Electrics

Basic Concepts

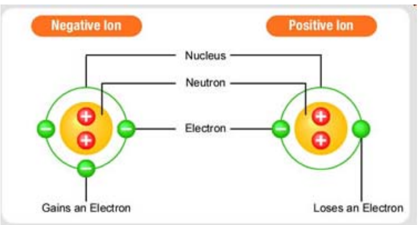
What is electricity?

Electricity is the set of physical phenomena associated with the presence and flow of electric charge. Electricity has well-known effects, such as lightning, static electricity, electromagnetic induction

What is electric charge?

All materials are made up from atoms, and all atoms consist of protons, neutrons and electrons.

- Protons, have a positive electrical charge.
- Neutrons have no electrical charge
- Electrons, have a negative electrical charge.



The charge is a measure of electron/proton balance in an atom and can be calculated by extracting number of protons from number of electrons

What is electric charge?

The unit of charge is called the Coulomb [C].

The smallest unit of "free" charge known in nature is the charge of an electron or proton, which has a magnitude of

$$e = 1.602 \times 10^{-19}\ [\mathrm{C}]$$

An electron carries one unit of negative charge *e*−, while a proton carries one unit of positive charge, *e+.*

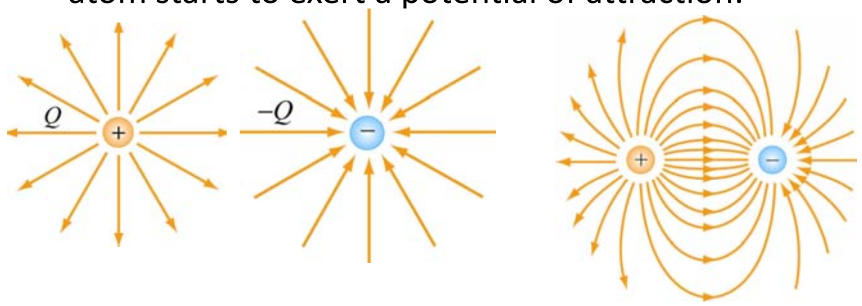
In a closed system, the total amount of charge is conserved since charge can neither be created nor destroyed.

A charge can, however, be transferred from one body to another.

What is electric charge?

If the numbers of the electrons and protons are equal in an atom, it is stable.

If there exist any inbalance in numbers of charged particles then atom becomes instable. This means that atom starts to exert a potential of attraction:



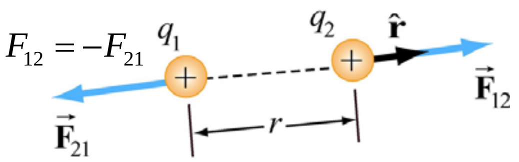
Like charges repel and opposite charges attract each other.

Coulomb Force

The magnitude and the direction of the force that two charged particle exerts eachother can be found using Coulomb Law

A system of two point charges, q_1 and q_2 , separated by a distance "d" in vacuum. The force is

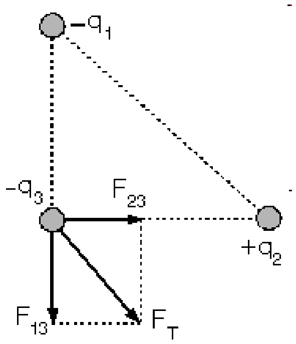
$$F_{12} = k_e \frac{q_1 q_2}{d^2}\,\vec{\mathrm{r}}\ [\mathrm{N}] \quad k_e = \frac{1}{4\pi\varepsilon_0} = 8.987\times10^9 \left[\frac{\mathrm{Nm}^2}{\mathrm{C}^2}\right]$$



r is the unit vector pointing the direction particle 1 to 2

Coulomb Force

Coulomb's law applies to any pair of point charges. When more than two charges are present, the net force on any one charge is simply the vector sum of the forces exerted on it by the other charges.

