Electrostatics Cont.

Physics Open House

Wednesday, November 5th
Lab Tours!
Free Pizza and Soft Drinks!
Star Party at Campus Observatory!
Learn about the Physics Department and our majors

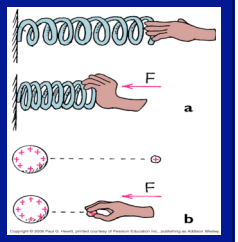
Potential Energy vs. Electric Potential

- A charged object has P.E. because of its location in an electric field

$$\text{electric potential} = \frac{\text{electric potential energy}}{\text{charge}}$$

  - Dividing by charge => electric potential only property of electric field
  - Voltage

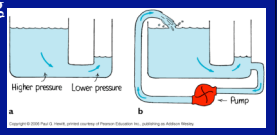
$$1 \text{ volt} = 1 \frac{\text{Joule}}{\text{Coulomb}}$$



Work is required to bring like charges together. Twice the charge = twice the work.

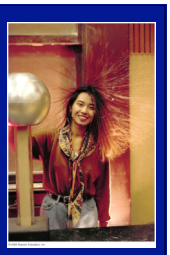
Voltage Sources

- Charge flows from one end of a conductor to the other as long as they are at different electric potentials
  - Current requires a potential difference or *voltage*
    - Acts like an "electrical pump" which keeps charge flowing
      - Batteries, generators, etc.
  - Similar to heat flow from hot to cold ends of a conductor
    - Ceases when temperatures equalize



Water will flow from a higher reservoir to a lower one. Once the water levels are equal, the flow stops. A pump can yield a continuous flow by maintaining a pressure difference.

Clicker Question:



What makes somebody's hair stand out when they touch the charged sphere?

A: Free protons try to spread out as far as they can.

B: Free electrons try to spread out as far as they can

C: Hair is highly conductive so the electrons travel down it more readily.

D: Actually has nothing to do with charge.

Clicker Question:

Is it possible to charge something up without making physical contact with another charged body?

A: Yes

B: No

C: Can't say.

Electric Currents

Incredibly useful for technology

- Moving power around, ...
- circuits (electronics)
- electric motors, fans, pumps, ...
- electric heaters, ovens, ...
- computers, phones, ipods, ...

Safety Tips

When working with delicate electronics:

PPE: wear a wrist strap (avoids static discharges)

PPE: take your shoes off, avoid carpet

When working with currents:

PPE: wear insulated shoes

put one hand behind your back

Electric Current

- Charge flows from one end of a conductor to the other <u>as long as they are at different electric potentials</u>
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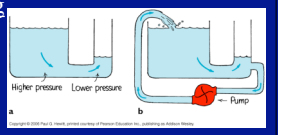
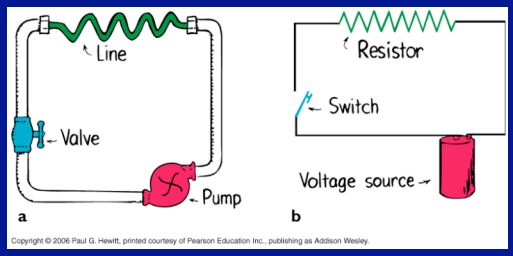


Water will flow from a higher reservoir to a lower one. Once the water levels are equal, the flow stops. A pump can yield a continuous flow by maintaining a pressure difference.

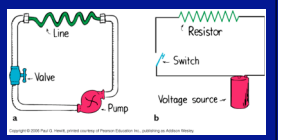
Circuits

- What is it that flows through an electrical circuit?



Circuits

- Charged particles flow through an electric circuit
  - In a metal, the free conduction electrons flow
  - In fluids, it is often the positive ions that flow
- Charge carriers flow *through* a circuit due to an applied voltage *across* the circuit



Water flows through a pipe as long as there is a difference in pressure between its ends. Only the water flows, not the pressure.

DEMO - High Current

Electrical Resistance

- What factors determine the rate that water flows through a pipe?

