Terminology and Definitions

EE 206 Circuits I

Jake Glower - Lecture #1

Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

English Units

English units are difficult to use since there is no standard unit. For example, to measure length, you could use

• Inch	1"	The length of one digit.
• Hand	4"	Width of your palm. Used to measure the height of horses.
• Foot	12"	Length of a foot.
• Cubit	18"	From fingertips to elbow
• Yard	36"	Distance from your nose to finger tip
• Ell	45"	From fingertip to opposite shoulder. Used for cloth.
• Fathom	6'	Distance fingertip to fingertip arms outstretched. Depth of water.
• Rod	16.5'	Used for surveying
• Chain	66'	Also used in surveying
• Furlong	660'	The distance a plough team can go without rest
• Mile	5280'	8 furlongs
• League	3 miles	The distance you walk in an hour

Problem: Which is more?

- A person who is 5'10",
- A horse which is 20 1/2 hands, or
- A pond which is 2 fathoms deep?

M.C. Escher "Ripples"

SI Units

Metric uses standard unit for everything (unless you are a chemistry major).

- a.k.a. System International

Fundamental Units:

- Basic definitions:

Name	Symbol	Parameter	Definition
Meter	m	length	Distance light travels in a vacuum
kilogram	kg	mass	mass of a the standard kilogram in Paris
second	s	time	Oscillations of a Cs_{133} atom
Coulomb	Q	charge	6.02E23 electrons
Kelvin	K	temperature	0K = -273 Celsius
radian		angle	180/pi degrees

Derived Units:

- Combination of fundamental units

Name	Symbol	Parameter	Units
Newton	N	Force	kg m / s^2
Joule	J	Energy	Force * distance = kg m^2 / s^2
Watt	W	Power	Joule / second = kg m^2 / s^3
Amp	A	current	Q / s
Volt	V	Electric potential	Watts / Amp
Ohm	Ω	Electrical resistance	Volts / Amp
Farad	F	Capacitance	Q^2 s^2 / kg m^2 = Coulomb / Volt
Henry	H	Inductance	kg m^2 / Q^2 = Joules / Amp^2

Prefixes (Engineering Notation)

To avoid large numbers the power is expressed in multiples of 1000

Prefix	Symbol	Multiplier	Comments
Giga	G	10^9	Population of Earth = 7.5 billion
Mega	M	10^6	North Dakota = 0.7 million
kilo	k	10^3	NDSU = 14,000
milli	m	10^{-3}	Grain of rice = 1mm
micro	u	10^{-6}	bacteria = 1um
nano	n	10^{-9}	Sucrose molecule
pico	p	10^{-12}	Hydrogen atom = 100pm

Solving problems by checking units

If you get the units to match up, you probably have the right equation.

Example: Determine the resistance of 100 meters of copper wire which has a cross sectional area of 1mm2. The conductivity of copper is

$$\rho = 1.68 \cdot 10^{-8}\Omega m$$

Solution: Somehow end up with Ohms

- $\rho = 1.68 \cdot 10^{-8}\Omega m$ conductivity
- $L = 100m$ length
- $A = 10^{-6}m^2$ cross sectional area

So

$$R = \frac{\rho L}{A} = \frac{(\Omega m)(m)}{(m^2)} = \frac{(1.68 \cdot 10^{-8}\Omega m)(100m)}{10^{-6}m^2} = 1.68\Omega$$

