The Nature of Light

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Supplementary Material for PHY1308 (General Physics - Electricity and Magnetism)
WHAT IS LIGHT?
Galileo Galilei
1564-1642

Considered the first “modern scientist,” Galileo combined mathematics with observation and argued that this was the way to understand the natural world.

He perfected the telescope and observed that the earth could not be the center of the universe. He was tried and convicted by the Inquisition for heresy and was placed under house arrest for the remainder of his life. He died the year before Isaac Newton was born.
SPEED OF SOUND

Make measurements of the round trip that sound takes from Dallas Hall to points 100m and 200m south of Dallas Hall.

(Don't get shut down by the cops)
SPEED OF LIGHT

Ole Roemer
First to measure speed of light to be finite (1676)

Roemer estimated the speed of light to be 220,000 km/s by observing Earth-seasonal variations in Io's orbit.

Jupiter

Io
Discovered by Galileo in 1610

Earth
THE 4 LAWS OF ELECTRICITY AND MAGNETISM

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$  
Faraday's Law - changing magnetic flux induces electric field

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$  
Ampere's Law - electric current is the source of magnetic field

$$\int \vec{E} \cdot d\vec{A} = \frac{1}{\epsilon_0} q$$  
Gauss's Law for Electric Fields - electric charge is the source of electric field

$$\int \vec{B} \cdot d\vec{A} = 0$$  
Gauss's Law for Magnetic Fields - there are no single magnetic charges
THE 4 LAWS OF ELECTRICITY AND MAGNETISM - “FREE SPACE”

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Gauss’s Law for Magnetic Fields - there are no single magnetic charges
James Clerk Maxwell
1831-1879

Brilliant scientist working in Britain.

- United electricity and magnetism into a single “force”
- Developed a theory of large numbers of particles
- Made the first true color photograph

Published in 1864 “A Dynamical Theory of the Electromagnetic Field,” which was seen by Faraday before his death in 1867.
THE 4 LAWS OF ELECTRICITY AND MAGNETISM - “FREE SPACE”

\[ \oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt} \]  
Faraday's Law - changing magnetic flux induces electric field

\[ \oint \vec{B} \cdot d\vec{l} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt} \]  
Ampere’s and Maxwell's Law - changing electric flux is the source of magnetic field

\[ \int \vec{E} \cdot d\vec{A} = 0 \]  
Gauss's Law for Electric Fields - electric charge is the source of electric field

\[ \int \vec{B} \cdot d\vec{A} = 0 \]  
Gauss's Law for Magnetic Fields - there are no single magnetic charges
The solutions to Maxwell’s equations for the electric field $\vec{E}(x, t)$ and magnetic field $\vec{B}(x, t)$ are:

\[
\vec{E}(x, t) = E_{\text{max}} \sin (kx - \omega t) \hat{j}
\]

\[
\vec{B}(x, t) = B_{\text{max}} \sin (kx - \omega t) \hat{k}
\]

What do these equations describe???
WAVES

\[ u(x, t) = A \sin \left( 2\pi \frac{x}{\lambda} - 2\pi f t \right) \]
WAVES

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ELECTROMAGNETIC WAVES
Robert Hyer  
(1860-1929)  
Physicist, Founder and First President of SMU  
First American to communicate using EM waves (1894)

Heinrich Hertz  
(1857-1894)  
First to satisfactorily demonstrate the existence of EM waves

Guglielmo Marconi  
(1874-1937)  
Italian inventor who developed the radio telegraph system (first demonstrated in 1894)
ELECTROMAGNETIC WAVES

At what speed do electro-magnetic waves travel?

Answer from Maxwell's Equations:

\[ v_{EM\ Wave} = \sqrt{\frac{1}{\varepsilon_0 \mu_0}} = \cdots \]
At what speed do electro-magnetic waves travel?

Answer from Maxwell’s Equations:

\[ v_{EM\, \text{Wave}} = \sqrt{\frac{1}{\varepsilon_0 \mu_0}} = 3.0 \times 10^8 \text{ m/s} \]
QUESTION

If water waves travel in water . . .

and sound waves travel in air . . .

in what medium does light travel?
ANSWER FROM MAXWELL'S EQUATIONS: NONE???

\[ \oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt} \]

Faraday's Law - changing magnetic flux induces electric field

\[ \oint \vec{B} \cdot d\vec{l} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt} \]

Ampere's and Maxwell's Law - changing electric flux is the source of magnetic field

\[ \int \vec{E} \cdot d\vec{A} = 0 \]

Gauss's Law for Electric Fields - electric charge is the source of electric field

\[ \int \vec{B} \cdot d\vec{A} = 0 \]

Gauss's Law for Magnetic Fields - there are no single magnetic charges
Albert Einstein
(1879-1955)

In 1905, published three papers on atomic theory, the nature of light, and the re-interpretation of space and time based on the theory of electromagnetism ("relativity").