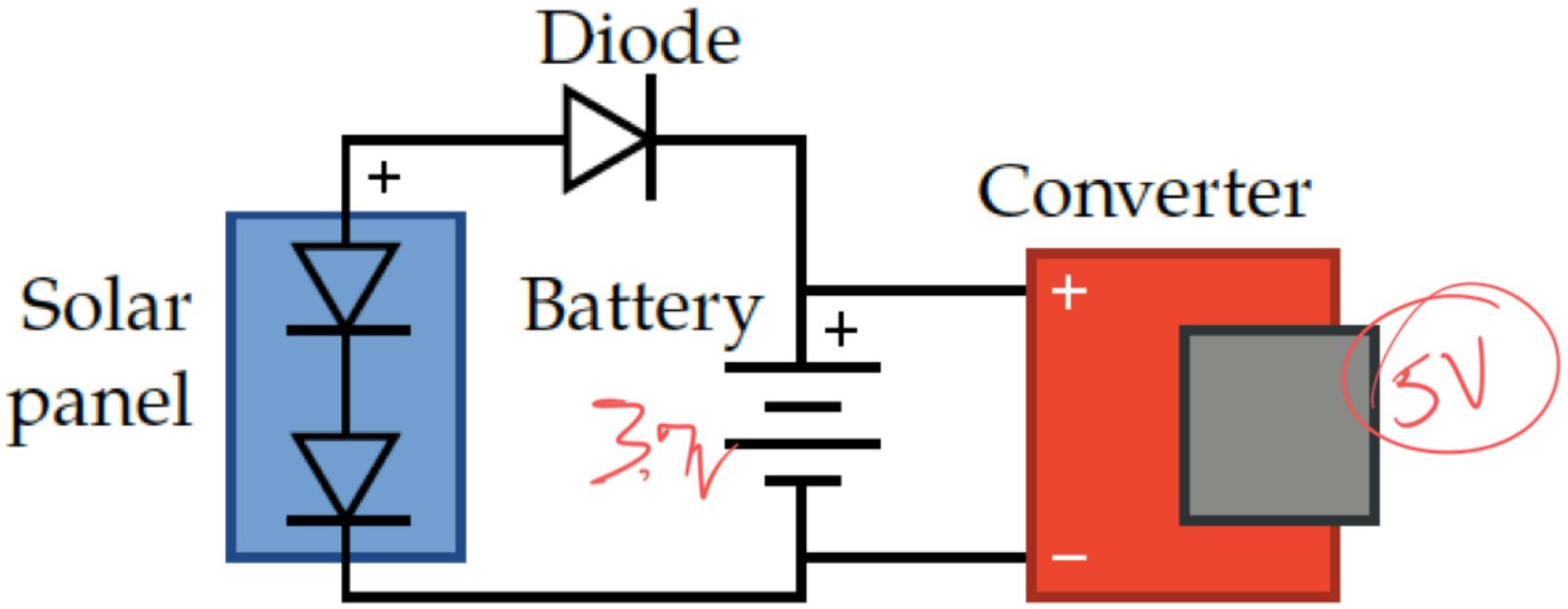
E40M
Charge, Current, Voltage and Electrical Circuits

Reading – Chpt 1
Course Readers

Understanding the Solar Charger – Lab Project #1

Just in time learning



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).

next several lectures

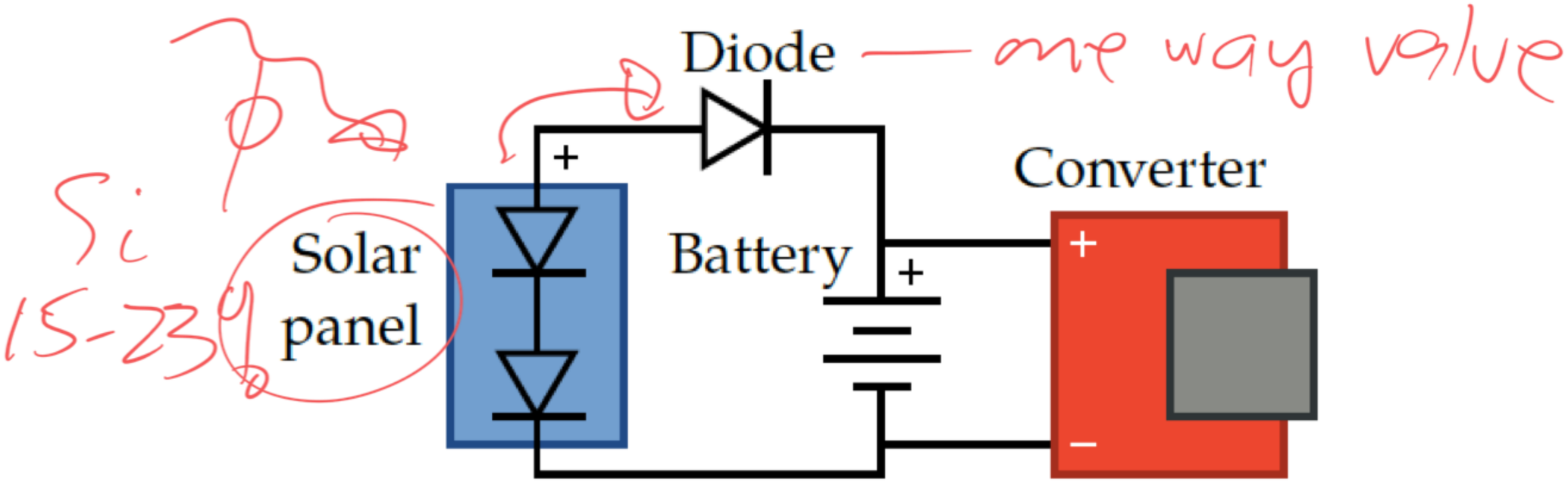
← late in Q

What Does It Do?

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

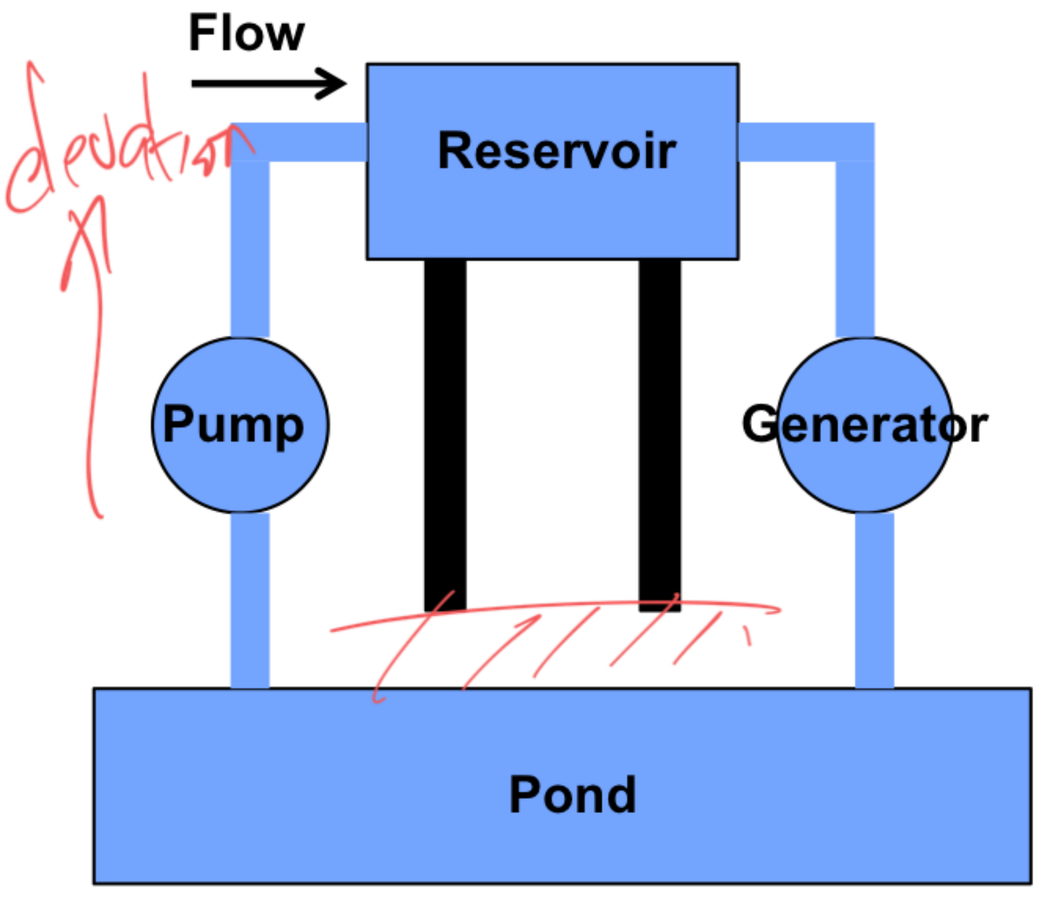
How does it do that?

