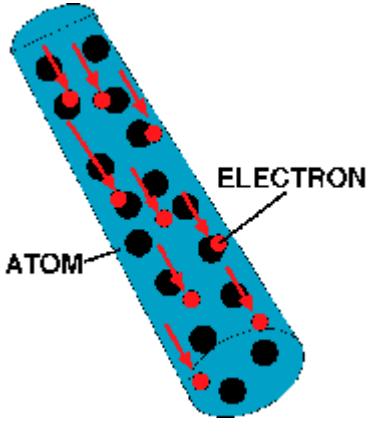
Intro to Electronics

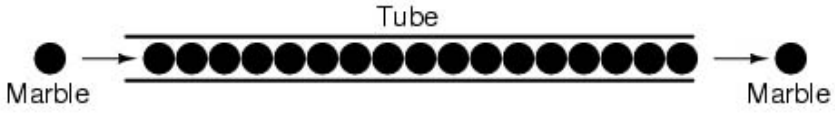
Things to be covered:

- What is electricity
- Voltage, Current, Resistance
- LEDs
- Ohm’s Law
- Capacitors
- Breadboards

Electricity is the flow of Electrons

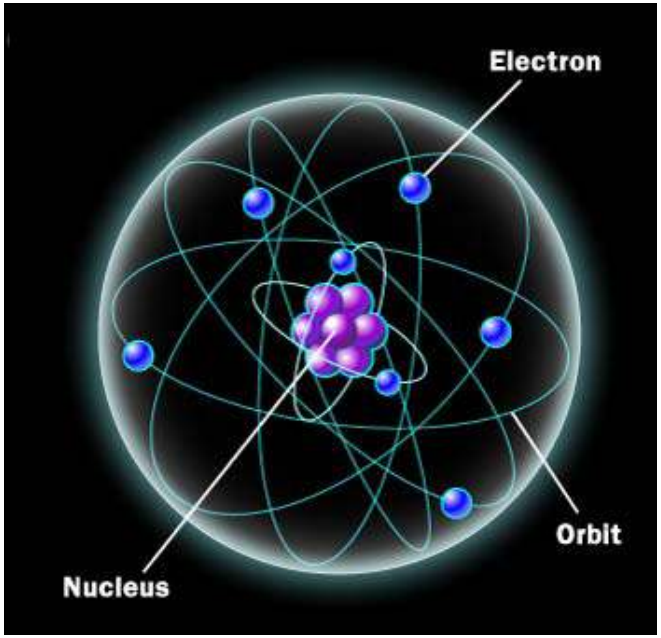
- Atoms in every material are made up of electrons and protons
- Electrons (- charge) are attracted to protons (+ charge), this holds the atom together
- Some materials have immobile electrons, these are called insulators (air, glass, rubber, most plastics)
- Some materials have electrons that are free to move, these are called conductors (copper, silver, gold, aluminum)
- In a conductor, electrons can be made to move from one atom to another, this is called a current of electricity.



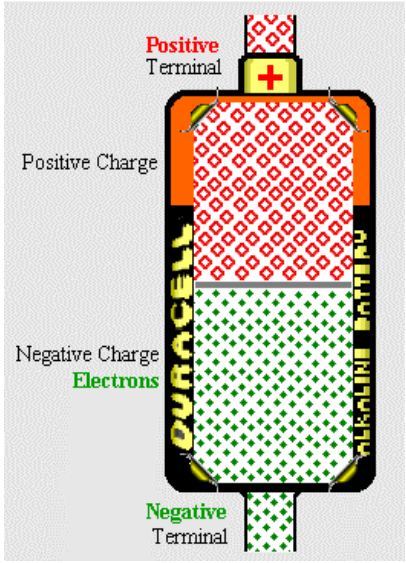


What is Electricity

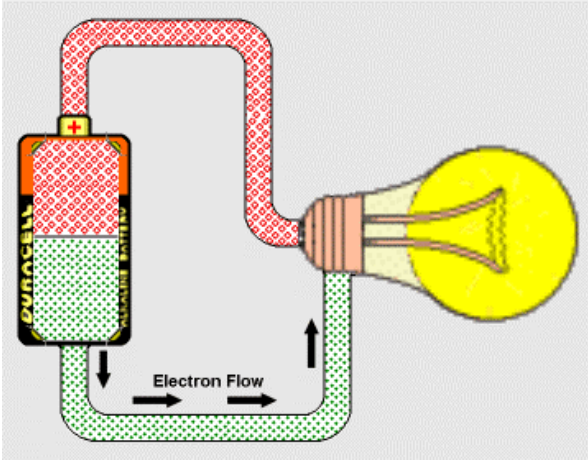
- Everything is made of atoms
- Atom consists of electrons, protons, and neutrons
- The electrons orbit the protons and neutrons in the nucleus
- The electrons in conductive materials are free to move from atom to atom



- Surplus of electrons is called a negative charge (-). A shortage of electrons is called a positive charge (+).
- A battery provides a surplus of electrons by chemical reaction.
- By connecting a conductor from the positive terminal to negative terminal electrons will flow.



- **A circuit must be closed loop**
- **By convention electricity runs from Positive (+) to Negative (-)**
- **Ben Franklin was wrong**

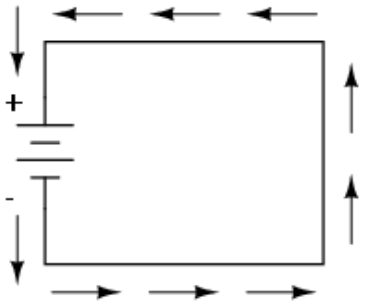


Current

Flow of Water

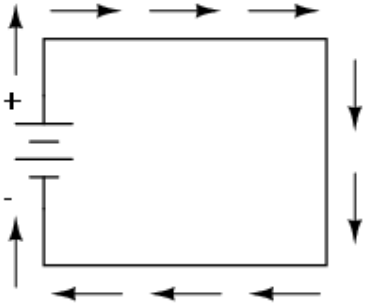
Flow of Charge

Electron flow notation



Electric charge moves from the negative (surplus) side of the battery to the positive (deficiency) side.

Conventional flow notation



Electric charge moves from the positive (surplus) side of the battery to the negative (deficiency) side.

WILL USE CONVENTIONAL FLOW NOTATION ON ALL SCHEMATICS

Voltage

- A battery has a positive terminal (+) and a negative terminal (-)
- The Voltage measured between the terminals of a battery is a measure of the ability of the battery to move charge through an external circuit.

Water Analogy

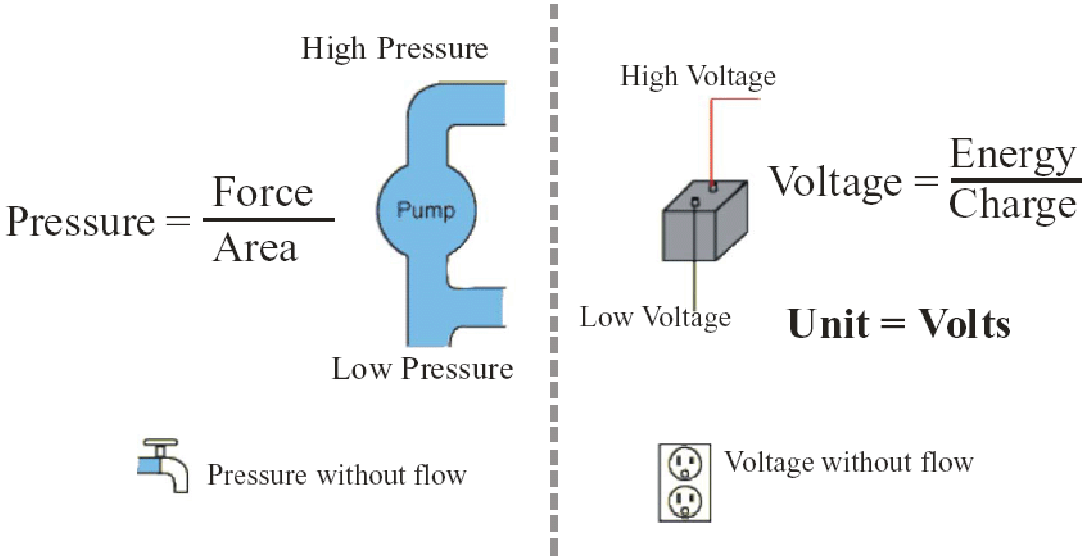
- A battery is analogous to a pump
- A **higher voltage** battery is analogous to a **higher pressure** pump

Voltage

V E Potential

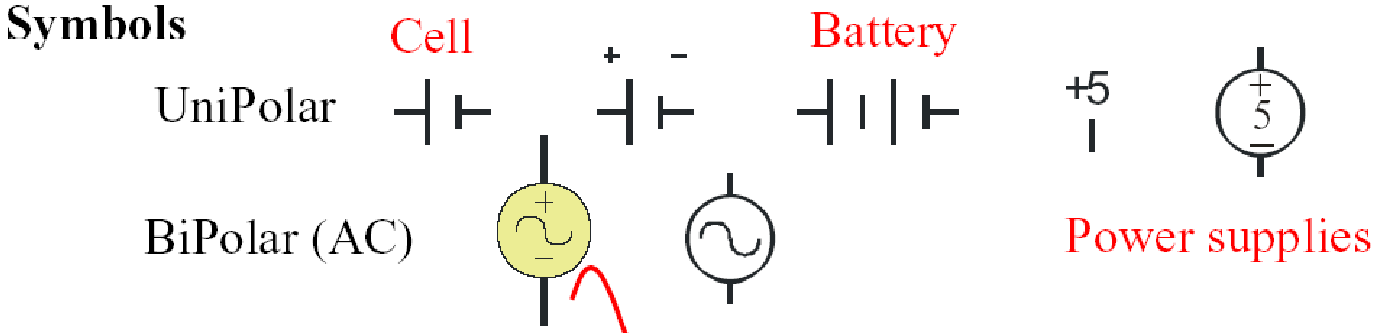
Voltage = **E**lectro-**M**otive **F**orce, the driving force in electron flow

Water Analogy | Electrical Equivalent



Voltage Sources:

