Lecture 2

Energy Flow and Resistors

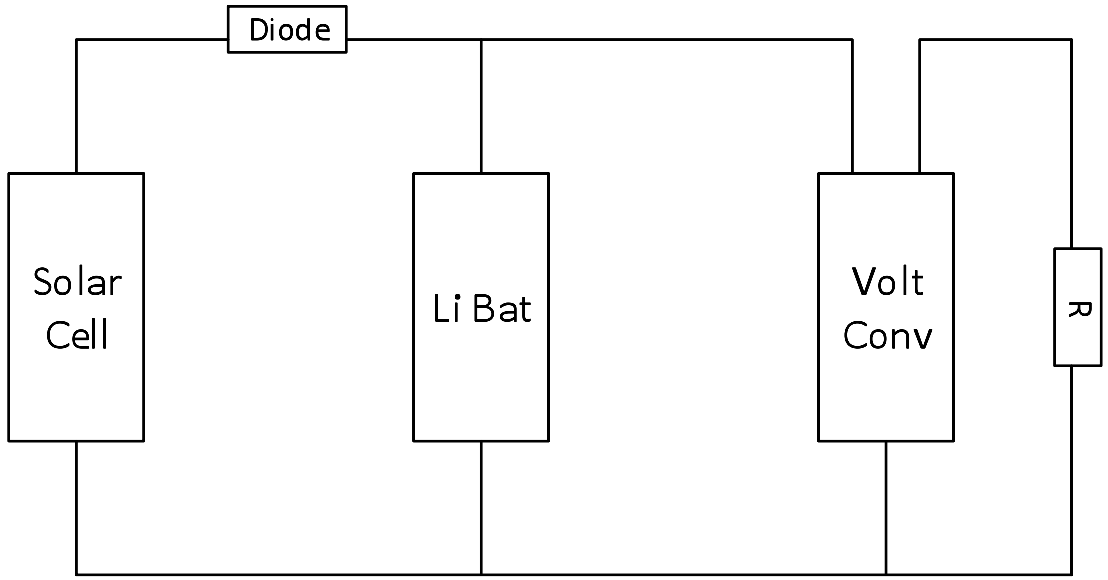
Reading For This Lecture

- Chapter 1 in the course reading

OR

- A&L 1.6-1.7 - Two terminal elements
  – Voltage source; resistor; wires
- A&L 2.1-2.2 – Circuit Laws KCL & KVL
- Optional on reading resistor values:
  – http://www.instructables.com/id/How-to-read-color-codes-from-resistors-1/

Roadmap



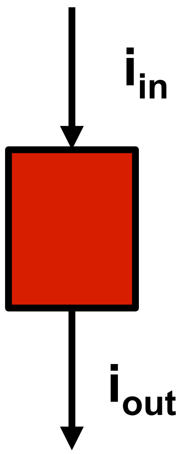
We need to understand:

1. Voltages and currents in simple circuits
2. Current sources, voltage sources, resistor characteristics.
3. Diodes including solar cells (next lecture).
4. Voltage converter.

Key Ideas From The Last lecture

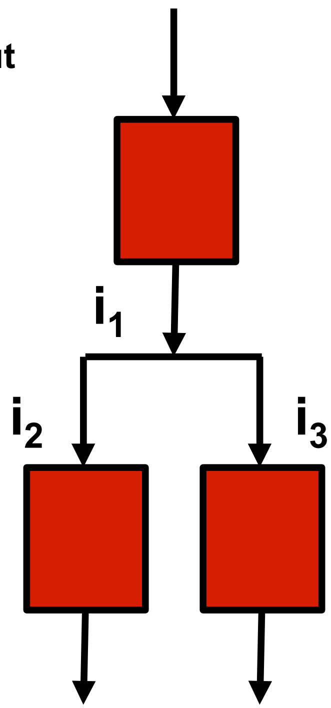
- Understand that **charge** is what makes components electrical
  - Moving charge is called **current**, and often represented by "**i**"
    - Measured in **Amps** = Coulombs/sec
- Understand that all components and wires are **charge neutral**
  - This means that the net charge flowing into an object 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
- Be able to use your **DMM** to measure voltage and current
- Learn SI prefixes

Key Ideas From The Last lecture



An electrical device is an object that charge can move through i.e. current (electrons) can flow through it. Devices are charge neutral so that

$$i_{in} = i_{out}$$

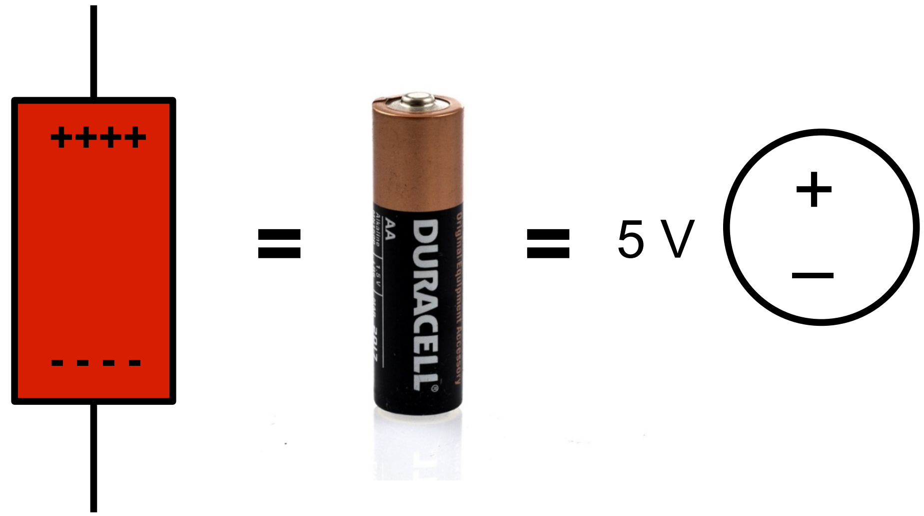


More generally, Kirchoff's Current Law (KCL) states that the current flowing out of any node must equal the current flowing in. So, for example,