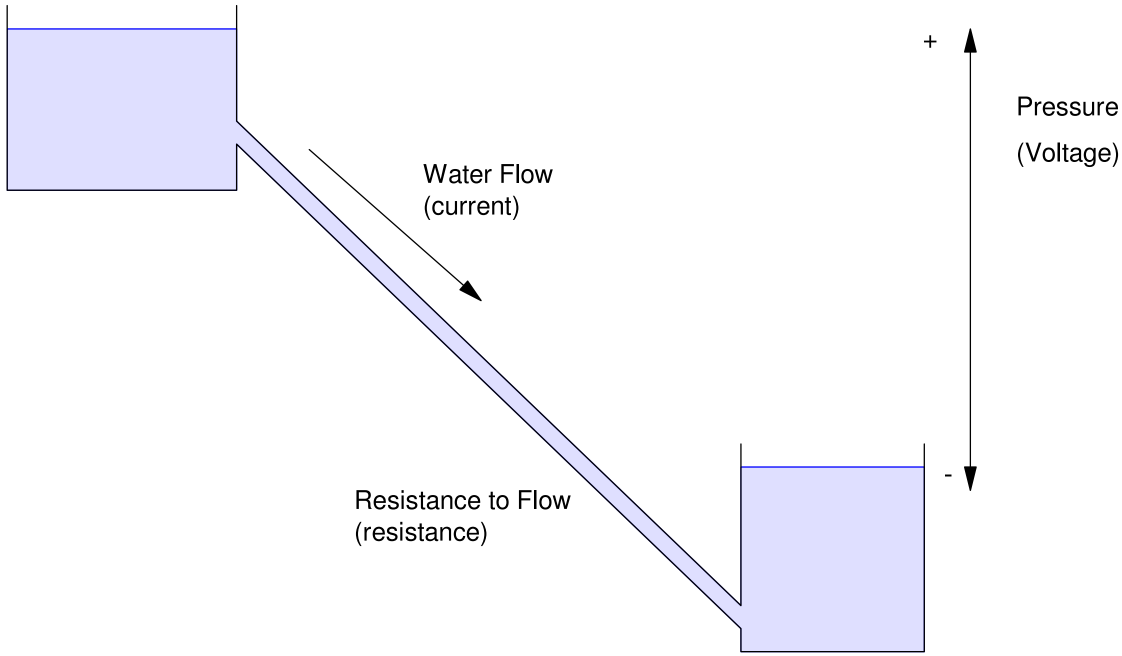
Voltage / Current / Power:

- **Protons:** Part of the nucleus of an atom. Protons do not move and are bound in place by chemical bonds.
- **Electrons:** Part particle, part wave. Electrons are negatively charged particles which are locked in place in insulators and free to move in conductors. Note that current was discovered before electrons. The definition of positive current flow was somewhat arbitrary at that point. They got it wrong. (The direction of current flow is opposite of the direction of electron flow.)
- **Current:** The flow of electrons. $1A = 6.02 * 10^{23}$ electrons per second.
- **Voltage:** The force that causes current to flow, or, the energy released when current flows. 1 Amp of current flowing across 1 Volt produces 1 Joule.
- **Resistance:** The resistance to current flow.

$V = I R$ 1 Volt = 1 Amp flowing across 1 Ohm

Water Analogy

- The pressure (or distance) the water flows downhill corresponds to voltage
- The actual flow of water corresponds to current
- The pipe which limits the flow of the water is resistance.



Conservation of Mass

- $E = m C^2$
- For current to flow, there must be an inlet and an outlet
- Water In = Water Out
- Current In = Current Out

Electrons (current) can neither be created nor destroyed. They can only be pushed around.

If you have a wire with only one end connected to a circuit, you know right away that the current is zero. The voltage can be anything - but the current must be zero.

Power (Watts) and Energy (Joules):

- Fundamental property in a system.
- Unless you are creating matter, energy is always conserved.

Many techniques in engineering use this property: if you understand how the energy in the system is moving around, you've gone a long way in understanding the system.

Newton's Laws of Thermodynamics (Energy)

1st Law: You can't win

- You can't get more energy out than you put in

2nd Law: You can't tie

- There are always some losses

3rd Law: You can't quit

- You can't change the laws of Thermodynamics

Types of Energy (Joules):

Thermal energy:

- It takes energy to raise the temperature
- 4.18 Joules are required to raise 1cc of water 1 degree C

Potential Energy:

- It takes energy to lift an object
- 9.8 Joules = Lifting 1kg by 1m

Kinetic Energy:

- It takes energy to move an object
- 9.8 Joules are required to speed up a 1kg mass to 1 m/s

Electric Energy:

- It takes energy to move electrons around
- 1 Joule = moving 1 Amp of current across 1 Volt for 1 second