Symbols



Properties

Constant Voltage, independent of the amount of current

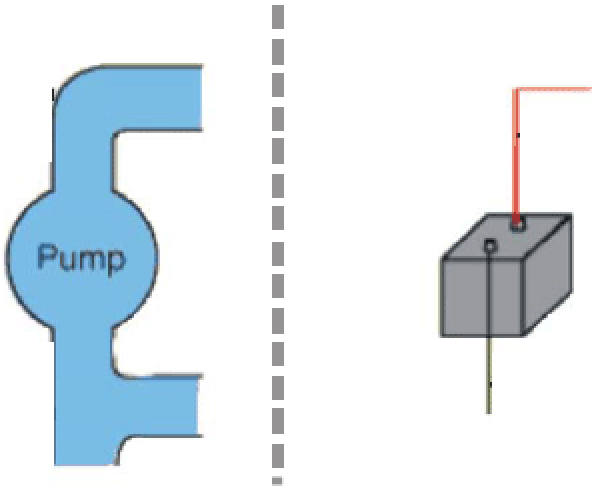
Usually ideal

Examples

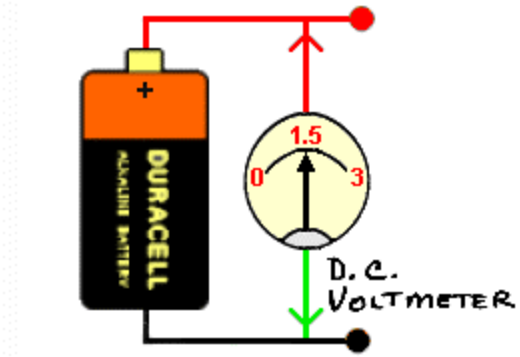
Batteries

Power Supplies

Signal Generators

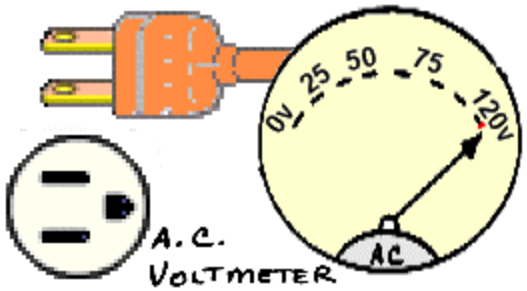


- Voltage is like differential pressure, **always measure between two points**.



- Measure voltage between two points or across a component in a circuit.

- When measuring DC voltage make sure polarity of meter is correct: **positive (+) red, negative (-) black**.



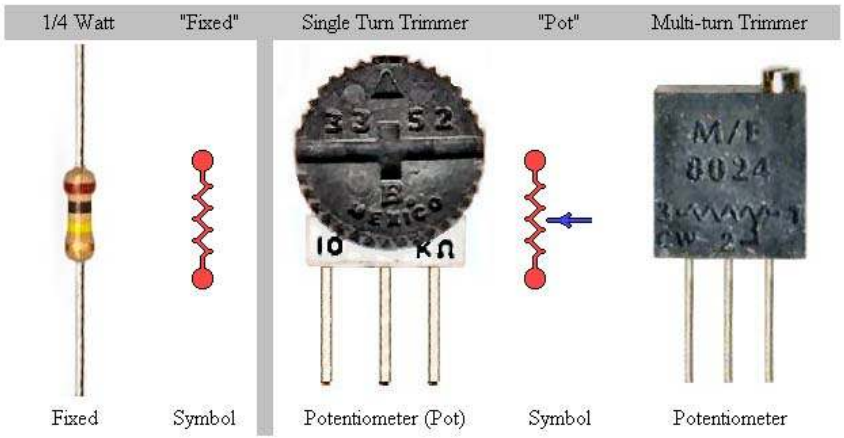
Resistance

Constriction
creates
Resistance to water flow

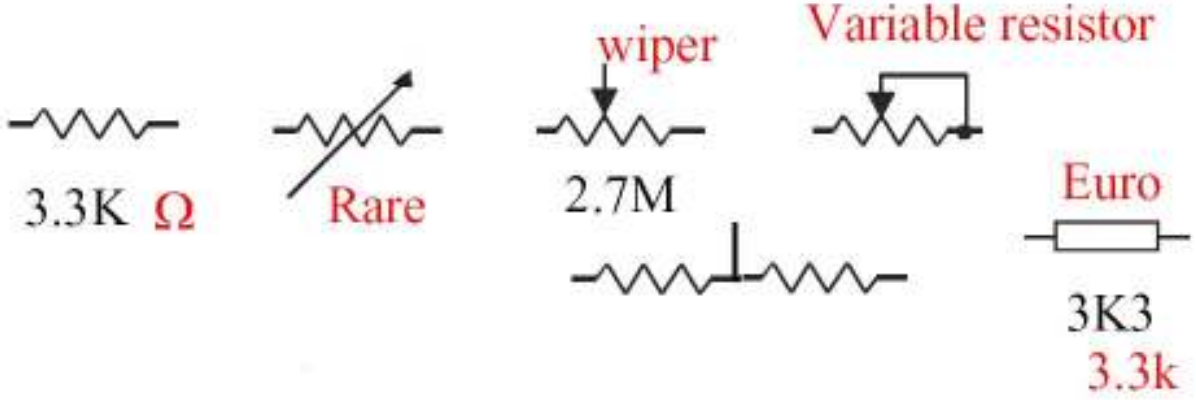
Resistor creates
Resistance to current
flow

- Used to control current
- The degree of resistance to electrical current flow is measured in Ohms.
- Common example: audio volume control

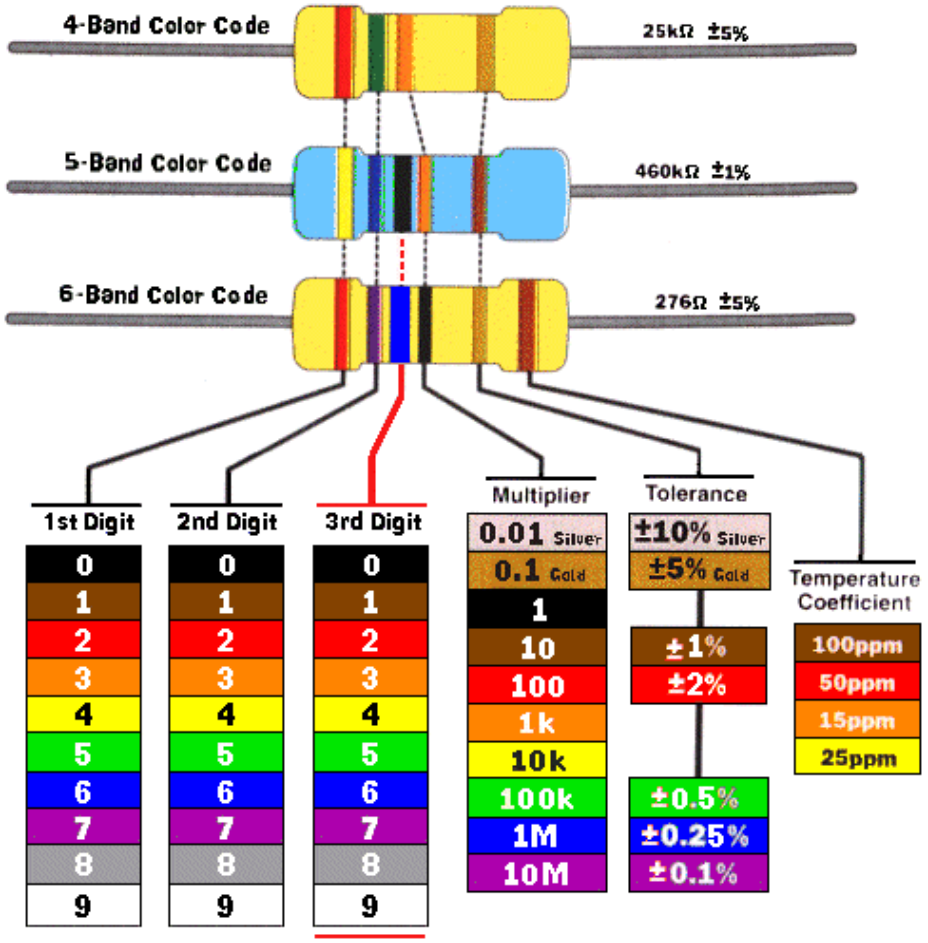
Various resistors types



Symbols



Resistor Color Code



Multimeter Overview

AC Voltage (ACV or ~)

DC Voltage (DCV)

Current (DCA)

Resistance (Ω)

High current

ACV, DCV, Ω, small current

Common connection

IMPORTANT: when set to **any** current scale,
meter must **only** be connected in series (like a “smart wire”)

