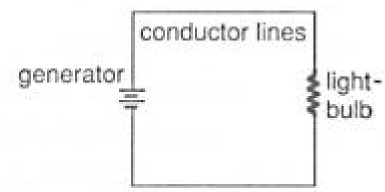
NETWORKS

Networks are based on electronic circuit, whose name derives from the latin word for a circle or loop. As you probably already know, the simplest form of circuit consists of a generator, line and resistor, such as a battery, wire and lightbulb. The schematic representation of this is as follows:

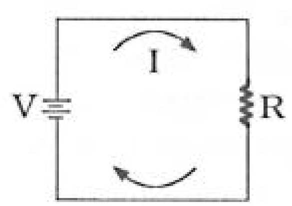


OHM'S LAW

All components of a circuit are described by a simple principle known as Ohm's Law. It simply states that voltage across a resistor equals the current through it times a quantity known as resistance.

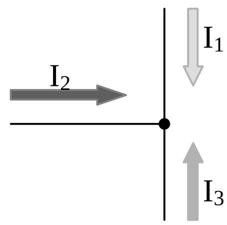
V = IR

Voltage is measured in volts (V), current in amps (A) and resistance in ohms (Ω). (These units are named after the scientists Volta, Ampere and Ohm)



KIRCHOFF'S LAW

Voltage:
The total voltage in a circuit must add up to zero. This means that voltage at the source must be equal to the total voltage drop across the resistors in a circuit. Ohm's law (V=IR) also governs the magnitude of the voltage drop across each resistive element in a circuit. (note: short wires also have a resistance, however, this is insignificant compared to the R of a resistor – we will address long wires later)
Current:
The sum of the currents flowing to any one point in a circuit, known as a node, must be zero.



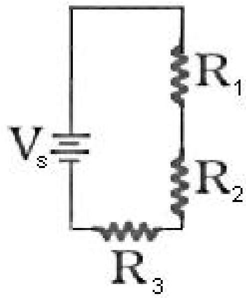
$$I_1 + I_2 + I_3 = 0$$

This means that if I_1 is +1 amp, and I_2 is +2 amps then I_3 must be –3 amps (in other words, I_3 is 3 amps flowing *away* from the node)

DETERMINING RESISTANCE

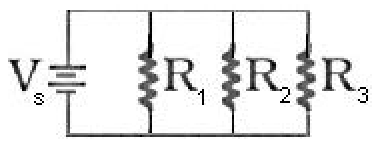
If you have more than one resistor in a circuit, they can be combined into a single equivalent resistance, R_T. The method for combining depends on whether resistors are in series or in parallel.

If resistors are in *series*:



$R_{Total} = R_1 + R_2 + R_3$
Current, I, is the same through each resistor, and equal to: $I = V_{Source}/R_{Total}$

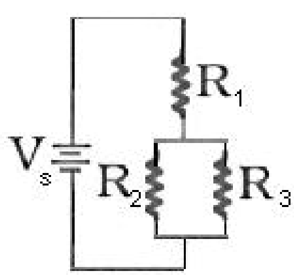
If resistors are wired in *parallel*:



$1/R_{Total} = 1/R_1 + 1/R_2 + 1/R_3$
Voltage, V, is the same across each resistor and equal to V_S.

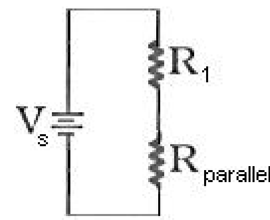
If you have a combination, convert the parallel portion of the circuit to one resistance, and then add the resistors as if they were in series.

EXAMPLE



$V_{Source} = 12V$
$R_1 = 1000\Omega$ $R_2 = 400\Omega$ $R_3 = 400\Omega$

First convert R_2 and R_3 to a single resistance, $R_{parallel}$.



$1/R_{parallel} = 1/R_2 + 1/R_3$
$1/R_{parallel} = 1/400\Omega + 1/400\Omega$
$1/R_{parallel} = 2/400\Omega$
$R_{parallel} = 200\Omega$

Now add R_1 and $R_{parallel}$.

$R_1 + R_{parallel} = R_{Total}$
$1000\Omega + 200\Omega = 1200\Omega$

Use R_{Total} to determine the current through the loop:

$V_{Source} = I_{Total}R_{Total}$
$12V = I_{Total} \times 1200\Omega$
$I_{Total} = .01$ A

Because R_1 and $R_{parallel}$ were in series, this is the current that passes through each of them. To find the voltage through each resistor, use Ohm's Law:

$V_1 = I_{Total}R_1$
$V_1 = .01 \text{ A} \times 1000\Omega$
$V_1 = 10V$

$V_{parallel} = I_{Total}R_{parallel}$
$V_{parallel} = .01 \text{ A} \times 200\Omega$
$V_{parallel} = 2V$

notice that the voltage drops add up to 12V $= V_{Source.}$

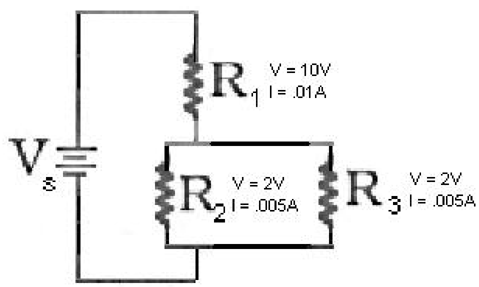
To find the current through and voltage across R_2 and R_3 you must use what you know about the voltage, $V_{parallel}$, across the two of them. Because they are wired in parallel, the voltage across each of them is the same. It is also equal to $V_{parallel.}$

$V_2 = V_3 = V_{parallel}$
$V_2 = 2V$
$V_3 = 2V$

To find the current through each, again use Ohm's law:

$V_2 = I_2R_2$
$2V = I_2 \times 400\Omega$
$I_2 = .005$ A

$V_3 = I_3R_3$
$2V = I_3 \times 400\Omega$
$I_3 = .005$ A



Resistance of a device can be a function of different properties, such as temperature. In a wire resistance is dependent upon the material used, the length of the wire, and its cross-sectional area:

Resistance = resistivity of the material × length of wire / cross-sectional area of the wire

$$R = \rho L/A$$

JOULE'S LAW

Another important equation relating to all circuits is Joule's Law. It states:

Power in a component (measured in watts) = Current through it times the voltage across it

$$P = VI$$

And, knowing that **V = IR,** we can substitute to create another relationship:

$$P = I \times (IR)$$

$$P = I^2R$$

From this, one is able to determine power losses due to resistance at different current levels.

Thomas Edison worked with these equations to help him develop his vision of a great New York network of electricity.

ELECTROMAGNETISM

Faraday observed that when current flows through a wire that is in a magnetic field, this wire experiences a force in a direction perpendicular to both the magnetic field and the current flow. The magnitude of the force on this wire is:

$$F = iLB$$

Where F is the force on the wire, i is the current running through the wire, L is the length of wire that is in the magnetic field, and B is the magnetic field strength.

This observation serves as the fundamental basis for many electromagnetic devices including motors, loudspeakers and electromagnetic meters.