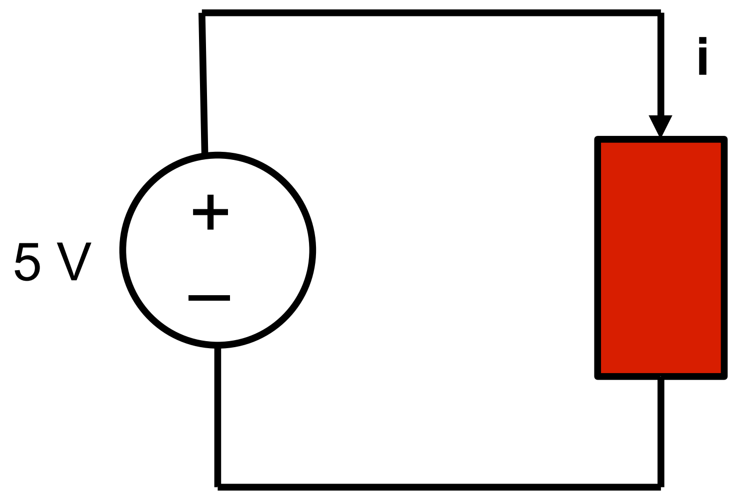
$$i_1 = i_2 + i_3$$

Key Ideas From The Last lecture

Charge can be separated in an electrical device if we provide the energy to “pull” the charges apart. Batteries use chemical reactions to separate the charges. Volts (joules/Coulomb) are units of potential energy.



If an electrical device is connected to a battery or voltage source, current measured in amperes (amps) will flow through the device.



Key Ideas From The Last lecture

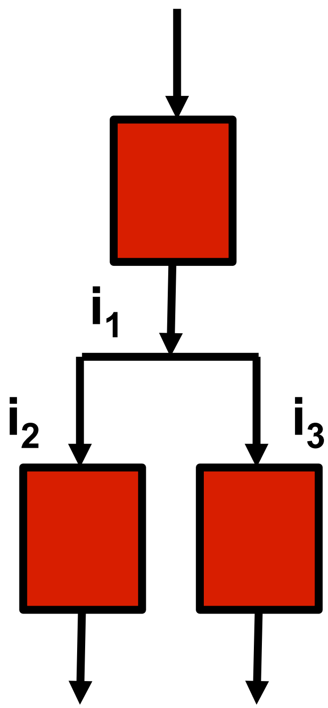
Standard Prefixes for SI Units

10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ (or u)
10^{-3}	milli	m
10^{+3}	kilo	k
10^{+6}	Mega	M
10^{+9}	Giga	G

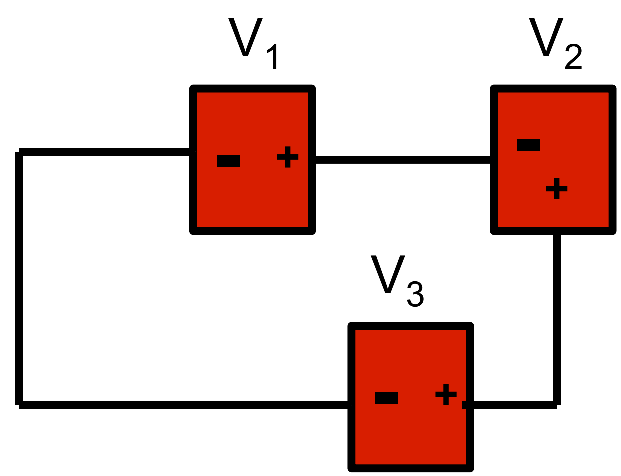
Learning Objectives For Today

- Sum of current into a device or a **node** is always 0
- Sum of voltage drop across any loop of devices is always 0
- Calculating the **power** used by a device or circuit
- The characteristics of a **resistor** (type of device)
- Be able to use your **DMM**

Kirchhoff's Current and Voltage Laws (KCL & KVL)

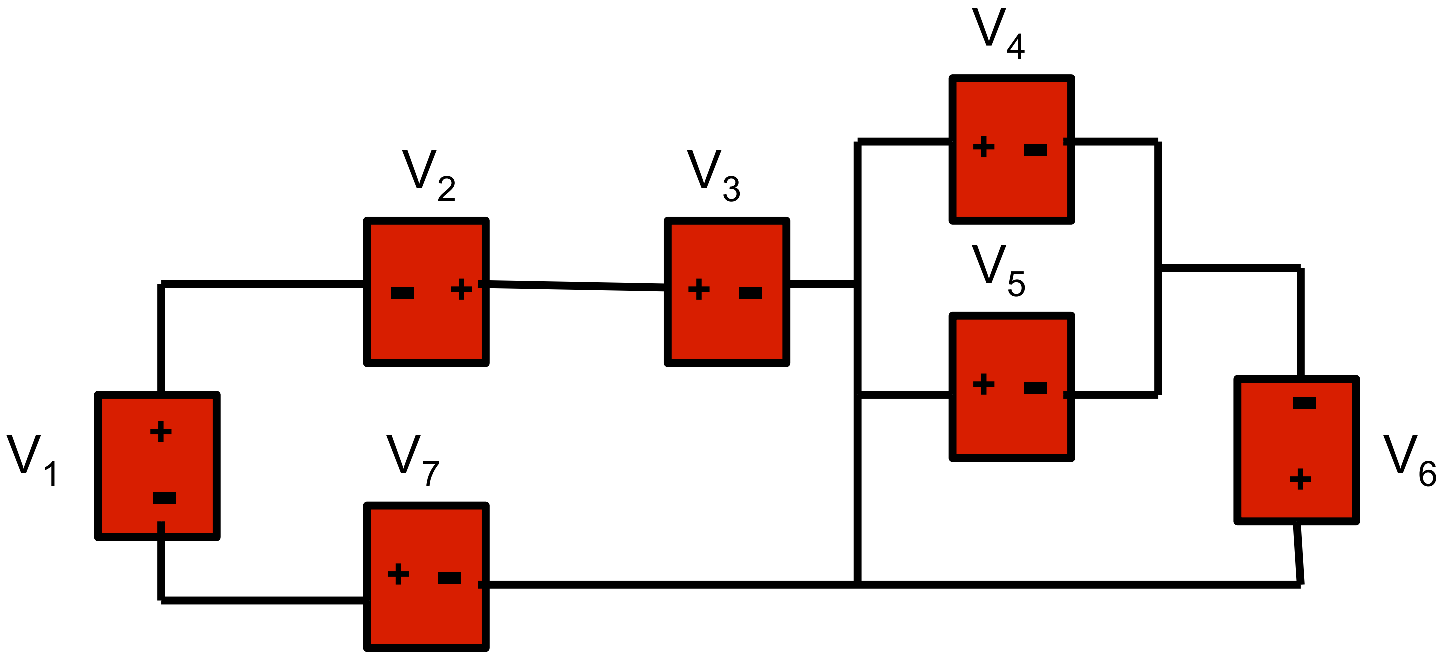


Kirchoff's Current Law (KCL) states that the current flowing out of any node must equal the current flowing in. So, for example, $i_1 = i_2 + i_3$