Multimeter Scales

V	1	Volts
mV	1/1000	millivolts

A	1	Amperes (Amps)
mA	1/1000	milliamps
μA	1/1,000,000	microamps

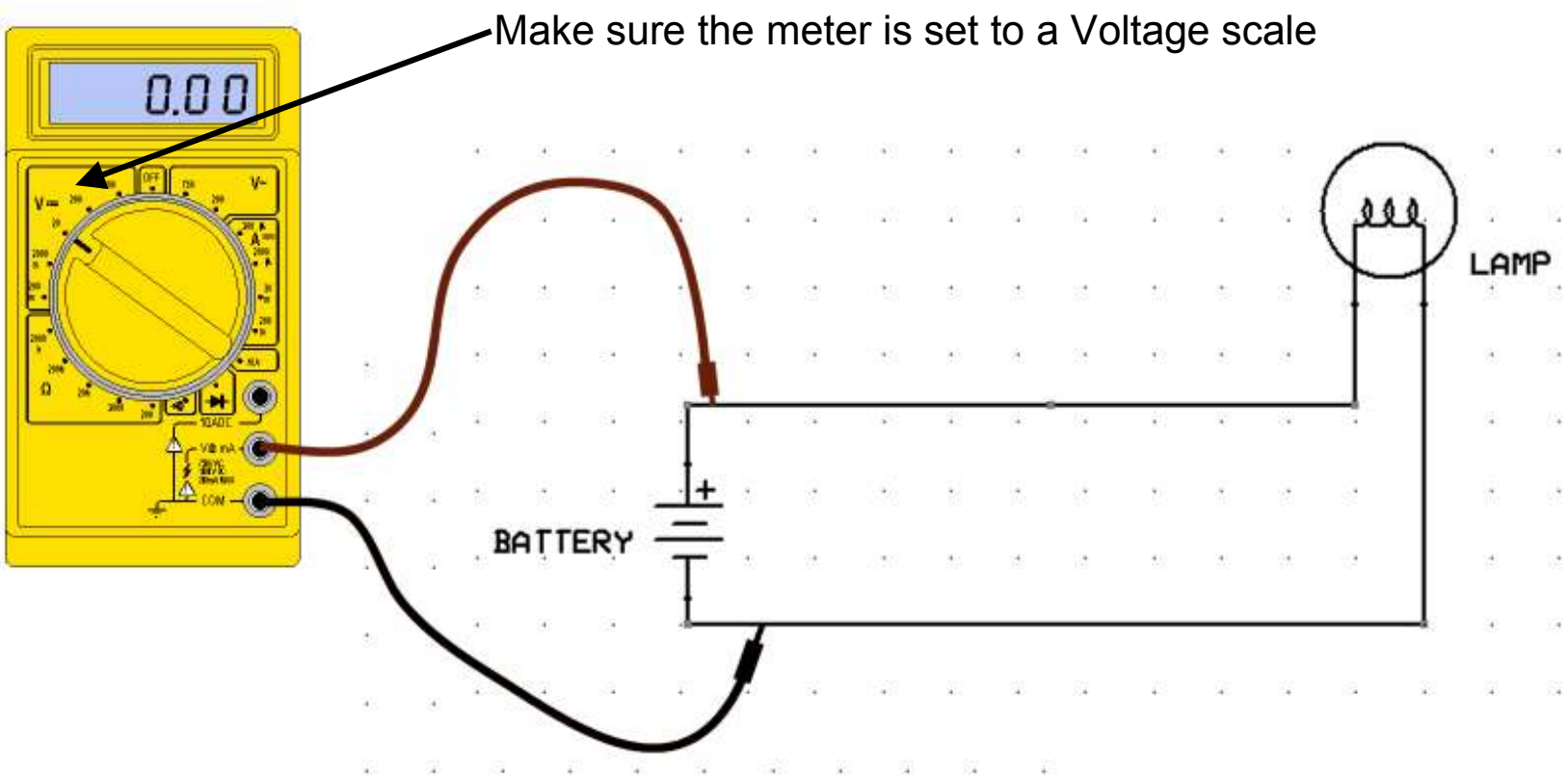
Ω	1	Ohms
kΩ	1000	kilohms
MΩ	1,000,000	megohms

Multimeter Notes

- IMPORTANT: when set to **any** current scale, the meter must **only** be connected in series (like a “smart wire”)
- When measuring current, start at a high scale and move down
- A resistor must be removed from a circuit before measuring its resistance

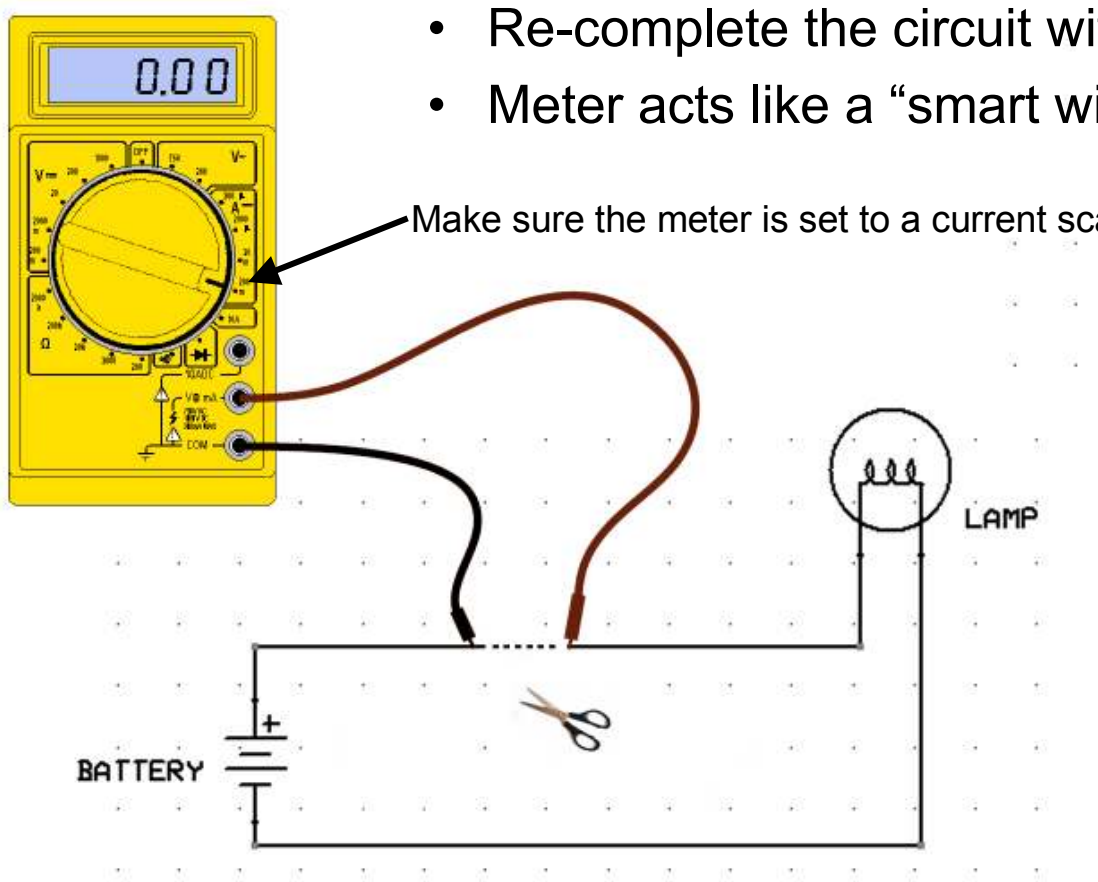
Measuring Voltage

- Always measured between two points in a circuit
- Negative (black lead) connects to a reference point
  (often ground or battery -)
- Positive (red lead) connects to another point in the circuit



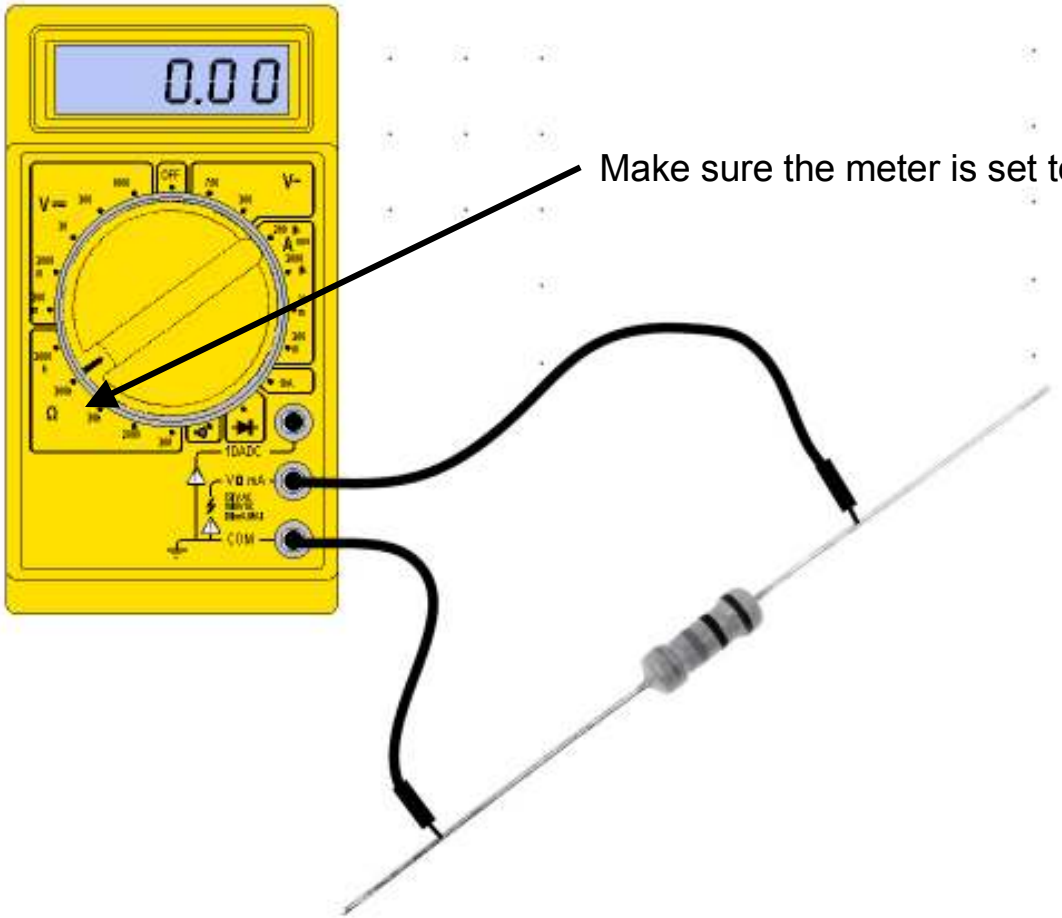
Measuring Current

- Current is measured **through a section** of a circuit
- Meter must be connected in series
- Open a section of the circuit
- Re-complete the circuit with the meter
- Meter acts like a “smart wire”



Measuring Resistance

- Measured with resistor (or other device) out of circuit
- Connect one lead to each lead of the component



