PHY294H

- Professor: Joey Huston
- email:huston@msu.edu
- office: BPS3230
- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - **Problem 29.77 (already assigned) will be the hand-in problem for 4th MP assignment (due Wed Feb. 10)**
  - **Help-room hours: 12:40-2:40 Tues; 3:00-4:00 PM Friday**
- Quizzes by iclicker (sometimes hand-written)
- Exam next Thursday: bring 1(-sided) 8.5X11” sheet of notes
  - practice exam available today
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

Conductivity and resistivity

- Define the conductivity of a material

$$\sigma = \text{conductivity} = \frac{n_e e^2 \tau}{m}$$

- The conductivity of a material characterizes the material as whole
- The current density J is related to the conductivity and the electric field by

$$J = \sigma E$$

- Can define the resistivity as the reciprocal of the conductivity->how difficult is it for the electrons to move

$$\rho = \text{resistivity} = \frac{1}{\sigma} = \frac{m}{n_e e^2 \tau}$$

Conductivity and resistivity

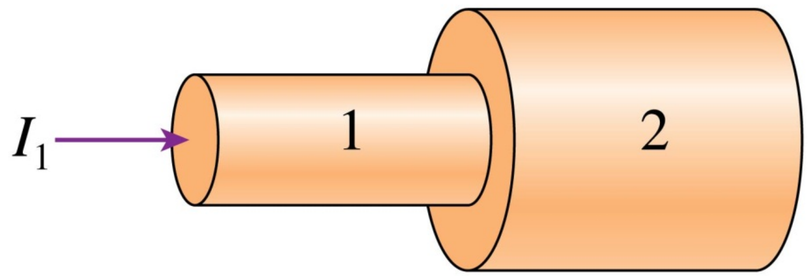
TABLE 30.2 Resistivity and conductivity of conducting materials

Material	Resistivity (Ω m)	Conductivity (Ω^{-1} m^{-1})
Aluminum	2.8×10^{-8}	3.5×10^{7}
Copper	1.7×10^{-8}	6.0×10^{7}
Gold	2.4×10^{-8}	4.1×10^{7}
Iron	9.7×10^{-8}	1.0×10^{7}
Silver	1.6×10^{-8}	6.2×10^{7}
Tungsten	5.6×10^{-8}	1.8×10^{7}
Nichrome*	1.5×10^{-6}	6.7×10^{5}
Carbon	3.5×10^{-5}	2.9×10^{4}

*Nickel-chromium alloy used for heating wires.

iclicker question

- Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left. How does current I_1 in segment 1 compare to current I_2 in segment 2?



A. $I_1 > I_2$.

B. $I_1 = I_2$.

C. $I_1 < I_2$.

D. There's not enough information to compare them.

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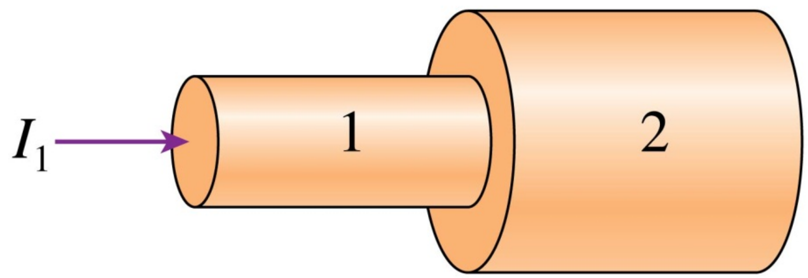


A. $I_1 > I_2$.

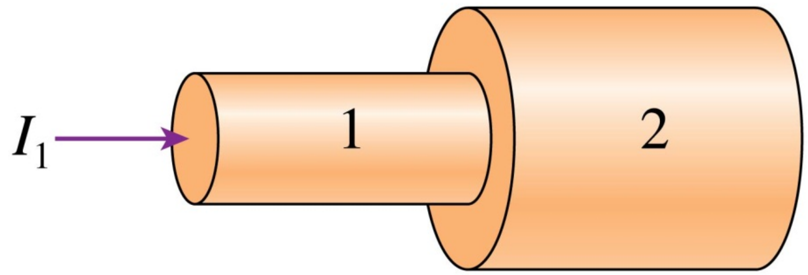
B. $\boldsymbol{I_1 = I_2}$. Conservation of current

C. $I_1 < I_2$.

D. There's not enough information to compare them.

iclicker question

- Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left. How does current density J_1 in segment 1 compare to current density J_2 in segment 2?