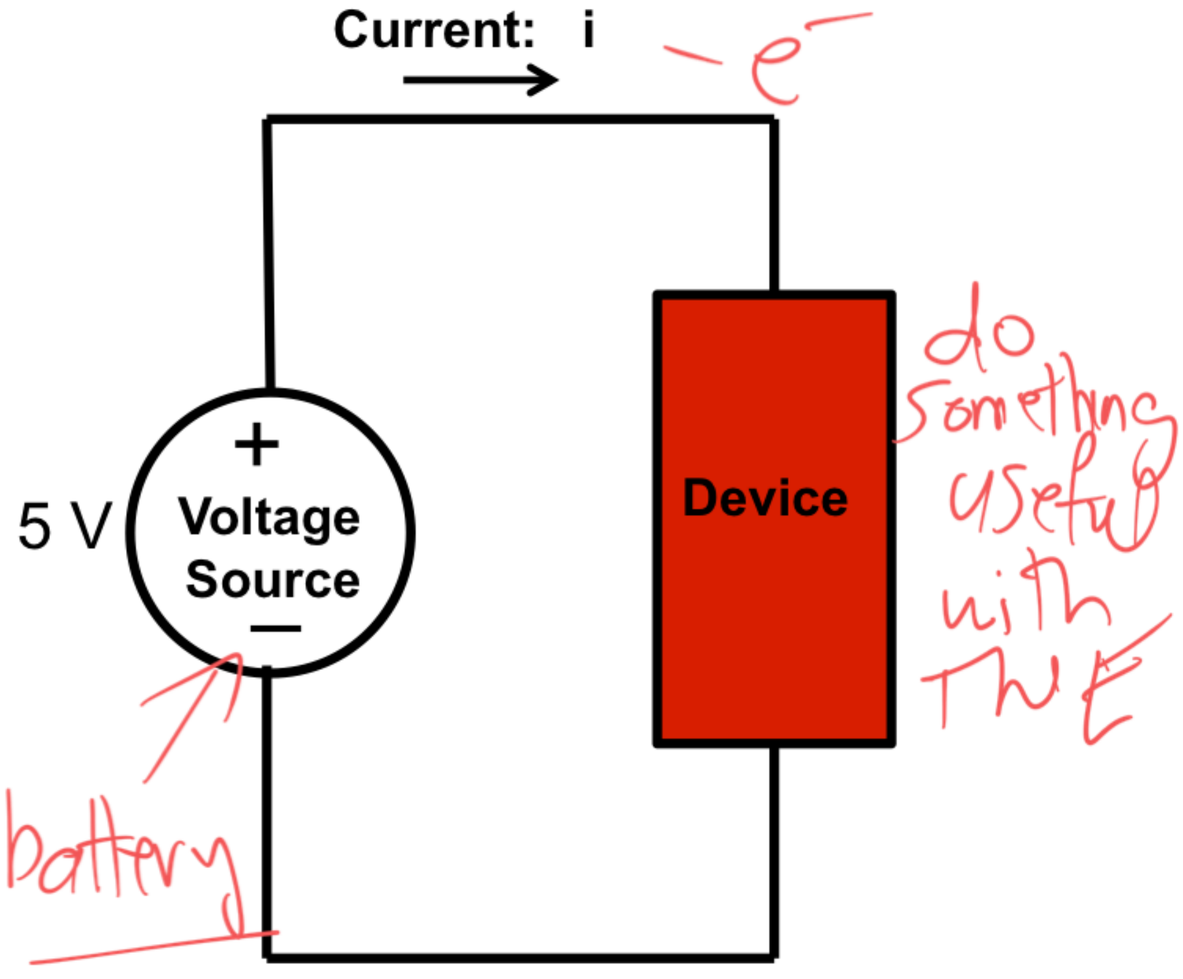
How Our Solar Charger Works



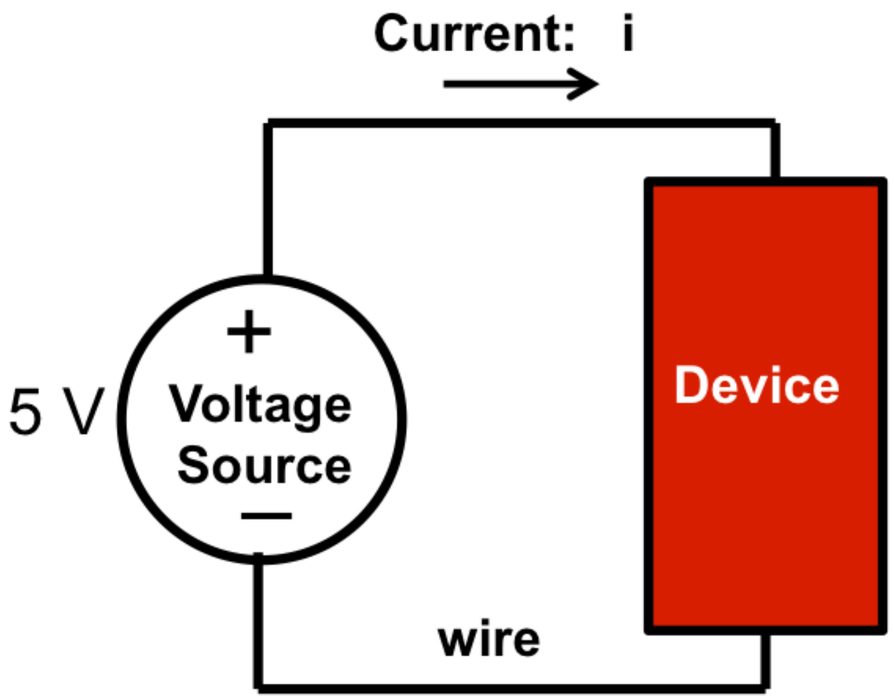
- Converts some energy from sunlight into an electrical signal
- That **electrical signal** connects to a rechargeable battery
  - So energy flows from solar cell to battery
- Another electrical signal connects the battery to the USB port
  - So energy can flow to the USB, and charge your phone
- So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

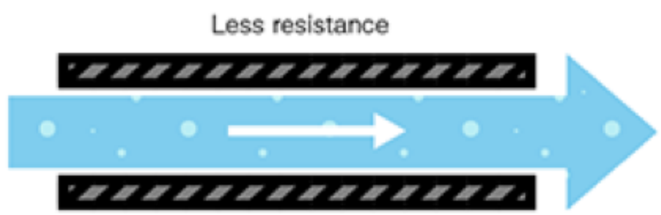
Fluidic “Circuits” ≅ Electrical Circuits