Electrical Resistance

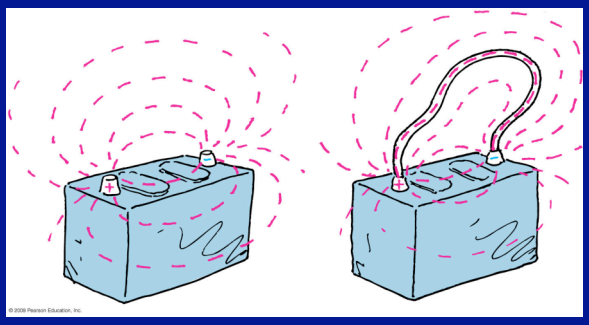
- What factors determine the rate that water flows through a pipe?
  - The pressure difference
  - The resistance of the pipe to flow
    - Thicker pipe => less resistance
    - Longer pipe => more resistance
- Similar to electrical resistance
  - Current depends on voltage and on properties of conductor
    - Thicker wire => less resistance
    - Longer wire => more resistance
    - Colder wire => less resistance
    - Copper less resistant than steel

More water flows through a thick hose than through a thin hose connected to the same water source (same pressure).

DEMO - resistence and temperature

Figure 23.13

How much current flows in these two cases?



Ohm's Law

- Does the current in a circuit increase or decrease as
  - the applied voltage is increased?
  - the resistance of the circuit is increased?

Ohm's Law

- Does the current in a circuit increase or decrease as
  - the applied voltage is increased? Increase
  - the resistance of the circuit is increased? Decrease
- *The current in a circuit is directly proportional to the voltage across the circuit and inversely proportional to the resistance.*

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}} \qquad \text{Amperes} = \frac{\text{volts}}{\text{ohms}}$$

Clicker Question:

Will you get shocked if you touch both terminals of a battery?

A: Yes

B: No

C: Depends on the voltage of the battery

Clicker Question:

Say you have a battery in a circuit with a total resistance of 1000 ohms. If you lower the resistance to 100 ohms, what happens to the amount of current flowing through the circuit?

A: Goes down by a factor 10

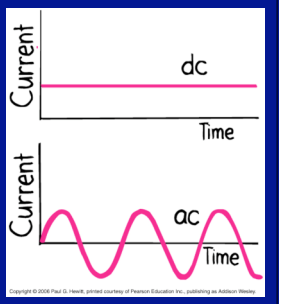
B: Stays the same

C: Goes up by a factor of 10

D: Goes up by a factor of 100

Direct Current and Alternating Current

- Direct Current (DC)
  - Charges flow in only one direction
  - Terminals of a battery always have the same polarity
    - Electrons repelled by negative terminal and attracted to positive terminal
- Alternating Current (AC)
  - Charges oscillate back and forth (no net displacement)
    - Generators, Power in homes
      - North America: 60-hertz



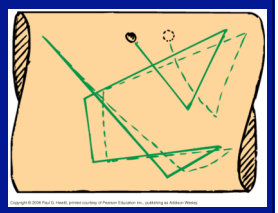
An AC generator changes the polarity of the voltage 60 times a second.

Speed and Source of Electrons in a Circuit

- How fast do the electrons move through
  - a DC circuit?
  - an AC circuit?

Speed and Source of Electrons in a Circuit

- DC circuit => *drift velocity* of about 1/100th cm/s
- Electrons in an AC circuit have a net drift velocity of zero!
- Electric field travels through the circuit at speed of light
  - Causes electrons all along wire to "move in step"
    - Current not caused by collisions
    - Collisions are related to resistance



Solid line: Random motion of an electron bouncing around in atomic lattice of a metal (~1/200th the speed of light)

Dashed line: Altered path in the presence of an electric field.

Superconductors

- Resistance in metals goes down with decreasing Temperature
- Some metals become superconducting at low temperatures.
- Some ceramics can be superconducting at higher temperatures.

