Physics 100 - February 9, 2009

Maxwell's Equations

1873

James Clerk Maxwell

1831 - 1879 (Edinburgh)

"E" is symbol for electric field

"B" is symbol for Magnetic field

$$\oint_s \vec{E} \bullet d\vec{a} = \frac{Q_{encl}}{\varepsilon_o}$$

$$\int_s \vec{B} \bullet d\vec{a} = 0$$

$$\int_c \vec{E} \bullet d\vec{l} = -\frac{d\int_s B \bullet d\vec{a}}{dt}$$

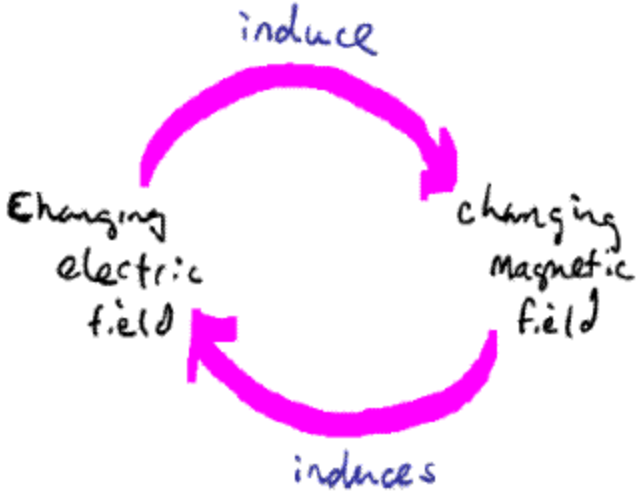
$$\int_c \vec{B} \bullet d\vec{l} = \mu_o I_{encl} + \mu_o \varepsilon_o \frac{d\int_s \vec{E} \bullet d\vec{a}}{dt}$$

- E, B are "unified" in one framework

  Deeper relationship understood by Einstein

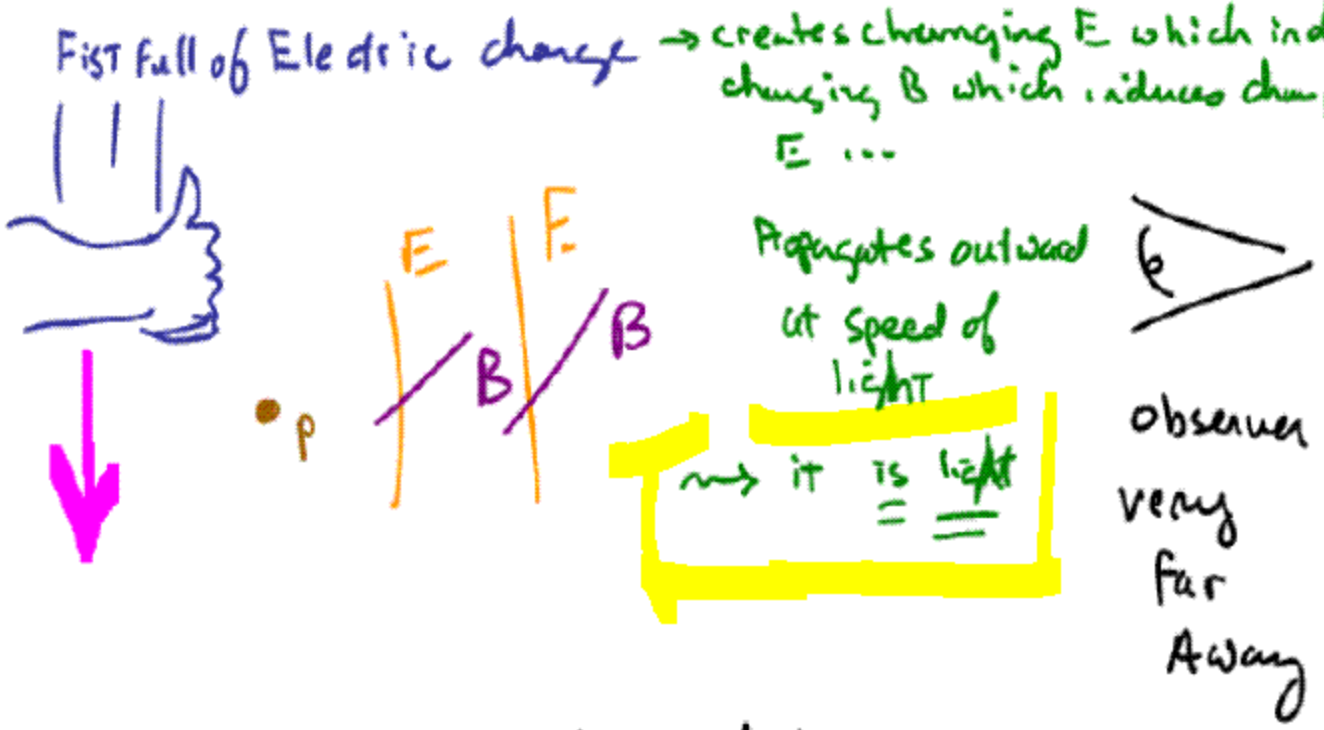
Maxwell unified Electric } forces
Magnetic }

