No lecture at 2 pm on Wed., Sept 30, 2009

PDF slides + mp3 audio file will be posted on class website ~ hopefully by 2 on Wed.

I will assume you have looked at/listened to this
Maxwell's Equations

James Clerk Maxwell

1831-1879 (Edinburgh)

integral form of Maxwell's eqns

\[ \int_s \vec{E} \cdot d\vec{a} = \frac{Q_{encl}}{\varepsilon_0} \]
\[ \int_s \vec{B} \cdot d\vec{a} = 0 \]
\[ \int_c \vec{E} \cdot d\vec{l} = -\frac{d\int_s \vec{B} \cdot d\vec{a}}{dt} \]
\[ \int_c \vec{B} \cdot d\vec{l} = \mu_0 I_{encl} + \mu_0 \varepsilon_0 \frac{d\int_s \vec{E} \cdot d\vec{a}}{dt} \]

"E" is symbol for electric field

"B" is symbol for magnetic field
E, B are "unified" in one framework. Deeper relationship understood by Einstein.

Maxwell united Electric + forces Magnetic = into Electromagnetism

- Changing electric field induces changing magnetic field
- Changing magnetic field induces changing electric field

Propagates out at speed of light!
Fist full of Electric charge \( \rightarrow \) creates changing \( E \) which induces changing \( B \) which induces changing \( E \) \( \ldots \) \( \rightarrow \) it is light

\( b > \) observer very far away

Maxwell's eqns also tell us that \( E, B \) satisfy wave equations

Waves are a well-known mechanical phenomenon

\( \rightarrow \) wave pulse traveling on a string
Waves

Anatomy of Wave

\[ v = \lambda f = \lambda \nu \]
\[ c = \lambda \nu \]

Period \( T \) of wave is time for "cork" to go through 1 full motion

Frequency \( f \) or \( \nu \) \( \equiv \frac{1}{T} \equiv \text{Hertz} \)

\( T \)
The variety of electromagnetic waves

Objects of Similar Size

wavelength (in meters)

radio waves

Infrared light

Visible light

Ultraviolet light

Microwaves

X-rays

Gamma rays

SM
All waves exhibit:

- Interference: Wave amplitudes add together.
- Diffraction: Waves spread out when going thru small openings.
- Refraction: Waves bend at interface between substances.

Java demos - waves
Java applet for waves interfering on string
http://mysite.verizon.net/vzeoacw1/wave_interference.html

Superposition of two waves - beats, standing waves
http://www.kettering.edu/~drussell/Demos/superposition/superposition.html

Refraction of light at interface
http://www.physics.uoguelph.ca/applets/Intro_physics/refraction/LightRefract.html

Different frequencies bend different amounts... called dispersion.
Colliding waves on a string interfere constructively.
Colliding waves on a string interfere destructively.
Diffraction

Water waves hit hole in seawall and spread out.

Refraction

Waves bend at interface between media.
light is a wave

Theory well understood

Numerous experiments show light behaves exactly like other wave phenomena such as sound, waves on strings, etc.

Only strangeness is that light is a wave that can travel in a vacuum apparently.
Max Planck
(1858-1947)
German national

Awarded 1918 Nobel Prize in physics for analysis of blackbody radiation which contributed to rise of Quantum Mechanics

http://www-history.mcs.st-andrews.ac.uk/Mathematicians/Planck.html
Planck was able to explain blackbody radiation experimental data perfectly. But assumed light comes in little packets with energy given by

\[ E = h \nu \]

\( h \) \text{ constant}

found experimentally.

Planck's constant