
Terminology and Definitions

ECE 211 Circuits I

Lecture #1

Please visit [Bison Academy](#) for corresponding
lecture notes, homework sets, and solutions

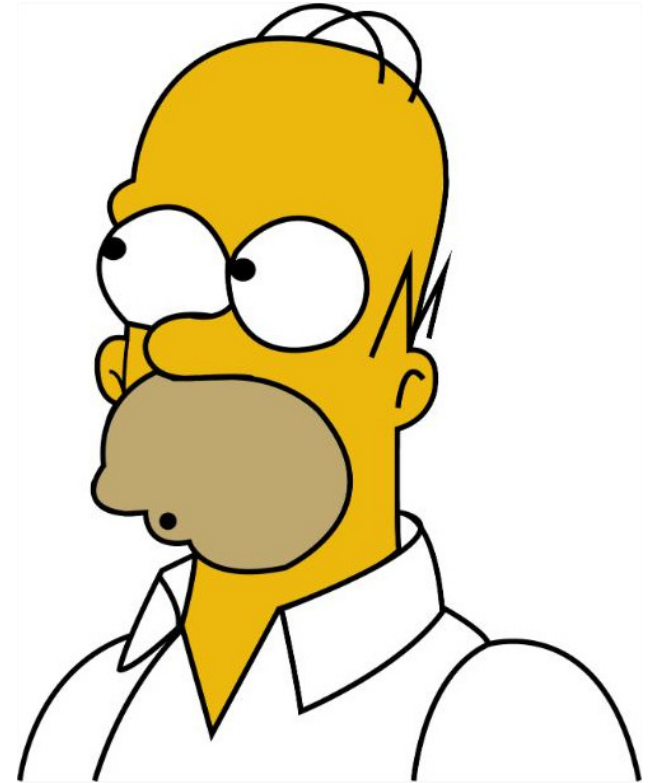
English Units

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?



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	$\text{kg m} / \text{s}^2$
Joule	J	Energy	Force * distance = $\text{kg m}^2 / \text{s}^2$
Watt	W	Power	Joule / second = $\text{kg m}^2 / \text{s}^3$
Amp	A	current	Q / s
Volt	V	Electric potential	Watts / Amp
Ohm	Ω	Electrical resistance	Volts / Amp
Farad	F	Capacitance	$Q^2 \text{s}^2 / \text{kg m}^2 = \text{Coulomb} / \text{Volt}$
Henry	H	Inductance	$\text{kg m}^2 / Q^2 = \text{Joules} / \text{Amp}^2$

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 1mm^2 . The conductivity of copper is