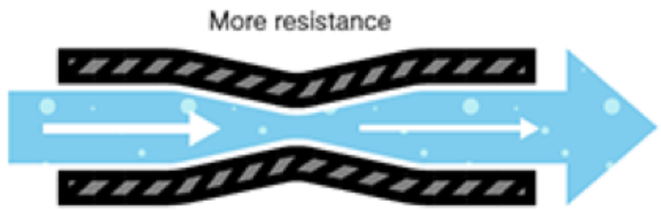




Electrical Charge

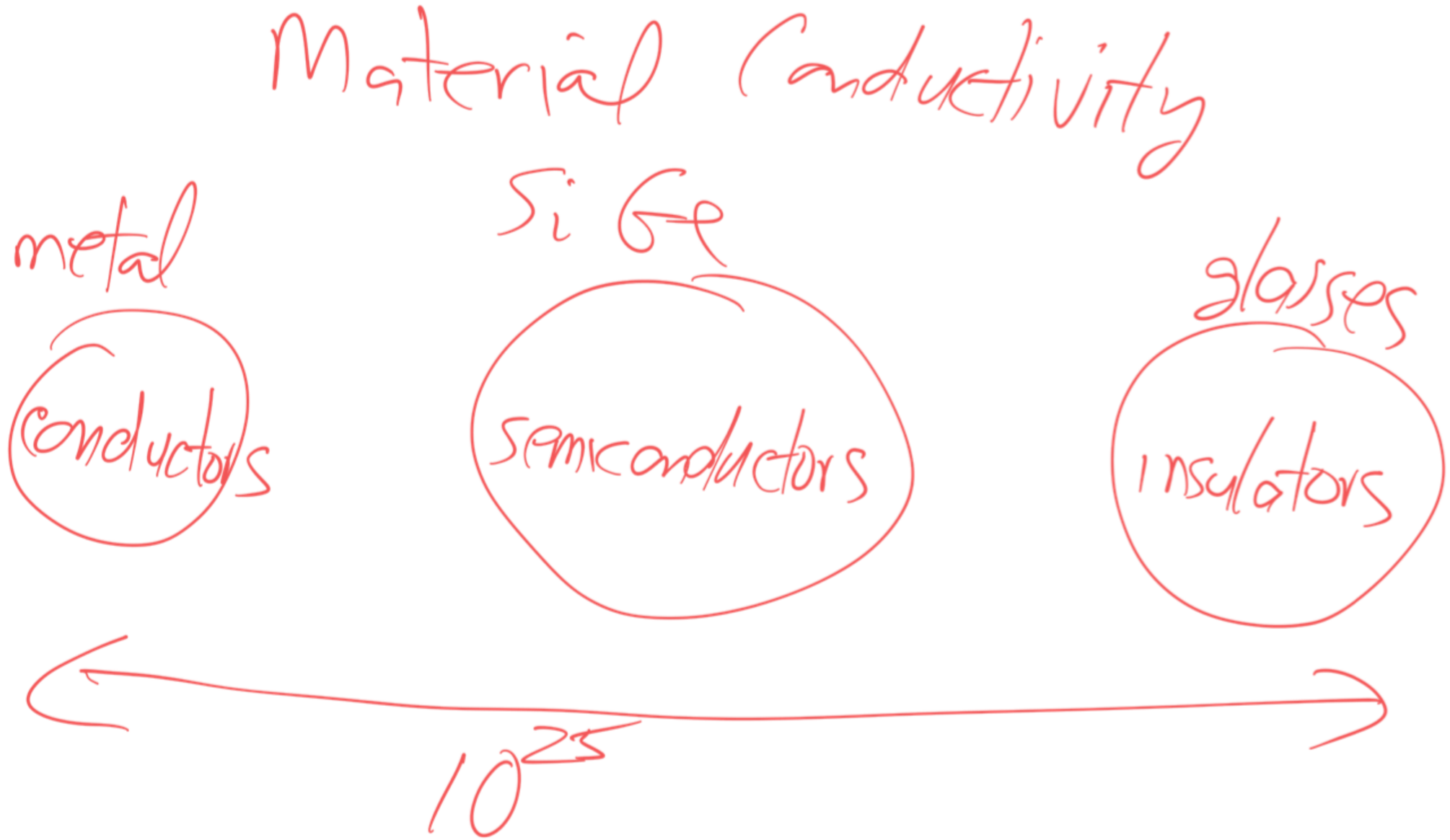




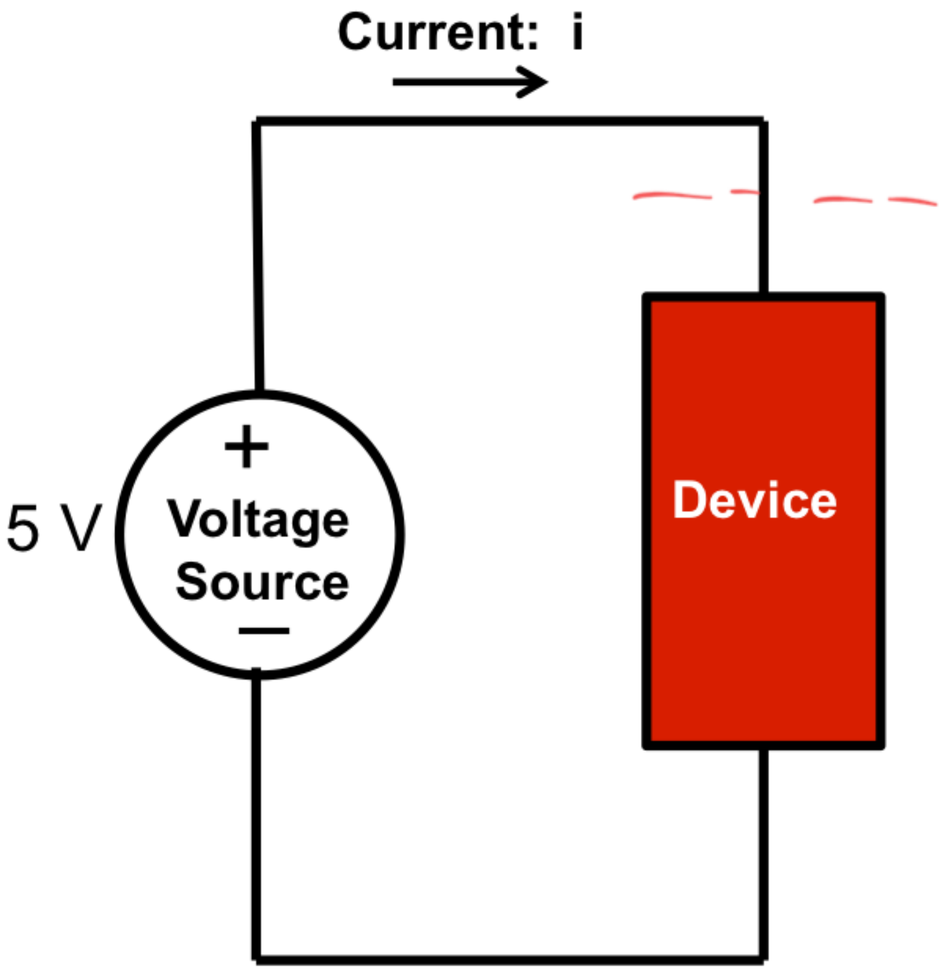


- In electrical systems current is carried by charges, usually electrons
- Charge is measured in **Coulombs**
  - 1 coulomb is a *lot* of charge
  - Each electron has a charge of -1.6×10^{-19} Coulombs
- Charge can flow (move) in a material that **conducts**
  - **wires**, **devices** (power is dissipated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

