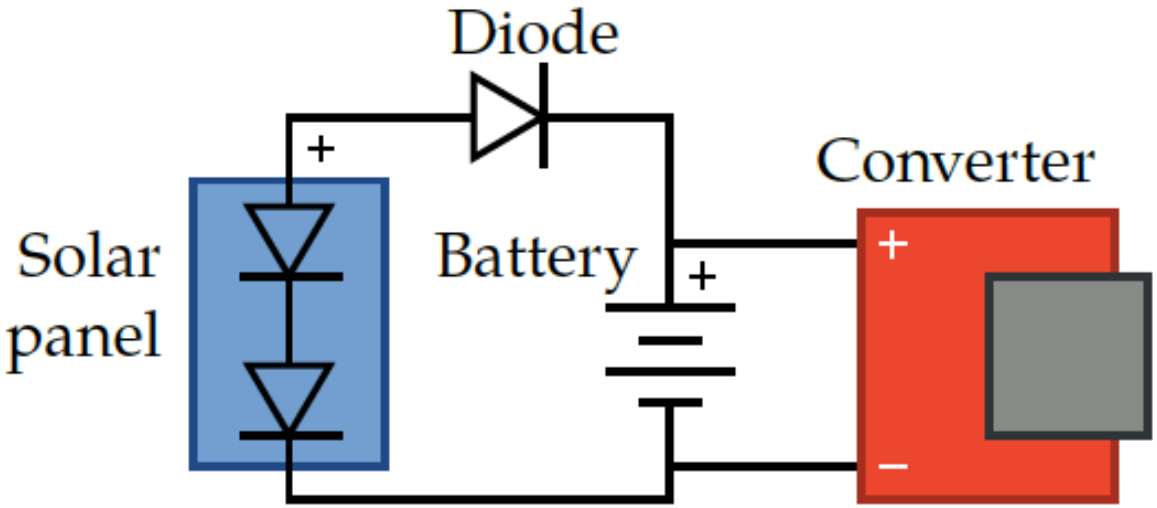
E40M
Charge, Current, Voltage and Electrical Circuits

Understanding the Solar Charger – Lab Project #1



We need to understand how:

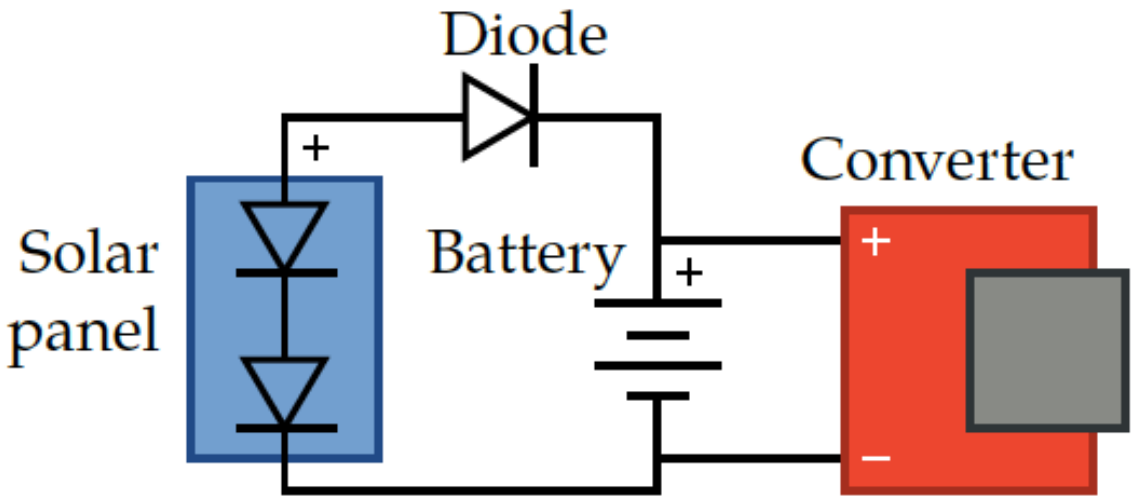
1. Current, voltage and power behave in circuits
2. Electrical devices constrain current and voltage
3. Diodes including solar cells work
4. Voltage converter works (later in the quarter).

What Does It Do?

- Takes energy from sun light
- Stores it
- Provides that energy later
  - To charge your cellphone
  - Create reading light, flashlight