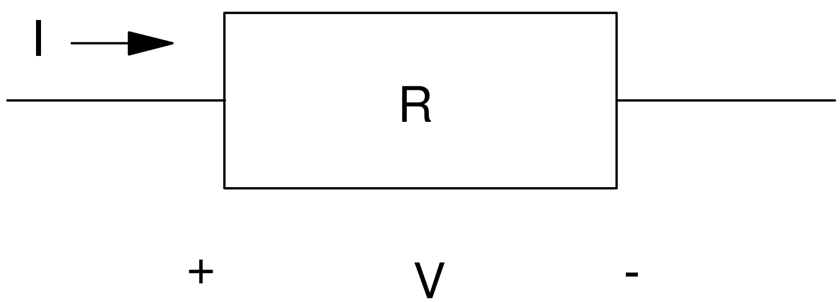
Power (Watts = Joules / second)

- The instantaneous rate of energy release

$$p = \frac{dw}{dt} = v \cdot i$$

$$w = \int p \cdot dt$$

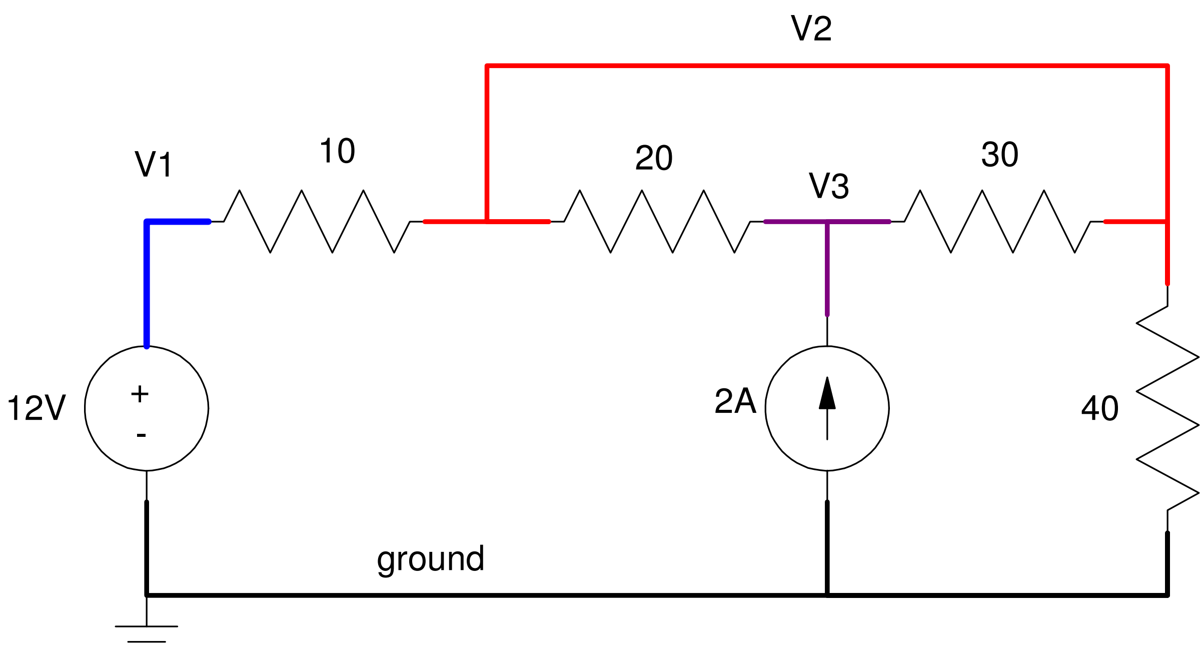
The notation used in electrical engineering is for current to flow into the + terminal for voltage. With this convention, positive energy is energy absorbed (you're producing heat or charging a battery for example.) Negative energy is energy produced (typically by a battery driving a circuit).



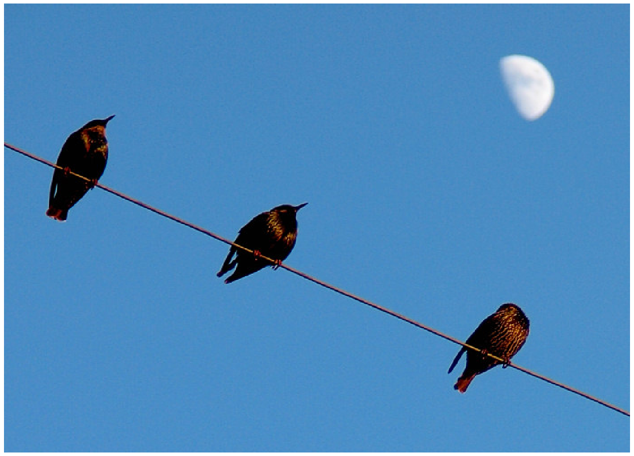
Circuit Notation:

Nodes:

- Indicated by a solid line. It represents a wire (with a resistance of zero ideally). The voltage at any point on the wire is the same. The following circuit, for example, has four voltage nodes including ground.