Material Conductivity



Electrical Current

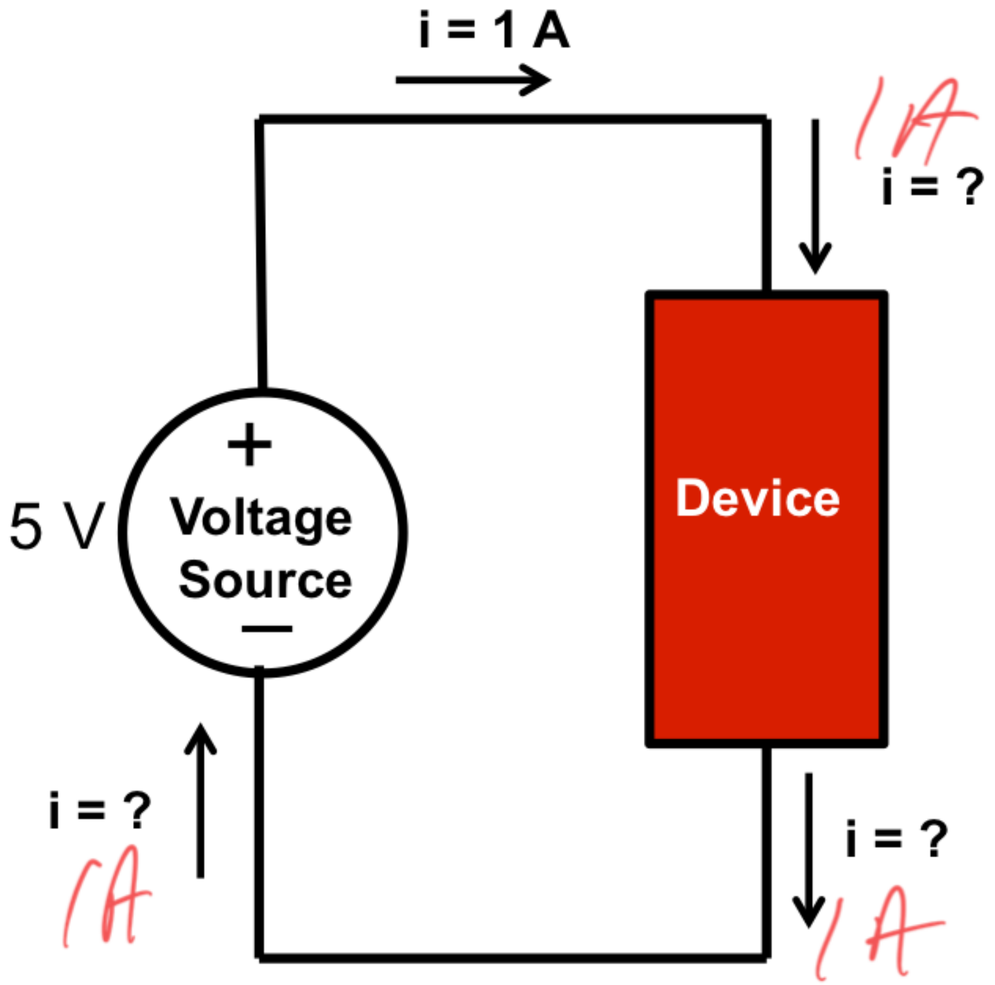


- Moving charge is called current
  - Current is the flow of charge per second
  - Past some measured point
- Its unit is the Ampere, usually called amps and abbreviated A
  - 1 A = 1 Coulomb/sec = 1 Cs^{-1}

6.25×10^{18} e/sec

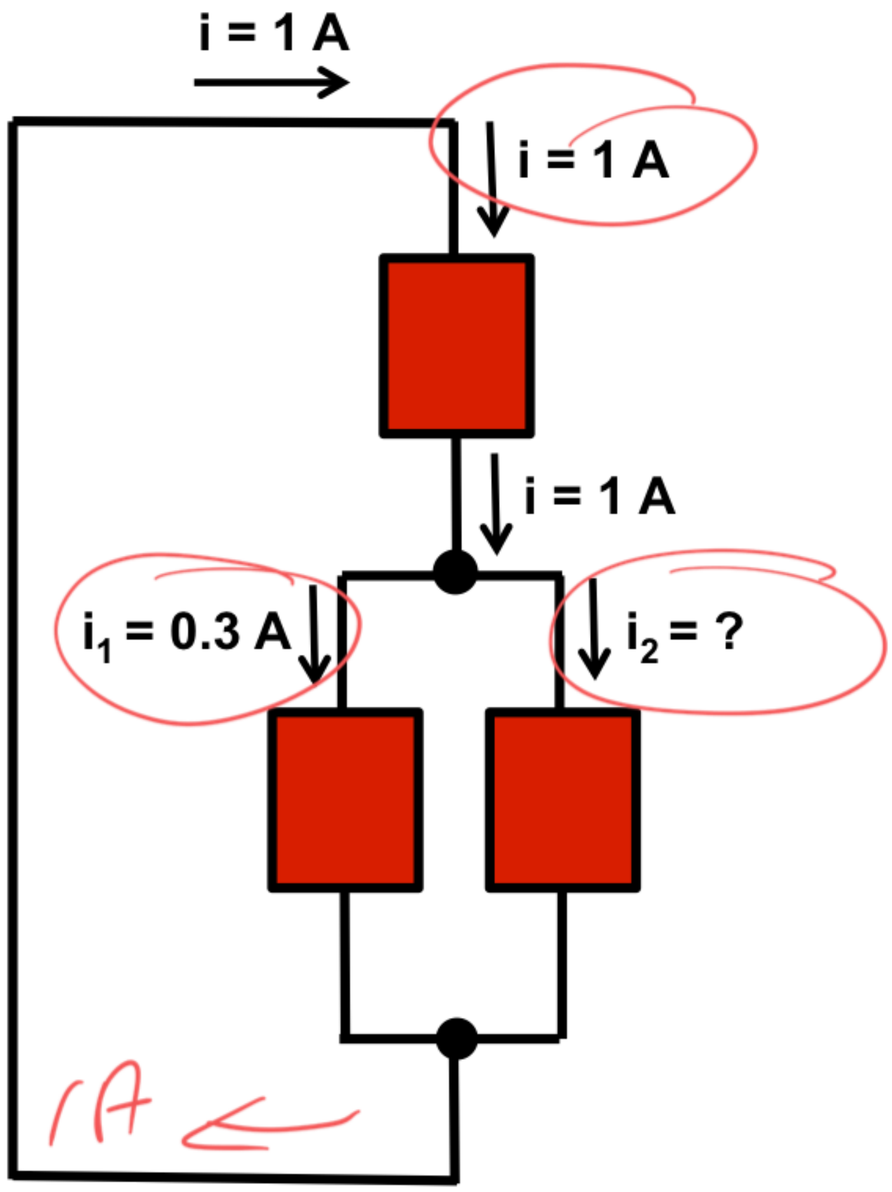
- The symbol for current is usually i

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)

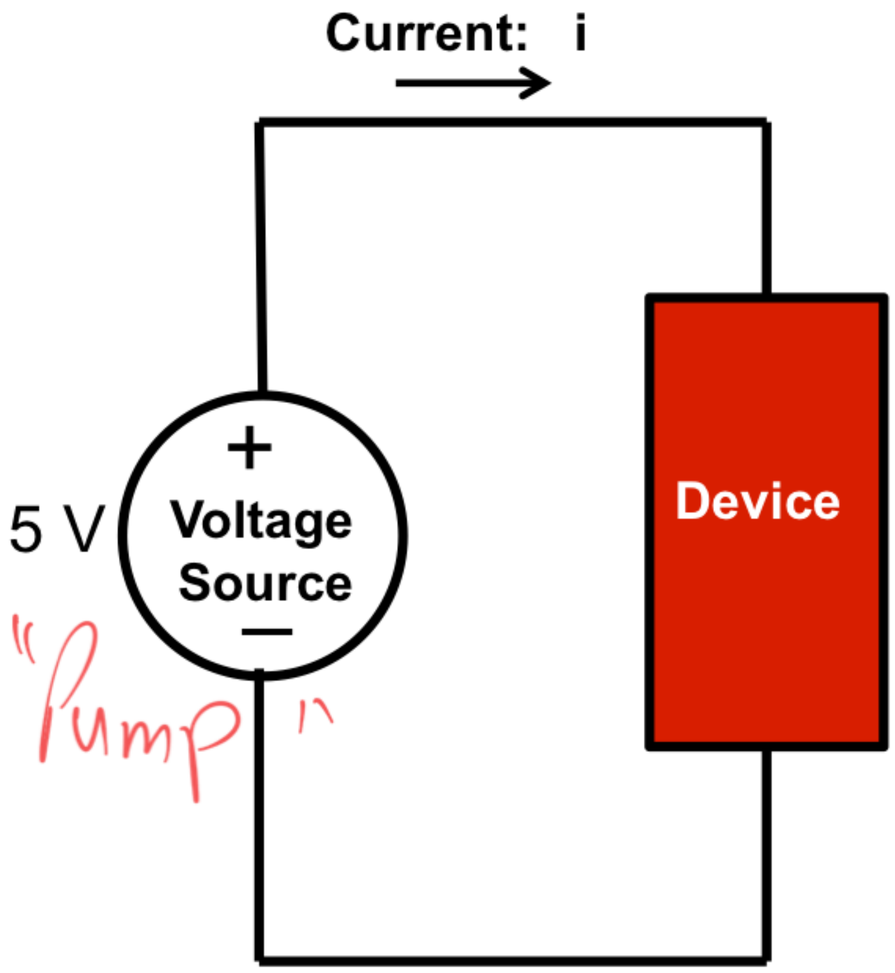


- The black dot is an electrical connection between the wires

- What is the value of the current i_2?