A. $J_1 > J_2$.

B. $J_1 = J_2$.

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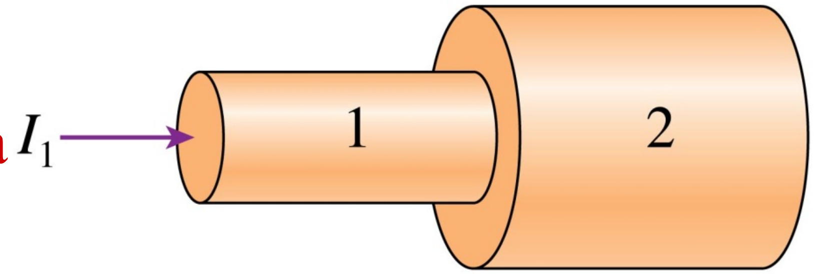


A. $\boldsymbol{J_1 > J_2}$. Smaller cross-section area

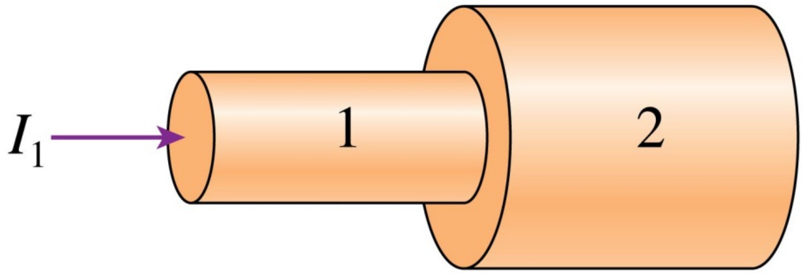
B. $J_1 = J_2$.

C. $J_1 < J_2$.

D. There's not enough information to compare them.

iclicker question

- Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left. How does the electric field E_1 in segment 1 compare to the electric field E_2 in segment 2?



A. $E_1 > E_2$.

B. $E_1 = E_2$ but not zero.

C. $E_1 < E_2$.

D. Both are zero because metal is a conductor.

E. There’s not enough information to compare them.

iclicker question

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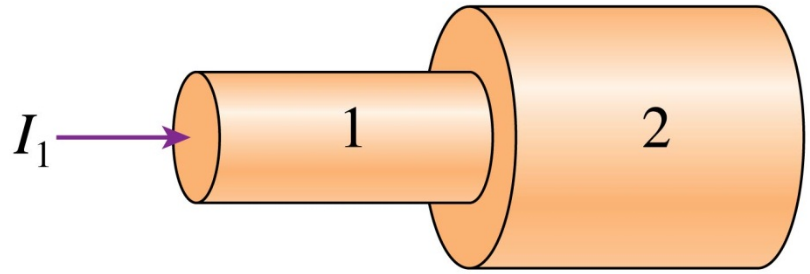