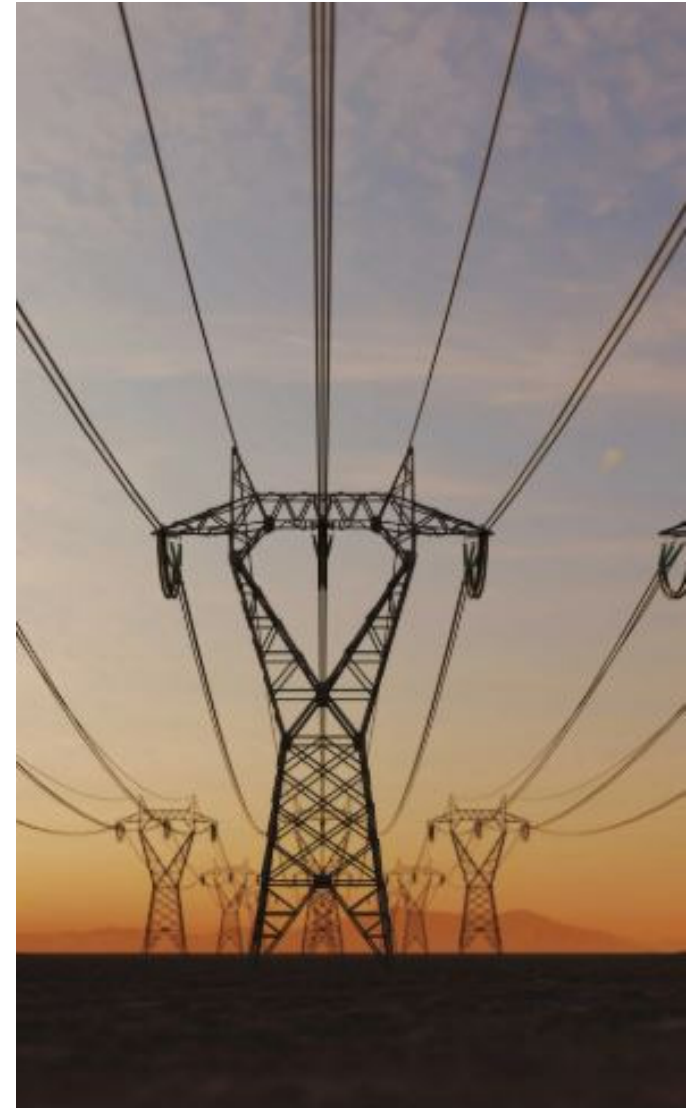
$$\rho = 1.68 \cdot 10^{-8} \Omega m$$

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

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



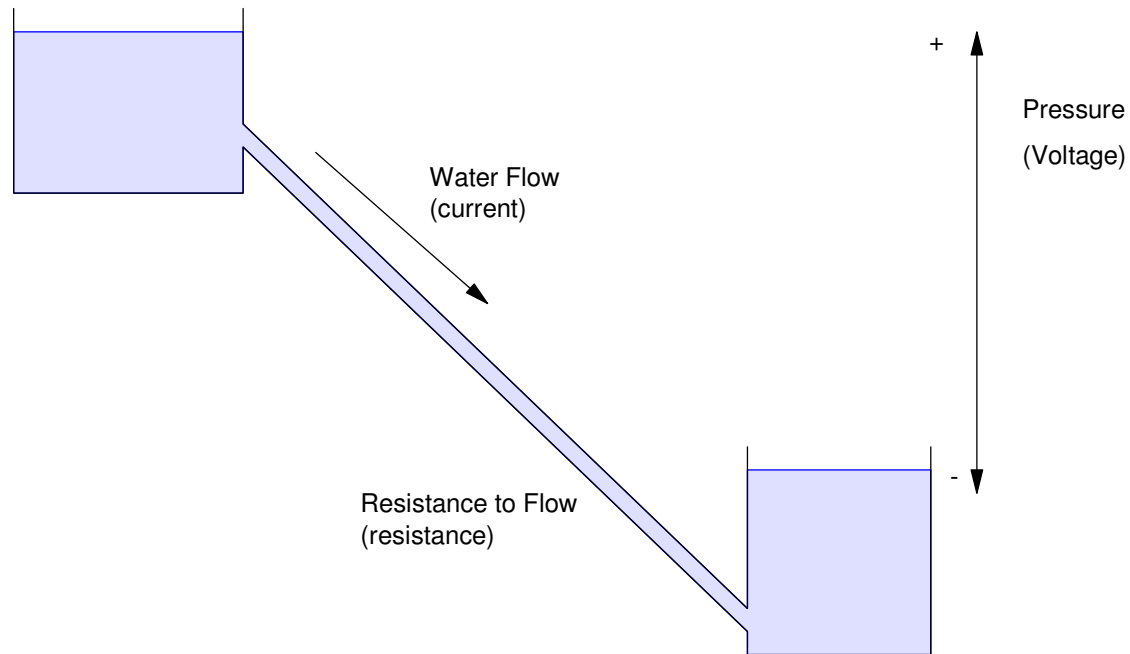
Voltage / Current / Power:

- **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. $1\text{A} = 6.02 * 10^{23}$ 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.

$$V = I R \qquad 1 \text{ Volt} = 1 \text{ Amp flowing across } 1 \text{ Ohm}$$

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

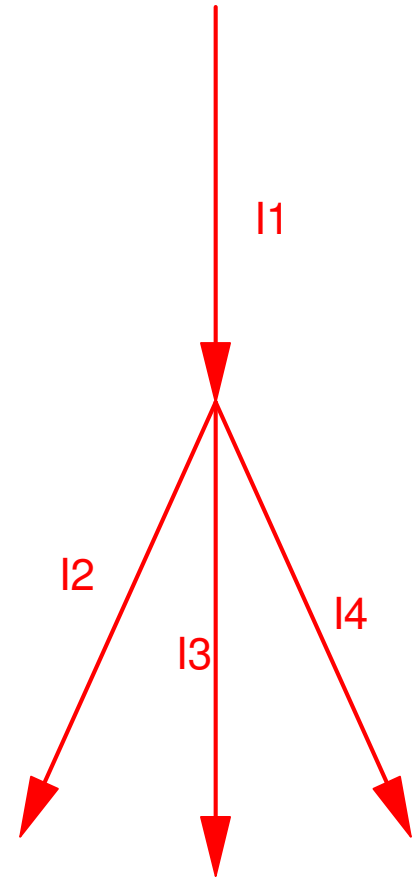
- Matter cannot be created or destroyed
- (usually)
- $E = m C^2$