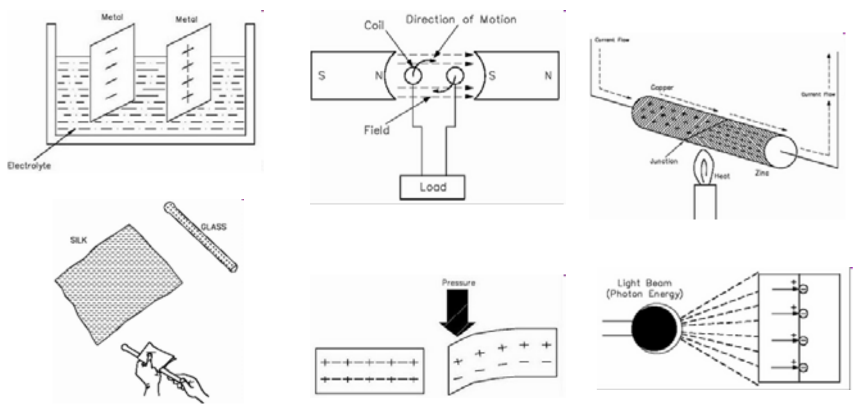


Using superposition rule:

$$F_T = F_{13} + F_{23}$$

Generating electricity

Some physical effect that causes electricity



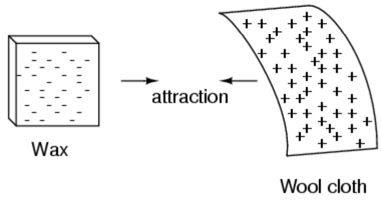
Back to basics: friction

If we take the examples of wax and wool which have been rubbed together,

we find that the surplus of electrons in the wax (negative charge)

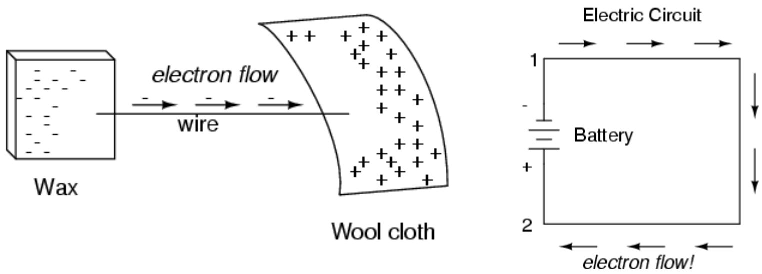
and the deficit of electrons in the wool (positive charge) creates an imbalance of charge between them.

This imbalance manifests itself as an attractive force between the two objects:



Back to basics: friction

If a conductive wire is placed between the charged wax and wool, electrons will flow through it.



Some of the excess electrons in the wax rush through the wire to get back to the wool, filling the deficiency of electrons

Electric Current

Electric current is the rate of charge flow past a given point in an electric circuit, measured in Coulombs/second which is named Amperes

As with all quantities defined as a rate, there are two ways to write the definition of electric current :

Average Current:

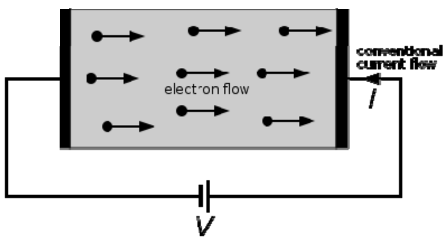
$$I = \frac{\Delta Q}{\Delta t}\left[A = \frac{C}{s}\right]$$

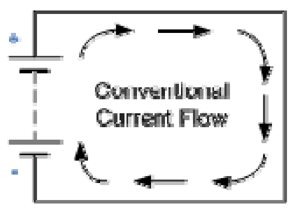
Instantaneous Current

$$I = \frac{dQ}{dt}[A]$$

Direction of Electric Current

The conventional current direction is the direction from high voltage to low voltage, high energy to low energy, and thus has some appeal in its parallel to the flow of water from high pressure to low

