02

Basic Electronics Review

Basic Electronics

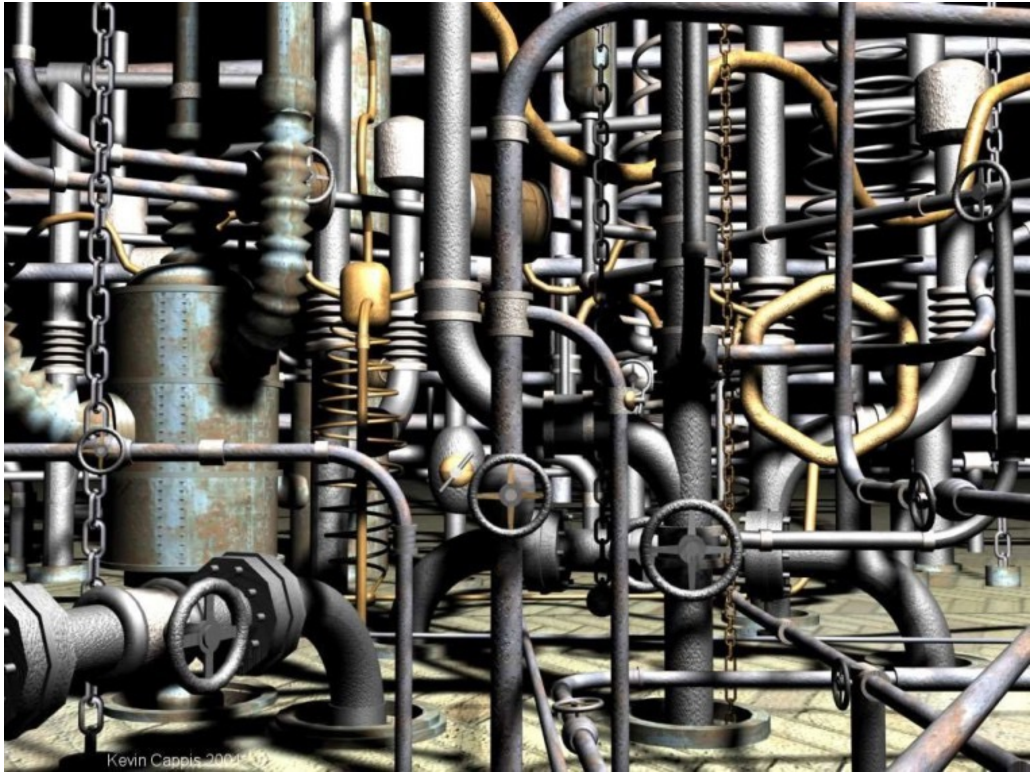
- What we will review:
  - Basics of voltage and current
    - Using instruments to measure them
    - Resistance
    - Capacitance
    - Combining them

Basic Circuits Review

- We make things happen with voltage and current
- We sense things by measuring voltage or current
- We compute things by varying voltage or current

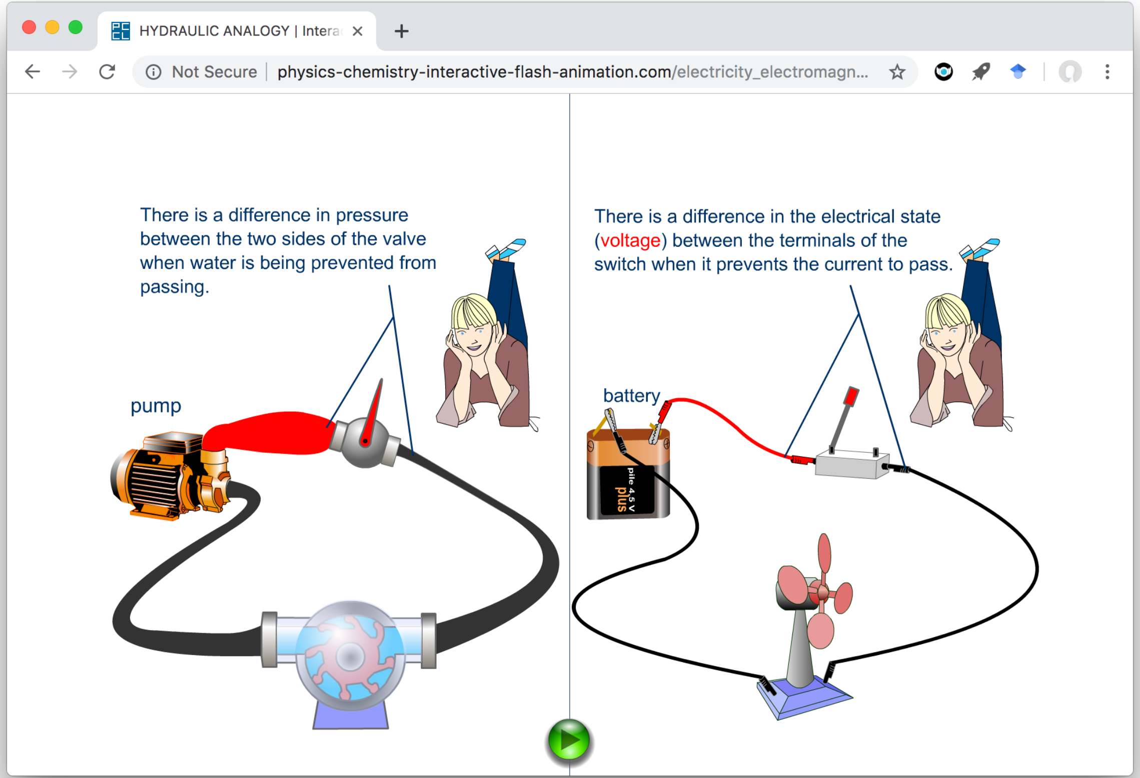
Basic Circuits Review

- Water Analogy
  - Voltage -> Pressure
  - Current -> Flow
  - Resistance -> ~Fluid shear
  - Capacitance -> ~Elastic membrane