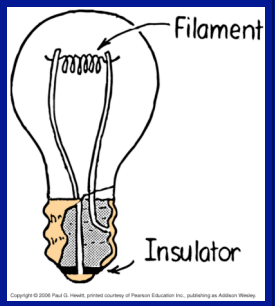
Material	Type	T_c(K)
Zinc	metal	0.88
Aluminum	metal	1.19
Tin	metal	3.72
Mercury	metal	4.15
$YBa_2Cu_3O_7$	ceramic	90
TlBaCaCuO	ceramic	125

- Superconductor:
  - resistance goes to 0
  - currents circulate forever

Demo superconductor

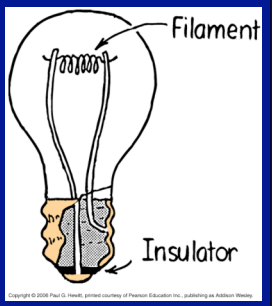
Let There Be Light!

- What makes the bulb give off light?



Let There Be Light!

- What makes the bulb give off light?
  - The resistance of the filament (due to collisions) causes heating => filament glows
- Where do the electrons come from?



Let There Be Light!

- What makes the bulb give off light?
  - The resistance of the filament (due to collisions) causes heating => filament glows
- Where do the electrons come from?
  - They are already there in the metal.
    - The electric company supplies energy (as an electric field) not electrons!

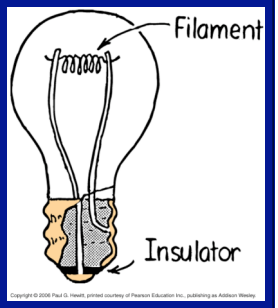
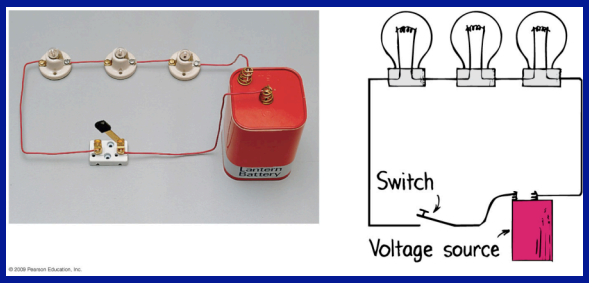


Figure 23.17

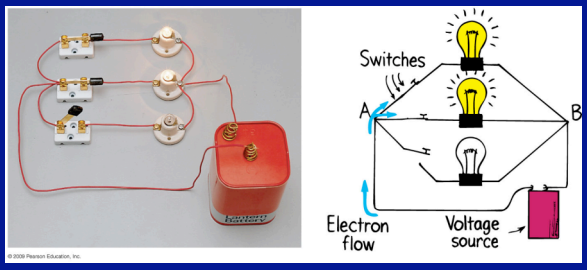
Circuit in Series



DEMO

Figure 23.18

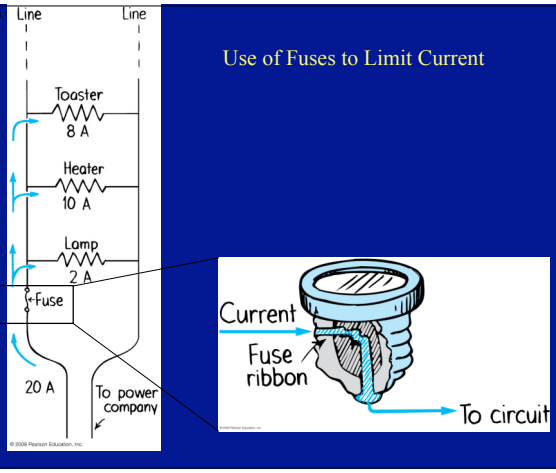
Circuit in Parallel



DEMO

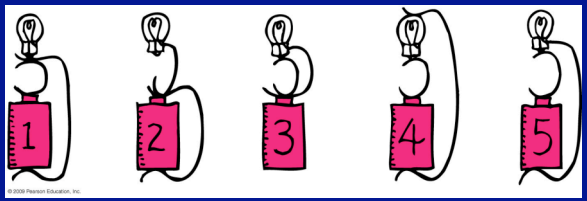
Figure 23.

Use of Fuses to Limit Current



Unnumbered Figure 23.2

Which one of these bulbs will be lit?



A B C D E

Clicker Question:

Would a room temperature superconducting filament make for a good lightbulb?

A: Yes

B: No