A. $\boldsymbol{E_1 > E_2}$**.** $J = \sigma E$

B. $E_1 = E_2$ but not zero.

C. $E_1 < E_2$.

D. Both are zero because metal is a conductor.

E. There's not enough information to compare them.

DC circuits

- Remember the current density

$$J = \sigma E = \frac{E}{\rho}$$

- So

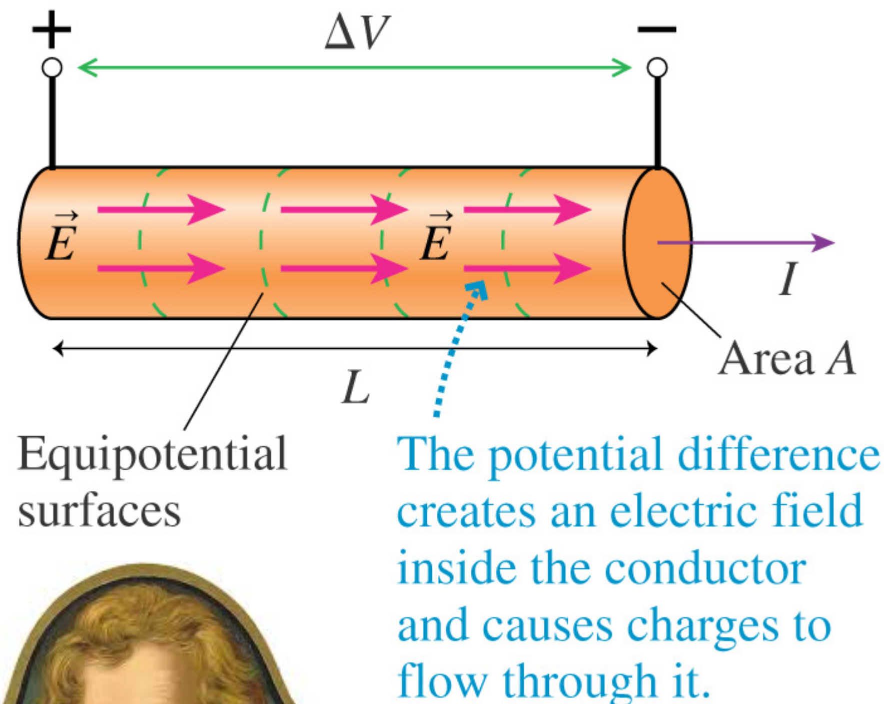
$$I = JA = \frac{E}{\rho} A = \frac{\Delta V / L A}{\rho} = \frac{\Delta V}{(\rho L / A)}$$

- The quantity R is the resistance of the conductor with units =V/A=Ω(ohms)

$$R = \rho \frac{L}{A}$$

- We can write the current I as

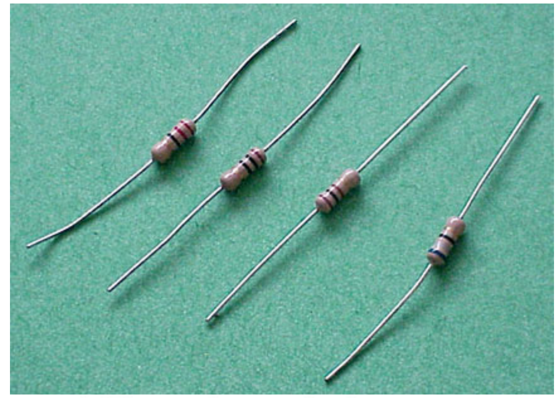
$$I = \frac{\Delta V}{R}$$

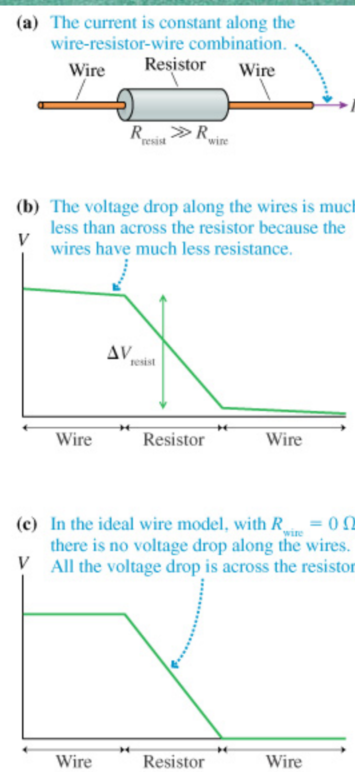


Current depends on voltage and resistance.

Resistors

- Conducting wires actually have a very small resistance
  - typically R<<1 Ω
- It's useful to use in circuits devices with a specific value of resistance (typically >> the resistance of the conducting wires)
- These devices are called resistors
  - typically 10 to 1E6 Ω
- Materials known as insulators have a very large resistance
  - typically $>>10^9$ Ω