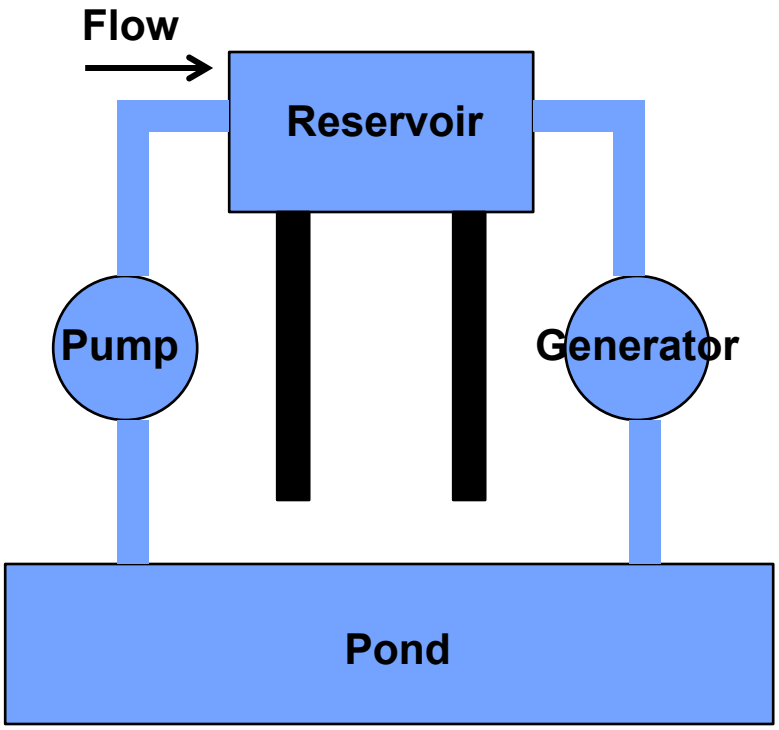
How does it do that?

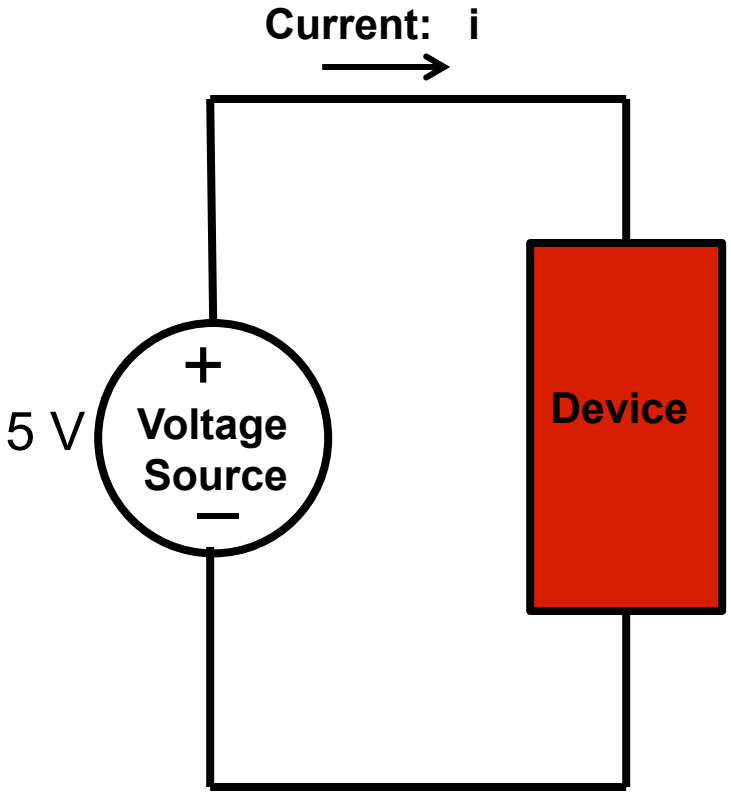
How Our Solar Charger Works



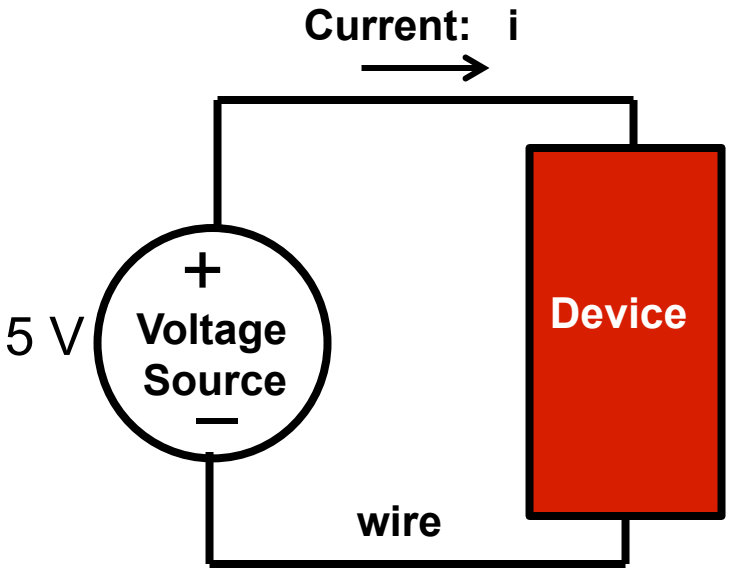
- Converts some energy from sunlight into an electrical signal
- That **electrical signal** connects to a rechargeable battery
  - So energy flows from solar cell to battery
- Another electrical signal connects the battery to the USB port
  - So energy can flow to the USB, and charge your phone
- So we need to understand electrical signals