Kirchoff's Voltage Law (KVL) states that the algebraic sum of the voltages around any closed path must be zero. So, for example, $V_1 + V_2 – V_3 = 0$

Example #1: Kirchhoff's Voltage Law (KVL)



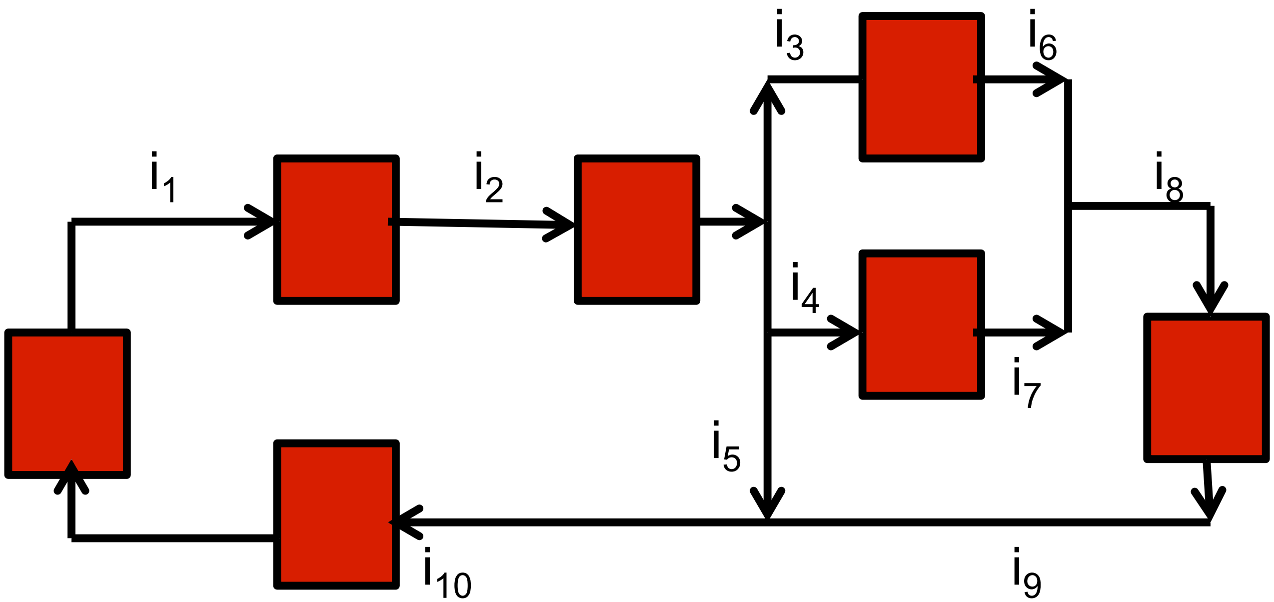
$$V_1 + V_2 - V_3 - V_4 + V_6 + V_7 = 0$$

$$V_1 + V_2 - V_3 + V_7 = 0$$

$$\therefore -V_4 + V_6 = 0 \qquad \text{(Check for consistency)}$$

Quiz: What can you say about V_4 and V_5?

Example #2: Kirchhoff's Current Law (KCL)



$i_1 = i_2 = i_{10}$ $i_2 = i_3 + i_4 + i_5$

$i_3 = i_6$ and $i_4 = i_7$ $i_8 = i_9 = i_{10} - i_5$

Please Note: What the '+' on a Device or an → on a Current Means

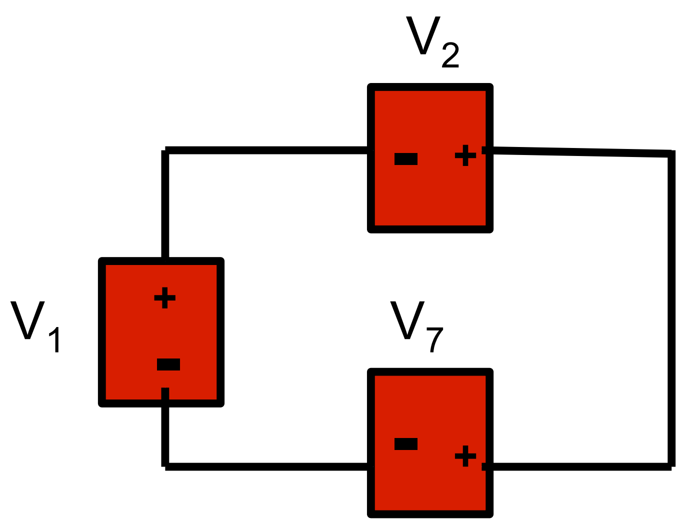
- Notice that when we measure a voltage across a device
  - We add a "+" to one lead and "-" to the other
  - These define the reference direction for the voltage measurement

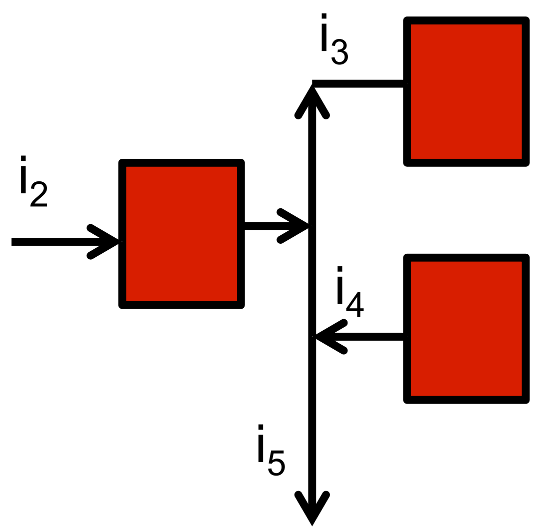
- **It does NOT mean that the "+" lead is higher than the "-" lead**

- It means that:
  - You should connect the red lead of your DMM to the "+" terminal
  - You should connect the black lead to the "-" terminal
  - The voltage you measure could be positive or negative

- Similarly an → is only an assumed current direction. The measured or calculated current can be positive or negative.