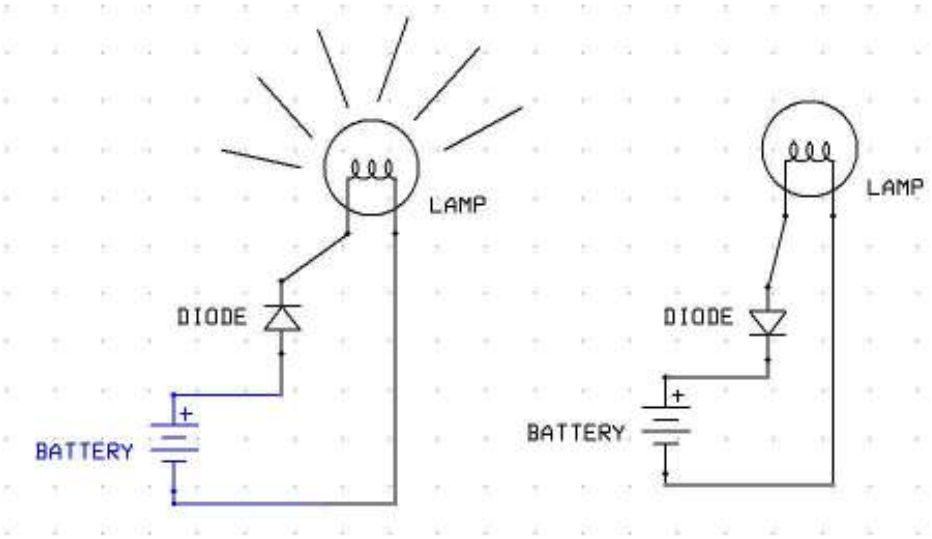
Exercise

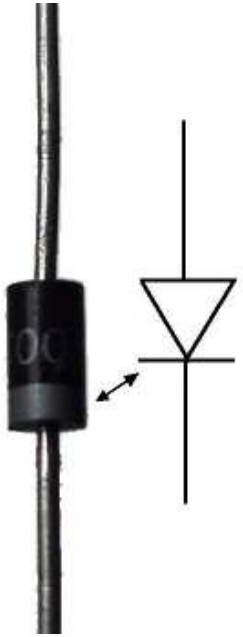
- Measure DC voltage from battery using multimeter
- Connect light bulb to 9 Volt battery
- Connect light bulb to 3 Volt battery
- Light should be brighter when connected to higher voltage
- Find a 50 Ohm resistor using multimeter
- Insert resistor into the circuit
- Light should be dimmer

Diode Exercise

- Diodes allow current to flow in only one direction
- The arrow on the symbol points in the direction of **positive** current flow

- Insert a diode into your lamp-battery circuit
- Reverse direction of diode
- Verify that current only flows one way

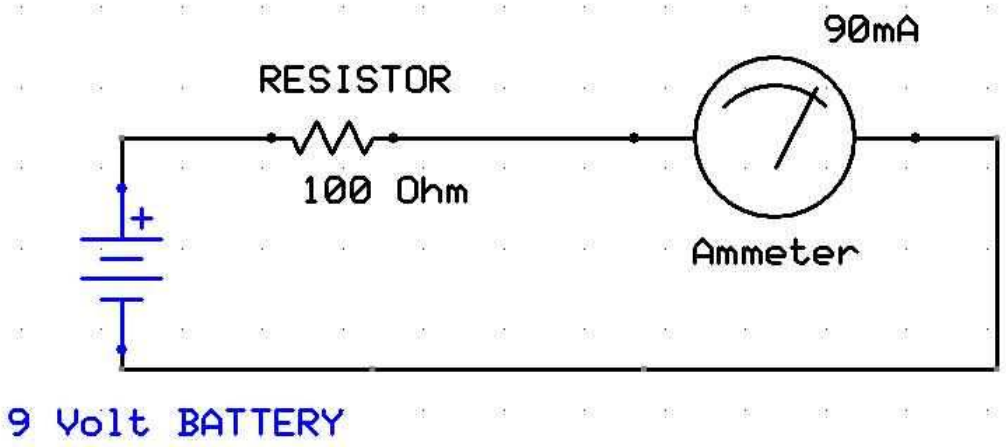




Current

- Electric current is a measure of the quantity of charge that is flowing
- It is measures in Amperes, “Amps” (or often milliamps)
- Current must be **measured in series** (you must interrupt the circuit)
- Voltage, current, and resistance are related by Ohm’s Law:

V=I*R 9 = 0.090 * 100



Assignment

Assignment for Thursday Jan 28th:

- Order Arduino Kit ! http://www.adafruit.com/index.php?main_page=product_info&cPath=17&products_id=68
- Complete survey
- Read *Physical Computing,* introduction and chapters 1-3
  (note info relating to specific microcontrollers and BASIC)
- Read soldering tutorial pp. 41-45 of *Physical Computing*.,
- Review online soldering information available at:
  http://www.aaroncake.net/electronics/solder.htm
  http://itp.nyu.edu/physcomp/Tutorials/SolderingAPerfBoard

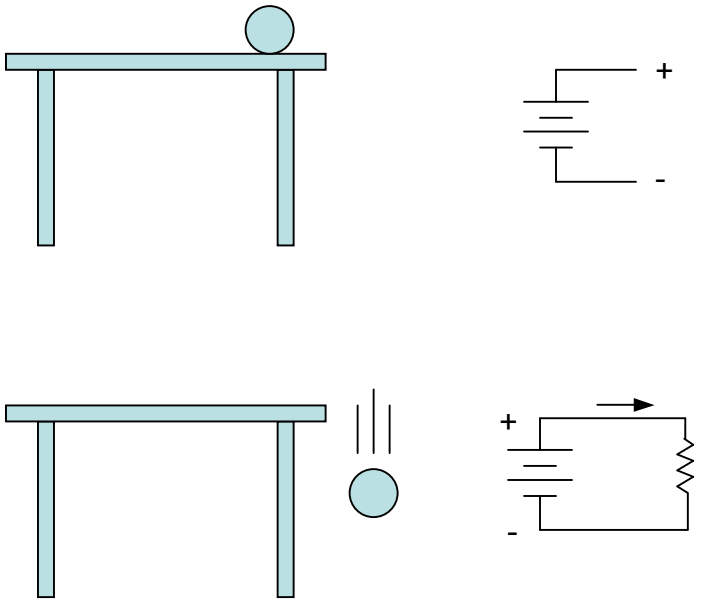
There is also a rather extensive video on soldering available at:
http://blog.makezine.com/archive/2007/01/soldering_tutor_1.html

More on Voltage

- Also called “electromotive force”
- Things fall because of gravitational force
- Currents flow in a circuit because of electromotive force (Voltage)

- Objects will only fall if they are given a path to the ground
- Electric current will only flow if given a path from high to low Voltage

Voltage Potential
Gravitational Potential Analogy



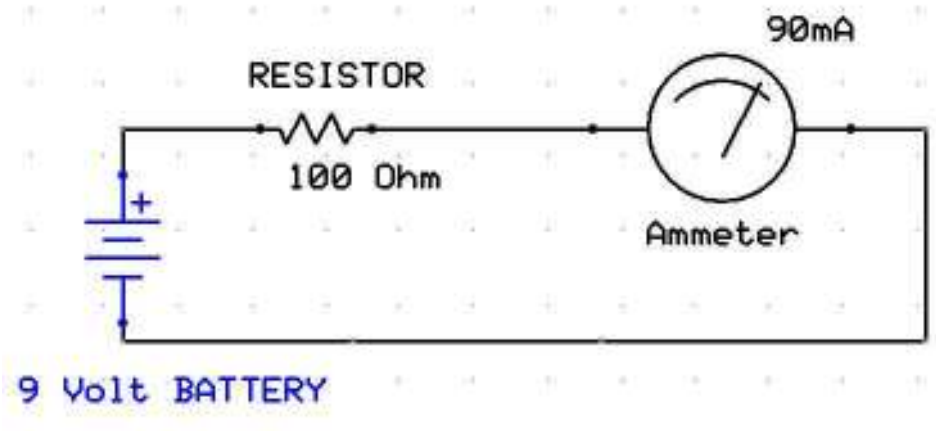
- a battery is like a bin of balls on the table, constantly supplying balls of a given potential
- imagine the table under water, air – low resistance, water - higher resistance

Voltage

- Voltage is always measured between two points in a circuit
- Sometimes we refer to a “voltage drop” or “voltage difference” between two points
- Other times voltage is stated with respect to a reference point called “ground” (usually the negative source of power)
- Voltage drops occur across components
- The voltage between one end of a wire to the other is zero

Current

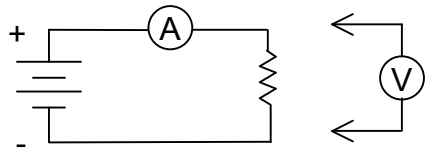
- Electric current (Amps) is the quantity of charge flowing through a section of a circuit
- Voltage may be present between two points, but current will only flow if there is a circuit between the points
- A current meter (Ammeter) must be inserted in series (you must interrupt the circuit)
- Think of an Ammeter as **a smart wire** telling you how much current is passing through it



Current & Voltage

- Voltage is always measured between **two points** in a circuit
- Sometimes we refer to a “voltage drop” or “voltage difference” between two points or across a component

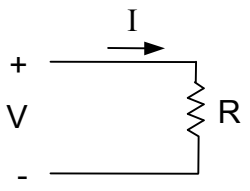
- Current is measured **at a point** in a circuit
- An **ammeter acts like a smart** wire telling you how much current is passing through it



Resistance

- Resistance determines the amount of current that will flow in the presence of a given Voltage
- The degree of resistance to electrical current flow is measured in Ohms (Ω)
- The **Voltage across** and the **current through** a resistor are related by Ohms law:

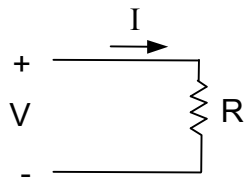
V=I*R



V	I (mA)	R (Ω)
9	90	100
9	9	1000
9	1.9	4700
6	6	1000
6	0.128	47k
1.5	0.15	10k

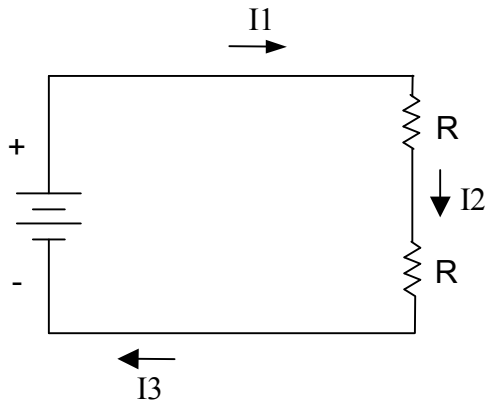
Resistance

- The resistance of a good wire is **much** less than 1 Ω
- A resistor of 1MΩ is still a **much** better conductor than the air around the circuit