Hydraulic Analogy Reference

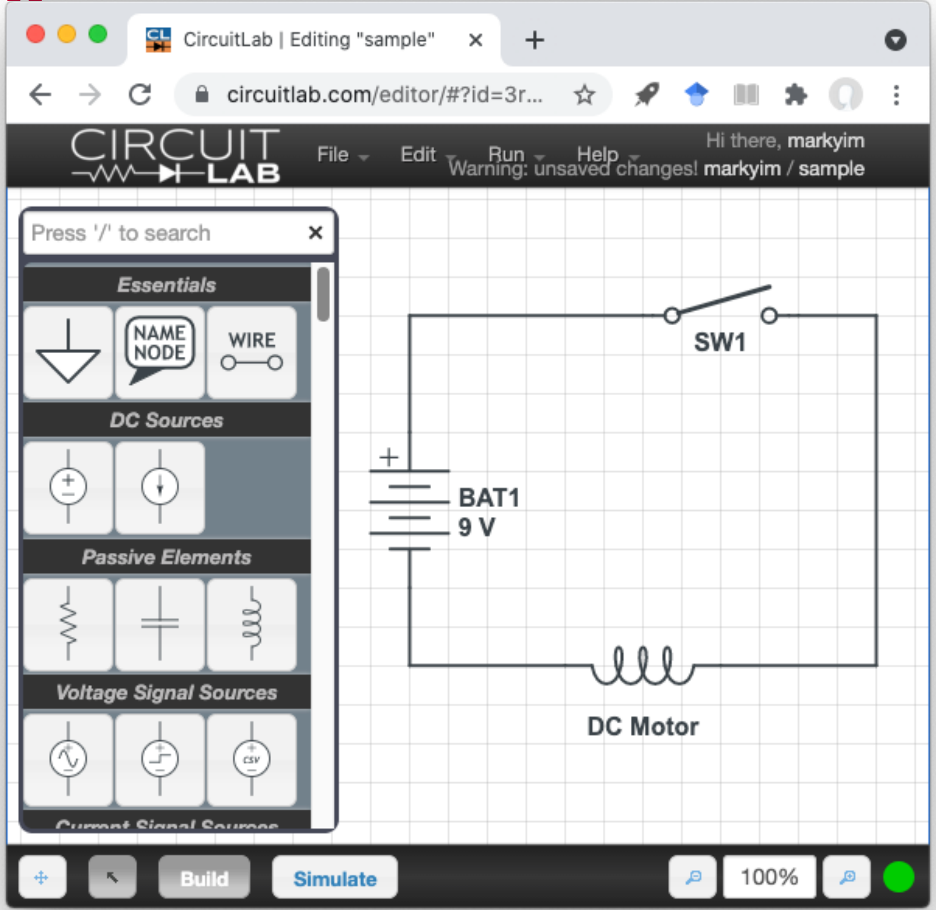
- Electrons (or alternatively positive ions) are analogous to water molecules.
- Conservation of mass (ions/electrons) applies even if they are flowing.



http://www.physics-chemistry-interactive-flash-animation.com/electricity_electromagnetism_interactive/hydraulic_analogy_difference_voltage_current.htm

Circuits and Circuitlab.com

- Symbols represent components connected with perfect conductors.
- Create an account (All upenn.edu email have student accounts)
- Use this to create diagrams for homeworks and project reports.



Voltage Sources

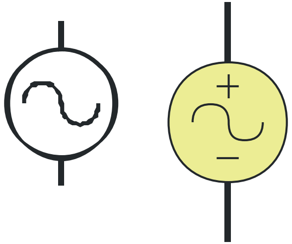
Symbols

Cell + − Battery Voltage value

UniPolar

Power supplies

BiPolar (AC)



Properties

Constant Voltage, independent of the amount of current

Up to some power limit

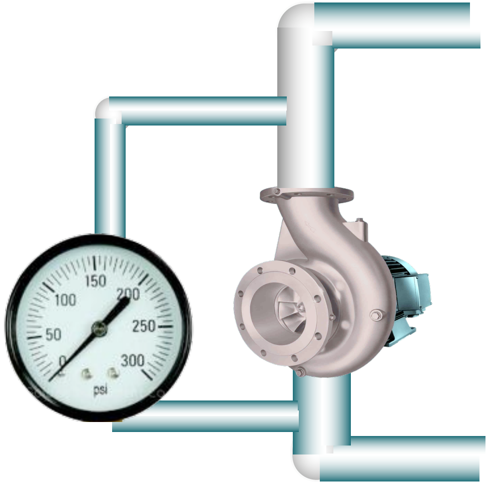
Examples

Batteries

Power Supplies,

Signal Generators, (function generators)

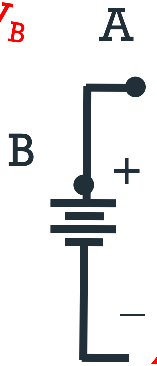
Measuring Voltage



Lines in a circuit diagram assume no resistance

$V_A = V_B$

Voltage @ A



Assume relative to negative (usually called ground)

Voltage is like differential pressure

Measured between two points

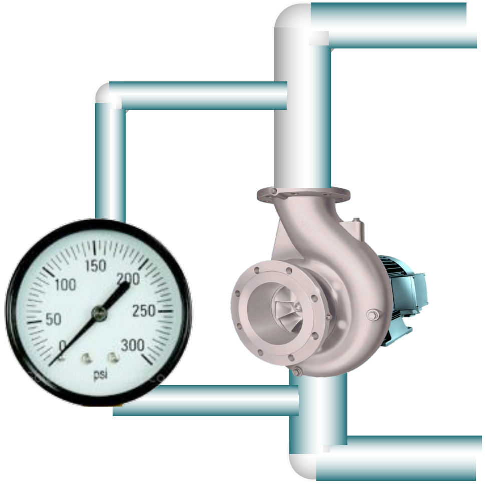
“The voltage at point A with respect to point B”

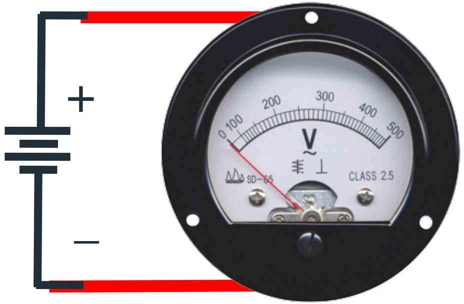
“The voltage across…”

“The voltage at point A…”