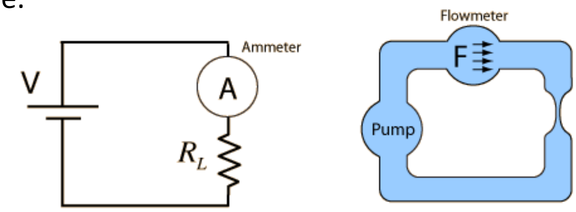




The flow of electrons around the circuit is opposite to the direction of the conventional current flow. This is because the charge on an electron is negative by definition and so is attracted to the positive terminal.

Measurement of Electric Current

An ammeter is an instrument for measuring the electric current in amperes in a branch of an electric circuit. It must be placed in series with the measured branch, and must have very low resistance to avoid significant alteration of the current it is to measure.



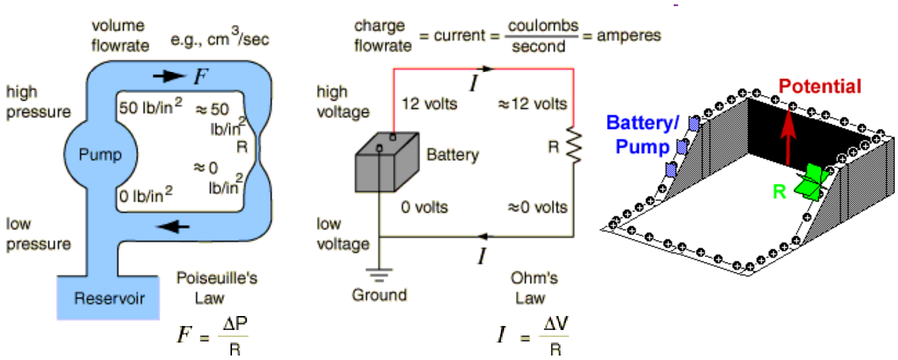
An ammeter is connected in series with a resistor to measure the current through the resistor.

A meter for volume flowrate must be in series to measure the flow, but must not appreciably affect the flow.

An ammeter is always connected in series with the part of the circuit in which you wish to measure current.

Electrical Potential Difference or Voltage

Voltage, (V) is the potential energy of an electrical supply stored in the form of an electrical charge.

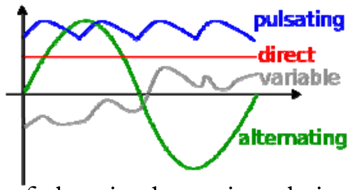


Voltage can be thought of as the force that pushes electrons through a conductor and the greater the voltage the greater is its ability to "push" the electrons through a given circuit.

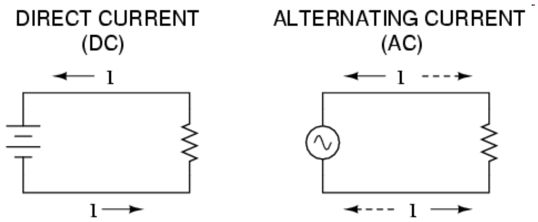
Alternating or Direct

The source of an electric circuit may be an Alternating or Direct current or voltage supply.

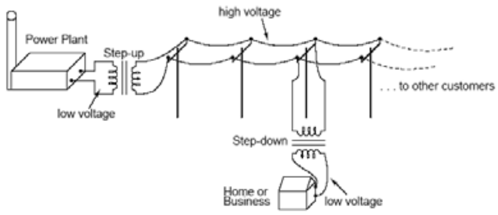
In alternating current (AC, also ac), the movement of electric charge periodically reverses direction.



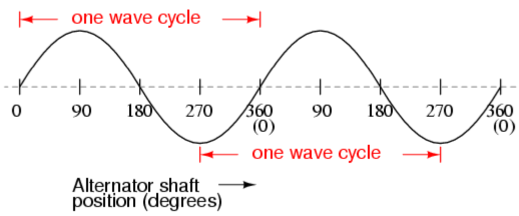
In direct current (DC, also dc), the flow of electric charge is only in one direction.