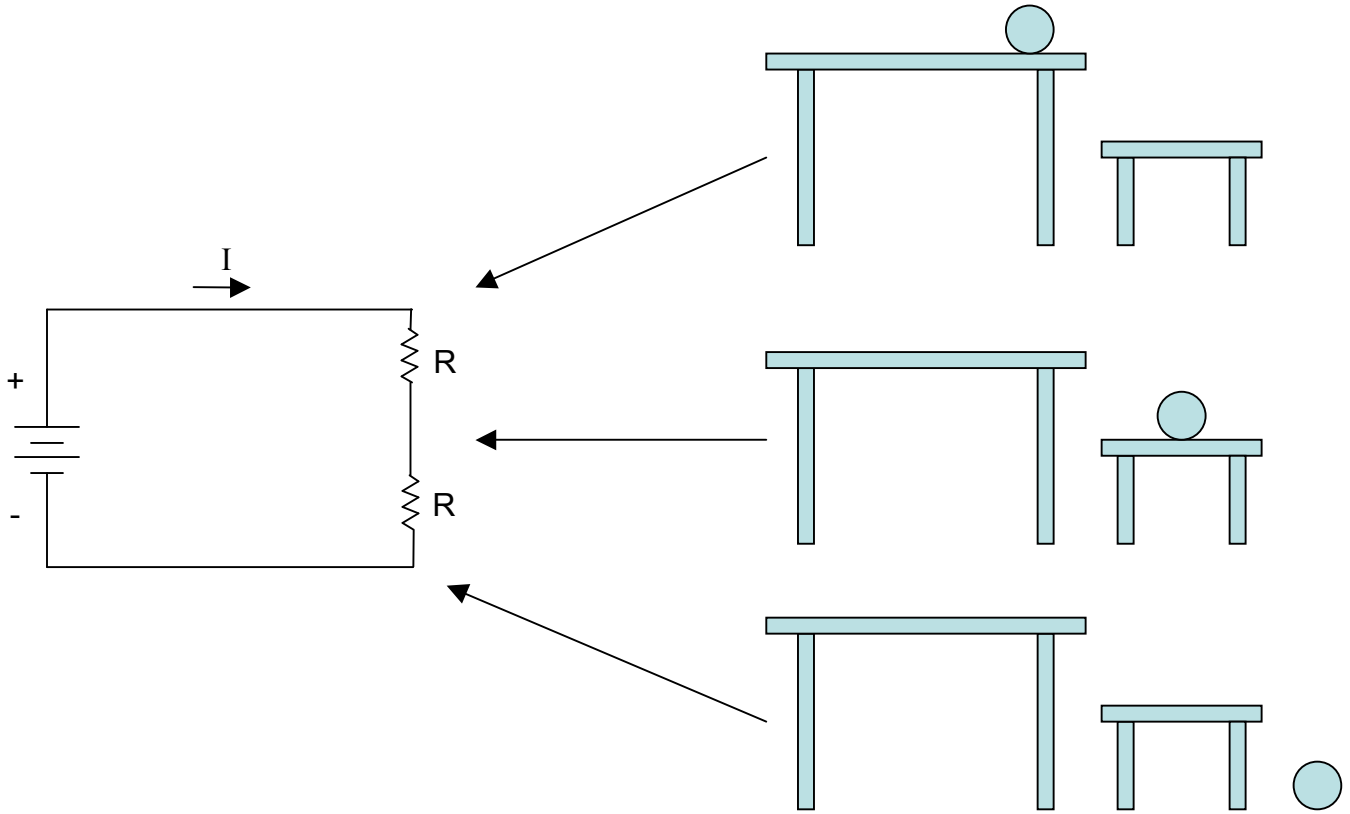


Series Circuits

- Current is conserved in a circuit
- $I1 = I2 = I3$
- The Voltage across each resistor depends on its individual resistance
- The voltage across each resistor obeys Ohms law

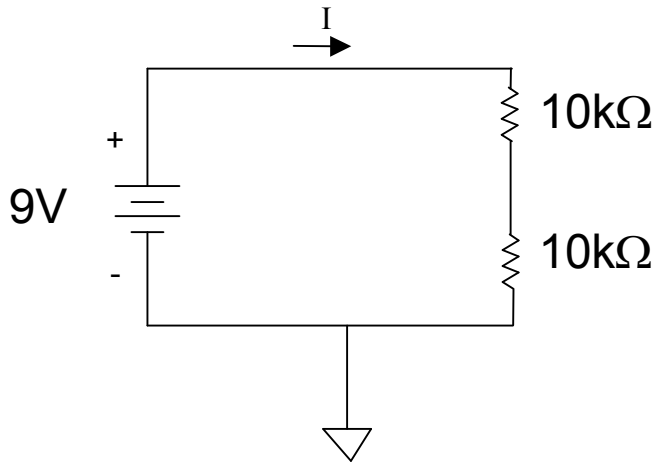


Series circuit Voltage drops



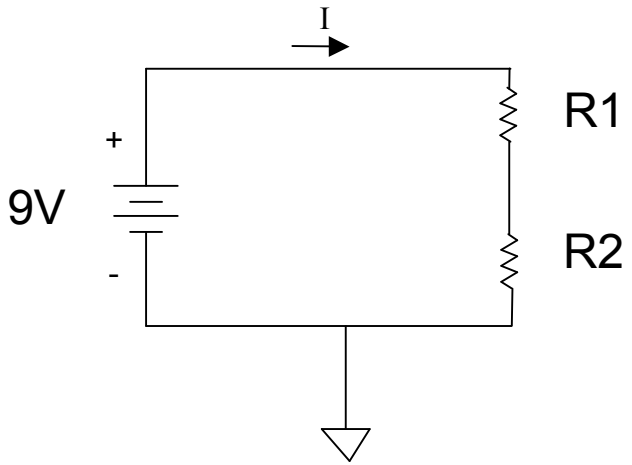
Voltage Divider Exercise

- Build the circuit shown below
- Measure the voltage (with respect to ground) at the point between the resistors
- Measure the voltage across the top resistor
- Change the bottom resistor to 1000Ω
- Measure the voltages once again

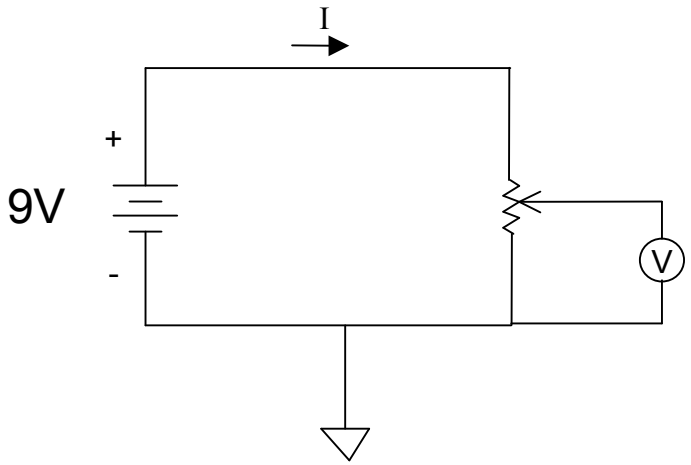


Voltage Divider Exercise

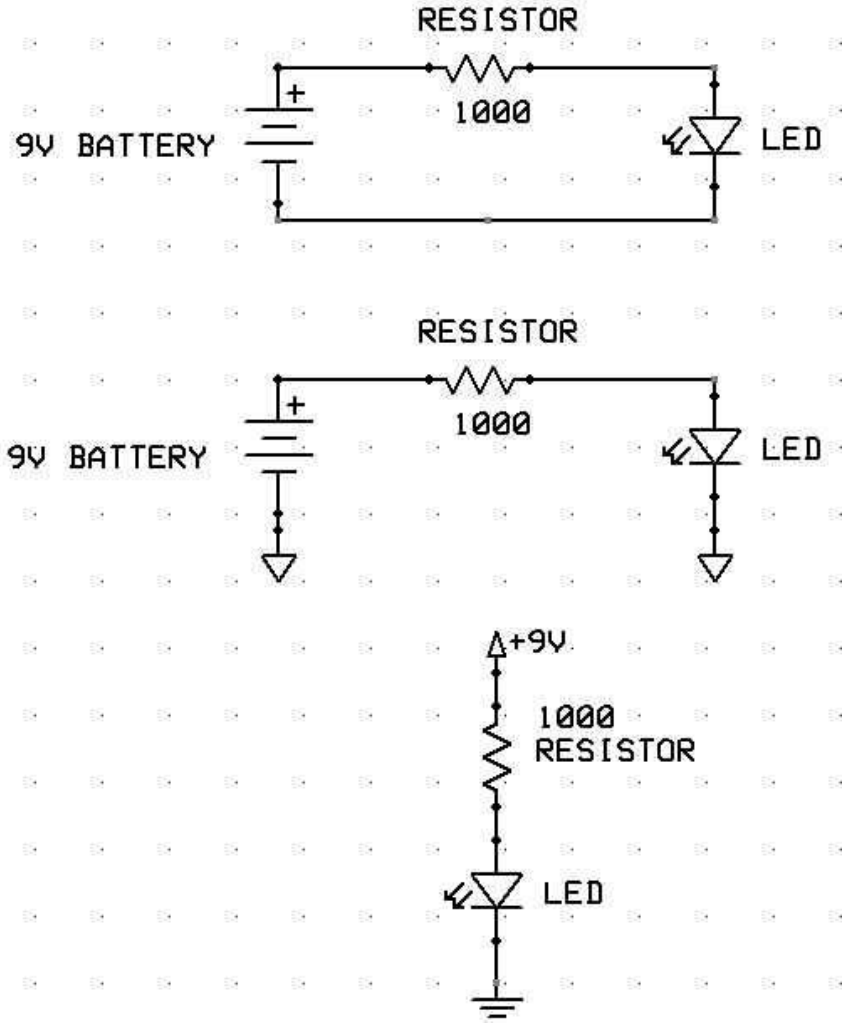
R1	R2	V1	V2
10kΩ	10kΩ	4.5	4.5
10kΩ	20kΩ	3	6
10kΩ	1kΩ	8.2	.82