Assumes measurement device draws no current

Measuring Voltage in Real Life





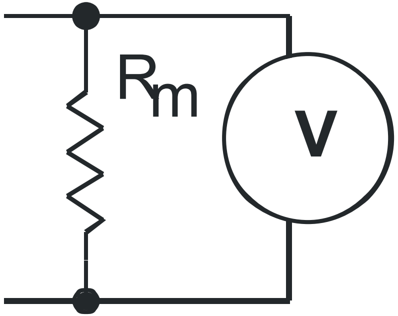
Digital Volt Meter

DVM DMM

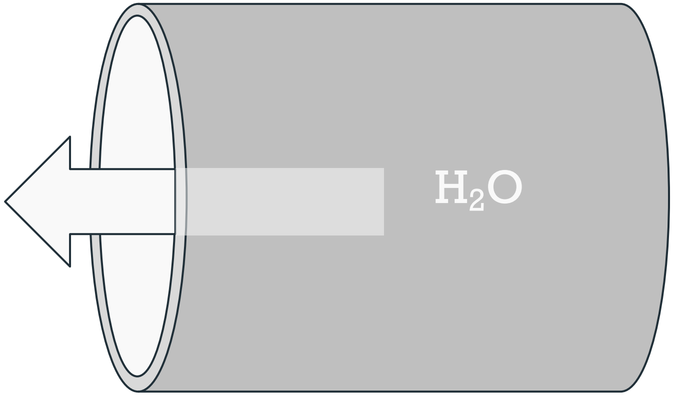
Digital Multi-Meter

Measurement is Imperfect

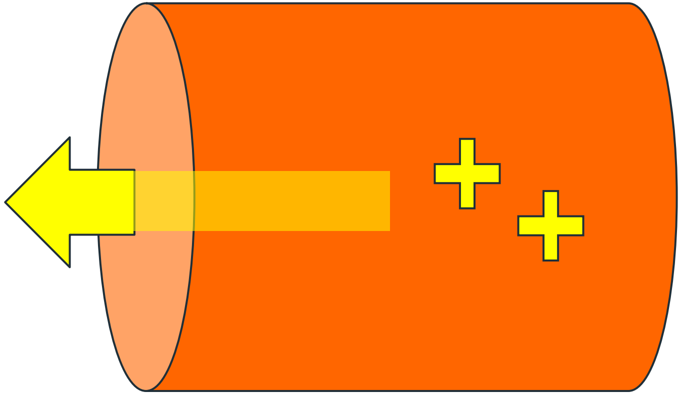
Draws tiny current/flow



Current



Flow of Water



Flow of Charge

We use Benjamin Franklin's Current

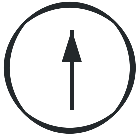
Positive charge flow –> In a circuit, current flows FROM positive TO negative

Unit = Amperes (A)

Sometimes referred to as *i*

Current Sources

Symbols



Properties

Delivers a constant current flow independent of voltage

Examples

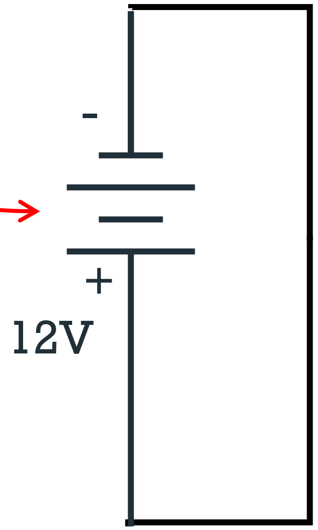
There are no natural current sources

We can build circuits to approximate a current source

Power supplies typically have C.C. (constant current) mode

Voltage Paradox

Ideal battery supplies as much current as necessary to keep voltage difference constant (e.g. 12V)

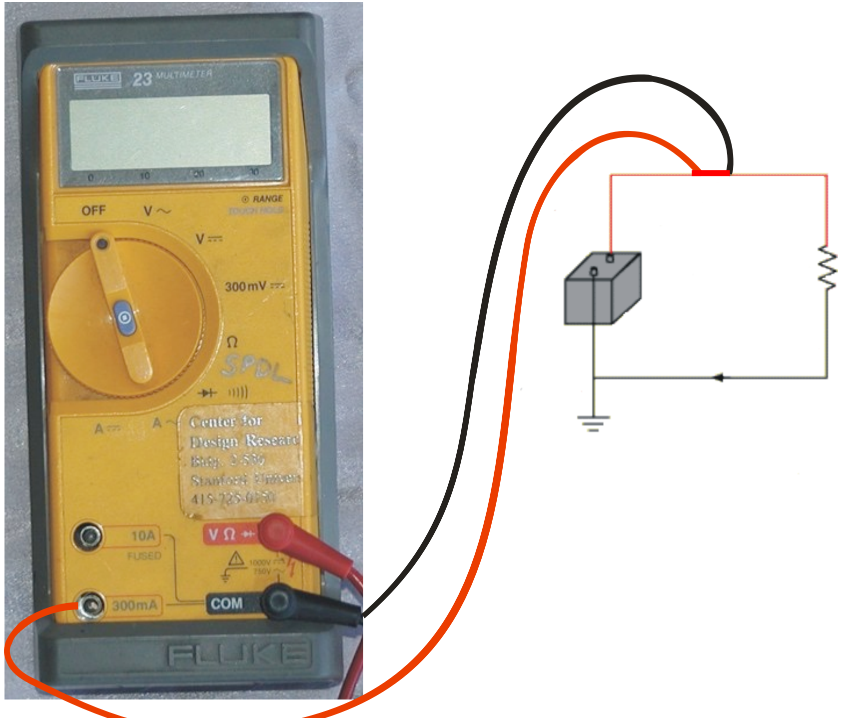


Ideal connections have 0 resistance, allowing as much current to flow to keep the voltage across the wire 0

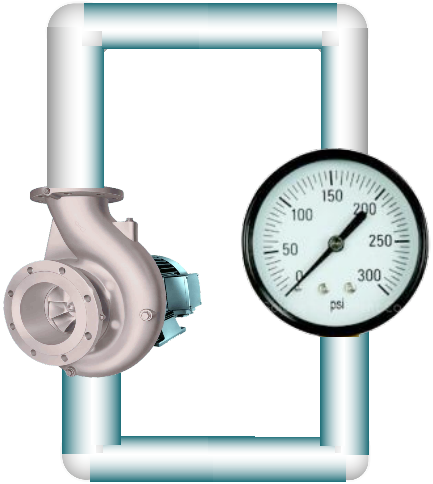
Measuring Current

Current is measured though a point

To Measure: break the circuit at that point and insert the measuring instrument. We will use a DMM.



Ammeter is fused,
Fuse is easy to blow. often blown in MEAM equipment.



Electricity in Actuation

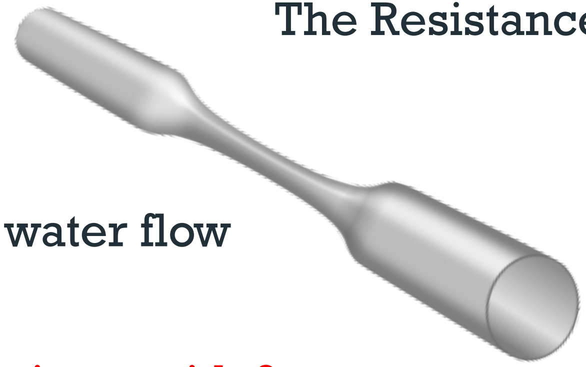
- Apply a voltage, amount of current through device determines magnitude.
- LED: apply a voltage, the amount of current determines how bright.
- Motor: apply voltage, the amount of current determines how much torque.