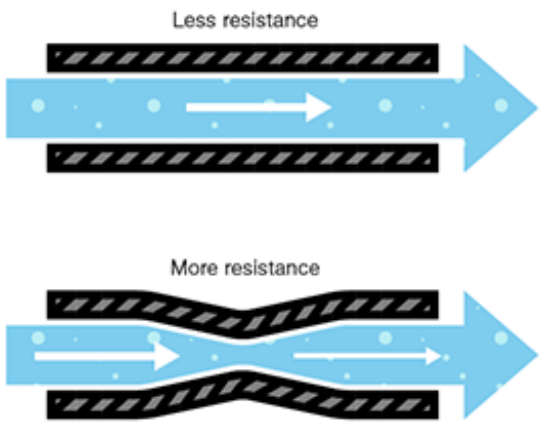
Fluidic "Circuits" ≅ Electrical Circuits





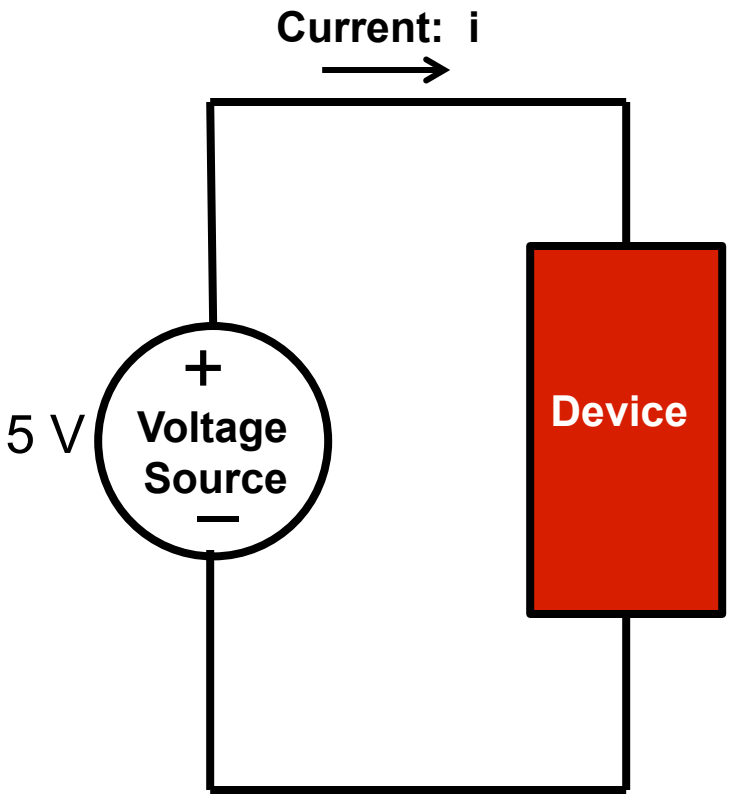
Electrical Charge





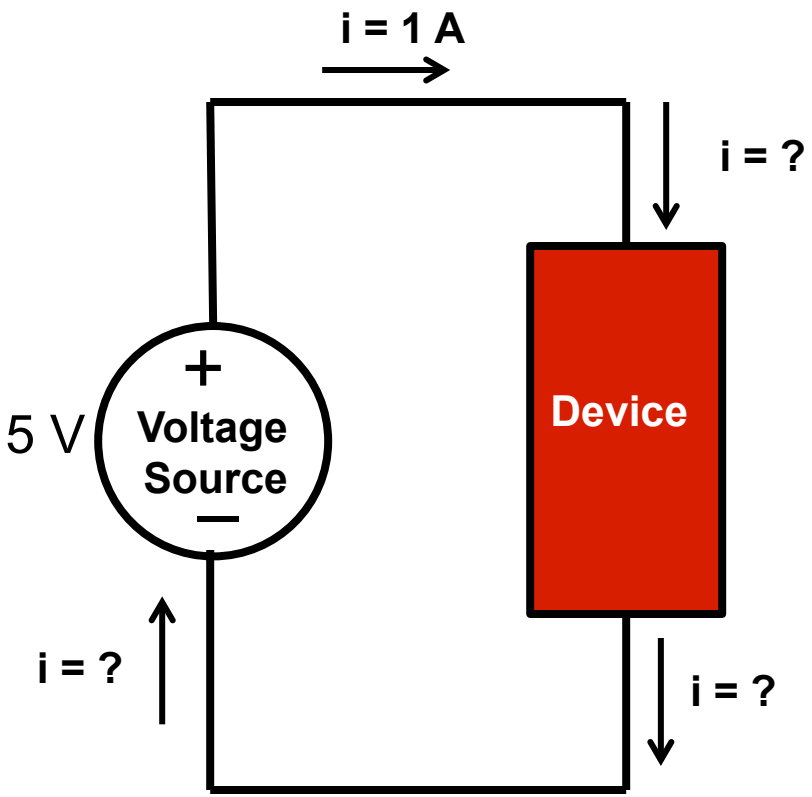
- In electrical systems current is carried by charges, usually electrons
- Charge is measured in **Coulombs**
  - 1 coulomb is a *lot* of charge
  - Each electron has a charge of -1.6×10^{-19} Coulombs
- Charge can flow (move) in a material that **conducts**
  - **wires**, **devices** (power is dissipated if they have resistance)
- Like magnets, opposite charges attract; like charges repel.