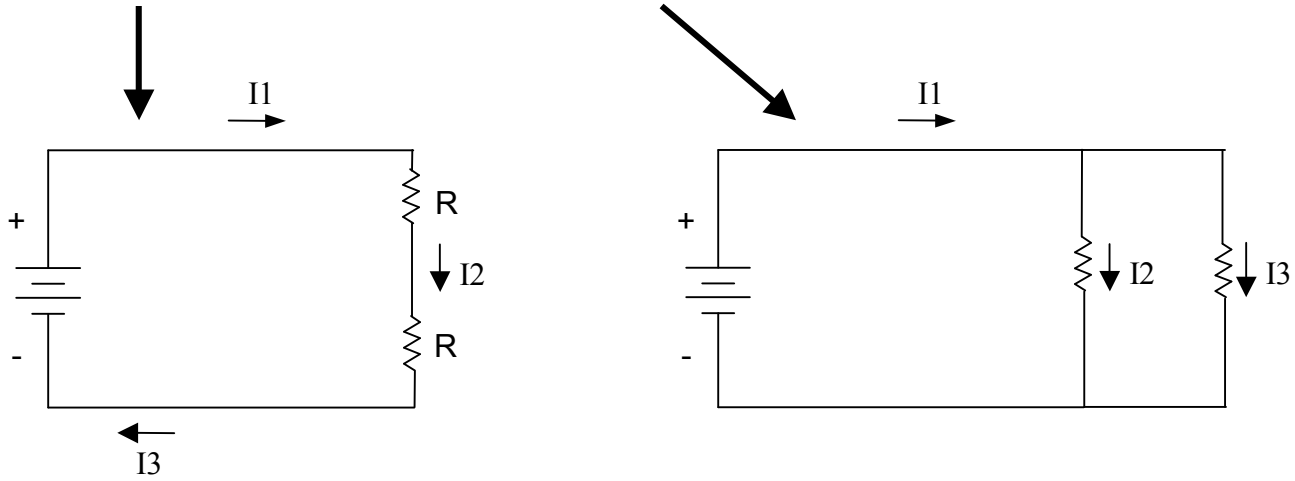
Potentiometer as Voltage Divider



Power & Ground Symbols



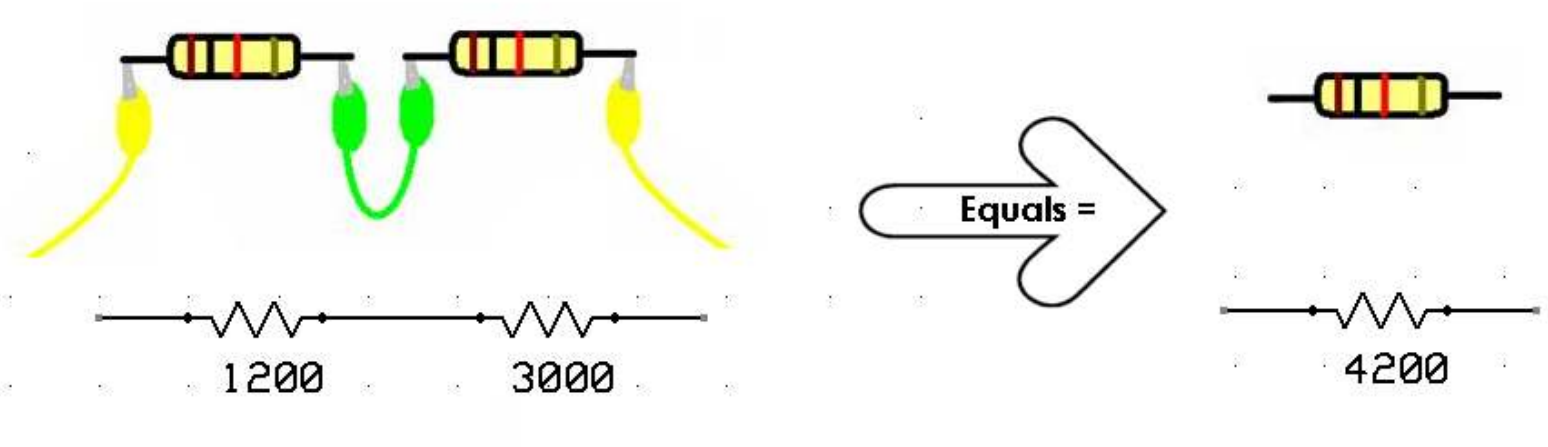
Series vs Parallel Circuits



In the parallel circuit:

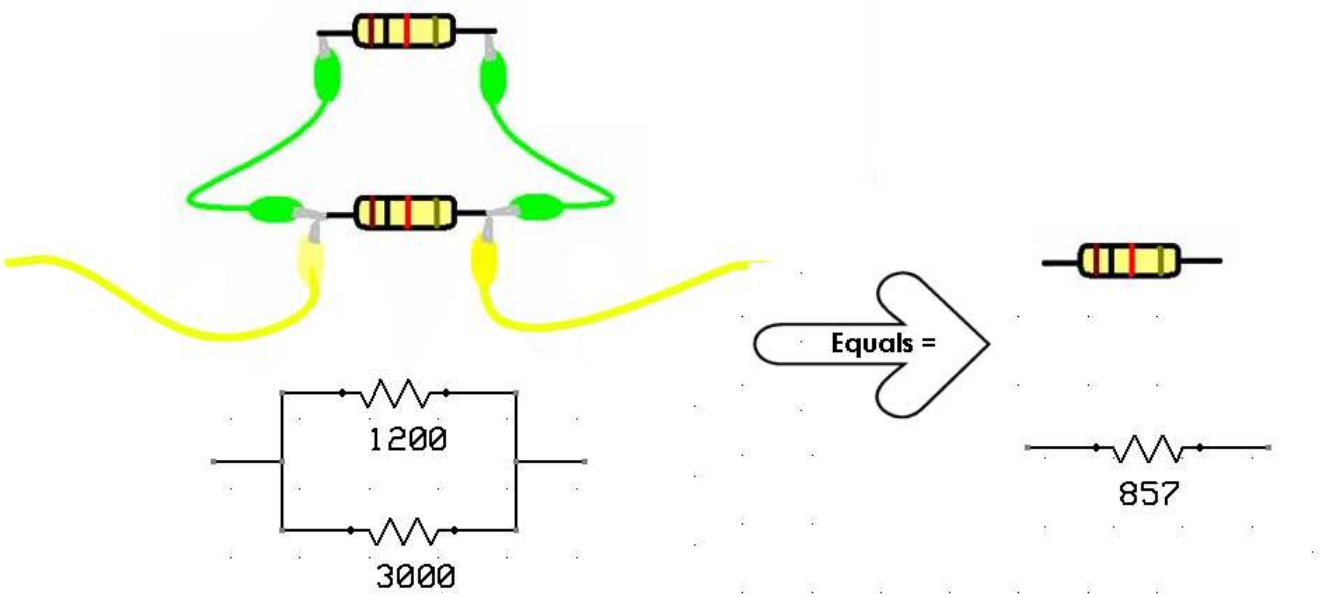
- Voltage across both resistors is the same
- Current divides between the two resistors
- $I1 = I2 + I3$
- The voltage across and current through each resistor still obey Ohms law

Resistors in Series



- Resistances add when wired in series
- $R_{total} = R_1 + R_2$
- Example: 1200Ω + 3000Ω = 4200Ω

Resistors in Parallel



- Resulting resistance is always less than either
- If resistors are equal, resulting resistance will be half
- Equation and example:

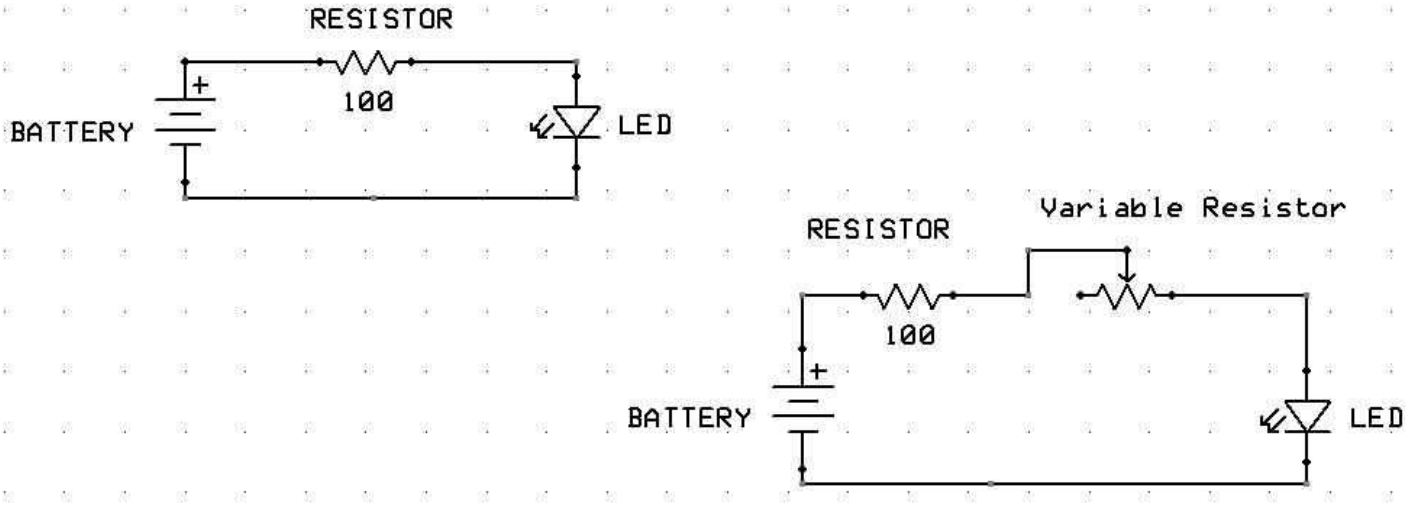
$$R_{total} = \left(\frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \right)$$

$$\left(\frac{1}{\frac{1}{1200} + \frac{1}{3000}} \right) = 857\Omega$$

Light Emitting Diodes (LEDs)

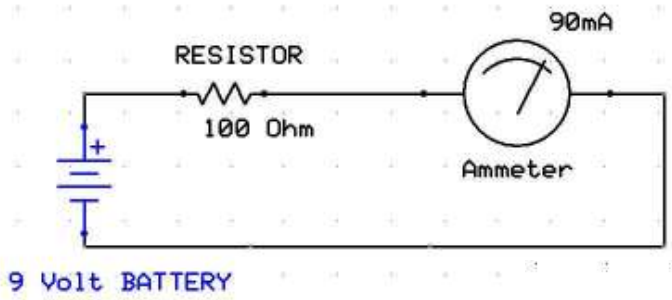
- Will only pass current in one direction
- Behave like 1-3 volt light bulbs
- Generally require a resistor in series with them