into Electromagnetism



changing E induces changing B
induces changing E
⋮

Propagates out at speed of light!



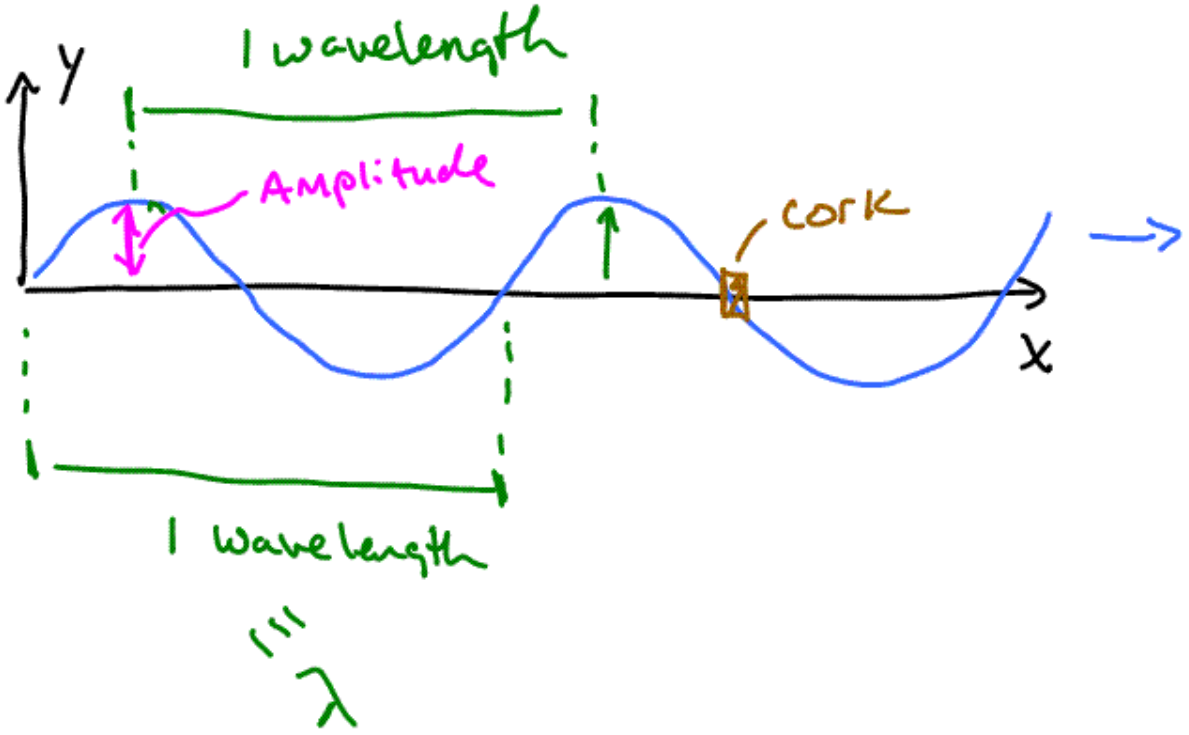
- Maxwell's eqns also tell us that
  E, B satisfy wave equations