Conservation of Current

- **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.



$$I_1 = I_2 + I_3 + I_4$$

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

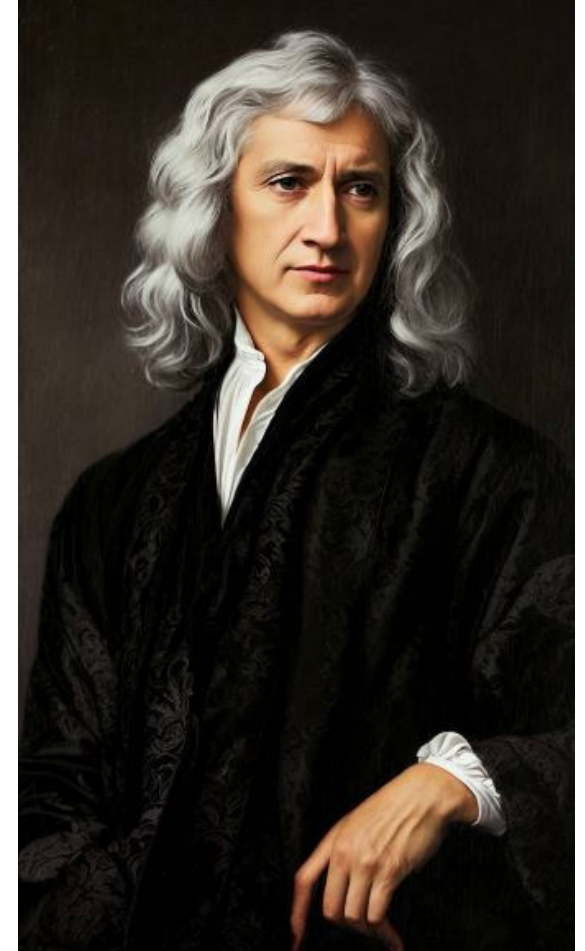
- You can't get more energy out than you put in

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:

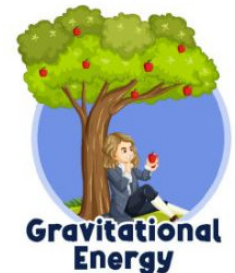
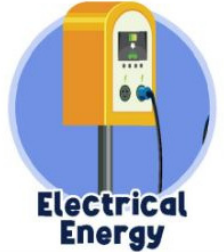
- It takes energy to lift an object
- 9.8 Joules = Lifting 1kg by 1m

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



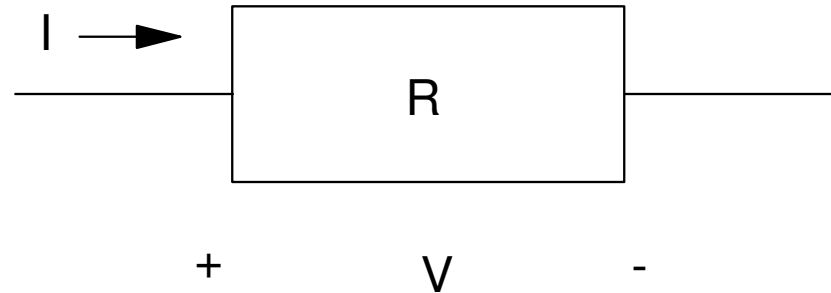
Power (Watts = Joules / second)