Reference Conventions





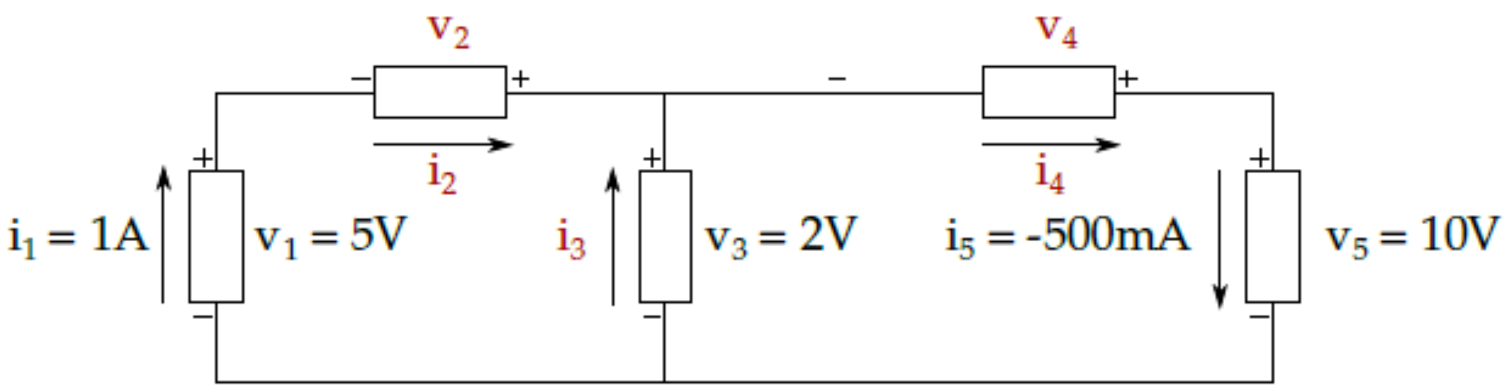
$V_1 + V_2 - V_7 = 0$

$i_2 + i_4 = i_3 + i_5$

When we do real problems like this we may calculate positive or negative answers for the various voltages and currents. It doesn't matter what assumptions you make in doing your analysis.

Using KCL and KVL

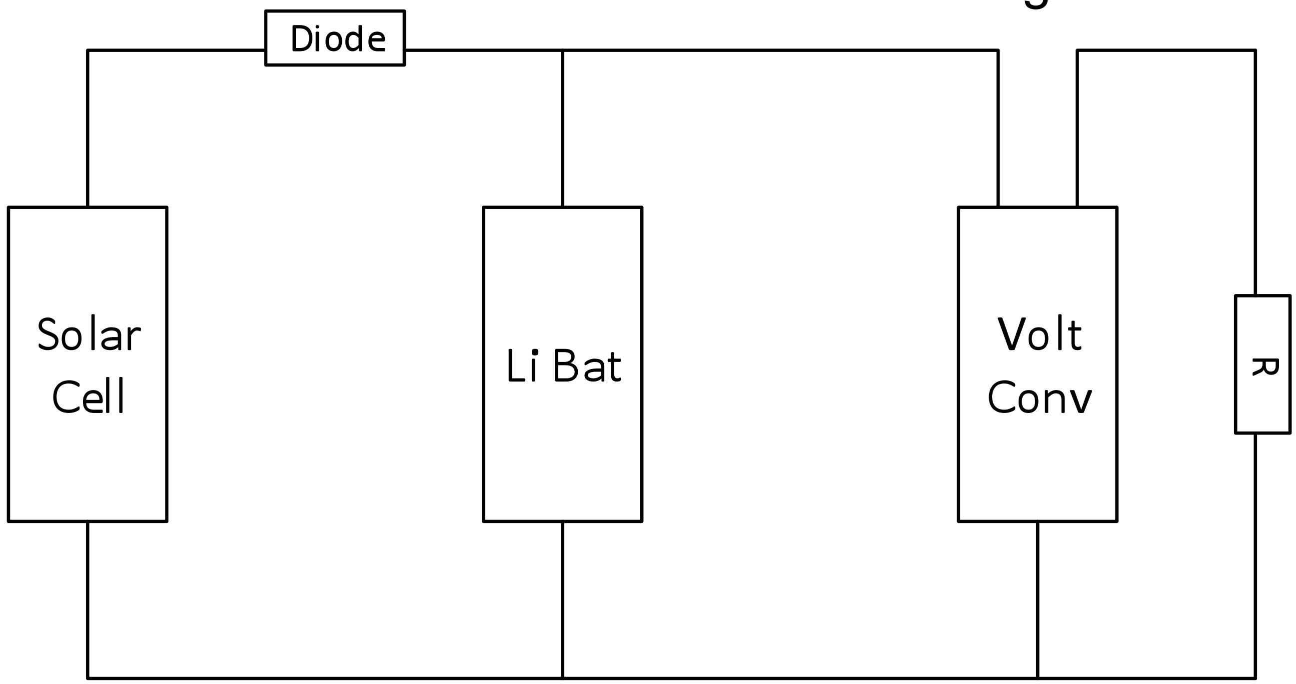
- Find the current, and voltages for the circuit below



ENERGY & POWER

Getting Back to the Solar Charger

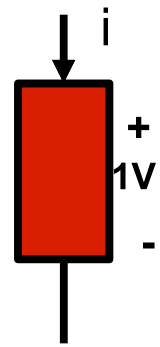
- Look inside:
  - See a number of different devices wired together in a circuit:



- Need to move energy around
  - And that is done with voltage and current

Electrical Energy

- Remember definition of a volt?
  - Joule/coulomb
  - Means moving1 coulomb of charge through 1V requires 1J



- Remember definition of an amp?
  - Coulomb/sec
- Power being “dissipated” in the electrical component
  - (1A)(1V) = 1 watt of energy
  - Generally this energy is converted to heat

PERHAPS A BETTER MOTIVATING EXAMPLE

If I Apply 110V Across a Hot Dog

- How much power does it dissipate?

- What will happen to its temperature?

