I. International System of units (SI Units)

Length: meter (m)
Mass: kilogram (kg)
Time: second (s)
Current: Ampere (A)
Temperature: Degrees Kelvin (ºK)

SI prefixes to signify powers of 10

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

Some extreme values:

1 Gbit = 10^9 bits or $10^3 10^6$ bits or one thousand million bits
10^{-5} sec = 0.00001 sec; use closest SI prefix
1×10^{-5} sec = 10×10^{-6} sec or 10 μsec
OR
1×10^{-5} sec = 0.01×10^{-3} sec or 0.01 msec

Typical ranges of voltages and currents we encounter everyday…

Voltage (V)	Current (A)
10^{-8} Antenna of radio receiver (10 nV)	10^{-12} Nerve cell in brain
10^{-3} EKG – voltage produced by heart	10^{-7} Integrated circuit memory cell (0.1 μA)
1.5 Flashlight battery	10×10^{-3} Threshold of sensation in humans
12 Car battery	100×10^{-3} Fatal to humans
110 House wiring (US)	1-2 Typical Household appliance
220 House wiring (Europe)	10^3 Large industrial appliance
10^7 Lightning bolt (10 MV)	10^4 Lightning bolt

II. Quantities

Fundamental quantity of electricity is electric charge (q) measured in Coulombs (C). Can be positive or negative; an electron is negatively charged:

$$q = 1.602\times10^{-19} \text{ C.}$$

Movement of charge is called current (i) measured in Amperes (A).

$i = dq/dt$ So 1 A = 1 C/s

Note: I and *i* are both used in this course but typically in Electrical Engineering, a lower case *i* is used to designate a current that is changing with time, ac current.

The energy required to move charge is the difference in energy levels between two points and is called voltage (v) which is measured in Volts (V). The work (w), or energy, required to move the charge is measured in Joules (J).

$$v = dw/dq$$

$$1 \text{ V} = 1 \text{ J/C}$$

You can break units down further…

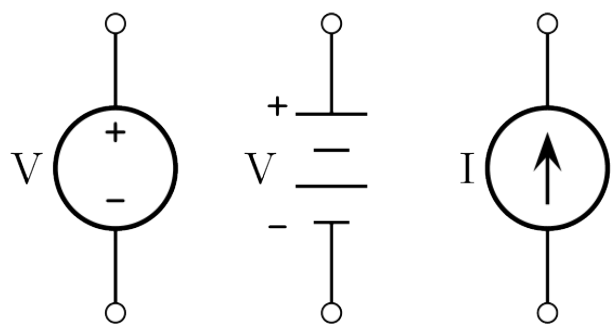
1 Joule is the work done by a constant 1 N force applied through a 1 m distance

so… $1 \text{ J} = 1 \text{ N}{\cdot}\text{m}$

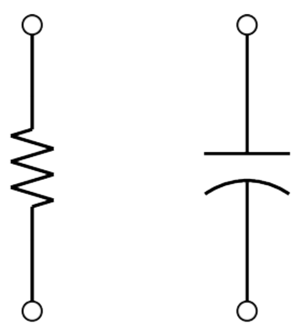
$1 \text{ V} = 1 \text{ N}{\cdot}\text{m /C}$

III. Circuit Elements

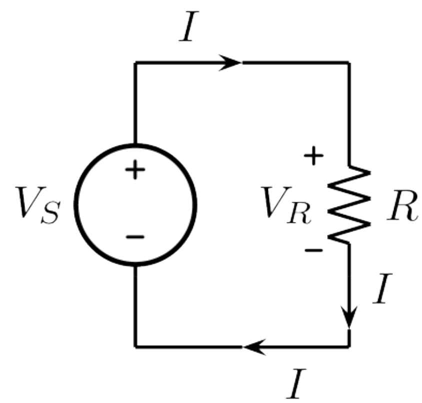
Voltage Source (V) **Current Source (I)**



Resistor (R) **Capacitor (C)** **Inductor (L)**
Ohms (Ω) Farads (F) Henrys (H)



Connect elements to form a circuit. One of the most basic is shown below. Current is flowing from the positive terminal of the voltage source to the passive element and back to the negative terminal of the source. Notice that current is shown in the direction of positive charge flow even though we know from vacuum tube theory that flow is the movement of electrons (it has become a standard way to define current flow from negative to positive terminals of a battery). In this circuit, $\mathbf{V_S = V_R}$ because both elements are connected to the same points electrically (from the top wire to the bottom wire).