Ground:



- Voltage is meaningless without a ground refrence
- Usually, ground is the same as earth ground - but it doesn't have to be
- Birds sitting on a high-voltage line treat the 13kV line as their ground reference.

Ground Sybols:

- Can use either one
- If both are used it indicates two different ground references
- Example: We see earth as ground, birds see 13kV as ground

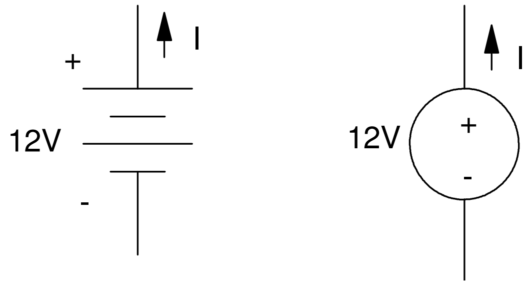
Done short the grounds if a circuit uses different symbols

- If you connect the two, however, the bird goes poof.

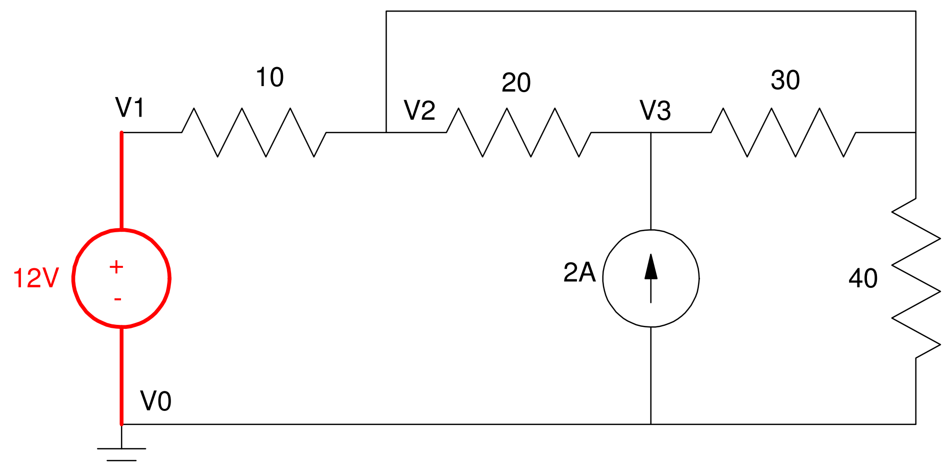
Independent Sources

Voltage: Voltage sources are like batteries: the voltage is fixed.

- Current can be anything (depends upon the load)



Example: V_1 - V_0 = 12V.