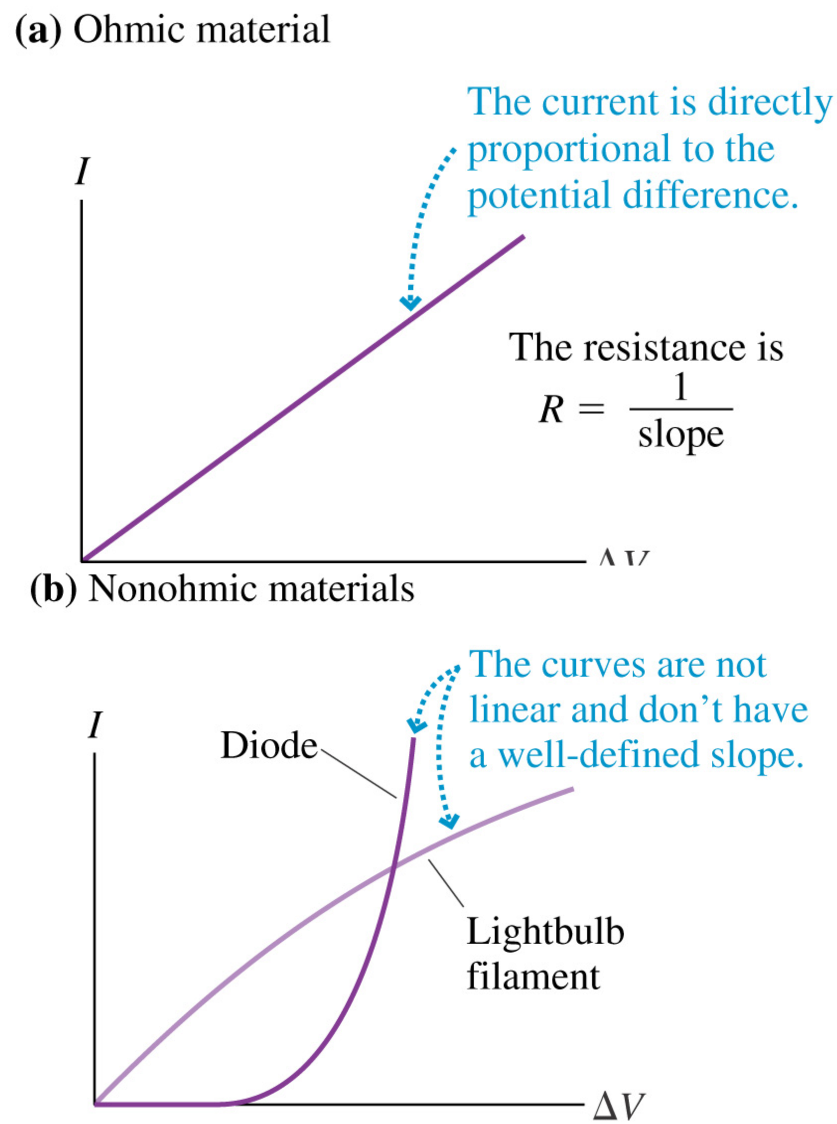





Resistance is futile
(if < 1 ohm)