Alternating Current or Voltage

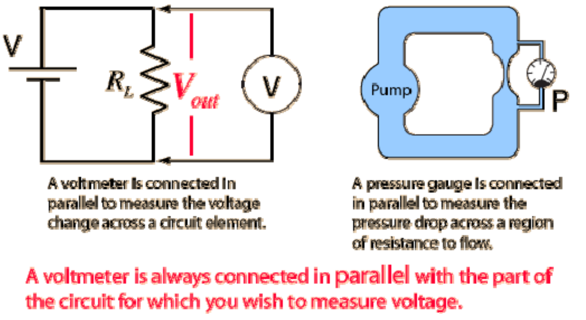


AC is the form in which electric power is delivered to businesses and residences. The usual waveform of an AC power circuit is a sine wave.



Measurement of Voltage

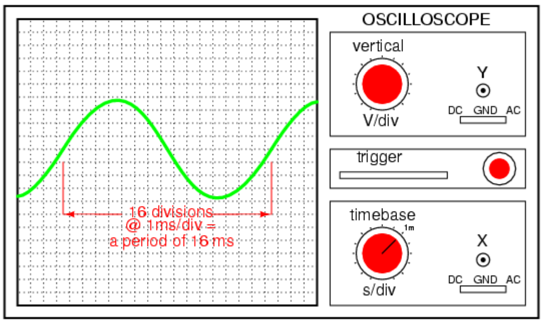
A voltmeter measures the change in voltage between two points in an electric circuit and therefore must be connected in parallel with the portion of the circuit on which the measurement is made.



The unit of the voltage is Volt [V]. In shematics letters V or E denotes the term “voltage”

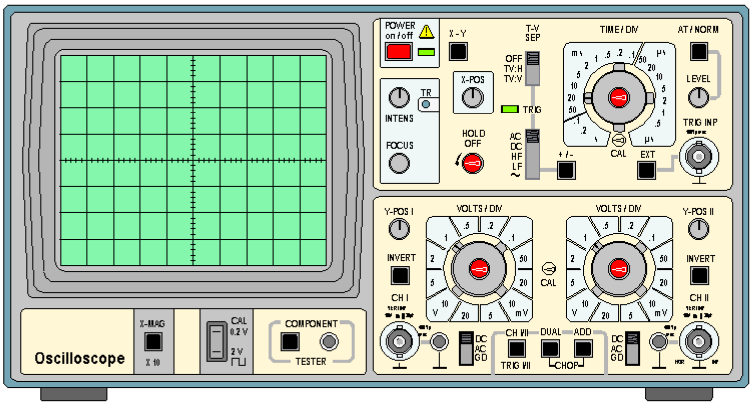
Measurement of AC Waveform

An instrument called an oscilloscope is used to display a changing voltage over time on a graphical screen.



$$\text{Frequency} = \frac{1}{\text{period}} = \frac{1}{16\ \text{ms}} = 62.5\ \text{Hz}$$

Osciloscope



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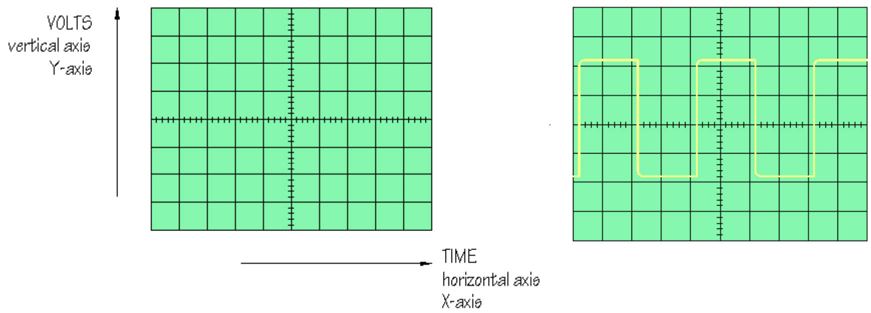
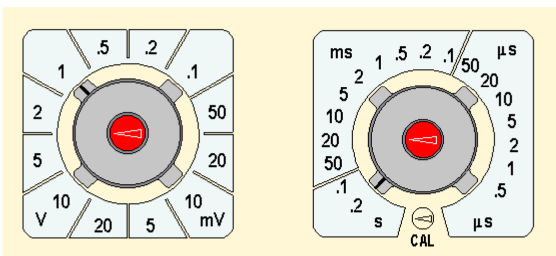