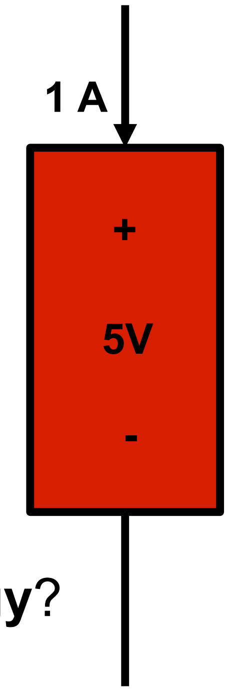
I happen to have one right here …

Getting a Feeling for a Watt

- Quick physics review
  - Unit of energy — Joule = Coul*Volt
  - Unit of power — Watt = Joule/sec = A*V

- If those mean nothing to you
  - You probably know about calories
    - Another unit of energy
    - Calorie = 4 kJ (a little c-calorie is only 4 J)
    - 2000 Calories = 10MJoules
  - 10M Joules/day = 10M/24*60*60 ~ 100W (power you put out)
    - 30% is your brain, so your brain uses around 30W

Energy Flow

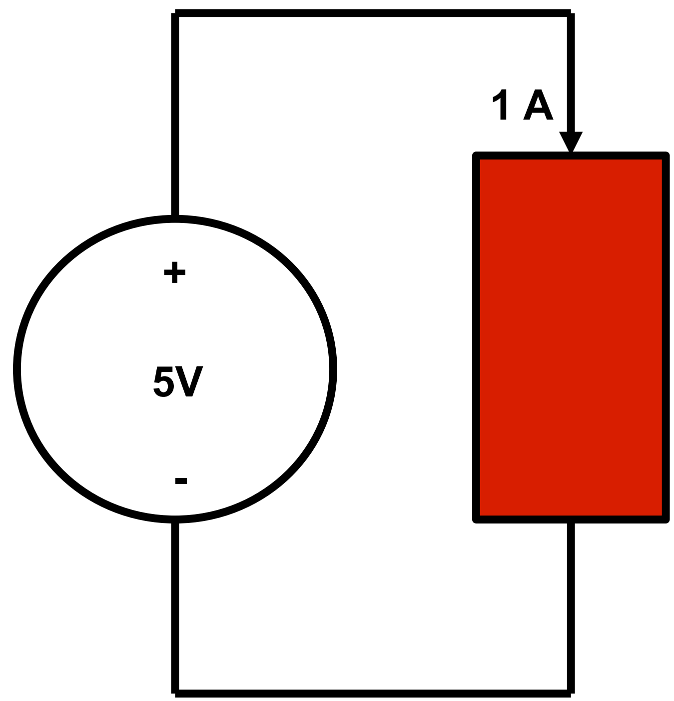


- The red box energy flow is:
  - 1A * 5V = 5W

- Is the box generating or consuming this power?
  - Every charge that enters, also leaves
    - Charge neutral
  - **Does the charge leave with more or less potential energy**?
    - More is higher voltage, less is lower voltage
  - If it leaves from the
    - Lower voltage lead – energy was lost;
      - The box absorbed some energy
    - Higher voltage lead – energy was gained;
      - The box supplied voltage

Energy Flow

- What generate/dissipates energy
  - The 5V voltage supply
  - The red box



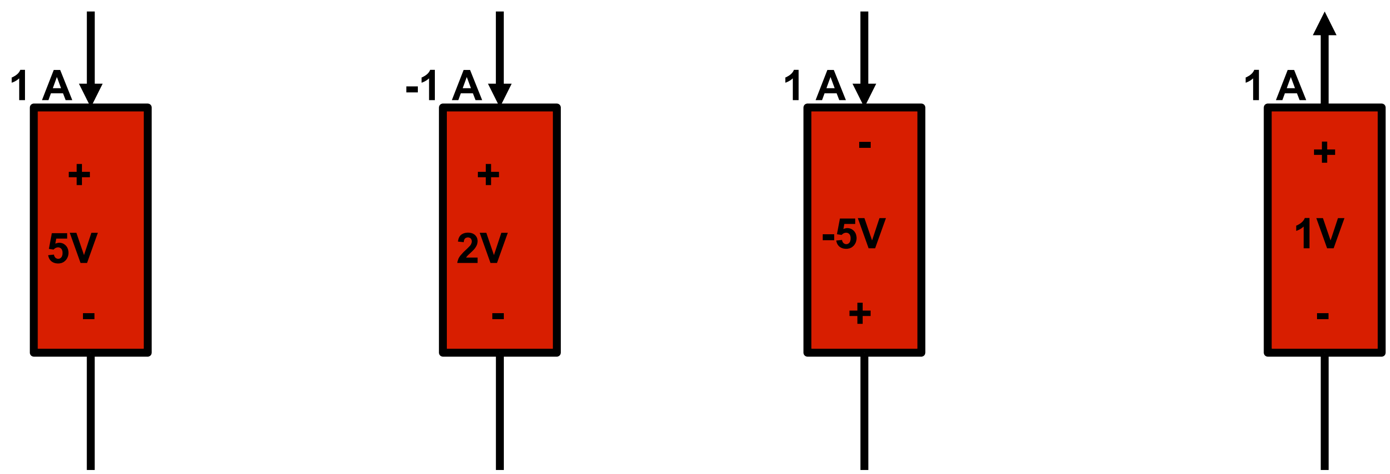
The Hot Dog

- Its voltage was 110V
  - The current was __________

- It dissipated ____________
  - And dissipating power makes things warm …

Find the Power Dissipated In Each Device

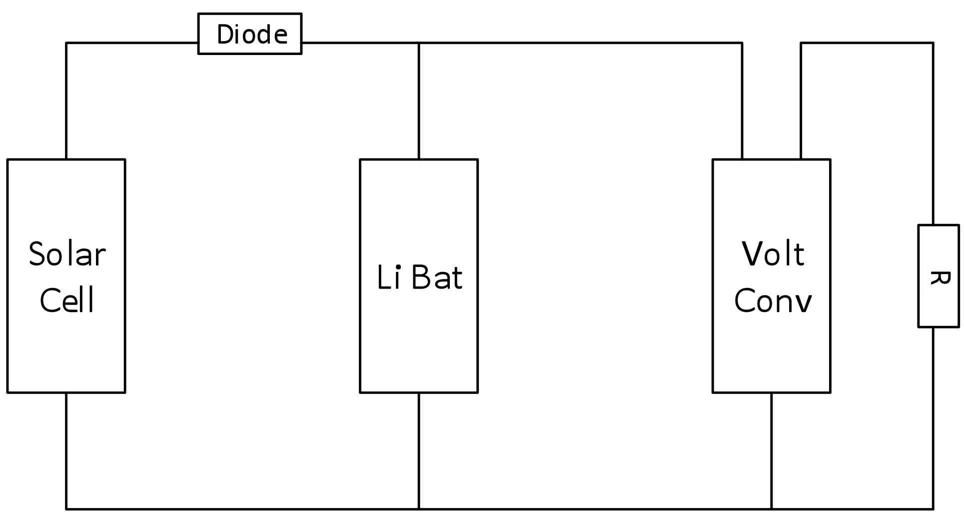
- First figure out which lead has the higher voltage
  - Then figure out whether current flow into or out of that lead