Electrical Current



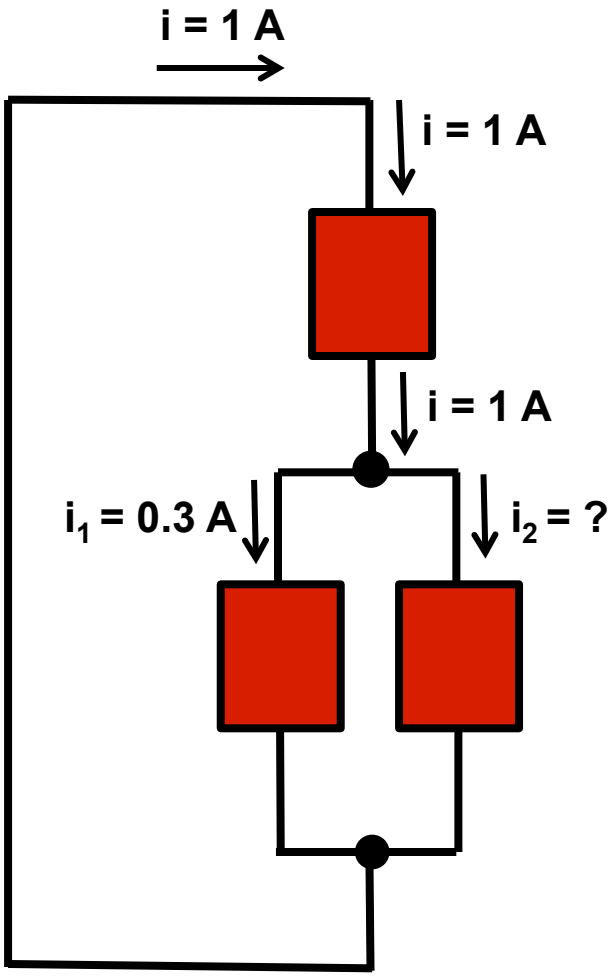
- Moving charge is called current
  - Current is the flow of charge per second
  - Past some measured point
- Its unit is the Ampere, usually called amps and abbreviated A
  - 1 A = 1 Coulomb/sec = 1 Cs^{-1}
- The symbol for current is usually i

Electrical Current is Continuous



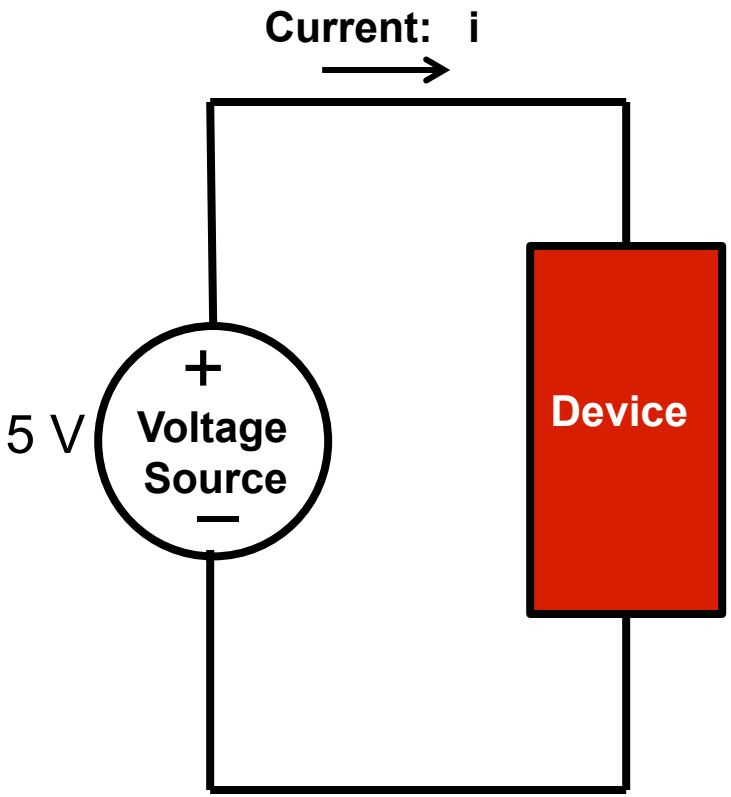
- The current flow in a wire remains the same along it, since there are no “leaks” of charge out of the wire
- The current flows in one terminal of the device and out the other
- The wires and the device are neutral (zero charge), even though current is flowing through them

Circuits with Branches: Constraints on Currents (KCL)



- The black dot is an electrical connection between the wires
- What is the value of the current i_2?