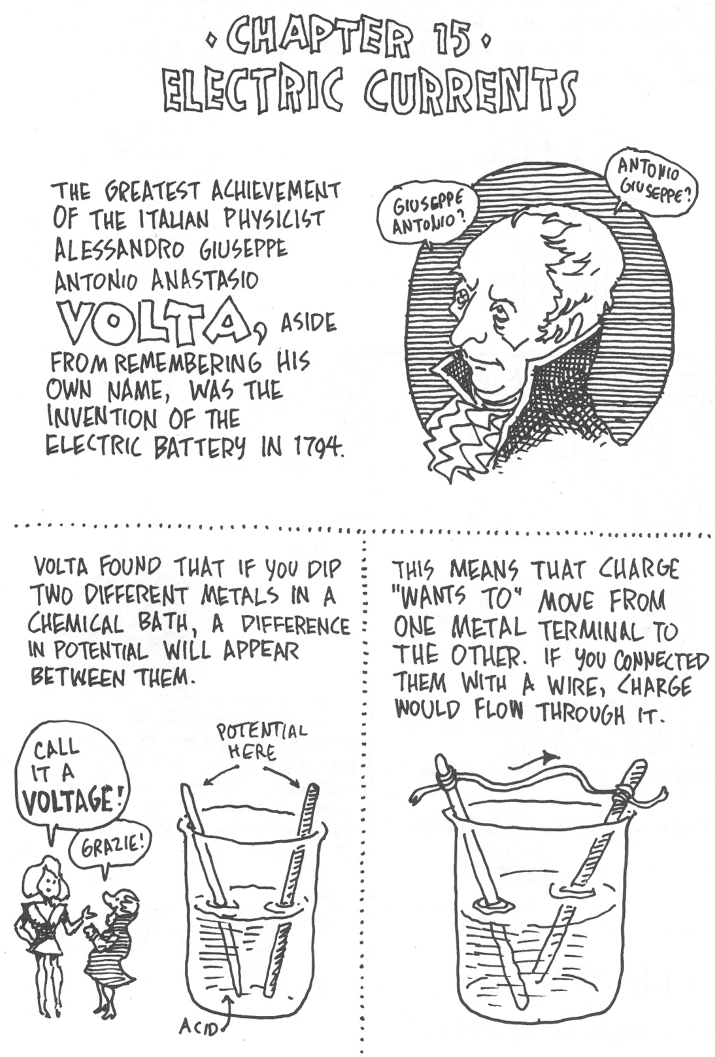
Ohm's law

- For some materials, the resistance is independent of the current, i.e. the current is directly proportional to the potential difference
  - these materials are said to follow Ohm's law
- Other materials are said to be non-Ohmic



Batteries

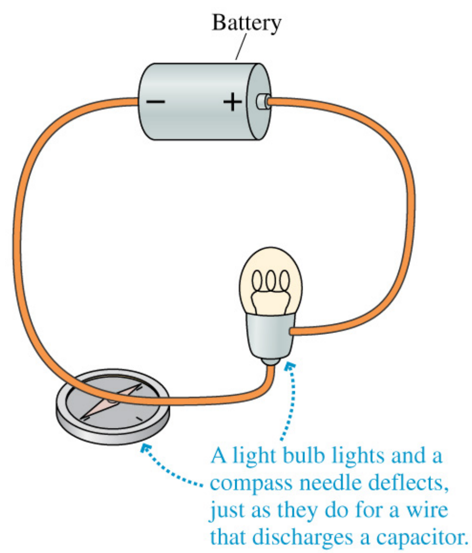
- Volta found that when he stuck two dissimilar metals on his tongue, he got an electric shock
  - kids, don't try this at home!
- He also found that he could create electric currents not using his tongue but with voltaic cells or batteries
- Galvani at this time also was performing experiments in which he showed that by touching a battery to dead frog legs, he could get them to move

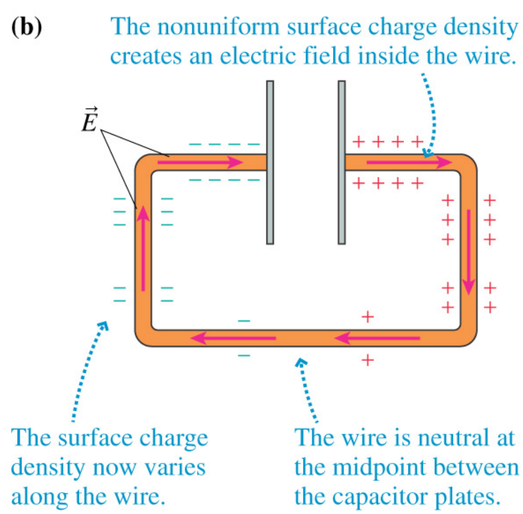


from cartoon history of physics

Battery and Current

- I can also get a current of electrons to move through a conductor using a battery
- The electrical current is the same as we got by discharging the capacitor, except that the current from the capacitor will quickly die away while the current from the battery will continue
  - as long as the chemical reactions in the battery continue





Don’t listen to “Ask Earl”