DEVICE MODELS:

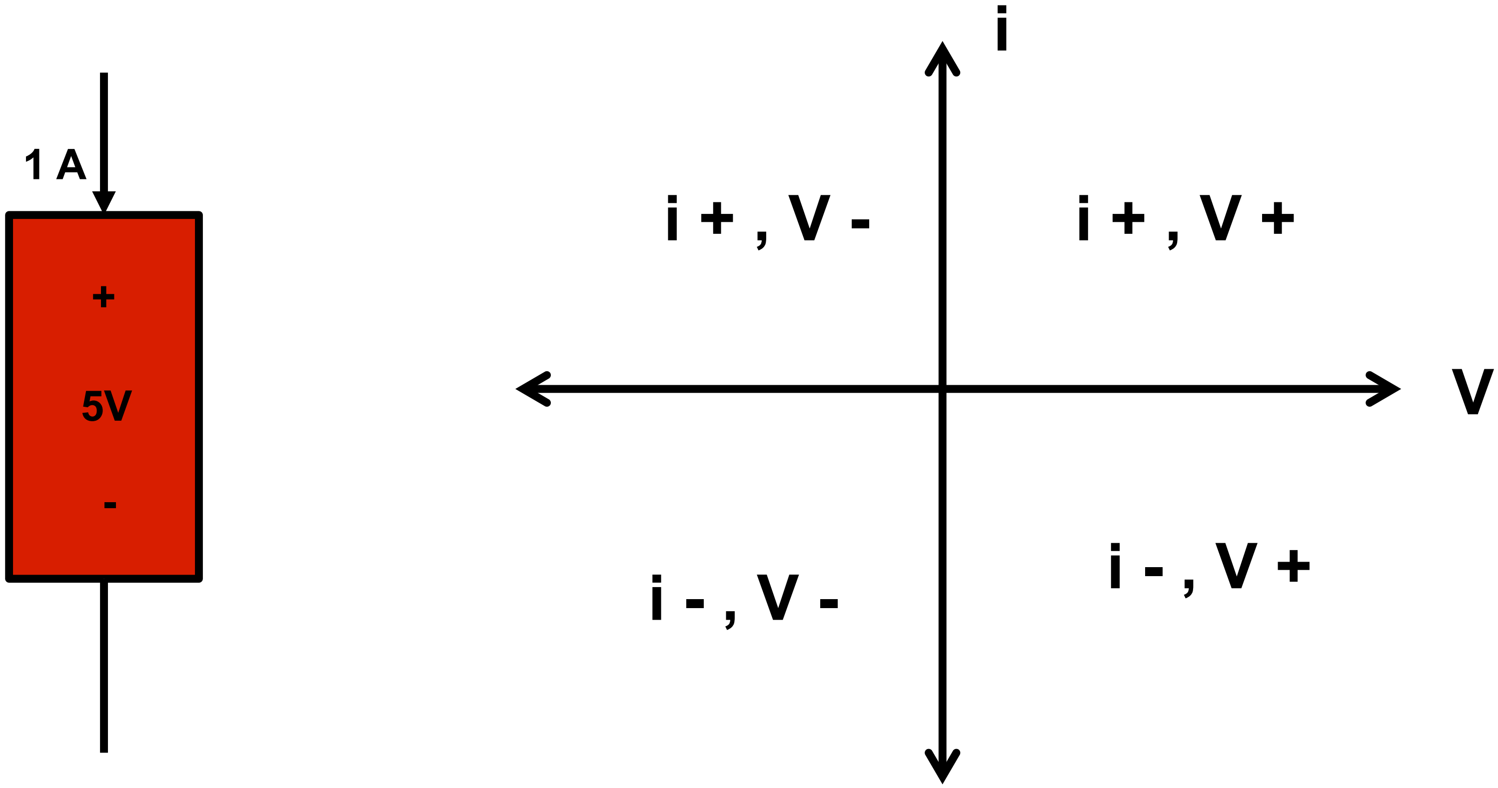
Almost Have Tools for Solar Charger

- Know about voltage and current
  - iV is the power used/generated by an element
- Now need to know the relationship between iV
  - For these devices:



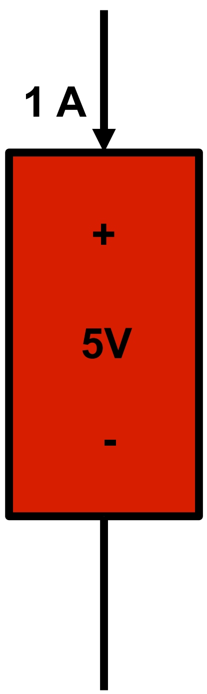
Device Models

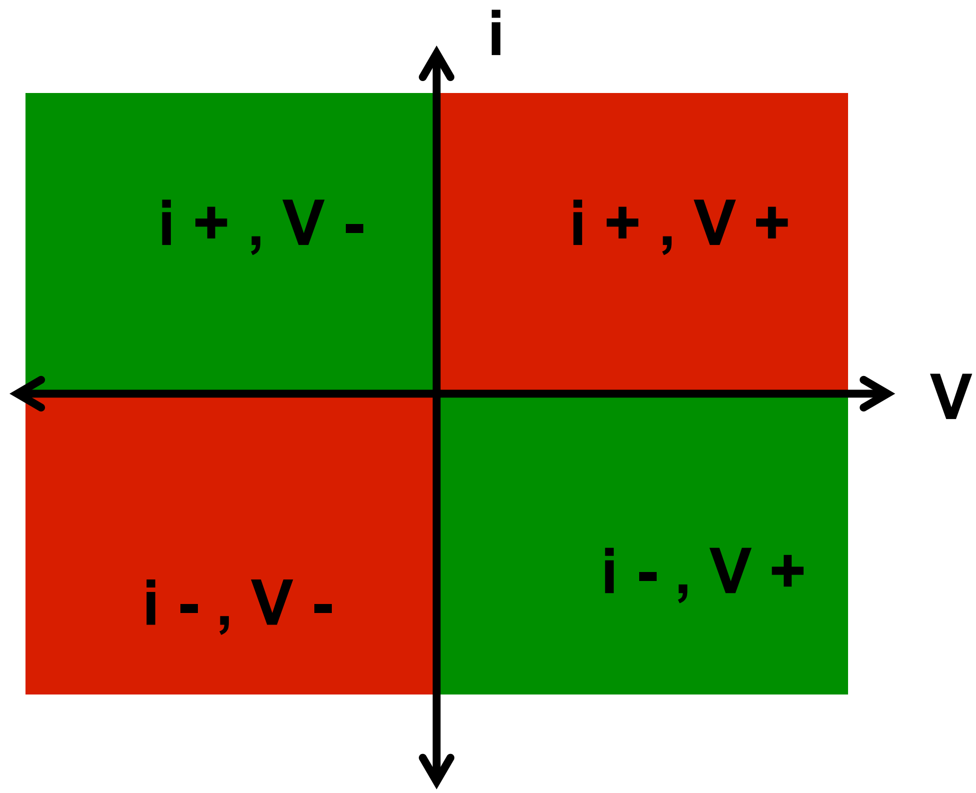
- It's useful to represent what a "device" does by plotting its characteristics on a plot of i vs. V.
- i is the current through the device, V is the voltage across the device.



