The Story So Far...

Light Waves and Maxwell's Electromagnetism

Historical Background:

*You've really made it in physics when they name a unit for you

- Newton*(him again) (1642-1727
  - Light is a particle
- Christian Huygens (1629 - 1695)
  - Light is a wave
- Henry Cavendish (1731-1810), Charles Coulomb*(1736-1806)
  - $F_E \propto q_1 q_2, \propto 1/d^2$ (1772, 1785)
- Thomas Young (1773-1829)
  - Double slit experiment => light behaves like a wave (1800)
- Hans Christian Oersted* (1777-1851)
  - Noticed that a current creates a magnetic field (1820)

Historical Background:

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- Andre-Marie Ampere* (1175-1836)
  - Quantized Oersted's discovery for spherical charges (1820)
- Joseph Henry* (1797-1878), Michael Faraday* (1791-1867)
  - A changing magnetic field creates a current (1829, 1831)
- Carl Friedrich Gauss* (1777-1855)
  - Expanded Coulomb's law to non-spherical charges (1835)
  - Quantized the monopole law
- James Maxwell* (1831-1879)
  - Unified the four ideas mathematically (1864)

Maxwell's Equations

- Gauss's law of electric fields/ Coulomb's law:
  - The shape of, and charge on, an object, determine the electric field
- Gauss's law of magnetic fields/Monopole law:
  - Magnetic field lines form closed loops -- no monopoles
  - (Electric field lines don't form closed loops)

Maxwell's Equations

- Faraday's law:

  A changing magnetic field creates an electric current
- Ampere's law:
  - A changing electric field produces a magnetic field

What does this mean?

- Accelerating charges give off radiation
- Electric and magnetic fields are mathematically related
  - Electromagnetic field
- Speed of EM wave is c
- Light is an EM wave

Properties of EM Fields

- Usually generated by oscillating charges
- Freq. of oscillation = freq. of EM fields
- Electric field always orthogonal to magnetic field
- $v = f\lambda$ Universal wave equation
- Depending on λ, we perceive different types of radiation
- Electromagnetic spectrum

But do they exist?

- In physics, the math is lovely but we need experimental results
- Henrich Hertz* (1857-1894) experimentally verified EM waves (1888)
- He determined using universal wave equation that $v = c$
- You will check this result using a microwave and chocolate chips (or marshmallows)

Maxwell's Results

- Light travels at 3.00×10^8 m/s *always*
- He found this hard to believe
- Newton's 1st: objects maintain constant velocity
- Constant relative to what?
- There must be an absolute reference frame

If Light is a Wave…

- Waves need a medium to travel in
- What is the medium for light in space?

Enter the Ether

- 18th century: the medium is the *luminiferous ether*
- The absolute reference frame
- Infinitely elastic: no energy lost when things collide with it
- Massless
- Search for the ether => Michelson-Morley
- Read ahead: §§13.1, 13.2

Useful References

- http://www.amanogawa.com/archive/PlaneWave/PlaneWave-2.html
  - Accessed 08-12-03. Propagation of an EM wave
- http://lectureonline.cl.msu.edu/%7Emmp/applist/Spectrum/s.htm
  - Accessed 08-12-03. The electromagnetic spectrum
- http://physicsed.buffalostate.edu/Wiley/CJ6e/links24.html
  - Accessed 08-12-03. Includes links to the applets used in the presentation as well as to a site about putting CDs in the microwave which I do not condone under any circumstance

EQUATION OF THE WEEK

Maxwell's Equations

In honour of the International Year of Physics, Ideas asked 10 Canadian scientists and mathematicians to share their favourite equations. This is the eighth instalment.

$$\oint E \cdot dA = \frac{q}{\varepsilon_0}$$

Gauss's Law for Electricity

$$\oint B \cdot dA = 0$$

Gauss's Law for Magnetism

$$\oint E \cdot ds = \frac{-d\Phi_B}{dt}$$

Faraday's Law

$$\oint B \cdot ds = \mu_0 i + \frac{\mu_0 \varepsilon_0 d\Phi_E}{dt}$$

Ampere's Law

E = electric field
A = area
q = charge
ε_0 = permittivity of free space (a constant)
B = magnetic field intensity
s = path length
Φ_B = magnetic flux
Φ_E = electric flux
t = time
μ_0 = permeability of free space (a constant)
i = current electric charge
$\mu_0\varepsilon_0$ = $1/c^2$, where c=speed of light

Who loves it:
Michael Steinitz, organizer for the International Year of Physics Canadian celebration in 2005, and physics professor at St. Francis Xavier University.

What it all means:
Steinitz notes that Maxwell's equations were individually proposed by other scientists: Gauss, Faraday and Ampere. However, Maxwell realized that the four equations, when put together, "provide a consistent picture of almost everything you would want to know about electricity and magnetism." He adds that while the equations are derived from experimental observations of things like compass needles, together they allowed scientists to make some pretty amazing deductions, eventually leading to predictions about the nature of electromagnetic radiation. "You combine them and you get the description of a wave. And that just comes out of (observations) about compass needles. And when you do that," he adds, "you get a number for the speed of the wave and it turns out to be the speed of light."

Why it's his fave:
"Symmetry is everything. And the beauty of Maxwell's equations is that you see the symmetry between electricity and magnetism." Steinitz also says the conclusions drawn from Maxwell's equations were revolutionary. "The more you measure it, the more Maxwell was right. It's absolutely remarkable."

Next week: The bell curve

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