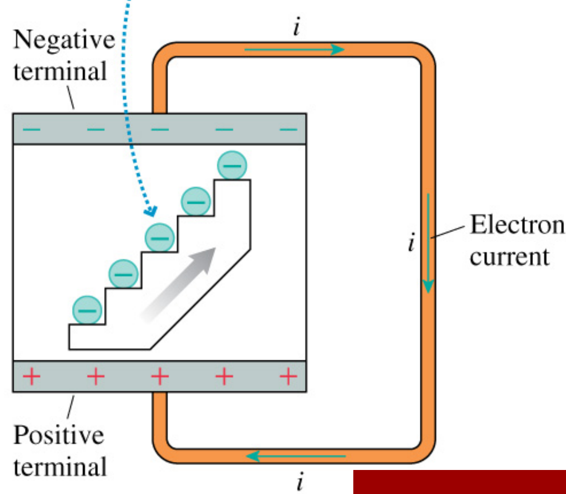
- Note that the battery does not supply the current; the electrons are already in the conductor
  - it only supplies the energy

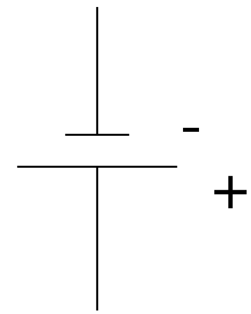
- **Dear Earl,** How does a battery work? ***Ashley, Age 13***
- **Dear Ashley,**A battery is basically a container of chemicals that creates electrons. When you put a battery in a radio, these electrons rush from the negative terminal of the battery to the positive terminal, powering the radio. **Electricity** is simply the movement of electrons through a conductive material like a copper wire. An Italian man named Alessandro Volta made the first battery in 1800. He discovered that different types of metals, when placed next to each other in salt water, create an electrochemical reaction which creates a current of electrons.***Earl***

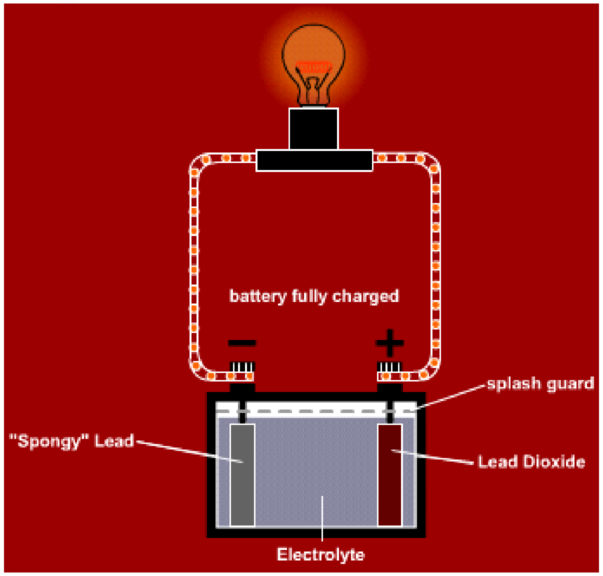
Workings of a battery

- Simple version: there's an escalator inside the battery that lifts the (negative) charges from the + terminal to the - terminal
- Slightly more complex version: there is a + terminal (anode), a - terminal (cathode) and an electrolyte that connects the two electrodes chemically. Chemical reactions proceed in the battery such as
  - $Pb + PbO_2 + 2H_2SO_4 \text{ ---> } 2PbSO_4 + 2H_2O$

The "charge escalator" inside a battery continuously "lifts" electrons from the positive to the negative terminal. This renewal of charge sustains the electron current.