Device Models

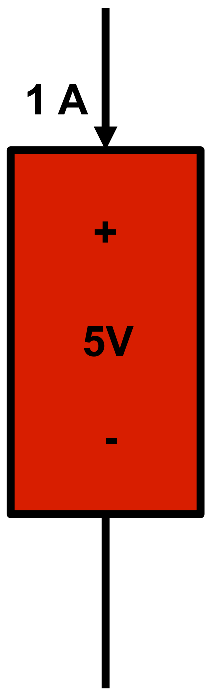
- Note that the energy is dissipated by the device in quadrants 1 and 3, and power is generated by the device in quadrants 2 and 4.

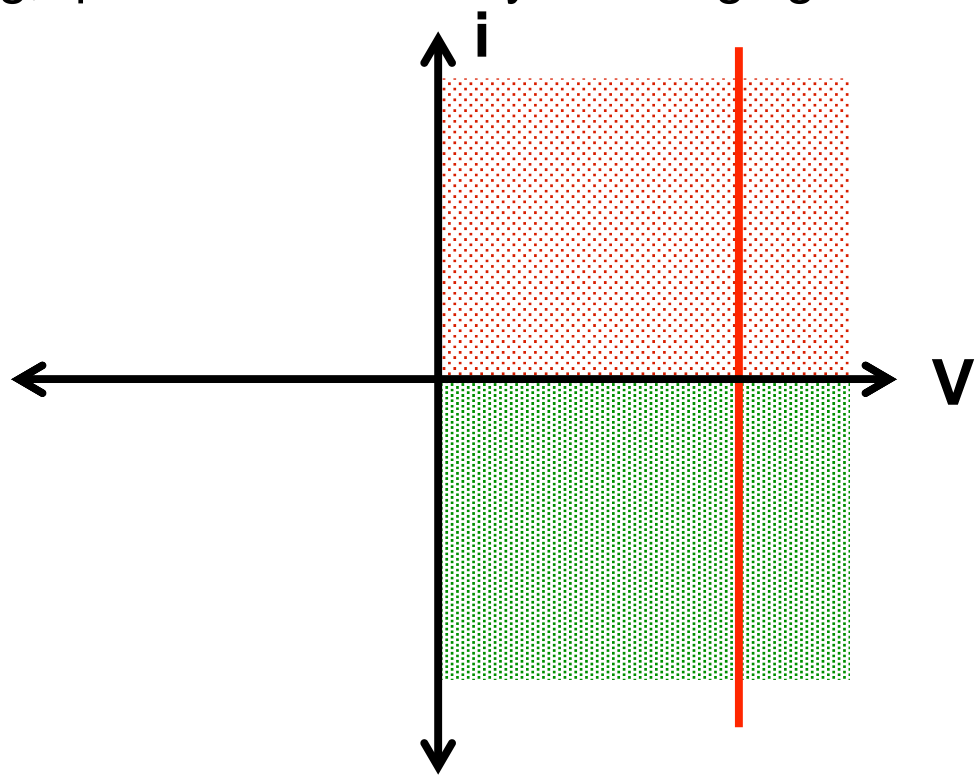




Device Models – Battery, Voltage Source

- A battery or a voltage source provide a fixed out put voltage no matter what current they are asked to provide or consume (“sink”).
- In quadrant 1 energy is consumed, in quadrant 4 energy is provided.
- Quadrant 1 = battery charging, quadrant 4 = battery discharging.