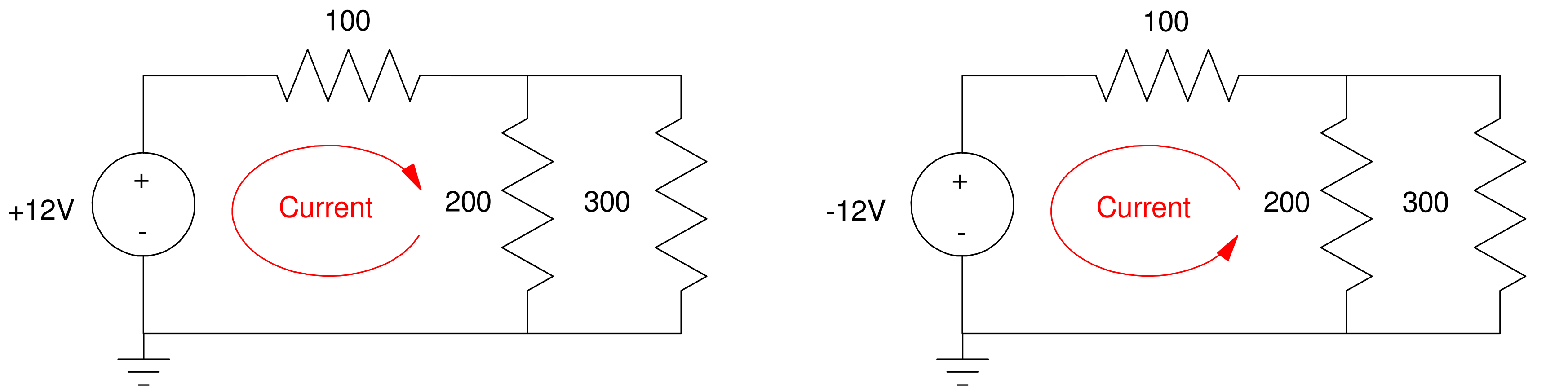
Positive and Negative Voltages

Voltage can be either

- Flip a battery around and +12V becomes -12V

\+ Voltage tries to push current through a circuit

\- Voltage tries to pull current through a circuit



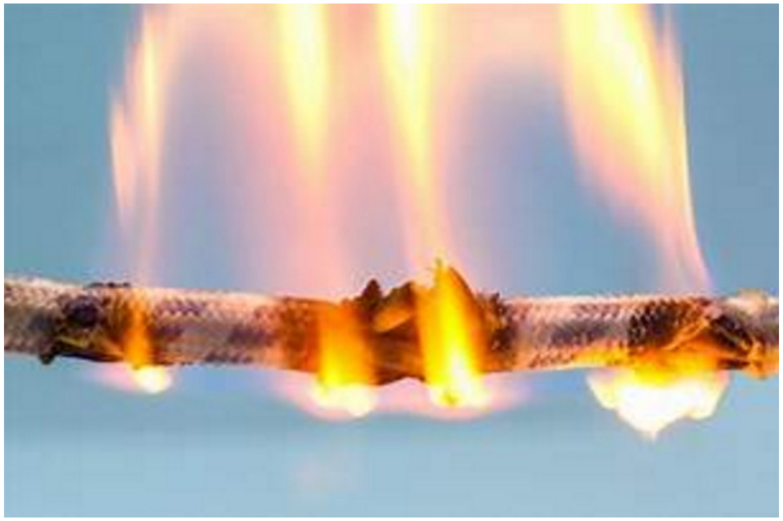
Voltage Safety

You cannot short out a votlage source

- The battery says it is +12V
- The wire says it is 0V

Whoever has the highest current capacity wins

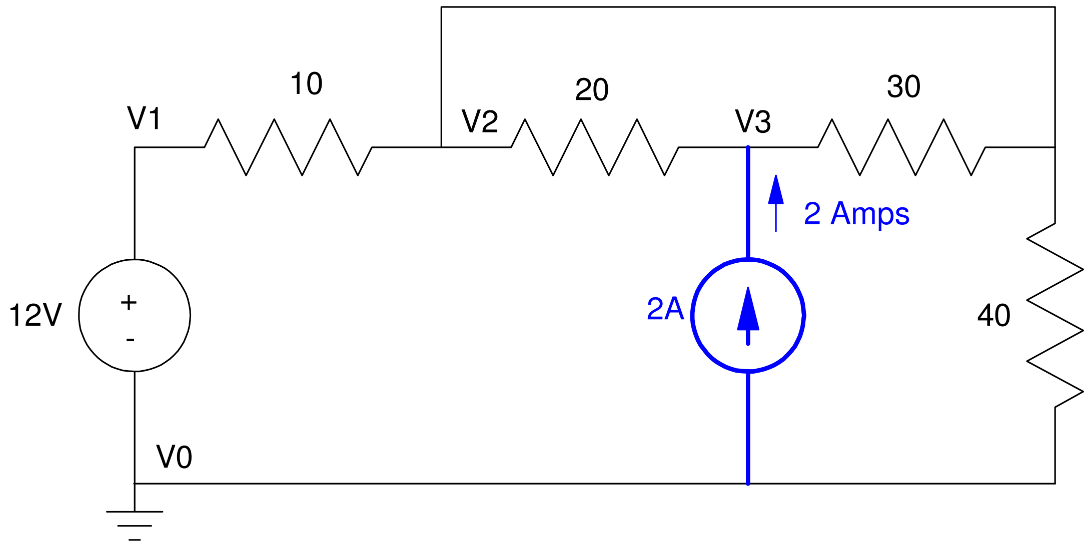
- If the battery wins, you burn out the wire
- If the wire wins, the battery heats up and possibly explodes



www.electri-serve.com

Current Sources

- Symbol = Arrow:
- Voltage can be anything (whatever it takes to set the current)
- Shorting a current source is OK (voltage is zero)
- Opening up a current source is bad (voltage goes to infinity)



