected inverted and reversed by the eye's lens onto the retina. The solution to this dilemma was not of particular importance to Kepler as he did not see it as pertaining to optics, although he did suggest that the image was later corrected "in the hollows of the brain" due to the "activity of the Soul."


QLI Lab **Willebrord Snellius:**
c. 1580–1626, Holland UIUC



Snell's Law

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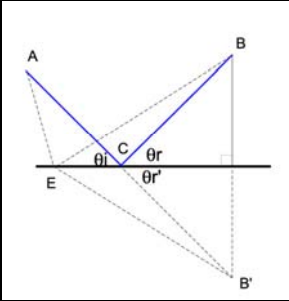
QLI Lab **Rene Descartes**
c. 1596–1650, "Father of Modern Philosophy" UIUC



- Independently finds Snell's law, finds the angle of the rainbow (42°)
- Major figure of the Scientific Revolution, a period when new ideas in science led to a rejection of doctrines that had prevailed from Ancient Greece through the Middle Ages, and laid the foundation of modern science
- "Religion, superstition, and fear were replaced by reason and knowledge".

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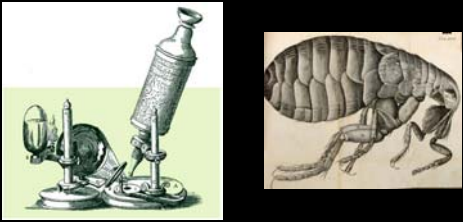
QLI Lab **Pierre de Fermat**
1601-1655 UIUC



Principle of least time

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Robert Hooke: 1665
Looks at biological samples

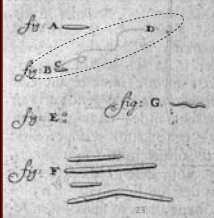


- Coined the term "cell"
- Described the wave theory of light
- Disputes with Newton over optics and theory of gravitation


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Anton von Leeuwenhoek
"Father of cell biology"

Motility of bacteria- 1683


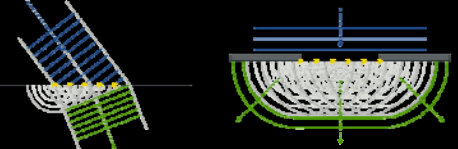


Red blood cells- 1682



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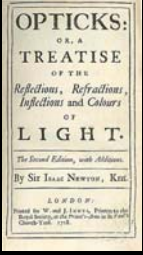
Christaan Huygens
c.1629-1695



- Huygens-Fresnel principle
- Double refraction (birefringence)
- Wave nature of light (contrasts Newton)

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QLJ Lab **Isaac Newton** c. 1643–1727 UIUC

•Worked on colors: prism, chromatic aberration → reflection telescope
 •Corpuscular model of light, with higher speed in denser media (wrong!)


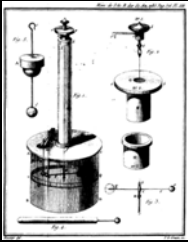
*"If I have seen further it is by standing on the shoulders of Giants"
 *"Philosophiæ Naturalis Principia Mathematica" - one of the most influential books ever written

QLJ Lab **Benjamin Franklin** 1706-1790 UIUC




Lightening is Electricity!
 Invented bifocal glasses

QLJ Lab **Charles-Augustin de Coulomb** 1736-1806 Inverse-square law of electrostatics UIUC





In 1785, Coulomb presented his three reports on Electricity and Magnetism

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

QLI Lab **William Herschel** UIUC

1800 Infrared radiation from the Sun


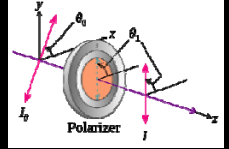
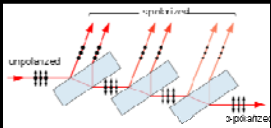


•Measured temperature increase at the red end of visible spectrum

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QLI Lab **Etienne Malus** UIUC

1808,1809 Polarization by reflection, Malus Law


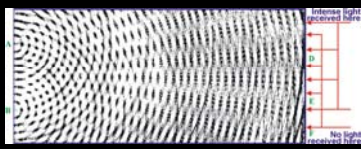

$$I = I_0 \cos^2 \theta_i$$

•Also studied birefringence

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QLI Lab **Thomas Young** UIUC


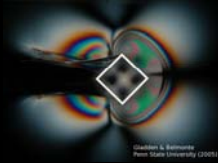
1773 – 1829
1801: Wave Nature of Light



•“Experiments and Calculations Relative to Physical Optics”
•Established experimentally that light was a wave, overcoming a century of Newton’s dogma

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QLJ Lab **David Brewster: 1816** Stress birefringence UIUC



•Brewster's angle

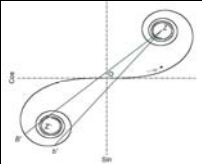

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QLJ Lab **1820 : Hans Oersted** Notices link between current and magnetic field UIUC





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QLJ Lab **Augustin-Jean Fresnel** 1788-1827 UIUC





- Contributes to the establishment of the theory of wave optics → Huygens-Fresnel principle
- 1821 Establishes that light is a transverse wave- contrasts Young
- Fresnel lens, Fresnel rhomb
- Phenomenologically explains Optical Activity