Waves are a well-known mechanical phenomenon

Wave pulse traveling on a string

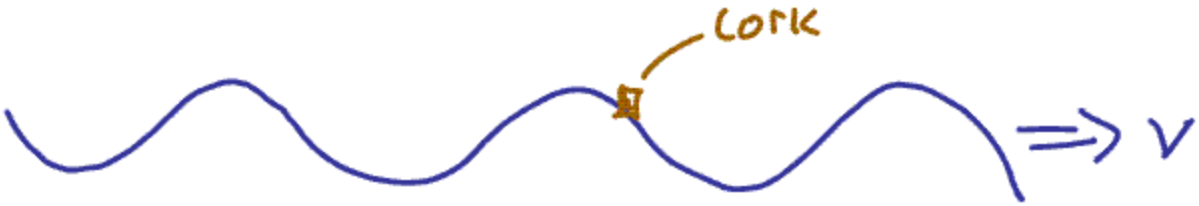
Waves

Anatomy of Wave



Period ≡ T of wave is time for "cork" to go through 1 full motion

$$\text{Frequency} \equiv \text{"f" or "}\nu\text{"} \equiv \frac{1}{T} = \text{Hertz} \quad \text{Hz}$$



imagine wave traveling on surface of water
with cork floating on surface

As wave moves past, the cork bobs up and down without moving to the right or left.
The amount of time it takes the cork to bob through one full cycle of its up and down motion is called a period. The symbol for the period of a wave is T.
T is measured in seconds.

The period is the amount of time it takes a wave to move a distance of one wavelength.

When I say E, B satisfy wave equations — it means Maxwell's equations can be written in a form similar to other equations whose solutions yield waves.

Light is a wave!

This is important because all waves share many basic properties ...

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

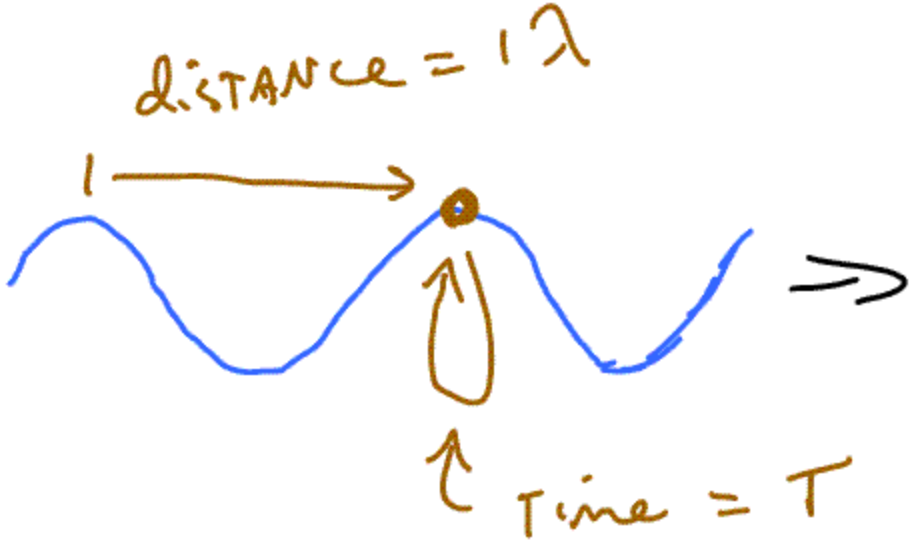
Superpostion of two waves – beats, standing waves
http://www.kettering.edu/~drussell/Demos/superposition/superposition.html

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

Different frequencies bend different Amounts ... called dispersion

Sound waves — Higher frequency → Higher pitch

Light waves — Higher frequency → bluer light



$$\text{Velocity of wave} = \frac{\lambda}{T}$$

Frequency of wave = $\frac{1}{T} = \frac{1}{\text{seconds}} \equiv$ Hertz $\equiv$ Hz