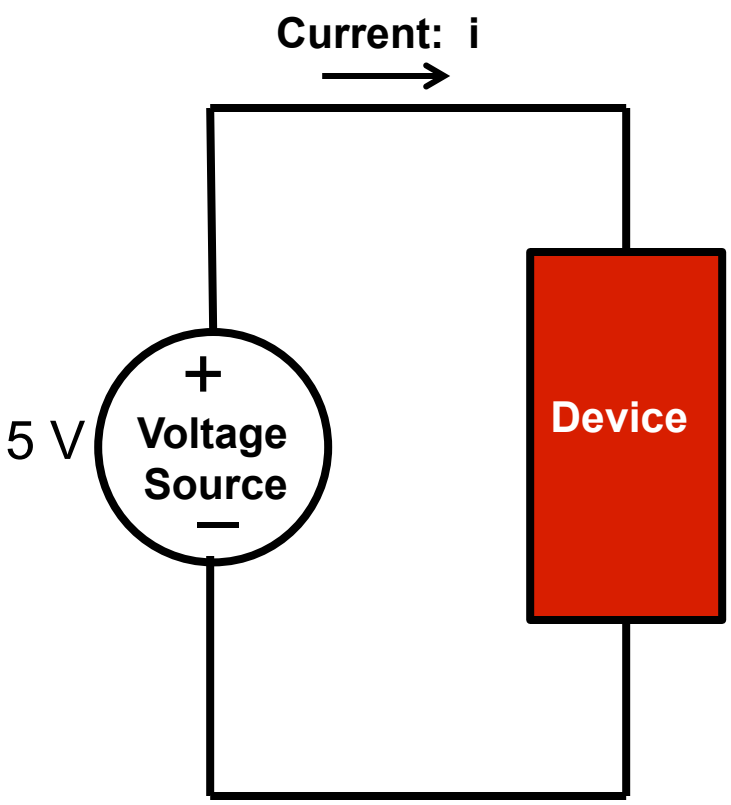
If You Think of Charge as a Fluid



- Current is then fluid flow
- Current constraints are then about fluid conservation
  - The fluid in any object is constant
- But we know that a fluid doesn't move unless it is pushed
  - What pushes charge to make it move?

A Voltage Source

Electrical Voltage



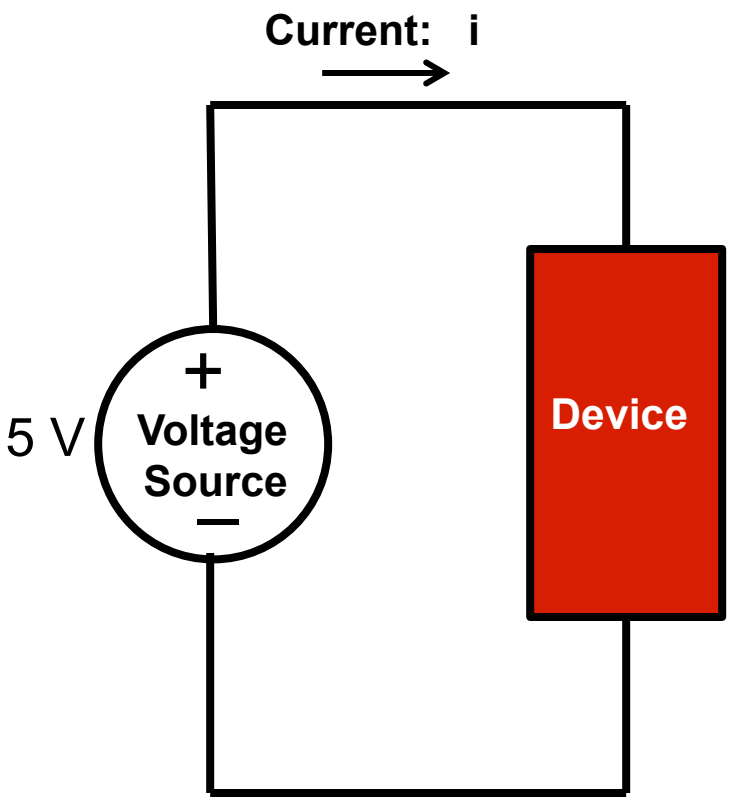
- **Voltage** is a measure of the potential energy per unit charge
  - It is measured in **Volts**
    - Which has the units of Joules per Coulomb.
- The charge on the higher energy side will move through an external path (a wire) to neutralize the negative charge on the other side of the device.
  - This causes the charge to flow in the wire, as well as through the device.

What is a Battery?

- It is a chemical pump for electrons!
  - There is a pair of chemical reactions that pump electrons from anode to cathode
    - Actually, a battery absorbs electrons at the anode and creates electrons at cathode (with ions moving through the middle), but it has exactly the same effect
  - The battery voltage is the potential energy given to electrons as a result of this pump.

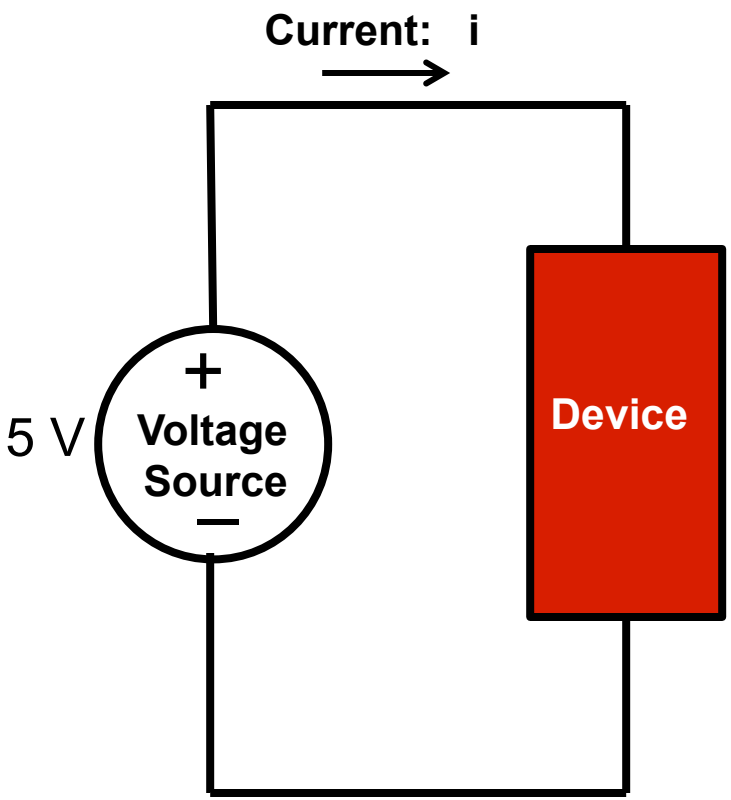
- The voltage of the battery depends on chemicals
  - Generally either 1.5 V, or multiples
  - Or around 3.5 V (lithium)