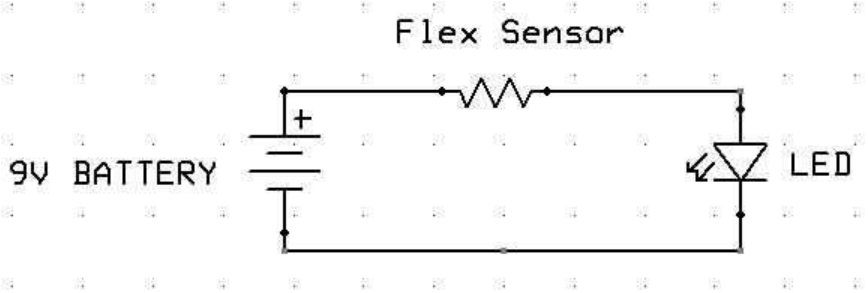
- Connect LED in series with 1000 Ohm resistor
- Connect LED in series with 100 Ohm resistor
- Add variable resistor (potentiometer) to the mix



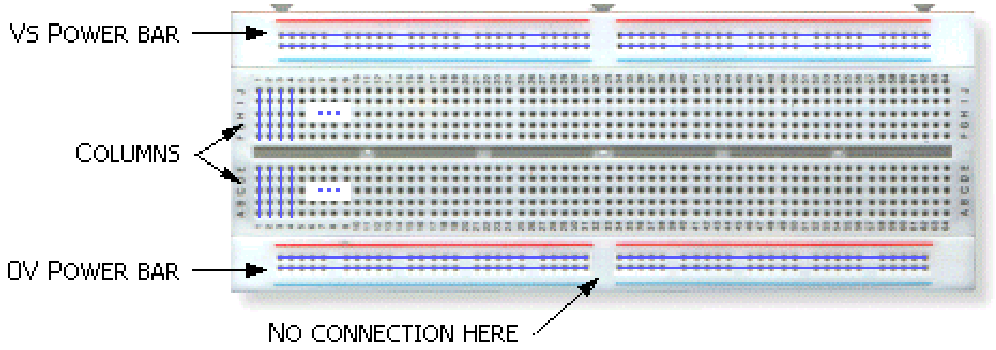
Exercises

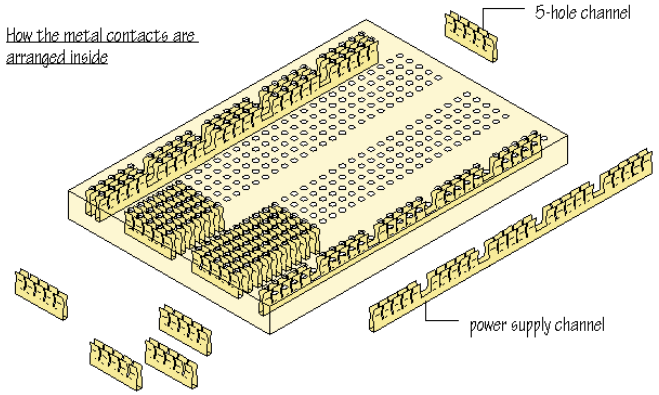
- Use the multimeter to measure the current through 1k and 100Ω resistors
- Build a series circuit using an LED and a flex sensor

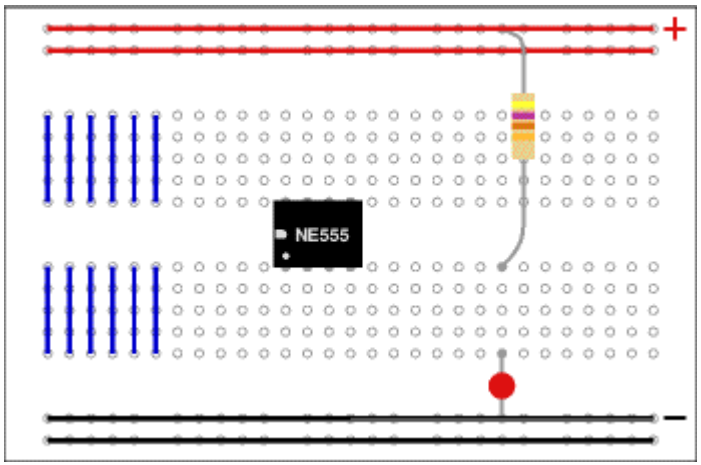




Prototyping Board



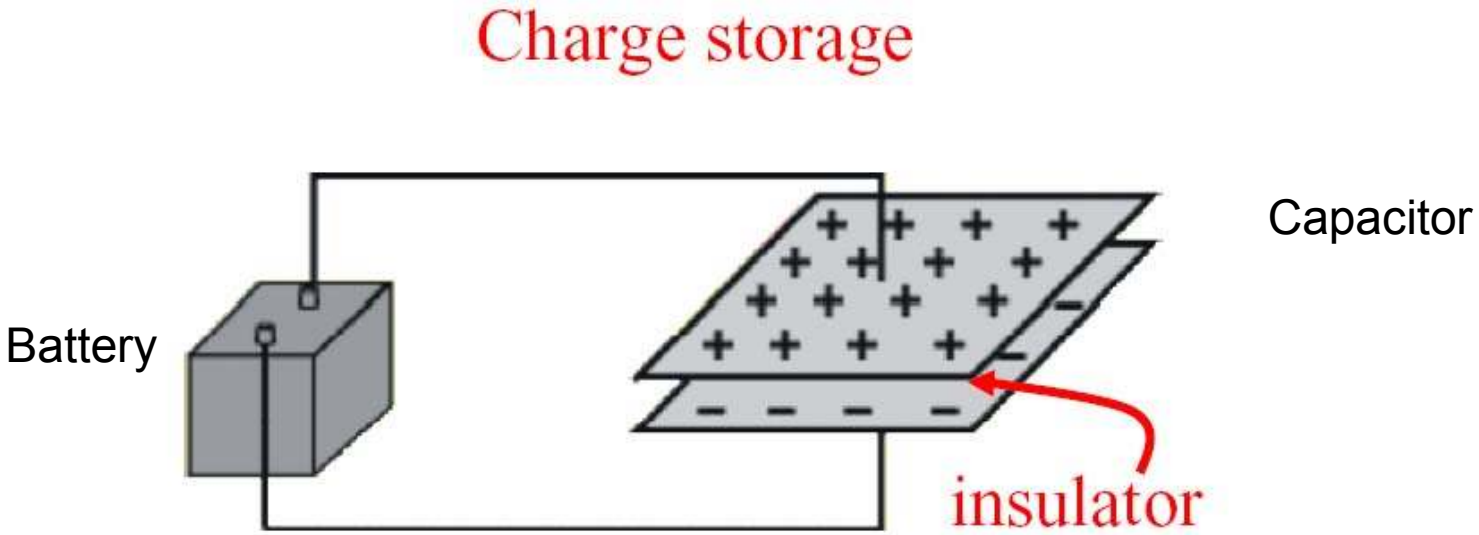




Example of how components are Inserted in the protoboard

Capacitance

- A capacitor is used to store charge for a short amount of time
- It is like a small rechargeable battery
- Capacitance is a measure of the quantity of charge that a capacitor can store (at a given voltage)
- Capacitance is measured in Farads (often microfarads)



Unit = Farad

Pico Farad - pF = 10^{-12}F

Micro Farad - uF = 10^{-6}F

Symbols nonPolar

Polar Euro

Properties

Characteristic Equations: $I = C\frac{dV}{dT}$

$$V = \frac{1}{C}\int IdT$$

Integrating
Charge (storage)

Markings

Polar vs Non-Polar

Values

Electrolytics mark (-)
Tantalums mark (+)
Longer lead

Examples

Mylar

Monolythic Cermamic

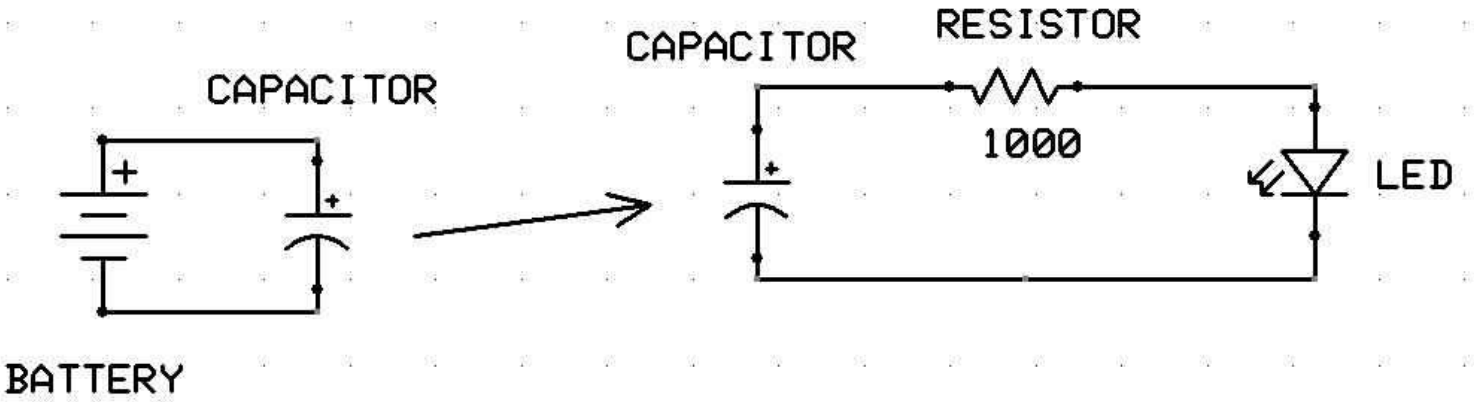
Tantalum

Ceramic

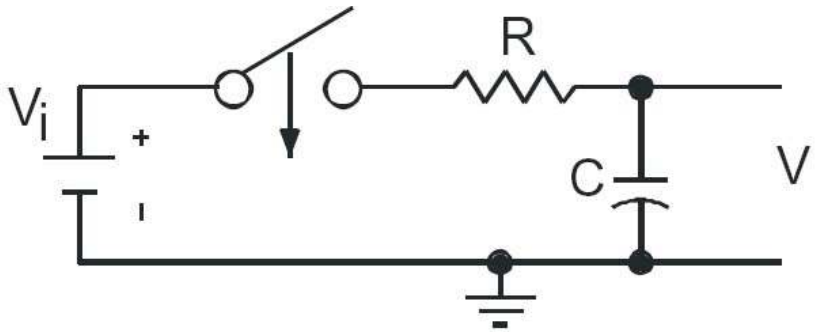
Electrolytic

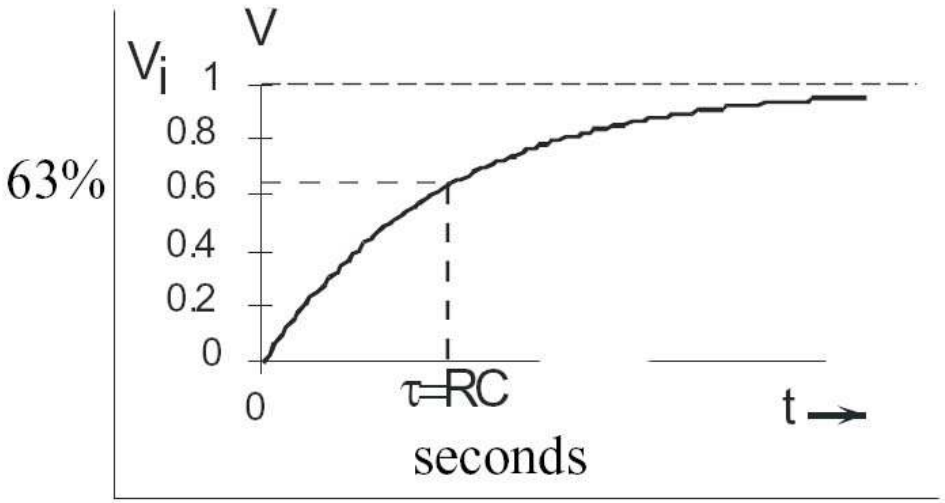
Capacitor Exercise

- Charge the capacitor by connecting it to the battery
- Observe polarity
- Use the capacitor to power the LED
- Use a smaller resistor in series with the LED