$i_1 + i_2 = 1A$

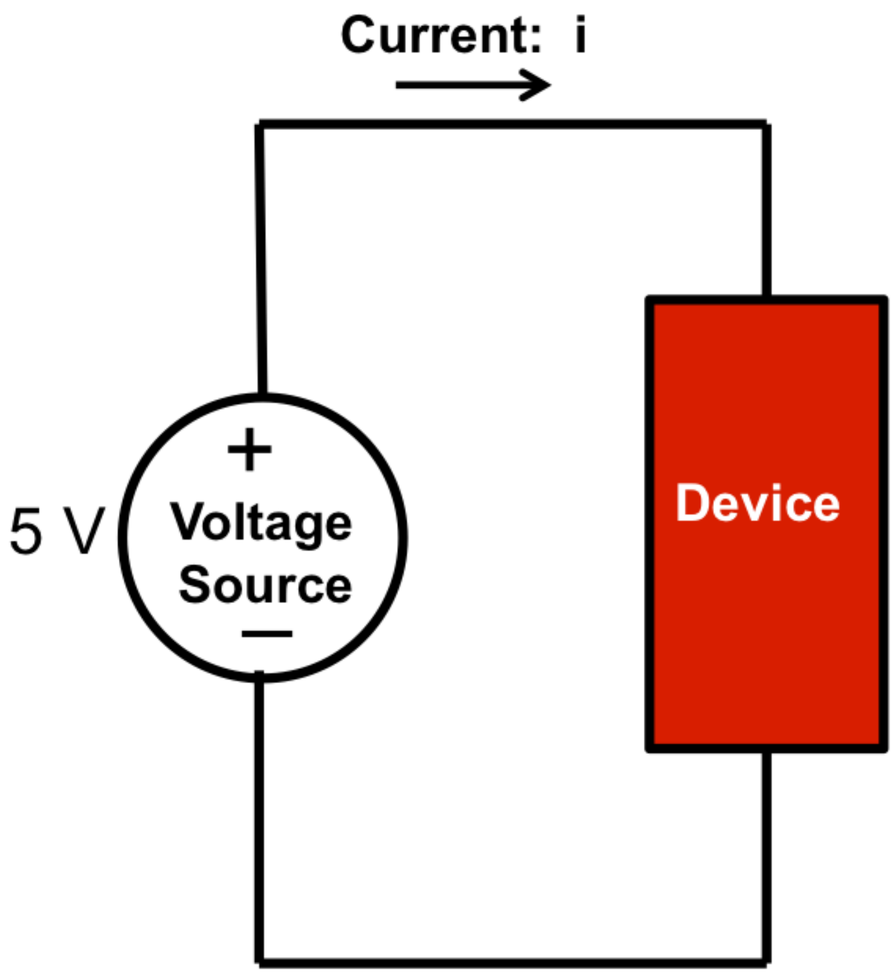
If You Think of Charge as a Fluid



- 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



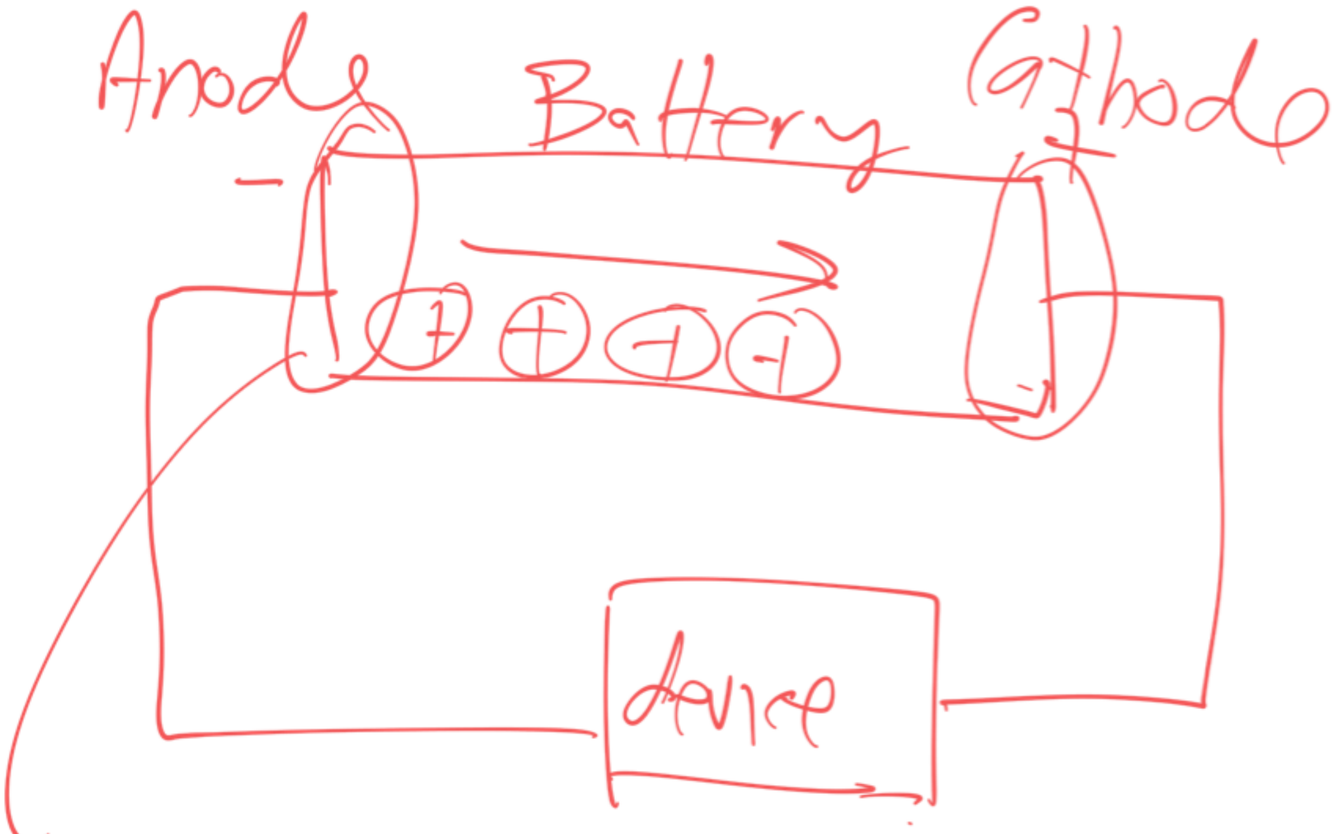
- **Voltage** is a measure of the potential energy per unit charge
  - It is measured in **Volts**
    - Which has the units of Joules per Coulomb.