Power = Volts * Current

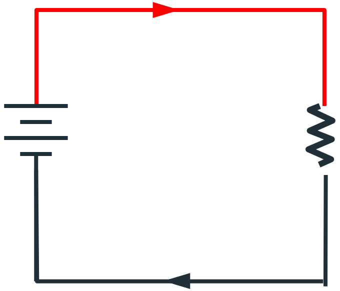
Resistance

The Resistance to Flow

Constriction
creates
Resistance to water flow



Conceptually pipes with 0
resistance are infinitely
wide



Resistor creates
resistance to current flow

Units = Ohms

V vs I Behavior described by
Ohm’s Law

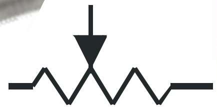
$$V = I\,R$$

Volts = Amperes * Ohms

Resistors

Symbols

3.3K Ω



2.7M

potentiometer

Properties

Constant resistance independent ariables

Though many are temperature sensitive

Dissipates power $VI = I^2R = \frac{V^2}{R}$ For this class typ 1/8W, 1/4 W

3 digits: 10% to 2% accuracy Markings: color coded bands represent value

1st sig. Digit,	2nd sig. Digit,	number of zeros,	silver/gold

4 digits: 1% and better accuracy

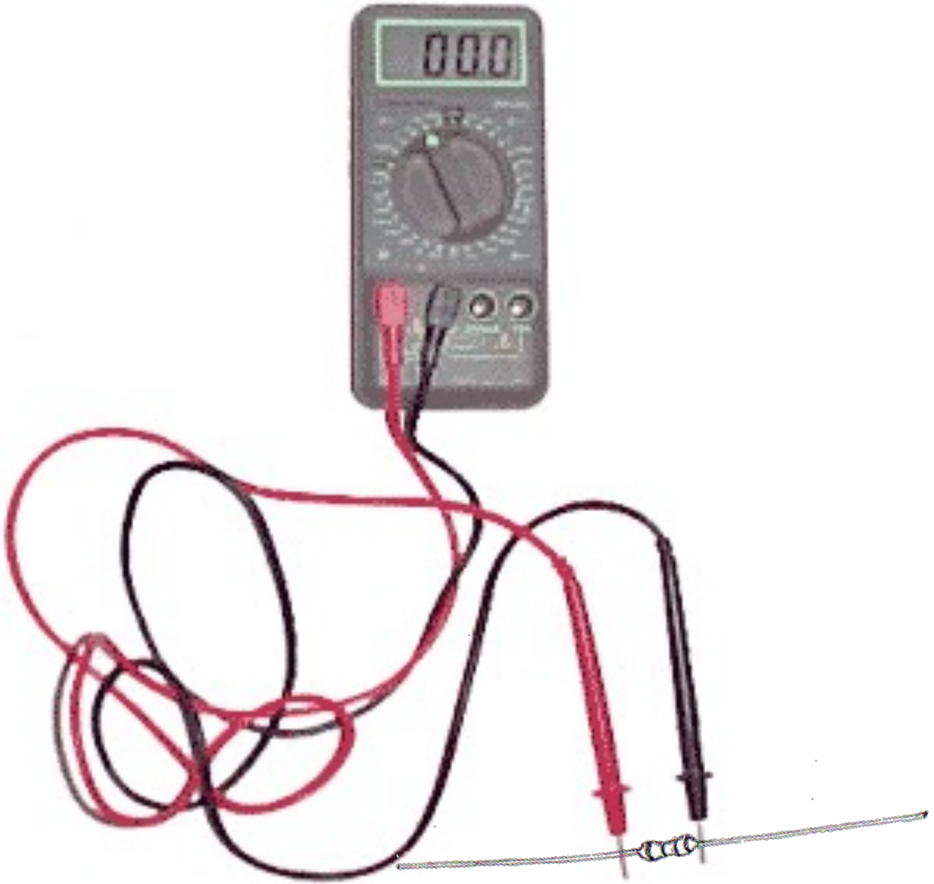
1st sig. Digit,	2nd sig. Digit,	3rd sig. Digit,	number of zeros

https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code

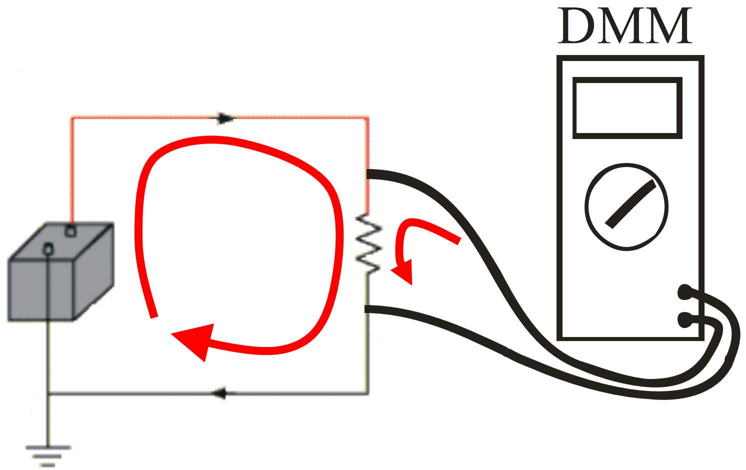
Measuring Resistance

Force a small current (~0.02mA) to flow and then measure the voltage drop

We will use the DMM for this



Measuring Resistance in situ

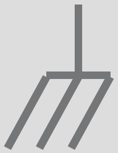


Will the DMM give the value of resistor?

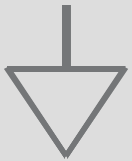
NO!