- The instantaneous rate of energy release

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

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

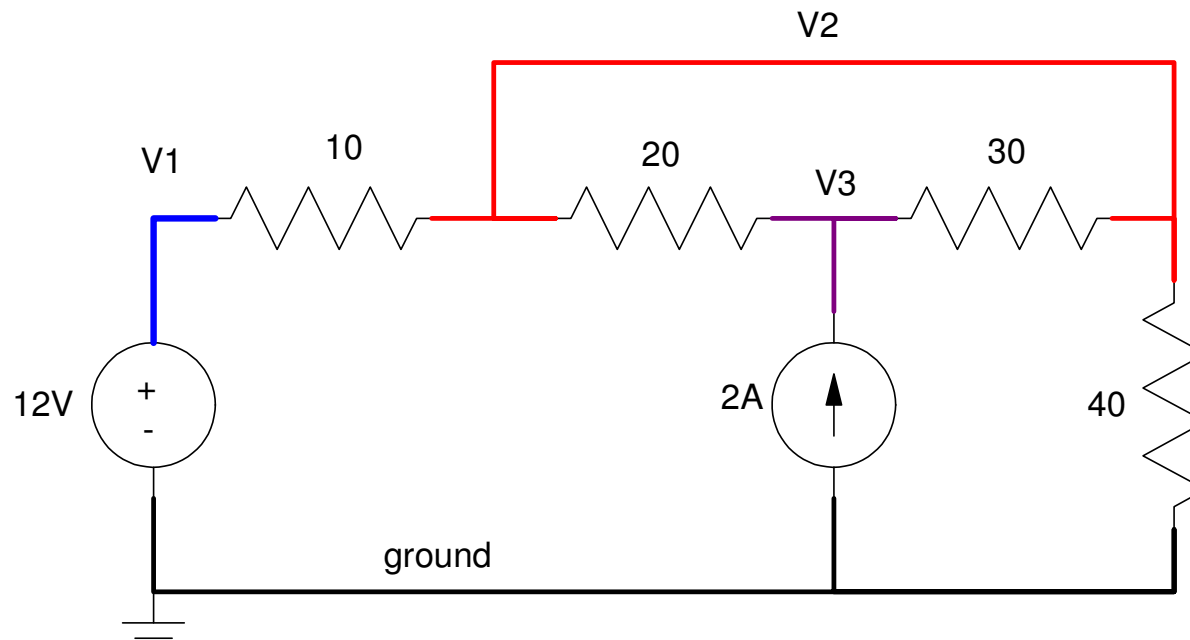
The notation used in electrical engineering is for current to flow into the + terminal for voltage. With this convention, positive energy is energy absorbed (you're producing heat or charging a battery for example.) Negative energy is energy produced (typically by a battery driving a circuit).



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 reference
- 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.

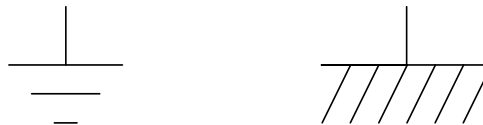


Ground Symbols:

- 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

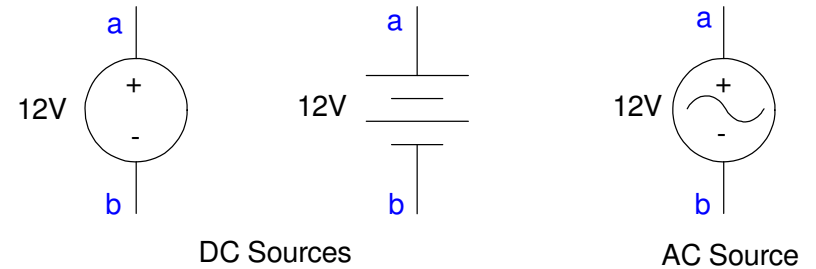
Don't short the grounds if a circuit uses different symbols

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



Voltage Source

- Basic circuit element
- Provides a constant voltage across terminals
- Think car battery



Voltage	Example	Enough voltage to...
1.5V	AA battery	Turn on a single LED
5.0V	USB Battery	Power a computer
13.2V	Car battery	Turn a motor (starter)
120V	Wall Outlet	Power a computer, hair dryer
13,200V	Residential transmission lines	Power a residential subdivision Kill a person
345,000V	Long distance transmission lines	Power a small city Create an arc 11cm long