Current Source: The current in the bold wire is forced to be 2A

Dependent Sources:

- A diamond indicates a controlled voltage source or a controlled current source.
- The voltage or current depends upon something else

ECE 320 & ECE 321 Electronics:

- Operational Amplifiers (voltage controlled voltage source)
- Transistors (current controlled current source)
- MOSFET (voltage controlled current source)

For this class, just treat them as a voltage or current source

Passive Devices

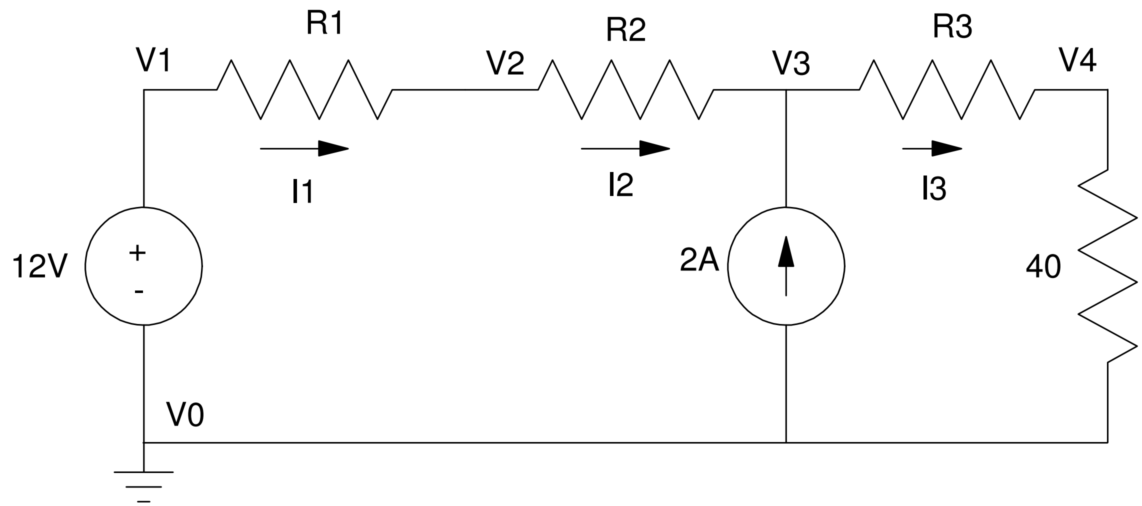
- Passive devices do not require energy (i.e. a battery) to operate

Resistance: A resistor limits current flow. It's symbol is a zig-zag line and has the relationship of $V = IR$

$$I_1 R_1 = V_1 - V_2$$

$$I_2 R_2 = V_2 - V_3$$

$$I_3 R_3 = V_3 - V_4$$



Power:

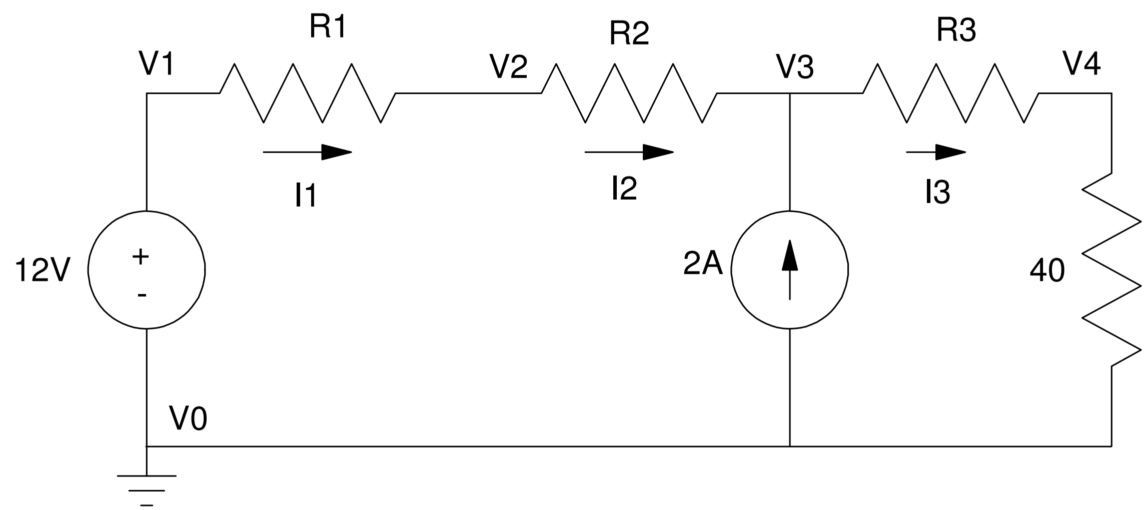
Power (Watts) is volts times amps:

$$P = VI$$

Since V = IR, power can also be

$$P = \frac{V^2}{R}$$

$$P = I^2 R$$



Example:

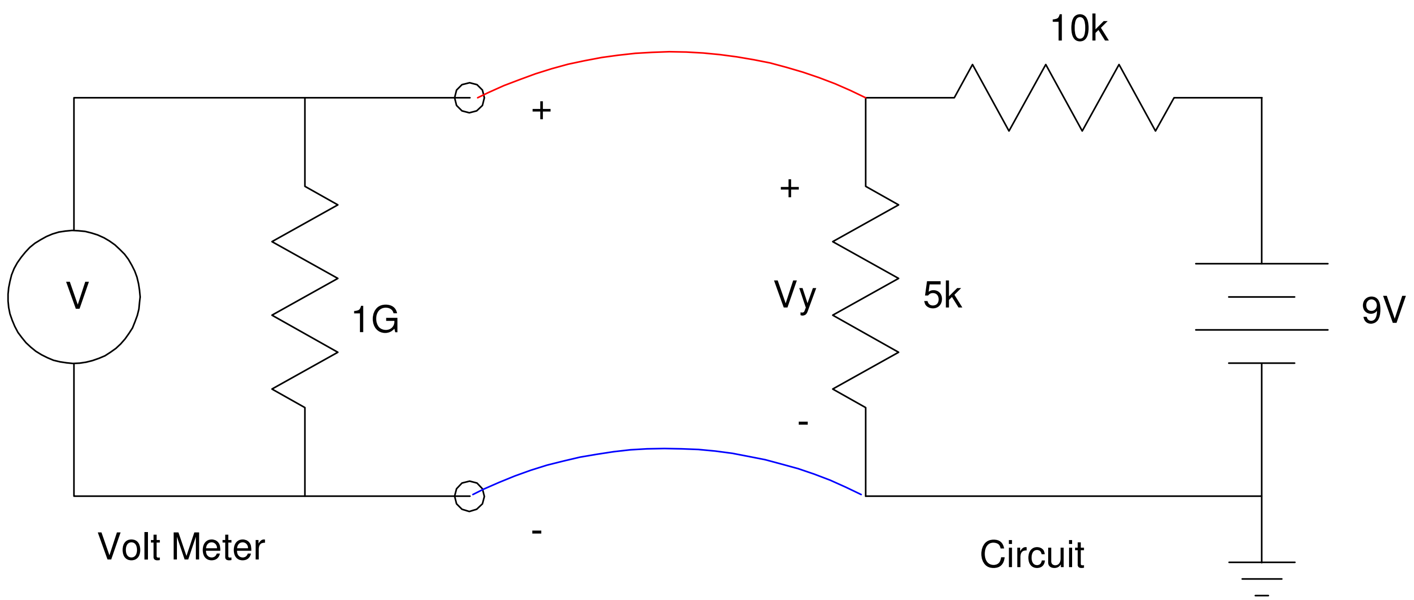
$$P_1 = V_1\ I_1$$

$$= \frac{V_1^2}{R_1}$$

$$= I_1^2\ R_1$$

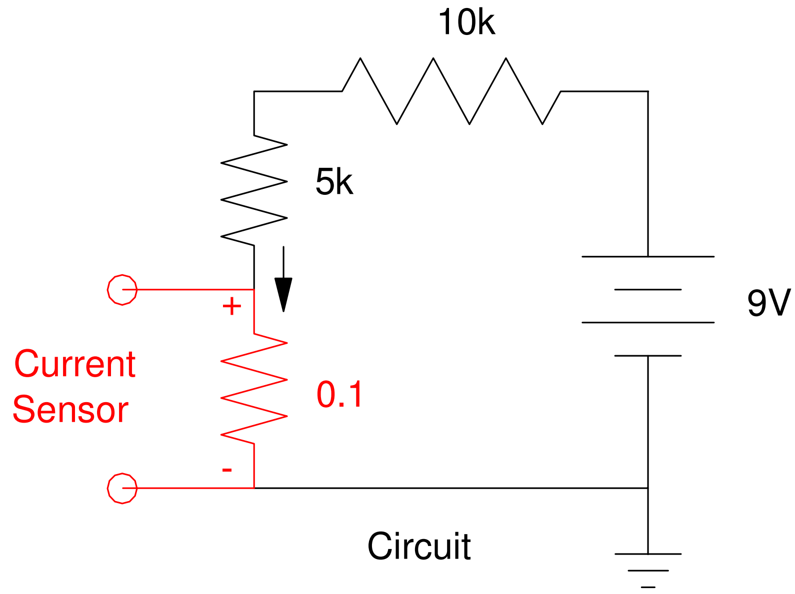
Volt Meters:

- Measures voltage
- Passive device (usually a microprocessor)
- High impedance (typically 100 M Ohms)
- Polarized: Flip the leads and you go from +12V to -12V
- Connect in parallel



Ammeters:

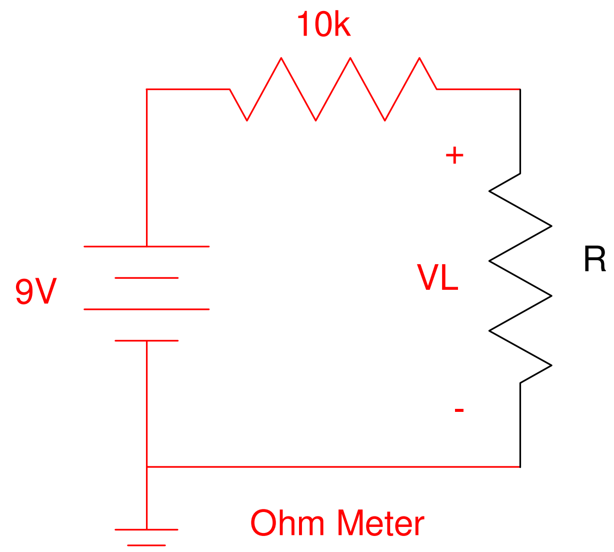
- Measure current.
- Passive device
- Low impedance (Place a small resistor (0.1 Ohm) in series and measure the votlage