Conductivity

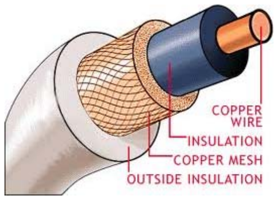
The electrons of different types of atoms have different degrees of freedom to move around.

With some types of materials, such as metals, the outermost electrons in the atoms are so loosely bound that they chaotically move in the space between the atoms.

In other types of materials such as glass, the atoms' electrons have very little freedom to move around.

This relative mobility of electrons within a material is known as electric conductivity.

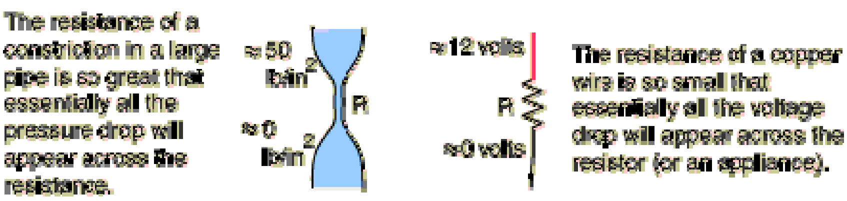
Conductors:	Insulators:
silver	glass
copper	rubber
gold	oil
aluminum	Asphalt
iron	porcelain
steel	ceramic



Conductivity=1/Resistance

When talking about circuits, the term resistance are used the describe the conductivity issue.

*The **Resistance**, (R) of a circuit or an element of the circuit is its ability to resist the flow of current (electron flow) through itself.*



Resistance is measured in **Ohms**, Greek symbol (**Ω**, Omega) with prefixes used to denote **Kilo-ohms** (kΩ = 10^3Ω) and **Mega-ohms** (MΩ = 10^6Ω). Resistance cannot be negative only positive.

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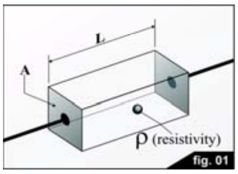
Using the given formula, the resistance of a substance with known shape and material properties can be calculated.

$$R=\rho\frac{L}{A}=\left[\Omega m\frac{m}{m^2}\right]$$

ρ: specific conductivity
L:length
A: Cross sectional area



Resistance (Temprature)

Most conductive materials change specific resistance with changes in temperature.

This is why figures of specific resistance are always specified at a standard temperature (usually 20° or 25° Celsius(T_0)).

Resistivities at 20°C

Material	Resistivity (Ω•m)
Aluminum	2.82×10^{-8}
Copper	1.72×10^{-8}
Gold	2.44×10^{-8}
Nichrome	$150. \times 10^{-8}$
Silver	1.59×10^{-8}
Tungsten	5.60×10^{-8}

The resistance-change factor per degree Celsius of temperature change is called the *temperature coefficient of resistance*. This factor is represented by the Greek lower-case letter "alpha" (α).

The formula used to determine the resistance of a conductor at any temperature T:

$$R(T)=R_0(1+\alpha(T-T_0))$$

Temperature coefficients of resistance or resistivity of some metals(10^{-3}/°C):

Silver	3.8	Copper	3.9
Gold	3.4	Aluminum	3.9
Iron	5.0	Tungsten	4.5
Nichrome	0.4	Platinum	3.92

Work and Energy

Work in electrical systems is defined as the amount of the necessary energy for moving the electrical charge Q under the effect of an potential difference V.

