Basics of Electricity & Magnetism

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What’s an electron?

Model of the atom
Cartoon is deceptive.
This is a better image of electrons.

Static Electricity

- What’s electric charge?
  - Scotch tape activity
- Induced Charge vs. Charge Transfer
- Demos
  - Balloons
  - Fur, wool, plastic, & glass

Electric Fields

- Where’s the field?
  - The field indicates a force that can push on a charged particle.
  - Van de Graaff generator

Electric Potential

- Equipotential Lines
  - Always perpendicular to lines of force
  - No work to move charges along lines
  - Takes work (energy) to cross lines

Current Electricity

- Circuit game - What’s it like to be an electron?
Series Circuits

What happens when a light burns out?
The problem with the Christmas lights…

Current vs. Voltage vs. Power
- Current = # of electrons per second
- Voltage = energy per electron
  - Also called “Electrical potential” or “Potential difference”
- Power = energy (of all electrons) per second
  - High voltage won’t kill, but high current will!

Parallel Circuits

What happens here?
- Act it out if you aren’t sure…

How do you jump start a car?
- Series or parallel?
What’s going on here?
- Tesla Coil & Fluorescent Light bulb
- Plasma Ball Lab

AC vs. DC
- Direct Current
  - Batteries
  - Current is constant
- Alternating Current
  - Wall socket
  - Current oscillates
- Why the difference?
  - AC travels better over long distances
  - $P=I^2R$, smaller current = less lost power

Generating AC current

Generating Electricity
- Identify the energy transformations:
  - Hand-held generator
  - Windmill
  - Hydroelectric Power
  - Nuclear Power
  - Coal Power (steam generator)

Magnetic Fields
- What do the fields look like?
  - Map using iron filings
- The presence of a field means there’s a force!

Types of Magnets
- The refrigerator vs. the fridge magnet
- Magnetic Domains
Examples
- Ring Magnets
  What forces are acting here? Why do they balance?
- Floating Globe
  The earth has a magnetic field, is this how it stays in orbit?

Electromagnetism
- What's the relationship?
- Use the compass and current-carrying wire to find out.

Electromagnetism (in reverse)
- Can a magnet create a current?

Examples - Eddy Currents
- Battery free flashlight
- Eddy currents
- Ring launcher
- Can Crusher (at Plasma Expo)

Motors
- A force is created by the current in the magnetic field. It makes the wire loop spin.

Can you make a motor from this?
Mini Motor

A motor in reverse.

Turning the loop creates a current in the wire.

Generating AC current

Maxwell’s Equations

- Gauss’ Law
  \[ \oint E \cdot dA = \frac{\partial \Phi_B}{\partial t} \]
- Faraday’s Law
  \[ \oint E \cdot ds = -\frac{d\Phi_B}{dt} \]
- Ampere’s Law
  \[ \oint B \cdot ds = \mu_0 \sigma_0 \frac{df}{dt} + \mu_0 \text{enc} \]

Electromagnetic Radiation

- Maxwell’s Equations predict the speed of light.
  \[ c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \]

- So light must be an electromagnetic wave

What is a light wave?

- Electromagnetic Waves
How do we make EM waves?

1. Start with an antenna with an AC current
2. Build up of electrons creates a net charge
3. Therefore, an E-field
4. As e⁻’s move, E-field oscillates
5. E-field makes a B-field we get an EM wave

The EM Spectrum

Measuring the speed of light in the microwave

- Recall standing waves…

- Microwave frequency = 2450 MHz