- 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)

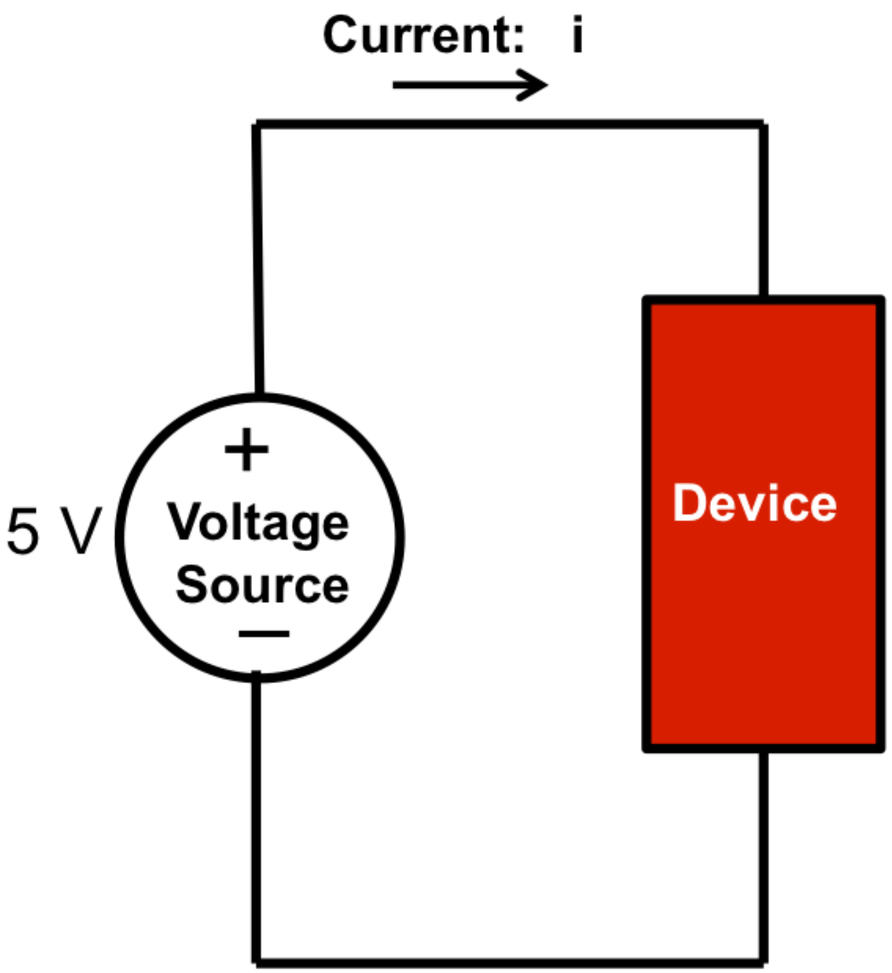


- oxidation reaction - loss of e^-
- reduction reaction - gain of e^-

chemical E → Elec E

Energy and Power

Power

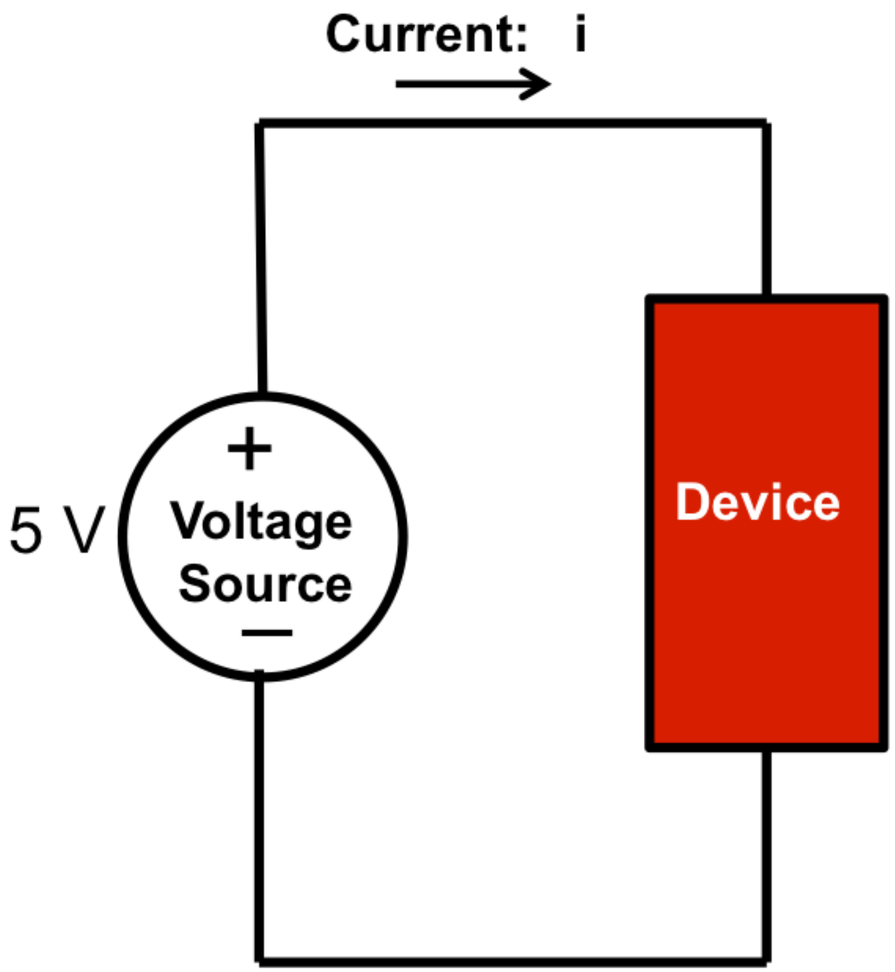


- The battery or power supply provides power to the device. (P = i·V)

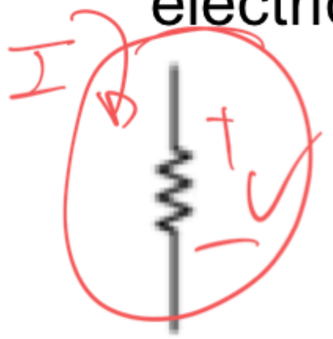
E = P·t

- 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.