Sound waves at high frequency → you perceive as having high pitch

low frequency → low pitch

frequency corresponds to pitch in sound waves

light waves ~ high frequency more blue

low frequency more red

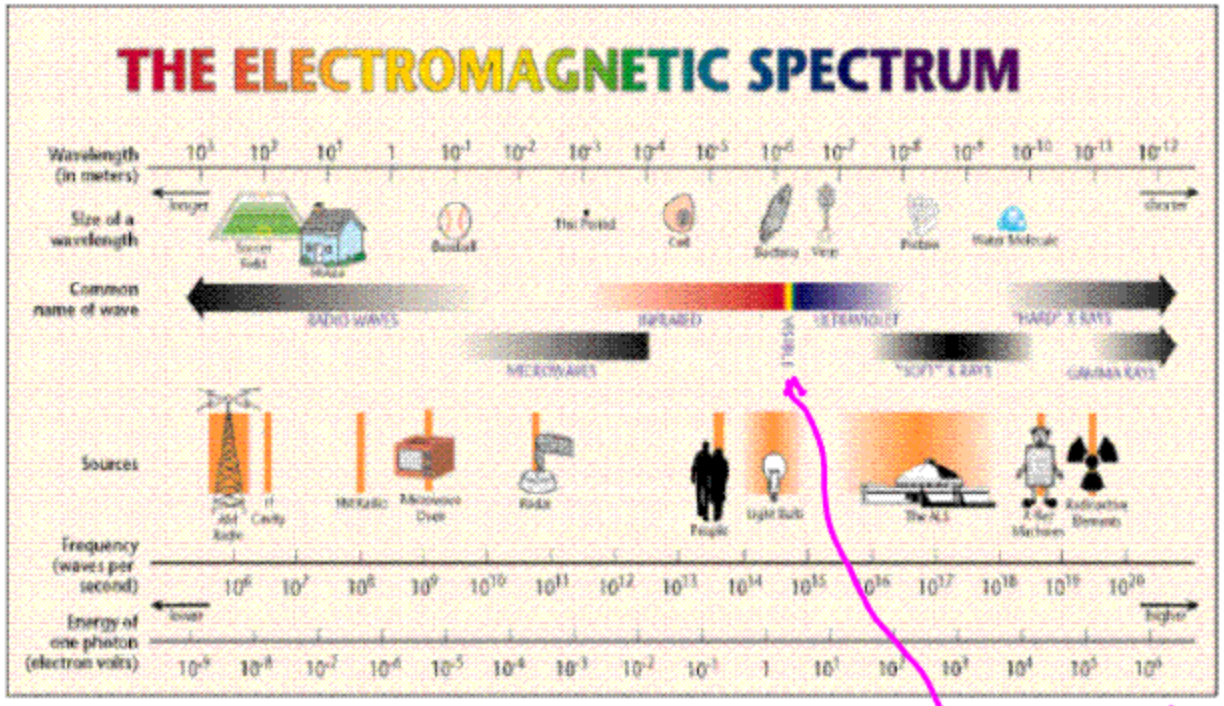
frequency corresponds to color in light waves

$$v = \frac{\lambda}{T} = \lambda\nu = \lambda f$$

Velocity = wavelength x frequency

upshot of all this...

We Know that light is a wave.



visible colors

- no real limits on wavelength / frequency
- visible light is but a tiny fraction of "colors" in universe

frequencies

interaction of light w/ matter is a very fundamental way to study the structure of matter.

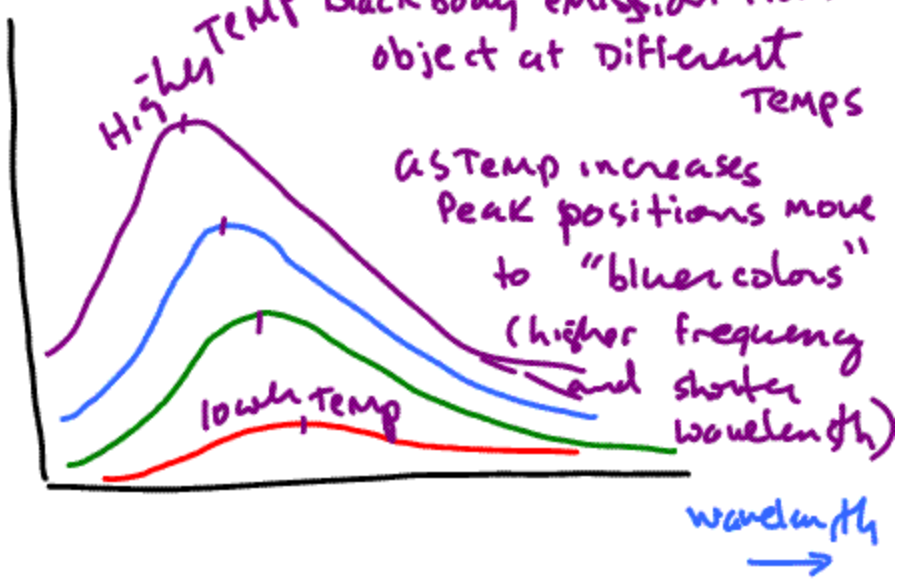
Best to study light emitted by object (not reflected)

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

"Blackbody radiation (emitted by object)



At time my best models of atoms and understanding of light as a wave physicists could NOT understand blackbody spectra theoretically.

Planck Succeeded!

But to do so he hypothesized

light → little packets w/ Energy given by

$$E = h\nu$$

Energy ↑ CONSTANT ↑ Freq.

Planck's CONSTANT

$\Rightarrow$ Blackbody

Planck's Theory worked perfectly ... but physicists thought it was a fortuitous Accident ... after all, light is a wave.