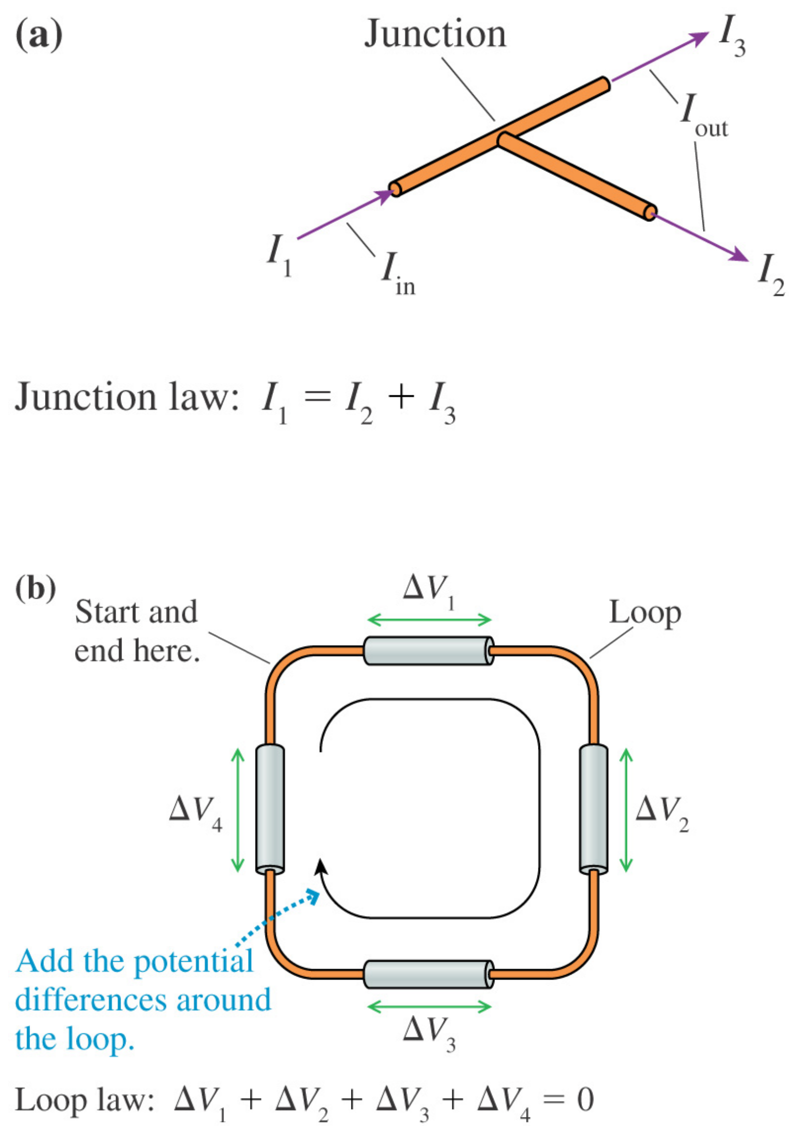






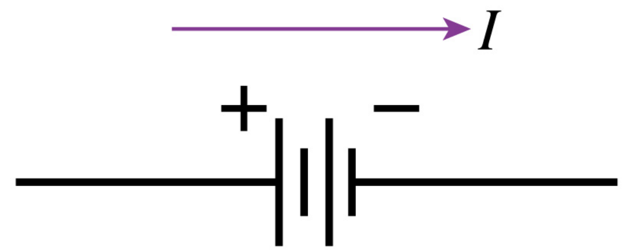
Kirchoff's laws

- We discussed them before, now we're going to use them
- The junction law is essentially a statement of the conservation of charge
- The loop rule is a statement of the conservation of energy

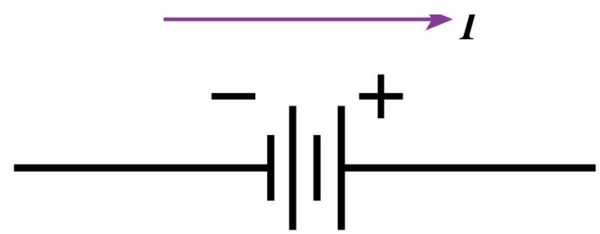


Rules

- Potential decreases in going from + terminal to - terminal
  - $\Delta V = -\varepsilon$
- And increases in going from - terminal to + terminal
- Potential decreases in going across resistor in direction of current flow
  - $\Delta V = -IR$
- And increases when going across resistor against the direction of current flow