Energy and Power



- The battery or power supply provides power to the device. ($P = i \cdot V$)
- Since energy is conserved, the device does something with this power
  - Resistor turns it into heat
  - LED turns it into light
  - Logic circuit computes something
  - Motor turns it into mechanical energy
  - Pump turns it into potential energy by pumping water uphill
  - . . . . . .

Electrical Devices



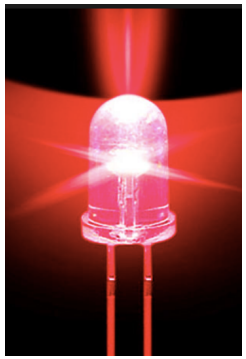
- We'll learn about many different electrical devices.

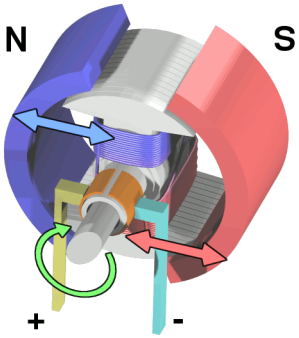

Resistors


Diodes

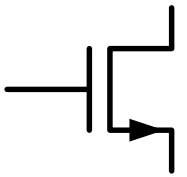

Inductors


Capacitors

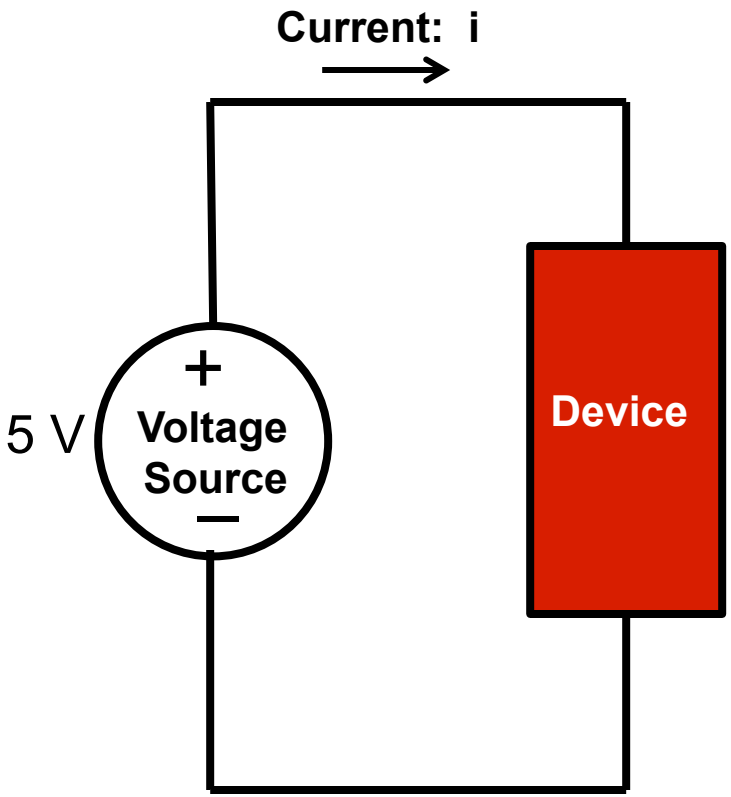

Light Emitting Diodes



Motors

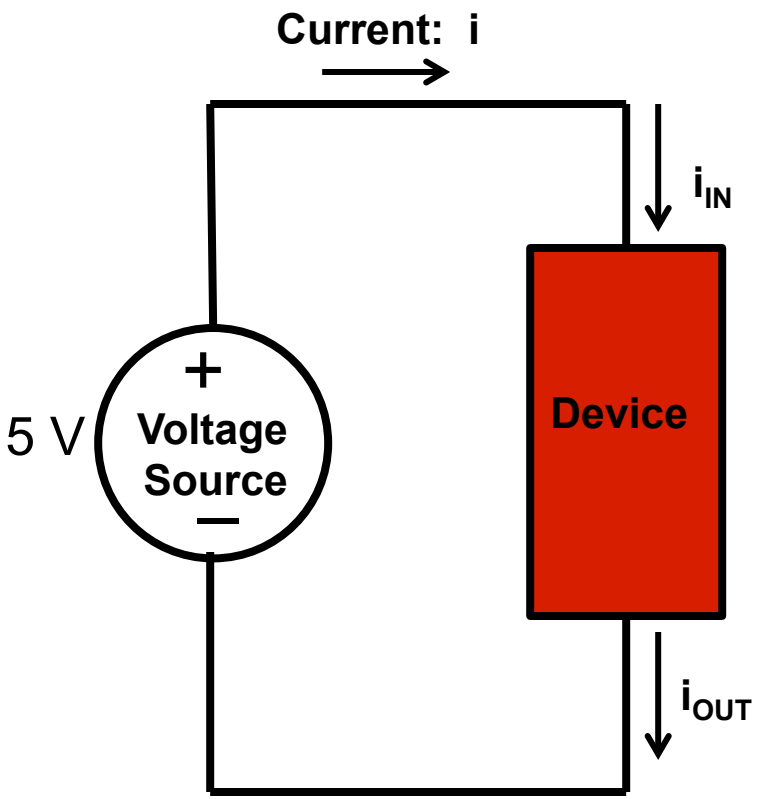

Transistors

Electrical Devices



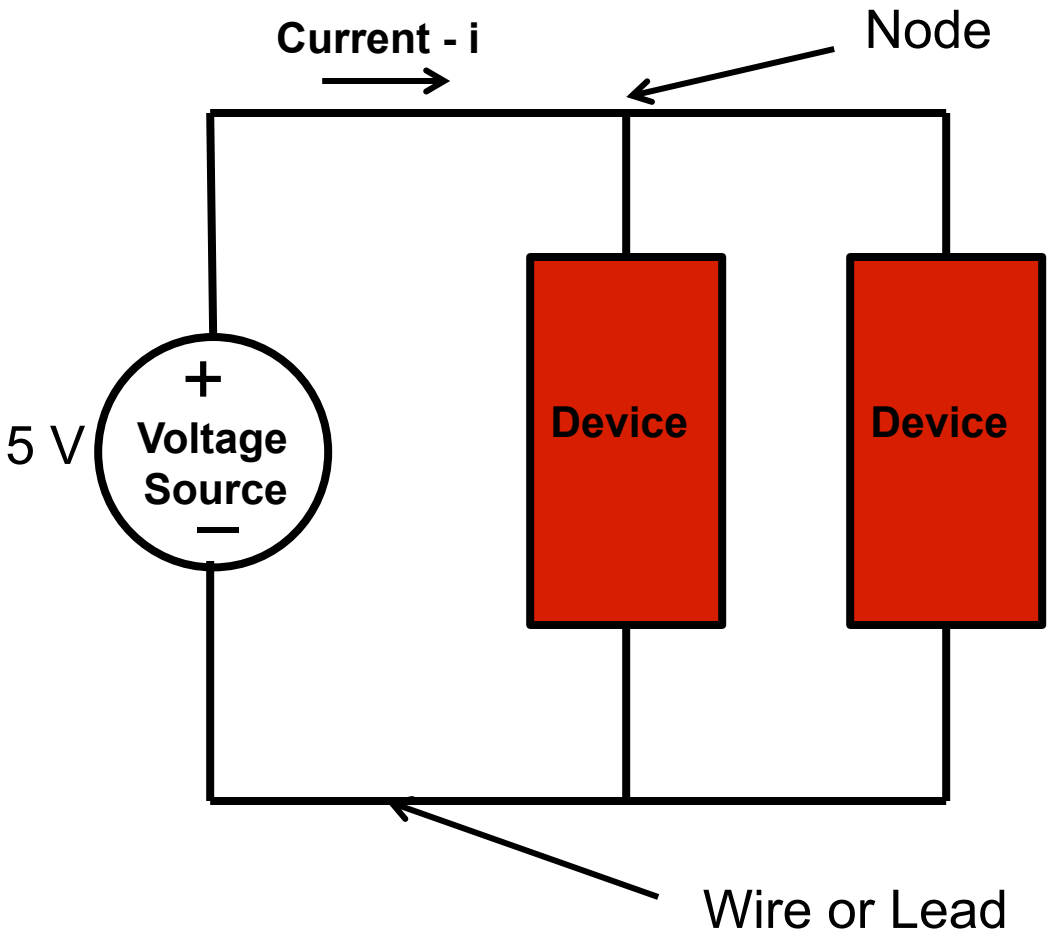
- Each electrical device responds differently to the voltage and current provided to it.
- Electrical engineers combine these devices to do interesting and useful things.
- You'll build and demonstrate several interesting examples in E40M.