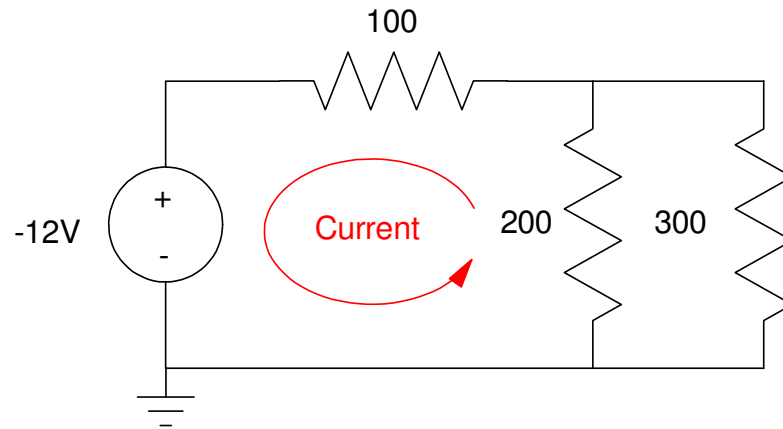
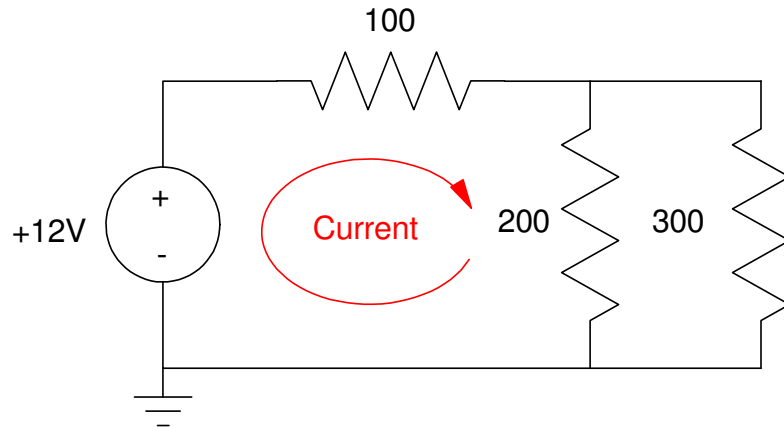
Positive and Negative Voltages

Voltage can be either

- Flip a battery around and $+12\text{V}$ 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 voltage 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

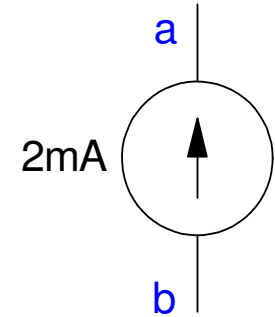


www.electri-serve.com

Current Source

A current source sets the current flowing in a circuit. These are used for

- LED lights: The current determines the light output.
- DC Motors: Current is torque



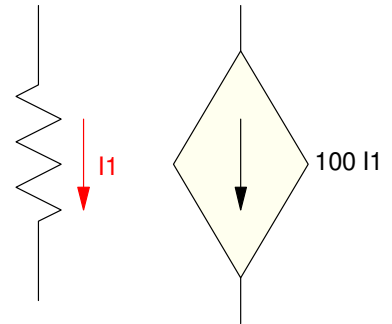
Current	Diameter of wire to carry.	Example
1uA	0.000 7mm	Sleep mode for a TV remote
1mA	0.021 mm	Power a single LED (dim)
1A	0.72mm	Charging a cell phone
10A	2.3mm	Hair dryer
100A	7.3mm	Welding

Dependent Sources:

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

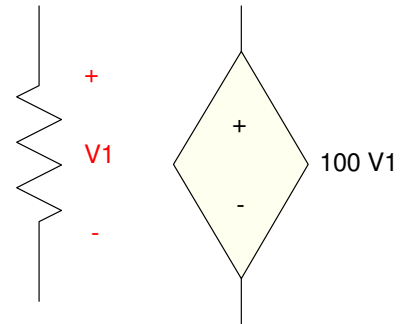
ECE 320 Electronics:

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



Current-Controlled Current Source

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



Voltage-Controlled Voltage Source

Passive Devices

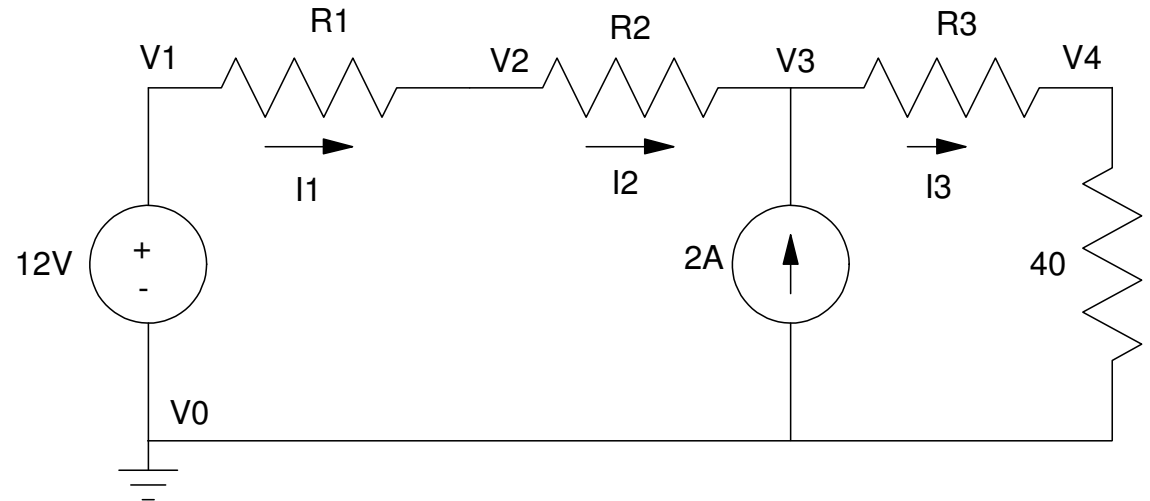
- Passive devices do not require energy (i.e. a battery) to operate