The *passive sign convention* is a set of rules to help simplify analysis. Power is determined by multiplying current and voltage together. If *I* and *V* are both positive quantities, the power product will be positive. If current changes direction **OR** if voltage changes polarity, the power product would be negative. If current changes direction **AND** voltage changes polarity, the power product would be positive (two negative quantities). Batteries supply energy; resistors can only absorb energy.

IV. Resistance

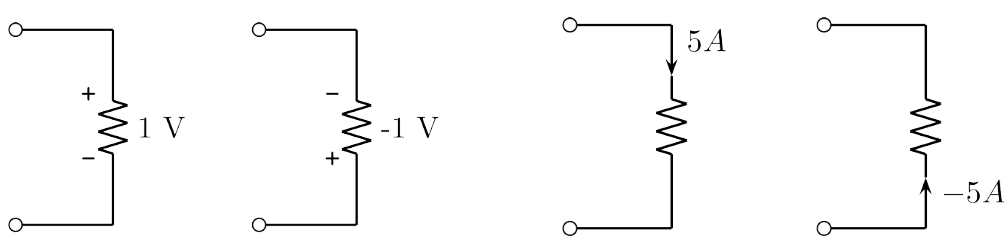
The most basic circuit equation is Ohm's Law:

$$\mathbf{V = IR}$$

The voltage ***across*** a resistor is equal to the current flowing ***through*** it times the resistance value.

The unit for resistance is Ohms (named after a German physicist, George Simon Ohm) with a symbol of Ω. ***A reminder***: you need to be careful when using Ohm's Law in a circuit with multiple resistors or multiple sources. This law refers to a single resistor and refers to the voltage ***across*** that particular resistor and the current flowing ***through*** it.

Equivalence: If polarity of voltage is reversed, the magnitude also has to be negated. The branches are equivalent. In the same way, if a current direction is reversed, the magnitude has to be negated. See below. Each representation is equivalent for both voltage and current.



There are two special cases for extreme values of resistance:

When R = 0 Ω, referred to as a short circuit, **V = IR = 0**, you can think of this situation as a perfect conductor that is capable of carrying current with no voltage drop across it.

When R = ∞, referred to as an open circuit, **I = V/R = 0**, you can think of this situation as a perfect insulator that is capable of supporting a voltage without permitting current flow.

V. Power Equation

As stated earlier, another important equation is the equation, **P = IV**. Power is measured in Watts (named after the Scottish engineer, James Watt). The unit of Watts can also be broken down further. I (Coulomb/sec) and V (Joule/Coulomb) multiplied together result in Coulombs cancelling out and therefore, the unit of Watt is equivalent to Joule/sec (rate of energy expenditure).

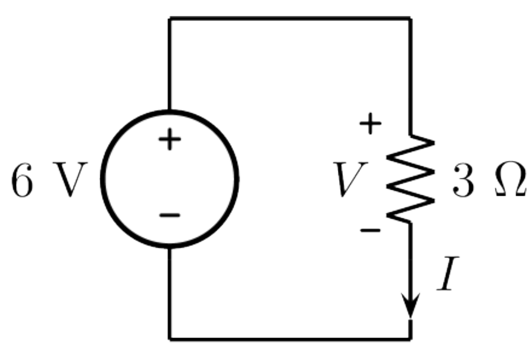
If Ohm's Law is substituted in the power equation, another form emerges that is commonly used.

$$P = IV = I*(IR) = I^2R \text{ or } P = (V/R)*V = V^2/R.$$

This form is useful when only current through or voltage across a resistor is known.

To find I in the circuit below, use Ohm's Law: V = IR. In this case, V and R are known so I = V/R or I = 6V/3Ω = 2 Amps. If you change the resistor value to 3 kΩ,

$I = 6/(3 \times 10^3) = 2 \times 10^{-3}$ or 2 mA. Increasing the value of resistance decreases the current flow.



Now look at power, $P = I^2R = 2^2(3) = 12$ W $\qquad P = V^2/R = 6^2/3 = 12$ W

$$P = IV = 2(6) = 12 \text{ W}$$

All forms of the equation yield the same magnitude for power. We can distinguish if an element is absorbing or supplying power by using the passive sign convention. In this circuit, "positive" current is entering the "positive" voltage terminal of the resistor. We use the "sign" of the power to show that a "positive" power indicates that the element (resistor) is absorbing power. Note in this circuit, "positive" current is entering the "negative" voltage terminal of the power supply. A "negative" power (2 * -6) = -12 W indicates this element is supplying 12 W of power.