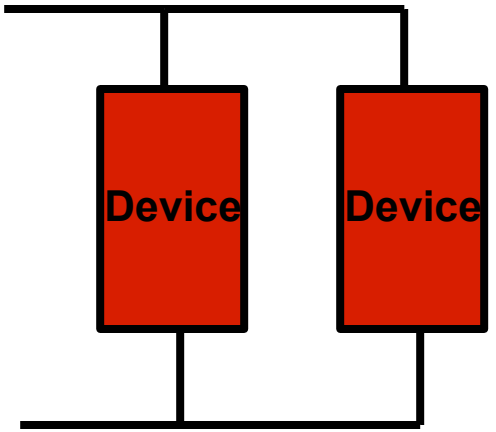
Electrical Devices – Some Properties



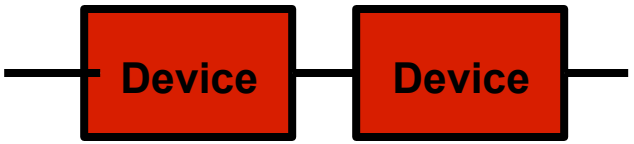
- Charge neutral; *i.e.*, charge entering = charge leaving
  - Batteries or power supplies separate charge but the overall device is still charge neutral
- The net current into any device is **always zero**, so $i_{IN} = i_{OUT}$
  - Current that flows into one end of a wire must flow out the other
  - Often called KCL (Kirchhoff's Current Law)
- Dissipate power ($P = i \cdot V$)

Electrical Circuit Terminology





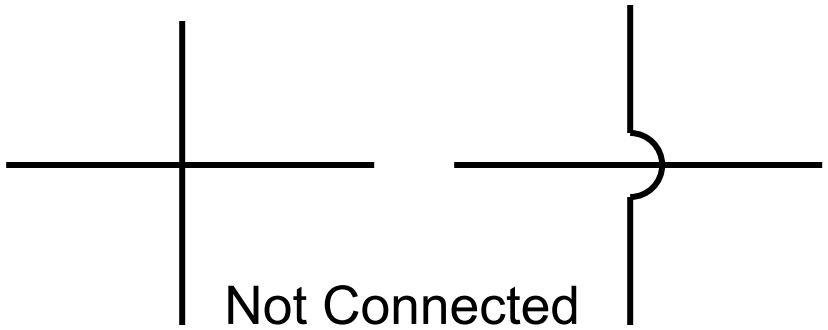
Devices in Parallel



Devices in Series

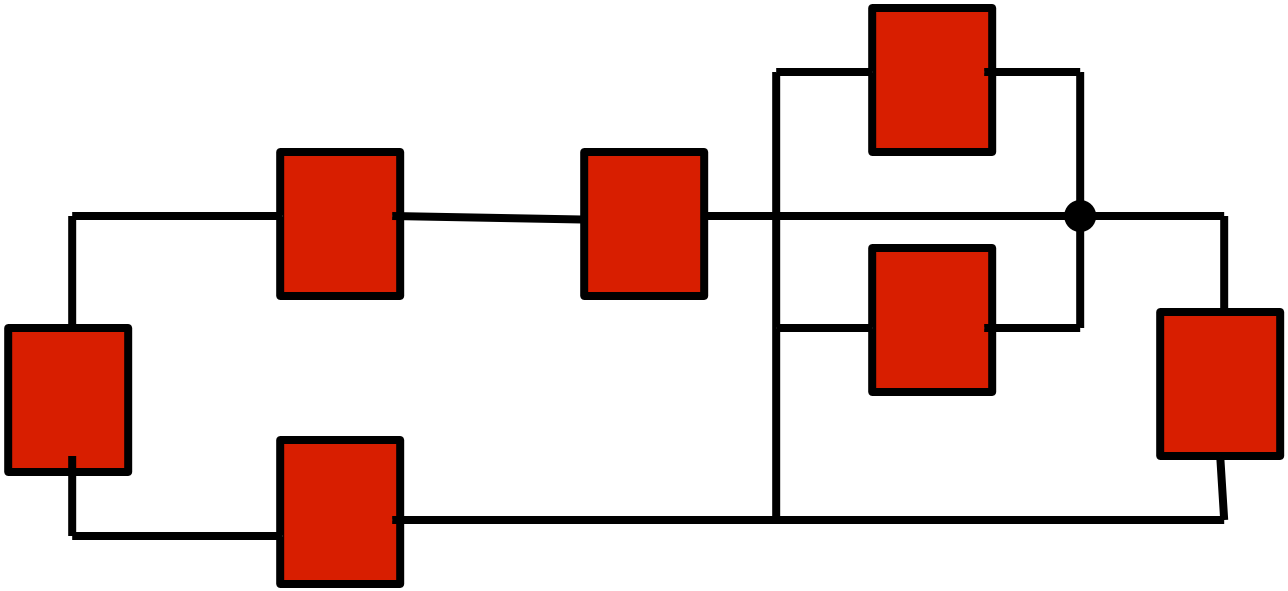
Electrical Circuit Terminology

Connected



Not Connected

Example:



Learning Objectives – Charge, Current, Voltage, Electrical Circuits

- Understand that **charge** is what makes components electrical
  - Moving charge is called **current**, and often represented by "**i**"
    - Measured in **Amps** = Coulombs/sec
- Understand that all components and wires are **charge neutral**
  - This means that the net charge flowing into an object is 0
  - KCL - The sum of the currents into an device or wire = 0

- The energy that causes the charge to move is called **Voltage**
  - Measured in **Volts** = Joules/Coulomb
  - Voltage is a potential energy difference
    - Measured between two nodes