- Polarized (flip the leads and you go from 100mA to -100mA)
- Connect in series



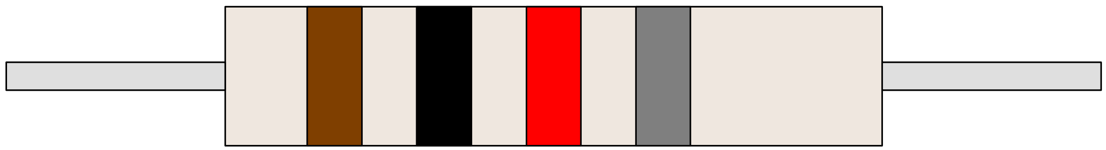
Current Sensors are placed in series and add a small resistance to the circuit.

Ohm Meters:

- Measures resistance
- **Active Device**
- Ohm meters apply a small test current to measure the votlage drop
  - Turn off all other sources (they will affect the reading)
  - Make sure it's safe to apply a small current (i.e. it's not a firing cap)



Resistor Color Code



Value

0	1	2	3	4	5	6	7	8	9
black	brown	red	orange	yellow	green	blue	violet	grey	white

Tolerance

Silver	Gold	Red	Brown	Green
+/- 10%	+/- 5%	+/- 2%	+/- 1%	+/- 0.5%