Ground

Symbols



Earth Gnd

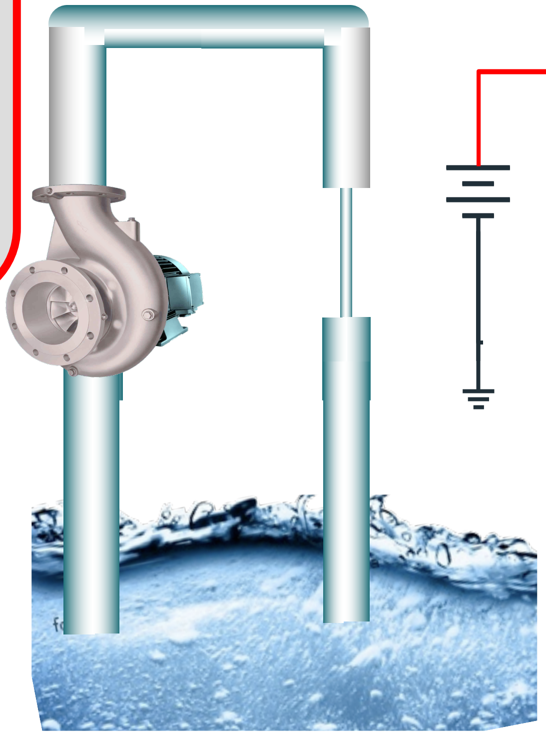


Analog Gnd

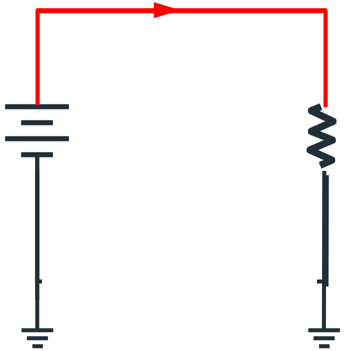
n/a for this course

For this class, it is useful to think of it as a symbol that provides a reference point, often but not always the most negative point.

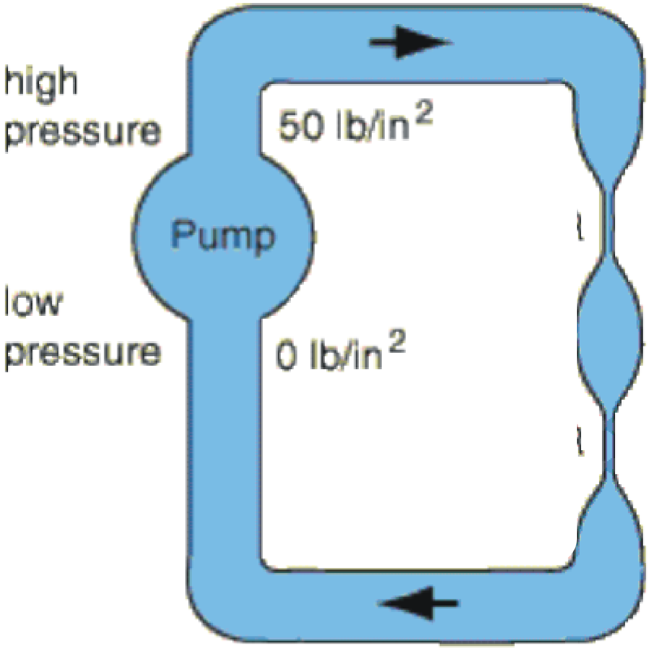
More generally – outside of this course, it is an integral path in the current flow that can mean other things.