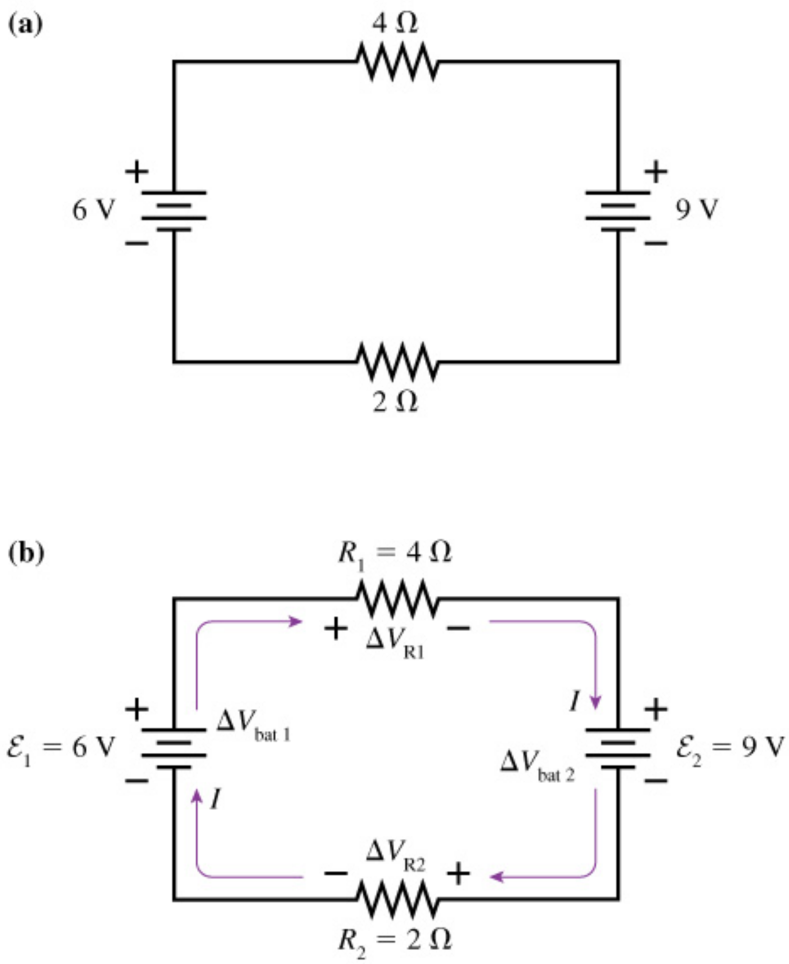
Potential decreases

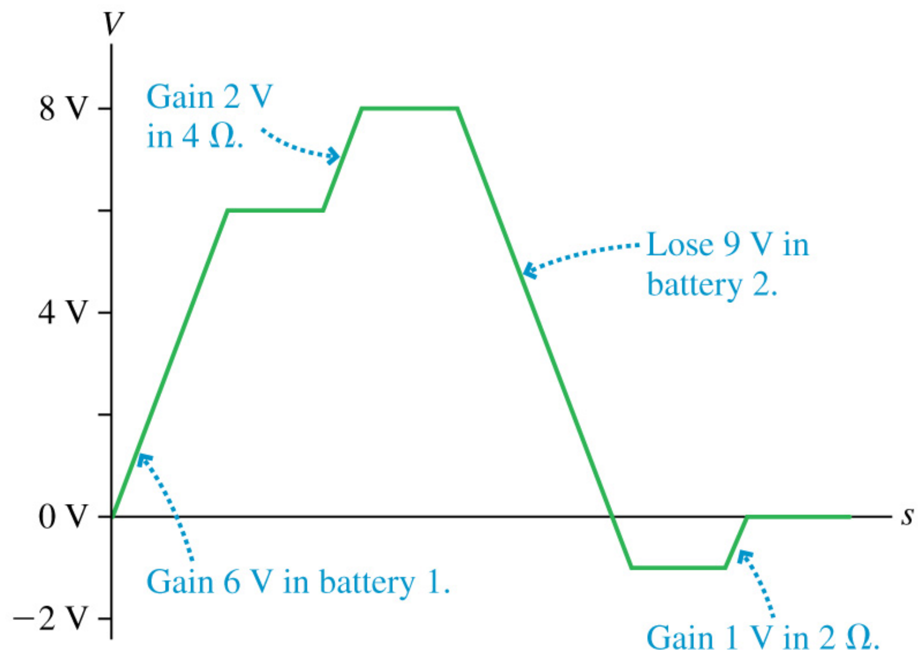


Potential increases

Potential decreases

Simple circuit





$$\sum_{loop} \Delta V = \varepsilon_1 - IR_1 - \varepsilon_2 - IR_2 = 0$$

$$I = \frac{\varepsilon_1 - \varepsilon_2}{R_1 + R_2} = \frac{6V - 9V}{4\Omega + 2\Omega} = -0.5A$$

current is opposite direction of what we drew