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 (Watts)

- Energy
- Energy must always balance (energy in = energy out)

Watts	Example
1mW	power-on indicator LED
1W	Human Heart
10W	1000 Lumen LED Light Bulb
100W	Bicycling (300W = Tour de France)
1kW	Max output of elite athletes Hair dryer
10kW	Lawn Tractor (15.6hp)

Power:

Power (Watts) is volts times amps:

$$P = VI$$

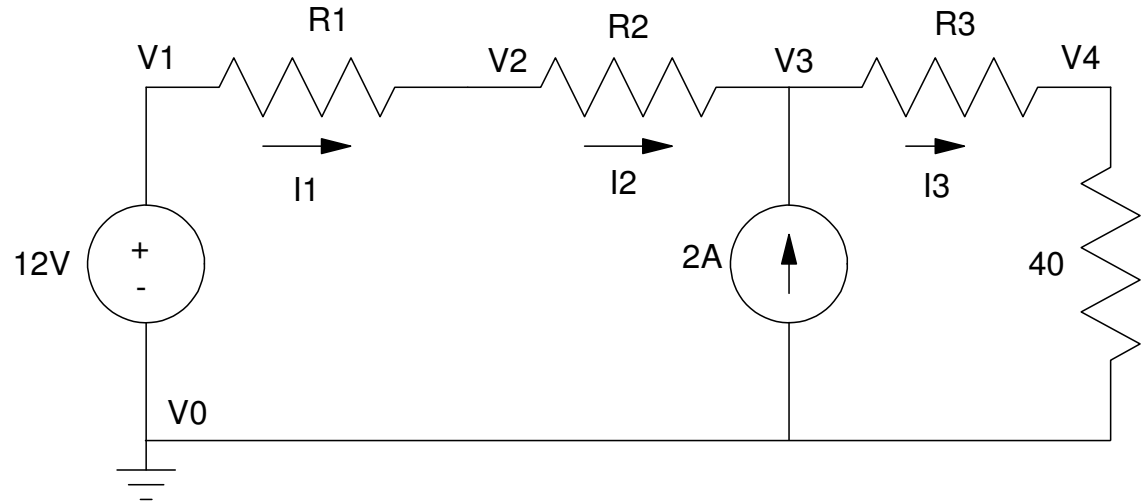
Since $V = IR$, power can also be

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

$$P = I^2 R$$

Example:

$$\begin{aligned} P_1 &= V_1 I_1 \\ &= \frac{V_1^2}{R_1} \\ &= I_1^2 R_1 \end{aligned}$$