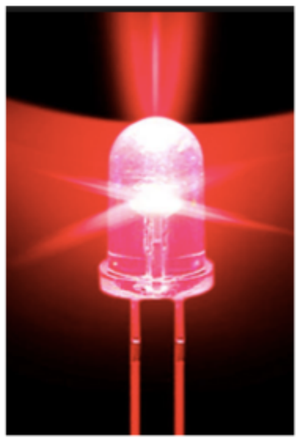


Resistors

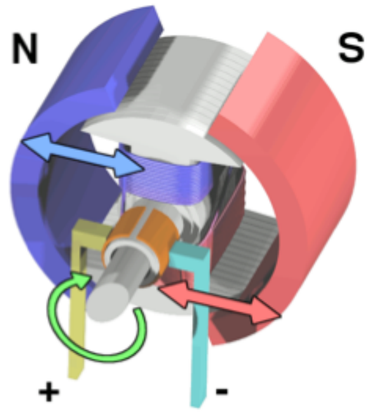
Diodes

Inductors

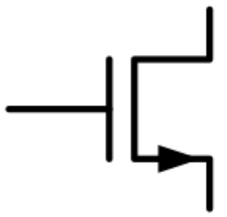
Capacitors



Light Emitting Diodes

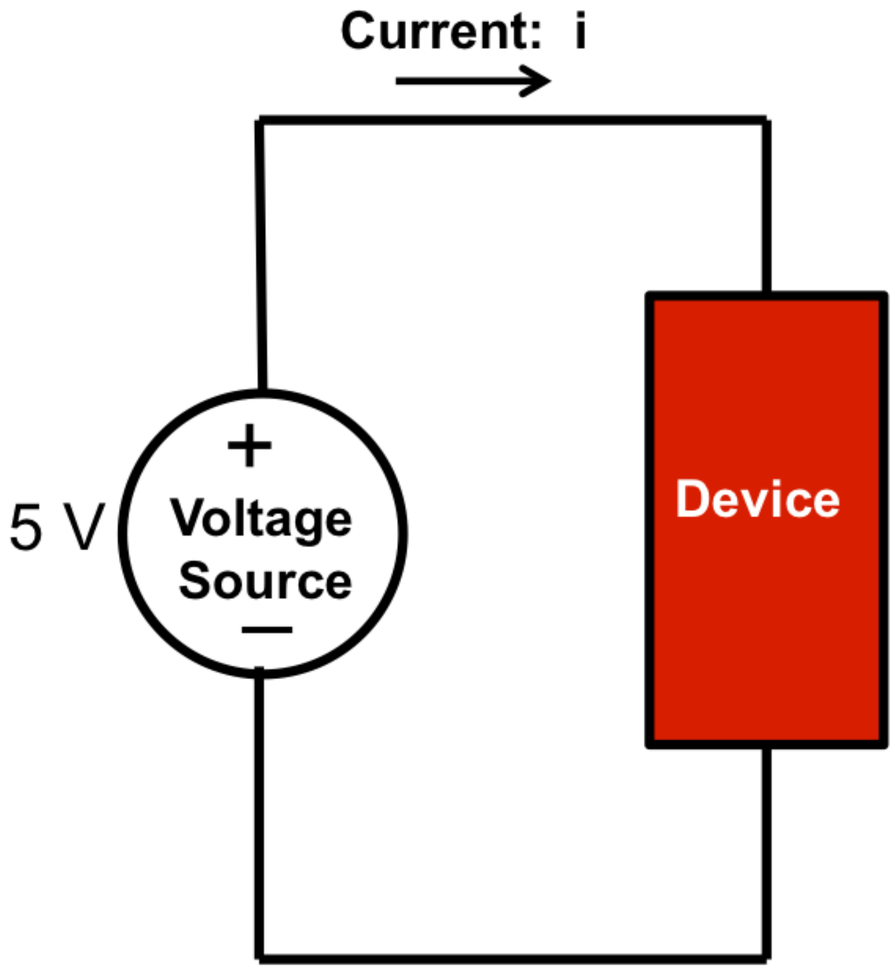


Motors



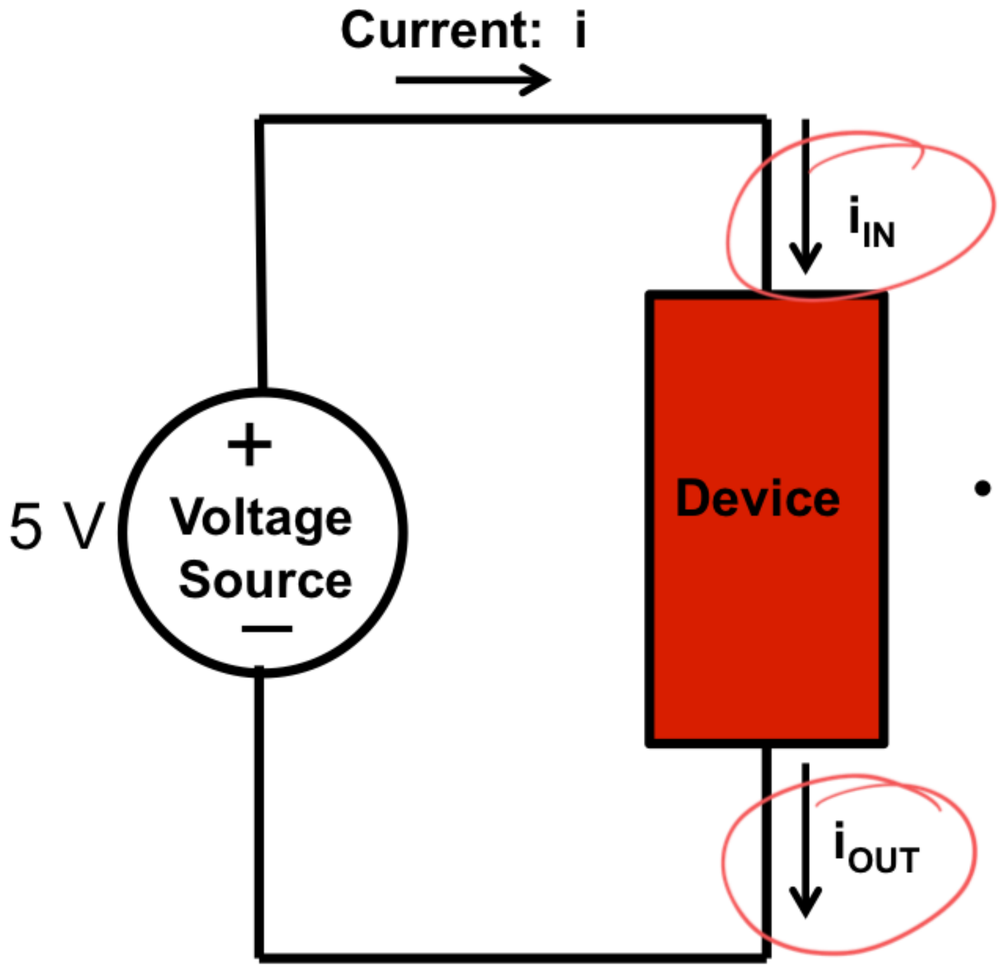
Transistors

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

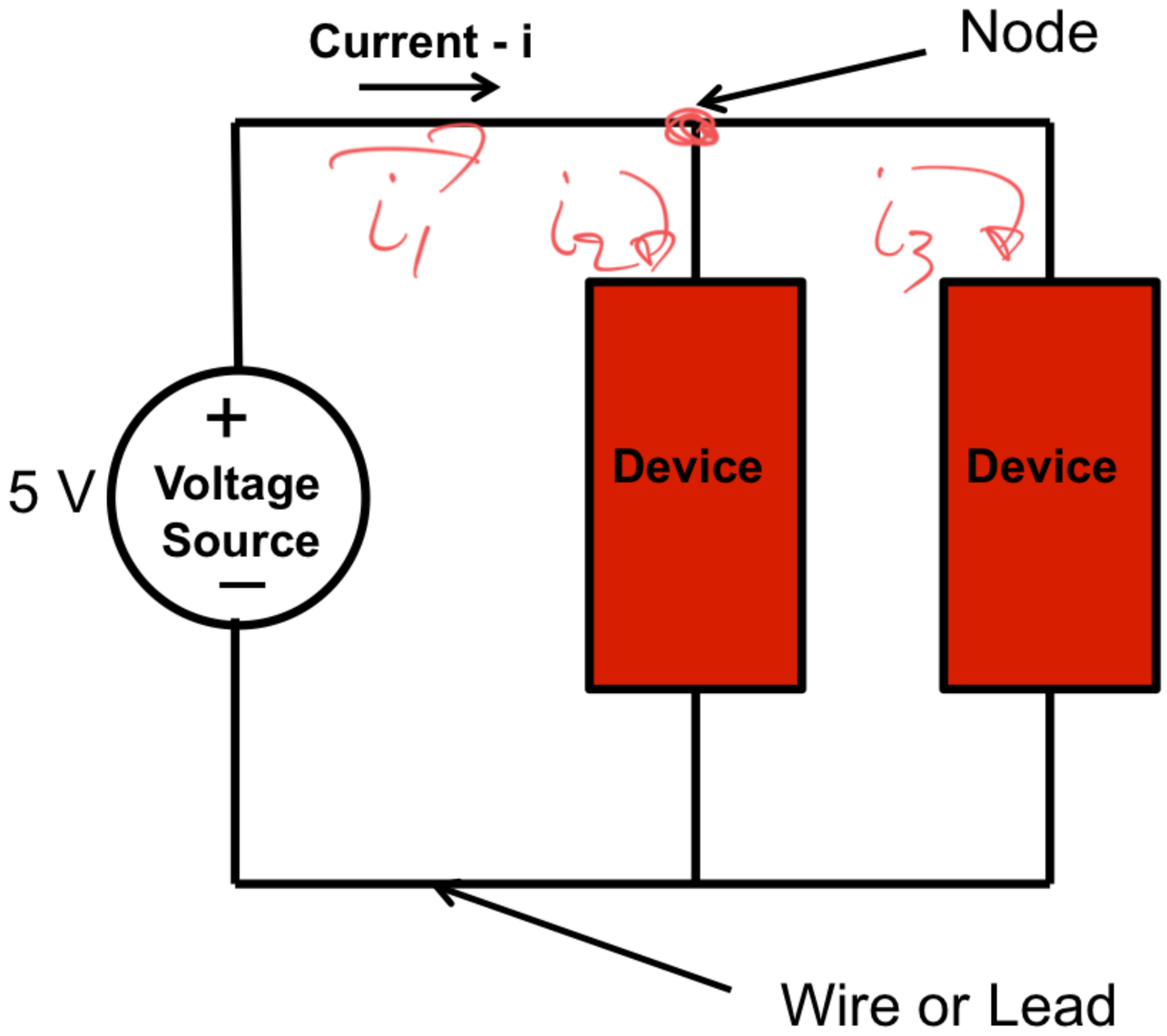


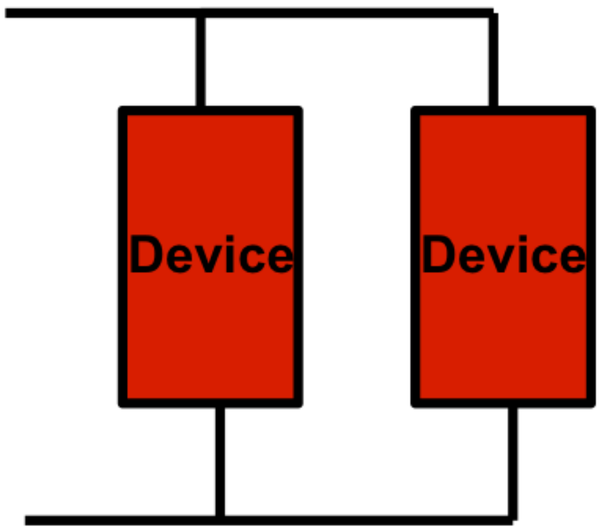
- Charge neutral; *i.e.*, charge entering = charge leaving