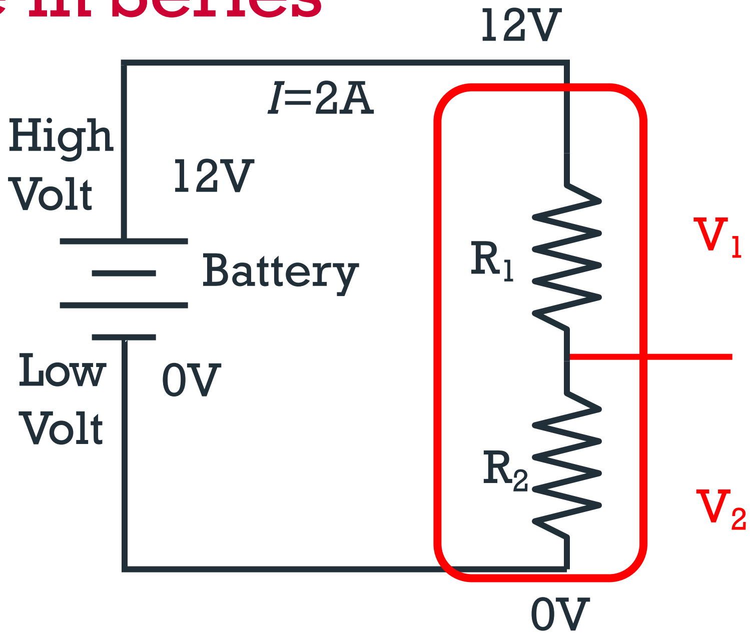
Like reservoir



Combining Resistance in Series



$$R_{Total} = R_1 + R_2$$



$V_1 = I\,R_1$

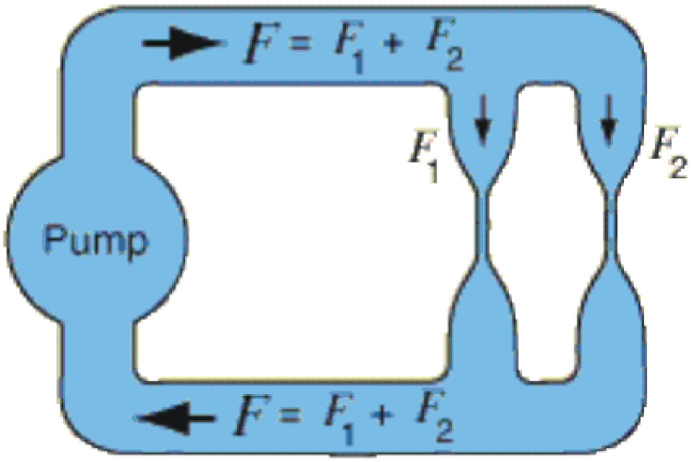
$V_2 = I\,R_2$

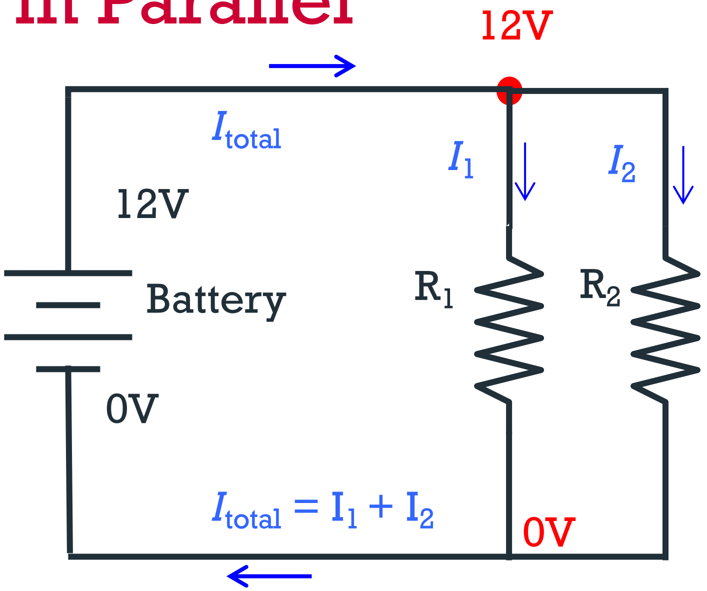
Ohms law $V_{total} = I\,R_{total}$

Kirchoffs Voltage law: $V_1 + V_2 = V_{total}$

$IR_1 + IR_2 = IR_{total}$

Combining Resistance in Parallel





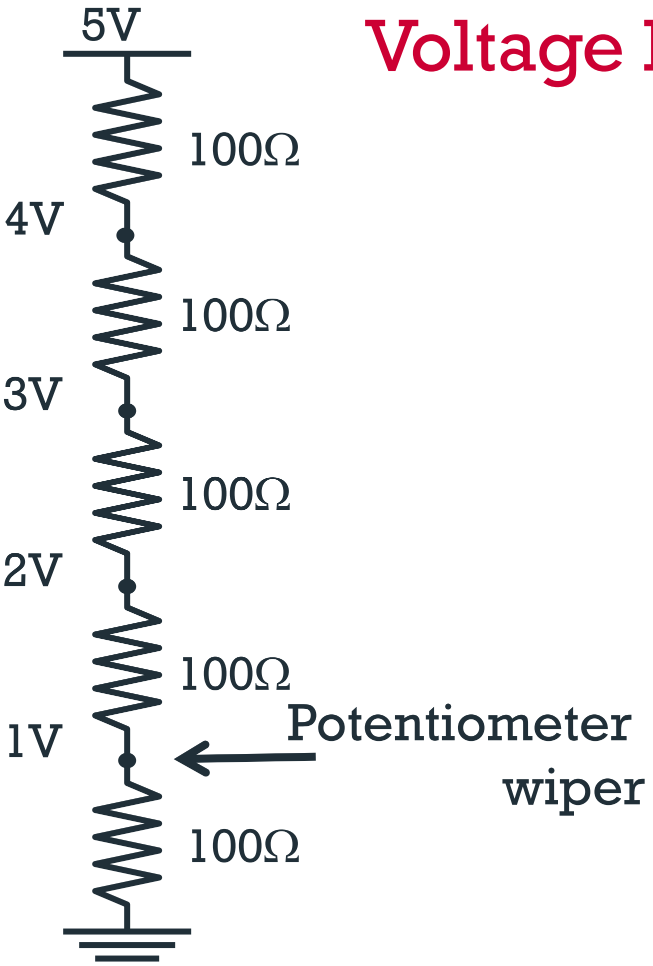
$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2}$$

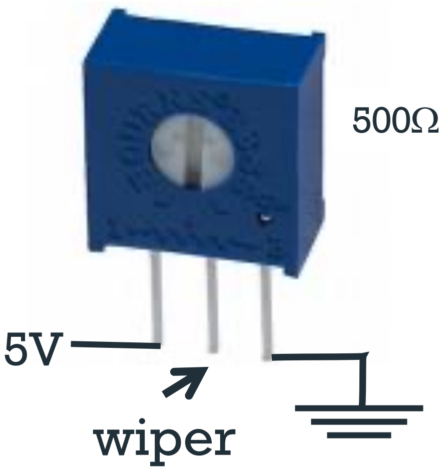
$$R_{Total} = \frac{R_1 R_2}{R_1 + R_2}$$

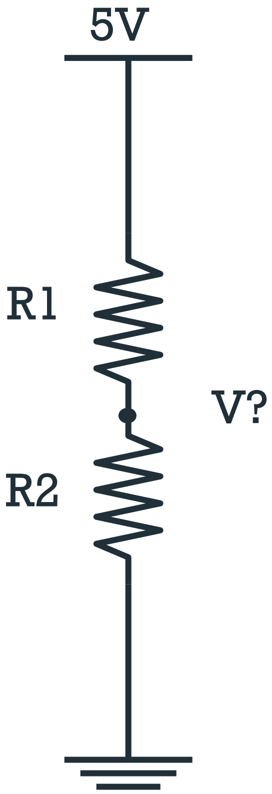
Ohm's law: $V_{total} = I_{total}\,R_{total} = I_1 R_1$
$V_{total} = I_{total}\,R_{total} = I_2 R_2$