Handout

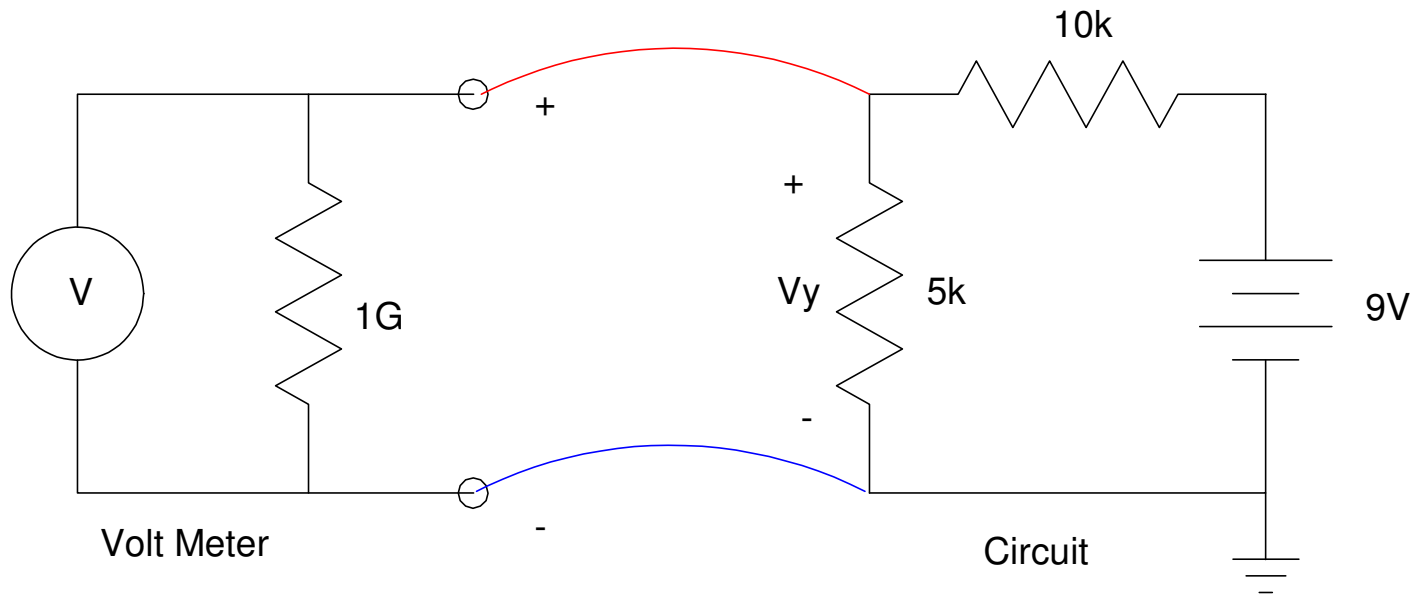
Determine the missing terms

- $V = I R$
- $P = V I$

	Volts (V)	Amps (I)	Ohms	Power (W)
a)	5.0 V	2.0 A		
b)	5.0 V		2.0 Ohms	
c)		5.0 A		20.0 W
d)			3.0 Ohms	15.0 W

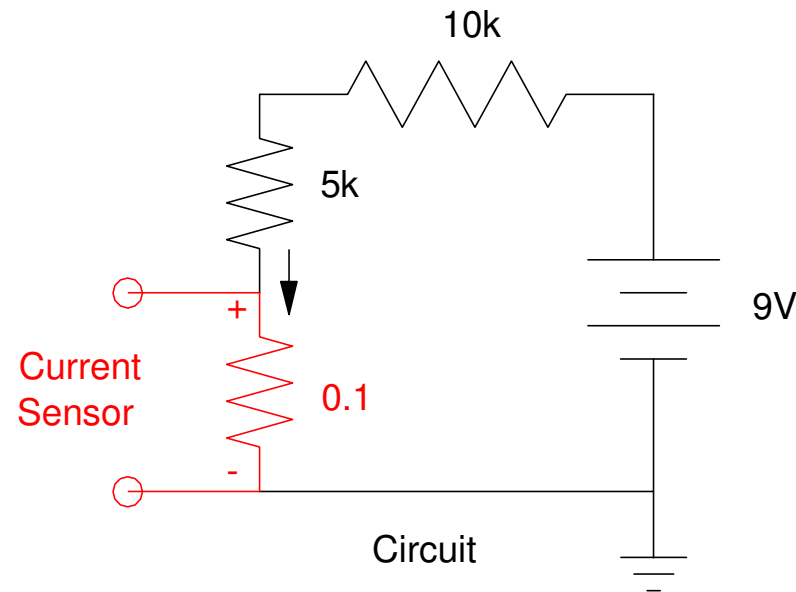
Volt Meters:

- 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:

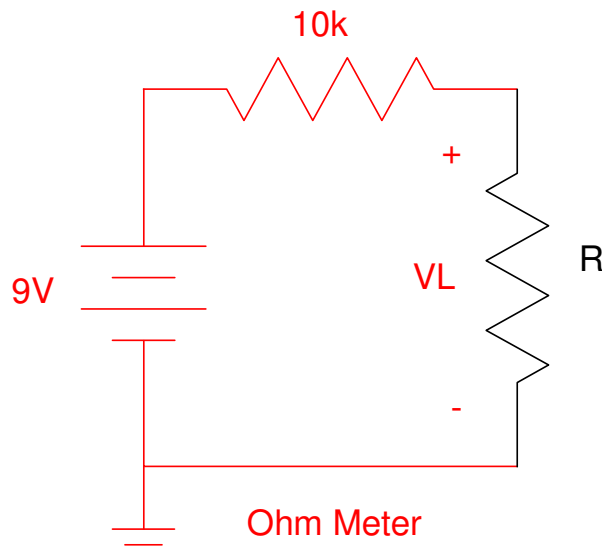
- Measure current.
- Passive device
- Low impedance (Place a small resistor (0.1 Ohm) in series and measure the voltage)
- Polarized (flip the leads and you go from 100mA to -100mA)
- Connect in series