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Michael Faraday



1831: States his law of induction
 1845: Magnetic field effects on light

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Carl Friedrich Gauss




1877-1855




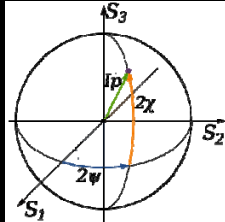
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$$

1835: Gauss Law


1852 : George Stokes



Stokes vectors of polarization

$$\vec{s} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

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James Clerk Maxwell
 1831-1879- Classical electromagnetic theory

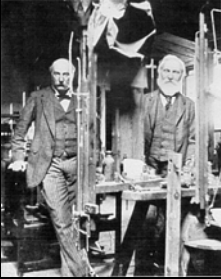
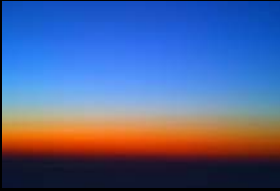


$$\begin{cases} \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} & \text{i} \\ \nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{j} & \text{ii} \\ \nabla \cdot \vec{D} = \rho & \text{iii} \\ \nabla \cdot \vec{B} = 0 & \text{iv} \end{cases}$$

$$\begin{cases} \vec{D} = \epsilon_0 \vec{E} + \vec{P} \\ \vec{H} = \frac{1}{\mu_0} \nabla \times \vec{A} + \vec{M} \end{cases}$$

- 1861 "On physical lines of force" (20 equations, 20 unknowns)
- 1873 "A Treatise on Electricity and Magnetism", 4 equations
- "most profound and the most fruitful that physics has experienced since the time of Newton." A. Einstein

Lord Rayleigh: 1871
 Blue skies and sunsets

$$I = I_0 \frac{1 + \cos^2 \theta}{2R^2} \left(\frac{2\pi}{\lambda} \right)^4 \left(\frac{n^2 - 1}{n^2 + 2} \right)^2 \left(\frac{d}{2} \right)^2$$

Rayleigh and Kelvin

Ernst Abbe: 1871
 Theory of the microscope
 Diffraction limit

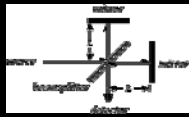



- Also: designed first refractometer, Abbe number (measure of dispersion), Abbe sine condition, Abbe condenser, co-owner of Carl Zeiss

Albert Michelson: 1852-1931 UIUC

Speed of light- absence of ether

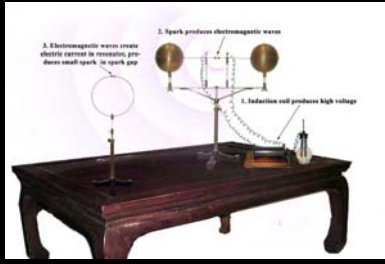





1887: Michelson-Morley experiment: the greatest failed experiment

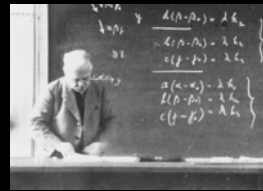
Heinrich Hertz: 1888 UIUC

Discovers radio waves

Arnold Sommerfeld: 1896 UIUC

Half-plane diffraction problem

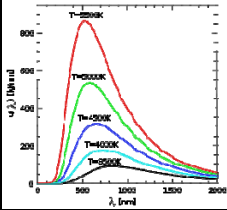



•Contributions to atomic and quantum physics (fine structure constant)
 •Sommerfeld's doctoral students: Heisenberg, Pauli, Debye, Bethe

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Max Planck: 1899

Blackbody Radiation and quanta



$u(\nu, T) = \frac{2h\nu^3}{c^2} \cdot \frac{1}{e^{\frac{h\nu}{k_B T}} - 1}$

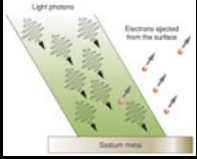

•“the founder of the quantum theory”
 $E = h\nu$

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Albert Einstein: 1905

Photoelectric Effect



•Special theory of relativity
•General theory of relativity

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Neils Bohr: 1913

Quantized atom


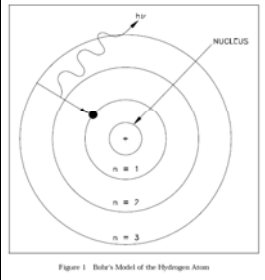


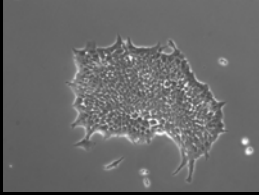



Figure 1 Bohr's Model of the Hydrogen Atom

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 **Frits Zernike: 1932** 
Phase Contrast microscope



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 **Townes, Gordon and Zeiger: 1953** 
First Maser




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 **Maiman: 1960** 
Built first LASER




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QLI Lab **Optics people** UIUC 
Nobel Laureates

[Physics](#)

The Nobel Prize in Chemistry 2008
"for the discovery and development of the green fluorescent protein, GFP"



Osamu Shimomura Martin Chalfie Roger Y. Tsien



QLI Lab **Next week** UIUC 
(Sept 17)

Prof. Scott Carney
"Computed Imaging"



QLI Lab **Thank you** UIUC 