Capacitors can be used for timing

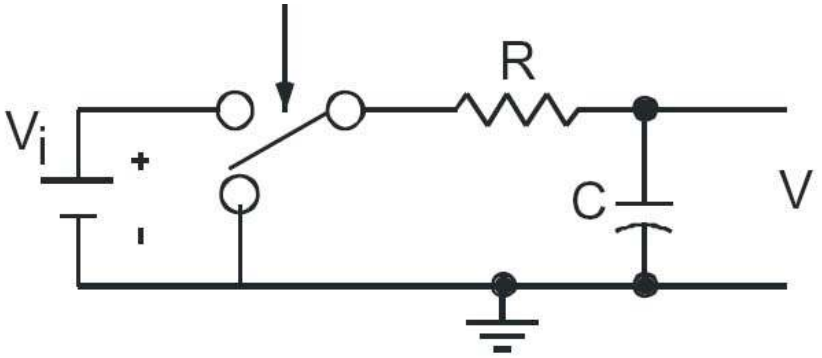


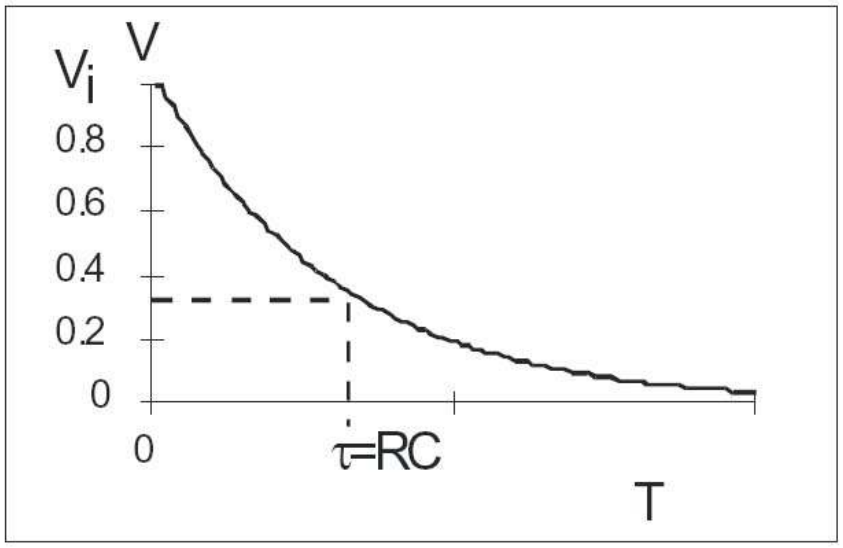


$$V = V_i + Ae^{-t/RC}$$

$$A = -V_i$$

Capacitor Discharge



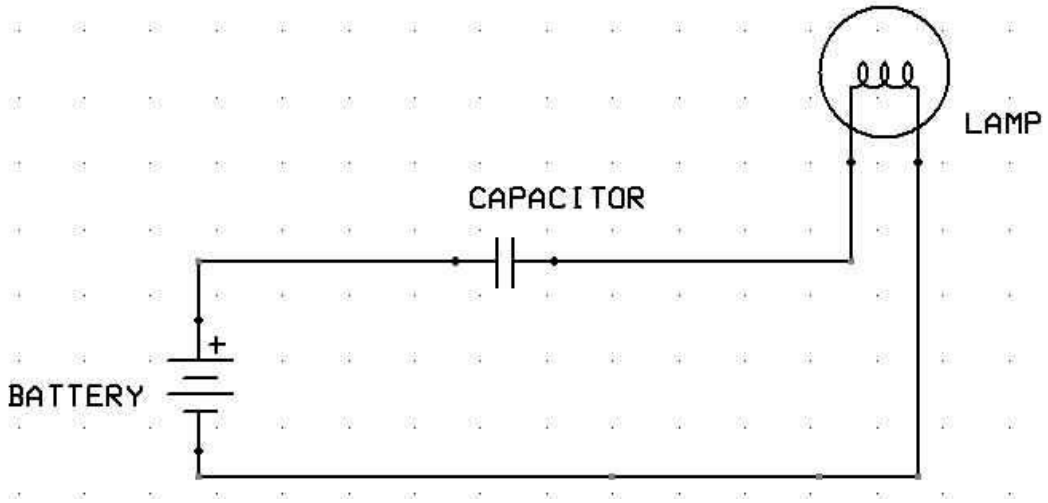


$$V = Ae^{-t/RC}$$

$$A = V_i$$

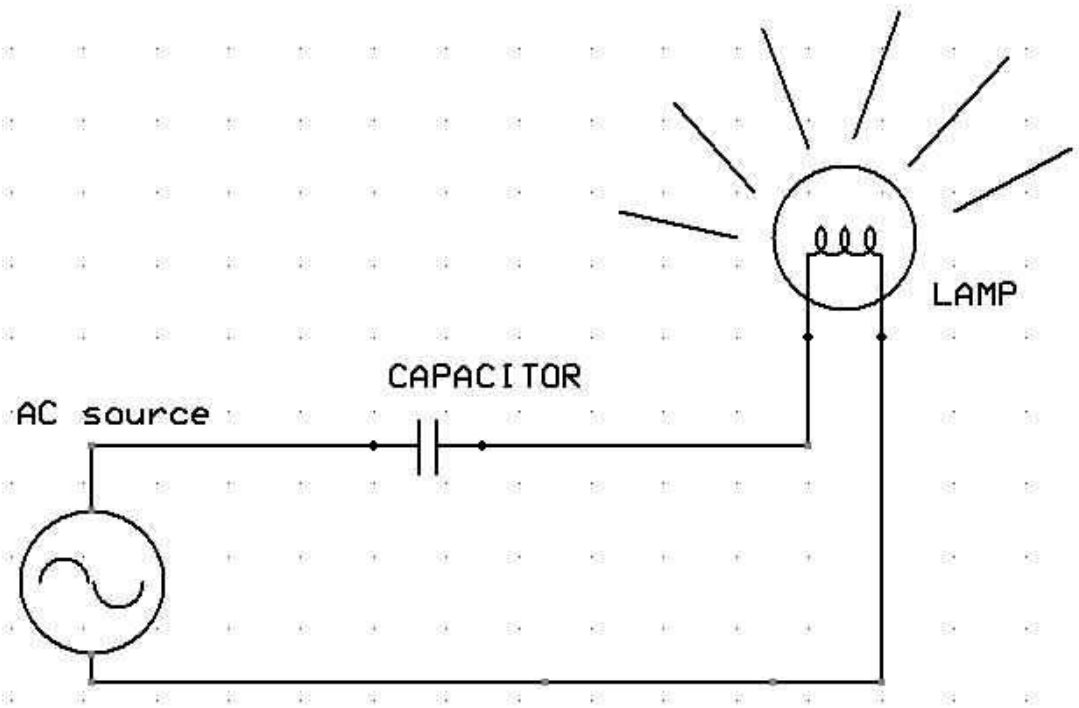
Capacitance

- What will happen with this circuit?
- What will happen if the battery polarity is reversed?



Capacitance & AC power

- In its simplest form AC is just DC switching polarity
- A capacitor will conduct AC but not DC



Resources

Technical texts
The Art of Electronics, by Horowitz and Hill
The Radio Amateurs Handbook
Anything by Forest Mims

Organizations:
Dorkbot.org
Make Magazine and MakePhilly http://www.makephilly.com/
The Hacktory http://thehacktory.org/content/about
NextFab http://nextfabstudio.com/
Hive 76 http://www.hive76.org/

Resources

Electronic Components, Transducers, & Sensors

http://www.acroname.com/products.html – robotics, sensors
http://www.mpja.com/ – components, sensors, transducers, interesting surplus
http://www.timeline-inc.com/ - LCD displays, odds & ends
http://www.allelectronics.com/– components, sensors, transducers, interesting surplus
http://www.hosfelt.com/ – components, sensors, transducers, interesting surplus
http://www.jameco.com/ – components, sensors, transducers, interesting surplus
http://www.bgmicro.com/ – components, sensors, transducers, interesting surplus
http://www.goldmine-elec-products.com/ – components, sensors, transducers, interesting surplus, robotics
http://www.digikey.com/ – components, sensors, transducers
http://www.sparkfun.com/ – components, sensors, transducers, cool kits, robotics
http://www.parallax.com – BasicStamp, sensors, transducers, robotics

Other Links of Interest

http://www.chaneyelectronics.com/ - kits
http://www.expresspcb.com/- free schematic and printed circuit board layout software
http://www.smallparts.com/ - all kinds of small mechanical components

Local source for used computers:
Nonprofit Technology Resources
http://ntronline.org/
1524 Brandywine Street

Computers and peripherals:
http://www.tigerdirect.com/

Summary

- Voltage (Volts)
- Resistance (Ohms)
- Current (Amps)
- Ohms law V=I*R

- Resistors
- Diodes
- LEDs
- Capacitors
- Schematic symbols
- Breadboards
- AC versus DC power
- Notation, terminology, algebra