Exam 1, Feb 23

- Here - During normal class time
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- Calculators
Maxwell's Equations

James Clerk Maxwell
1831-1879 (Edinburgh)

"E" is symbol for electric field
"B" is symbol for magnetic field

Wave equations
Refraction
Diffraction
Interference

The variety of electromagnetic waves

Objects of similar size

Wavelength (in meters)

Radio waves
Infrarad light
Microwaves
Visible light
Ultraviolet light
X-rays
Gamma rays

1000
100
10
1
0.1
0.01
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
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 succeeded in describing Black body radiation

Light exists in packets of energy
Discrete Particle

"photons"

\[ E = h \nu \]

Planck's constant

Energy

Frequency

Planck's Theory worked perfectly... but physicists thought it was a fortuitous accident... after all, light is a wave.
Classical Wave theory was unable to account for the shape of the blackbody spectrum. Planck's theory fit the data perfectly but made the outlandish assumption that light comes in little packets.

Fantastic Blackbody radiation applet
From PhET, Interactive Simulations
Univ. of Colorado, Boulder

http://phet.colorado.edu/sims/blackbody-spectrum_en.html
Photoelectric effect

\[ E = h \nu \]
\[ E_{e^-} = E_\gamma - W \]
\[ E \geq \text{photon} \]

light incident on a metal surface ejects electrons

Energy of electron

\[ E_{e^-} \]

\[ \nu \text{ of light} \]

\[ \text{frequency of light} \]
Again—classical wave theory unable to describe photoelectric effect data.

Einstein—in 1905—proposed a model that accounted for the data—Assumed light comes in little packets of energy (E=\textbf{hv}) ... just like Planck’s assumption!

Fantastic Photoelectric effect applet from PhET, Interactive Simulations
Univ. of Colorado, Boulder

http://phet.colorado.edu/en/simulation/photoelectric
Standing waves demo

... discussed at length in recitation 4
Slight detour

MKS system $\rightarrow$ energy Joule

Power $\quad 1 \text{ watt} = 1 \text{ Joule/second}$

"Normal" unit

\[ 1 \text{ electron-volt} = 1 \text{ eV} \]
\[ = 1.6 \times 10^{-19} \text{ Joule} \]

has an energy of 1 electron-volt
\[ E = mc^2 \]
\[ \text{mass} = \frac{\text{eV}}{c^2} \]

- Mass of electron: \(0.511 \text{ MeV}/c^2 \rightarrow 0.511 \text{ MeV}\)
- Mass of proton: \(1 \text{ GeV}/c^2 \rightarrow 1 \text{ GeV}\)
mid-1920's
Louis de Broglie

hypothesized particles might have wavelike properties

Wavelength of particle $\lambda = \frac{h}{p} = \frac{h}{mv}$

$E = h\nu$
$\nu = \frac{c}{\lambda}$
$c = \lambda \nu$

$E = \sqrt{p^2c^2 + m^2c^4}$
$m = 0$  photon

$E = pc$  $p = \frac{E}{c}$

$\lambda = \frac{h}{p}$