  - Batteries or power supplies separate charge but the overall device is still charge neutral

- 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)

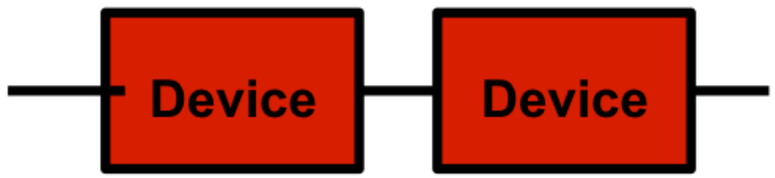
- Dissipate power ($P = i \cdot V$)

Electrical Circuit Terminology



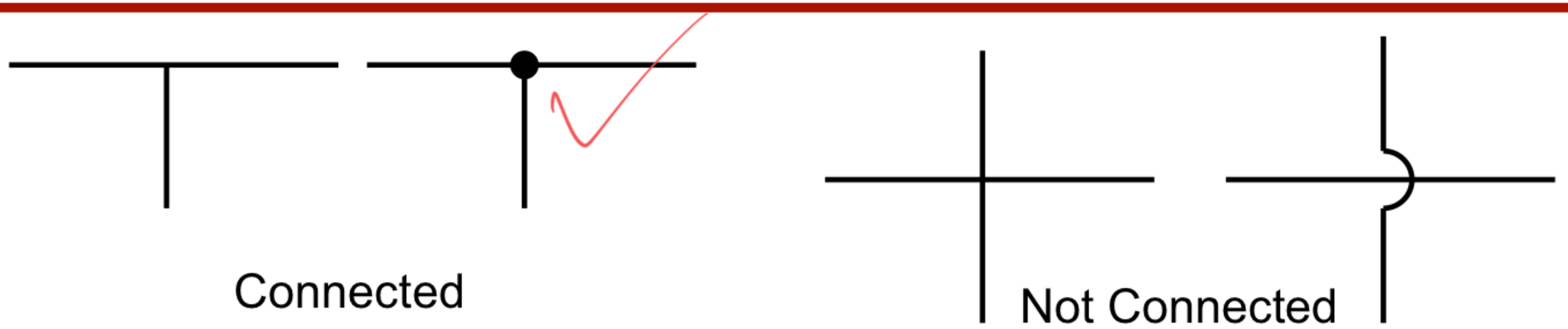


Devices in Parallel

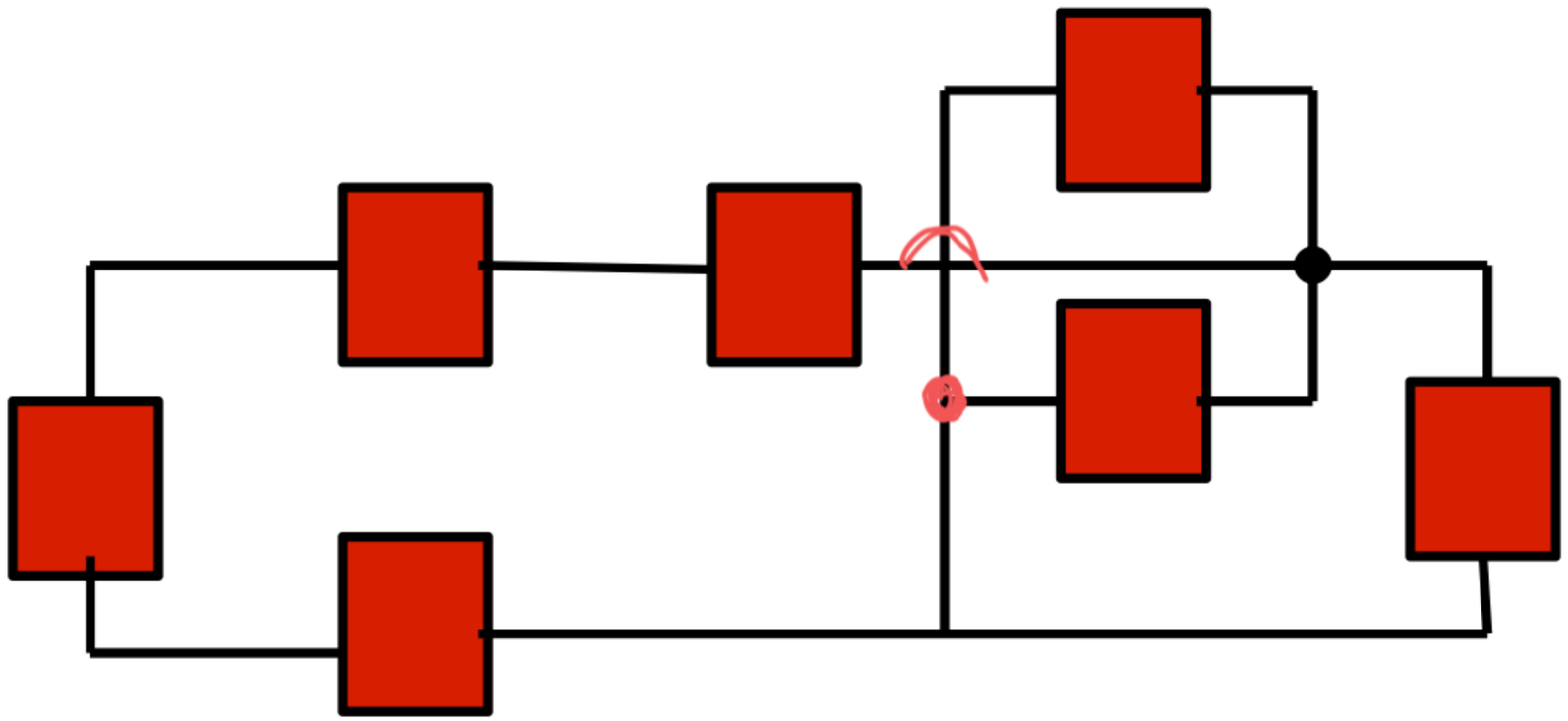


Devices in Series

Electrical Circuit Terminology



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