Kirchoff's Current law: $-I_1 - I_2 + I_{total} = 0$

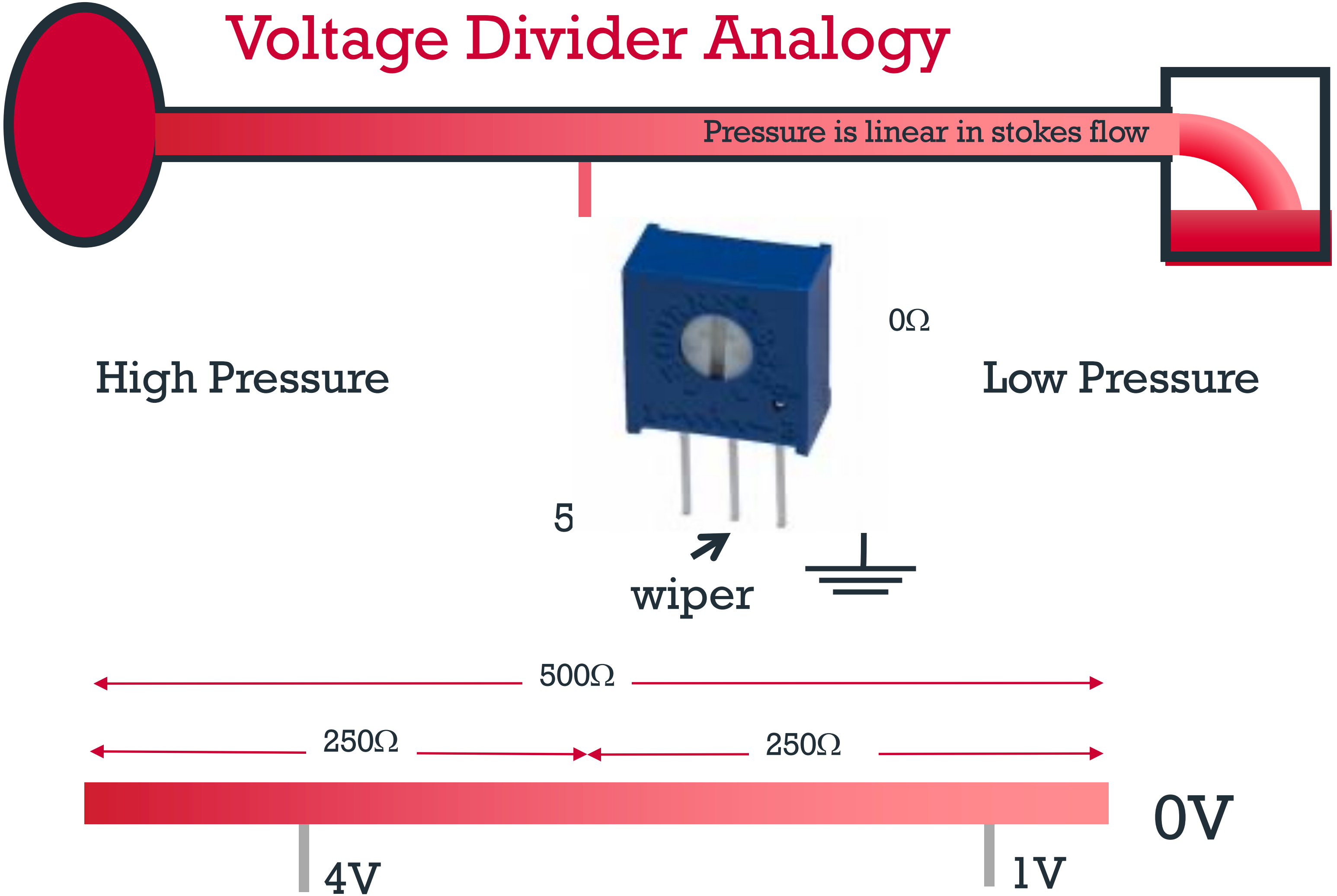
Voltage Divider & Potentiometers



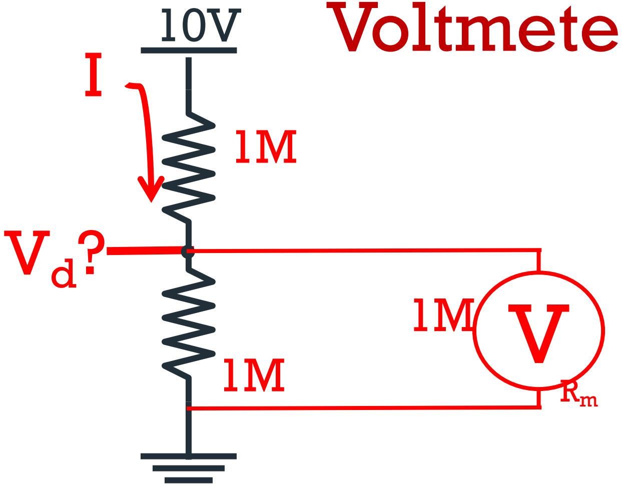




Voltage Divider Analogy



Voltmeter non-ideality



$$I = \frac{10V}{R_1 + R_2}$$

$$V_d = I\,R_2$$

$$V_d = 10V \frac{10K}{10K + 10K}$$

cheap meters, R_m = ~1M Ω

good meters, R_m = ~10M Ω

Example 1: $R_1 = R_2 = 10K\ \Omega$

10K + 9.9K

$$\frac{10{,}000M}{1.010M}$$

V_d should be 5.00 but measured is 4.975V

Example 2: $R_1 = R_2 = 1M\ \Omega$

Use 1/4W resistors
10Ω<< R <<10MΩ

Question 1: V_d should be 5.00 but measured is ??? V

Capacitors

Symbols

nonPolar Polar Euro

Integrating
Charge (storage)

Properties

Characteristic Equations: $I = C\frac{dV}{dT}$ $V = \frac{1}{C}\int IdT$

Markings Polar vs Non-Polar Polar may EXPLODE Electrolytics mark (-)
Tantalums mark (+)
Longer lead

Values Capacitance uF (10^{-6}) if polar
Voltage rating pF (10^{-12}) if nonPolar

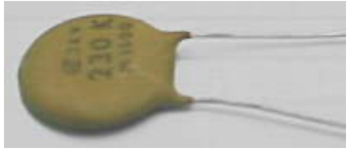
103 (pF) = 10 x 1000pF

See http://kiloohm.info/3-digit-capacitor/103

Examples

Mylar

Monolythic Cermamic

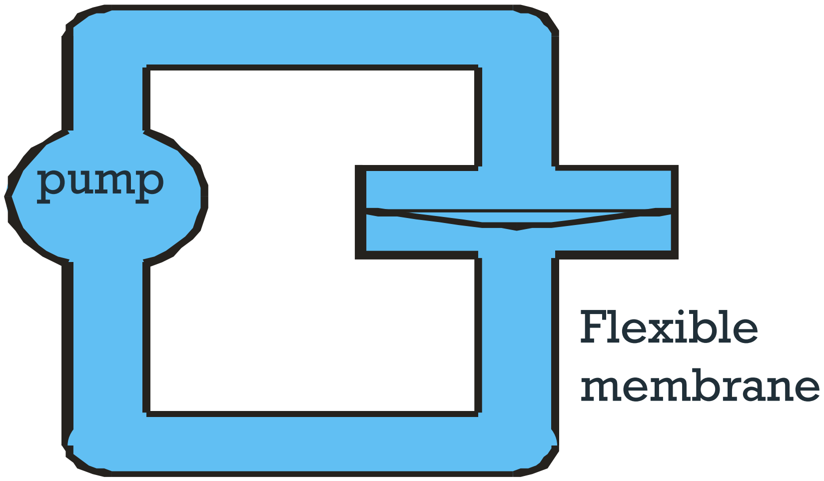


Ceramic

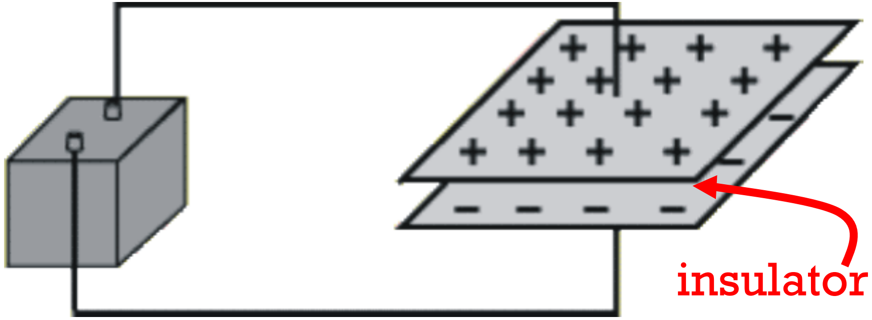
Tantalum

Electrolytic

Capacitors



Charge storage



Unit = Farad

$$I = C\frac{dV}{dT}$$

pico pF = 10^{-12}F

micro uF = 10^{-6}F

Capacitors in parallel & Series

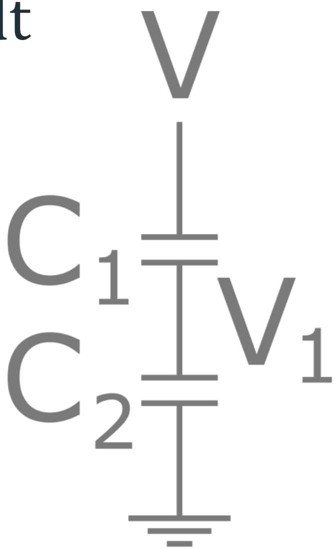
$$I = C\frac{dV}{dT}$$

$$I_1 = I_2 = C_1\frac{d(V - V_1)}{dt} = \mathrm{C}_2\frac{\mathrm{dV}_1}{\mathrm{dt}}$$

$$C_1\frac{dV}{\mathrm{dt}} - C_1\frac{\mathrm{dV}_1}{\mathrm{dt}} = \mathrm{C}_2\frac{\mathrm{dV}_1}{\mathrm{dt}}$$