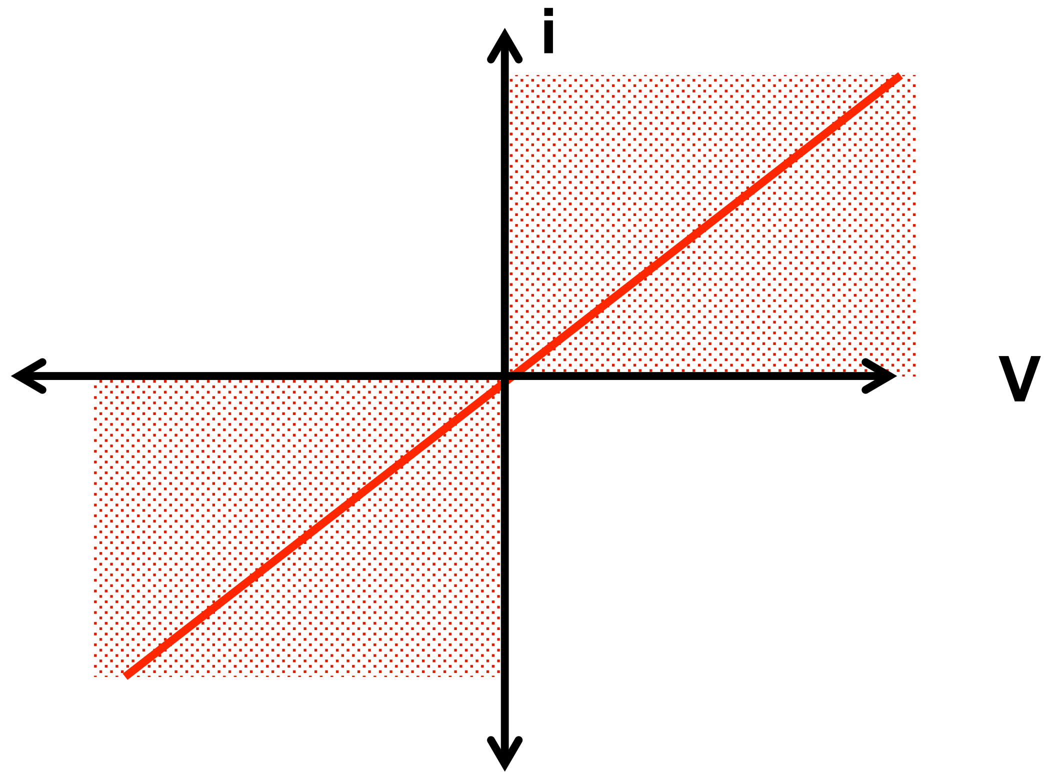




Device Models – Resistors

- Current is proportional to voltage
  - V=iR – Ohm's Law

- Symbol

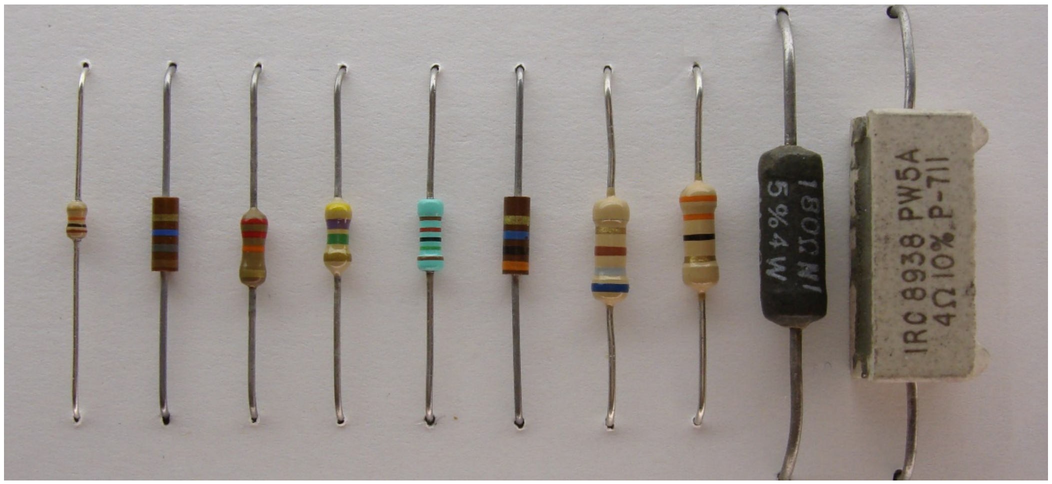


Why Does Resistance Exist (What Physical Effect Does it Model)

- Conductors are not perfect
  - They use a little energy to get current to flow through a wire[1]
- Since the energy flow into the wire is (i ΔV)
  - There must be a voltage drop along the wire
  - Generally this drop is proportional to the current
    - V = k * i
    - Call the constant of proportionality, Resistance
- Make resistors by using material that doesn't conduct well

[1]Well except for superconductors which are magical. They have interesting properties, like current can flow in a loop forever! And this is used in MRI machines to make large magnetic fields.

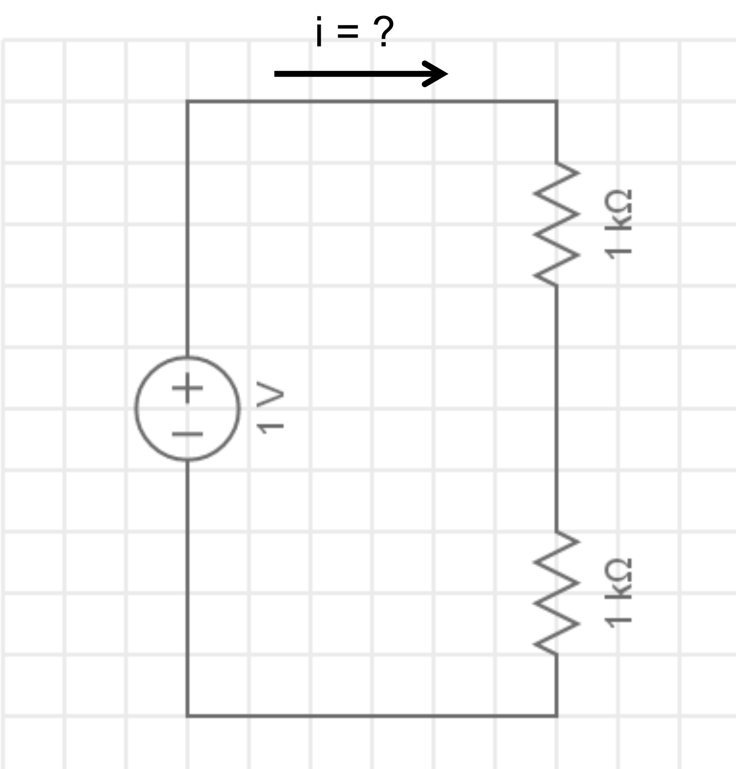
Resistors



http://ecee.colorado.edu/~mathys/ecen1400/labs/resistors.html

http://www.instructables.com/id/Reading-Surface-Mount-Resistor-codes/

Resistance Problem #1

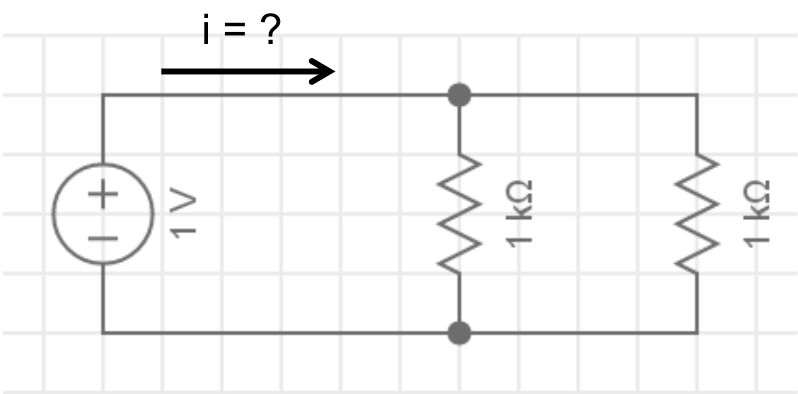


What current flows in the loop?

What is the voltage across the bottom resistor?

Resistance Problem #2

What is the current i?



Learning Objectives for Today

- Sum of current into a device or a **node** is always 0
  - (**KCL**)
- Sum of voltage drop across any loop of devices is always 0
  - (**KVL**)
- Calculating the **power** used by a device or circuit
  - Power is energy/sec
  - Power = iV
- A **resistor** is a device
  - The current through a resistor is proportional to the voltage across it.
- Be able to use your **DMM** to measure:
  - Voltage, current, and resistance of a resistor