How Things Work II
(Lecture #14)

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Course web site available through COD and Toolkit
or at http://people.virginia.edu/~gdc4k/phys106/spring08

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Quiz directions
(and other announcements)

• Please do not open your quiz booklet until told to do so.
• On your quiz booklet, please fill out your name, email address, and sign the pledge.
• On your bubble sheet, be certain to bubble in your UVA COMPUTING ID. Also, please fill out your name, the date, and the class name (Physics 106). All other fields may be left empty.
• Office hours today (Monday) from 2 until 3:30. They will probably start in my office (106a), and may move to Room 120.
Power

- Power is energy per unit time.
- Power is measured in Joules/second or Watts.
- Batteries are power sources.
- Loads are power consumers.
Power produced by batteries

- **Current**: units of charge pumped per second. In SI units current is measured in Amperes = Coulombs/second.

- **Voltage**: energy imparted per unit of charge. In SI units voltage is measured in Volts = Joules/Coulomb.

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\text{power produced} = \text{current} \cdot \text{voltage rise}
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Power consumed by loads

- Current is units of charge that pass through per second.
- Voltage drop: energy consumed per unit of charge.

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\[
\text{Coulombs per second} \times \frac{\text{Joules}}{\text{Coulombs}}
\]
Power consumed by loads

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Electric Power Distribution
Question:

Electric power reaches the University via high voltage transmission lines. What fraction of the electric charge in the electricity we are using in this lecture hall traveled on those transmissions lines?

A. Roughly 100%
B. Roughly 10%
C. Roughly 1%
D. Roughly 0.01%
E. Exactly 0.0%.
Observations About Power Distribution
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• Power transformers are visible everywhere.
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• Household power is AC (alternating current).
• Power comes in voltages like 120 V and 240 V.
• Power is transmitted at “high voltage”.
• Power transformers are visible everywhere.
• Power substations are visible on occasion.
Ohm’s Law

• The currents passing through most wires and other devices experience voltage drops.
• In an “ohmic device”, the voltage drop is proportional to the current:

\[ \text{voltage drop} = \text{current} \cdot \text{resistance} \]

\[ V = I \cdot R \]

where resistance is considered constant for the device
Power in Ohmic Devices

- A calculation:
  \[ \text{power consumed} = \text{current} \cdot \text{voltage drop} \]
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Power in Ohmic Devices

- **A calculation:**
  \[ \text{power consumed} = \text{current} \cdot \text{voltage drop} \]

  - Ohm's Law:
    \[ \text{voltage drop} = \text{current} \cdot \text{resistance} \]
  
- **So ....**
  \[ \text{power consumed} = \text{current} \cdot \text{current} \cdot \text{resistance} \]
  
- **Power consumed:**
  \[ \text{power consumed} = \text{current}^2 \cdot \text{resistance} \]

- **Impact of the calculation:**
  - Wires waste power as heat.
  - Doubling current QUADRUPLES wasted power.
Power Transmission

• Power delivered to a city is given by:
  \[ \text{power consumed} = \text{current} \cdot \text{voltage drop} \]

• Power wasted in transmission wires is given by:
  \[ \text{power wasted} = \text{current}^2 \cdot \text{resistance} \]

• For efficient power transmission:
  – Use low resistance wires (thick, short copper).
  – Use low current and high voltage drop.
Voltage Hierarchy

• High voltage is dangerous.
• High current is wasteful.
• Use the following hierarchy:
  – Low voltage circuits in neighborhoods.
  – Medium voltage circuits in cities.
  – High voltage circuits for transmission across the countryside.
• Use transformers to transfer power and convert from one voltage to another.
Transformers

- Alternating current in one circuit induces an alternating current in a second circuit.
- The transformer can convert the voltage up or down!
- Transfers power between the two circuits.
- Doesn't transfer charge between the two circuits.