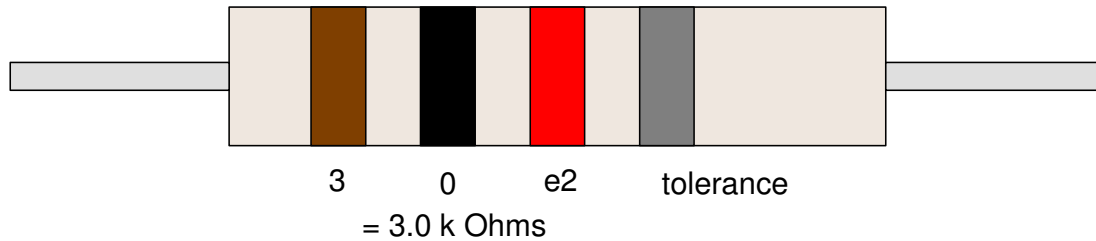
Current Sensors are placed in series and add a small resistance to the circuit.

Ohm Meters:

- Measures resistance
- **Active Device**
- Ohm meters apply a small test current to measure the voltage 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

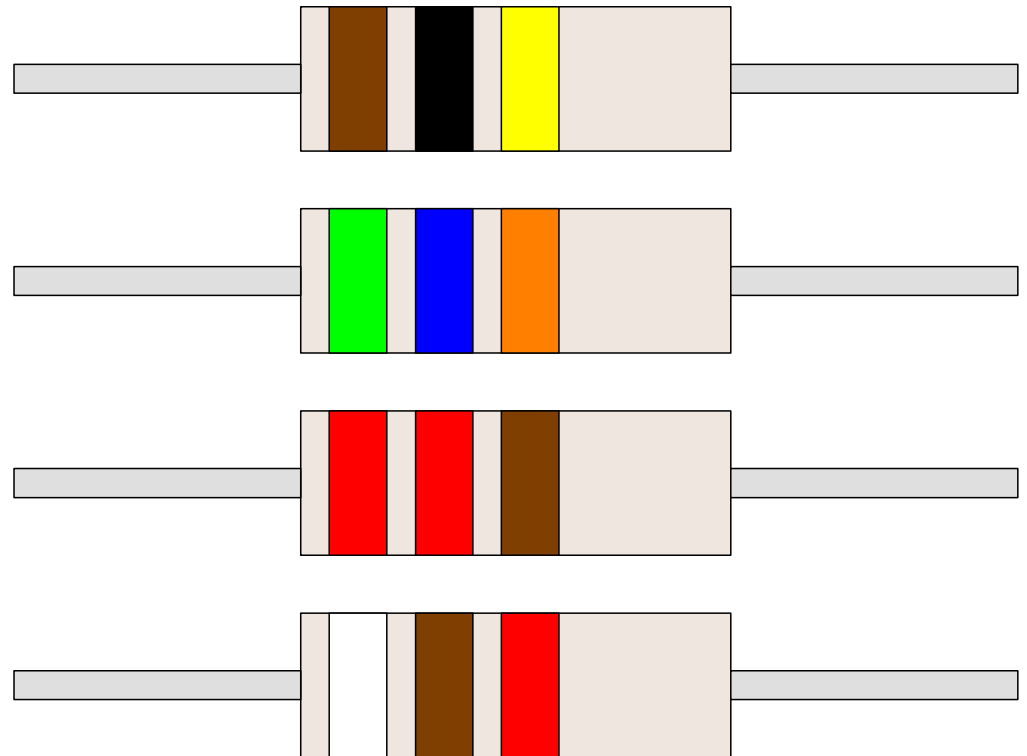
Tolerance

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

Handout

Determine the value of each resistor

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



Summary

We'll be using metric units in this course

Many problems can be solved using

- Conservation of Current
 - Current In = Current Out
- Conservation of Voltage
 - Sum of voltages around a closed-loop is zero
- Conservation of Energy
 - Energy In = Energy Out

The basic equations used in this course are

- Ohms Law
 - $V = I R$
 - Power
 - $P = V I$
-