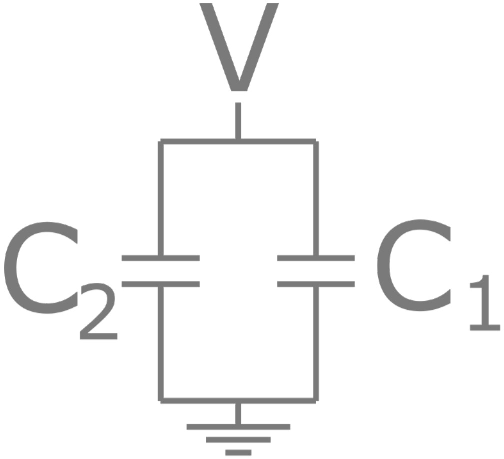
$$\frac{\mathrm{dV}_1}{\mathrm{dt}} = \frac{C_1}{C_1 + C_2}\frac{dV}{\mathrm{dt}}$$

$$\boxed{I = \mathrm{C}_2\frac{\mathrm{dV}_1}{\mathrm{dt}} = \frac{C_1 C_2}{C_1 + C_2}\frac{dV}{\mathrm{dt}}}$$



$$I = I_1 + I_2 = C_1\frac{dV}{dt} + C_2\frac{dV}{dt}$$

$$\boxed{I = (C_1 + C_2)\frac{dV}{dt} = \mathrm{C}_{\mathrm{eq}}\frac{dV}{dt}}$$

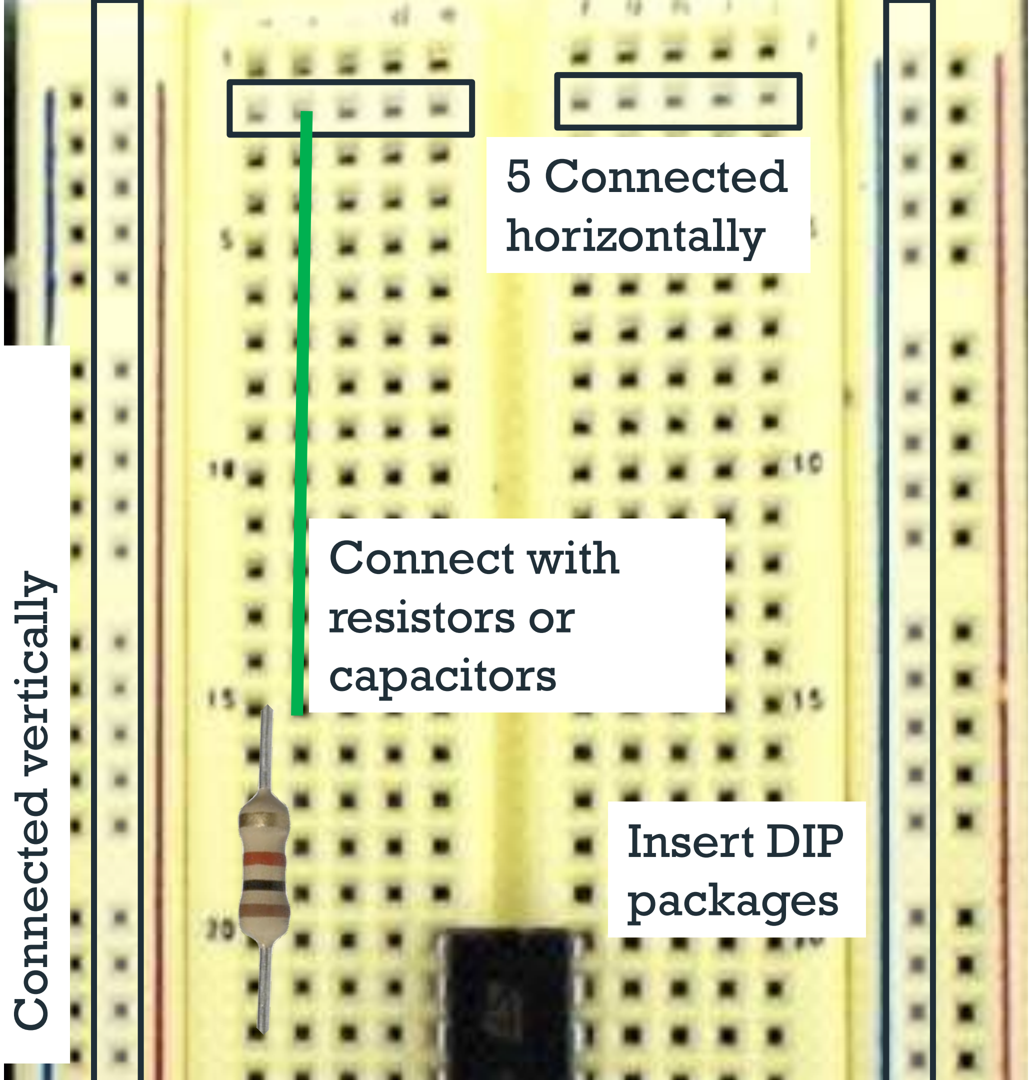


Protoboard "Solderless Breadboard"

Vertical bus typically used for power (red for positive blue/black for negative)

Use solidcore wires to make connections from one row to another

Google solderless breadboard
https://www.youtube.com/watch?v=6WReFkfrUIk



Things to do before next Wednesday:

- Pickup classkit from TA during Office Hours (OH).
- If you are unregistered and want to take this course:
  - Juniors: Email Katie (meamugra@seas), cc:me
  - All others can add the course as normal.
- If you want to place out of this course:
  - Send request email to yim@seas.upenn.edu to get tested.
- Lab 0: Equipment usage - is due next Wednesday
  - Recitation Friday will cover some of the material that is due