Because energy is the capacity to do work , we measure energy and work in the same units (N*m or joules).

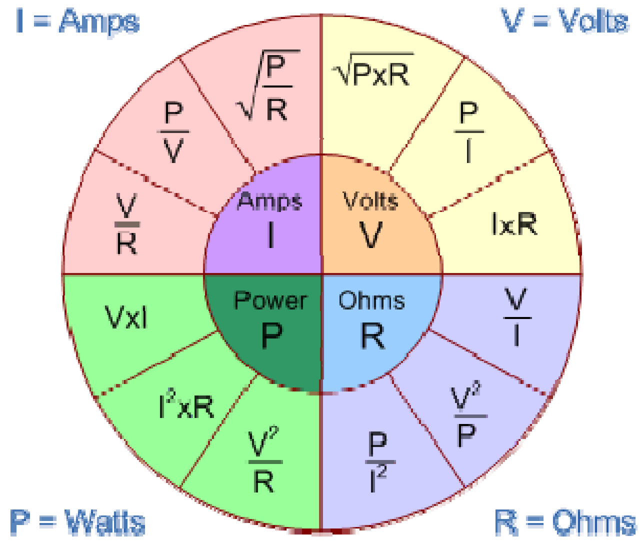
$$W = QV = [\text{Joule} = \text{Coulomb} \times \text{Volt}]$$

POWER (P) is the rate of energy generation (or absorption) over time:

$$W = \frac{dQ}{dt}V = IV\left[\text{Watt} = \frac{\text{Joule}}{\text{saniye}} = \frac{\text{Coulomb}}{\text{saniye}} \times \text{Volt}\right]$$

The unit Joule may also be interpreted as Watt times time. That convention is widely used in daily use as Watt-hours [Wh].

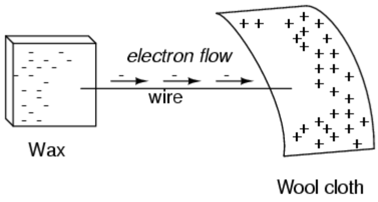
Work and Energy

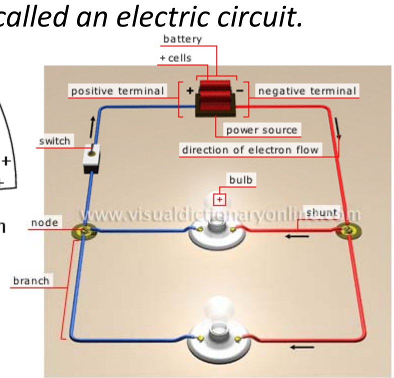


Electric Circuit

Most practical applications of electricity involve the flow of electric current in a closed path under the influence of a driving voltage, analogous to the flow in a water circuit under the influence of a driving pressure.

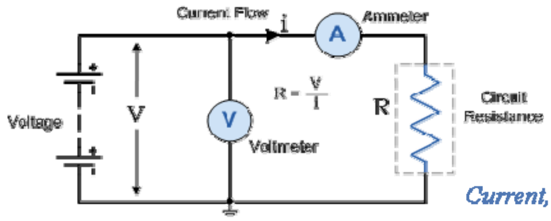
A complete path, typically through conductors such as wires and through circuit elements, is called an electric circuit.



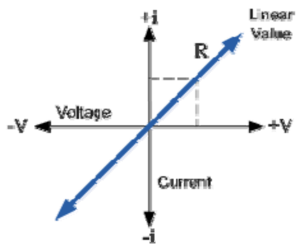


Electric Circuit Analysis/Ohm

The relation between voltage and the current in a circuit/component is given by Ohm's law.



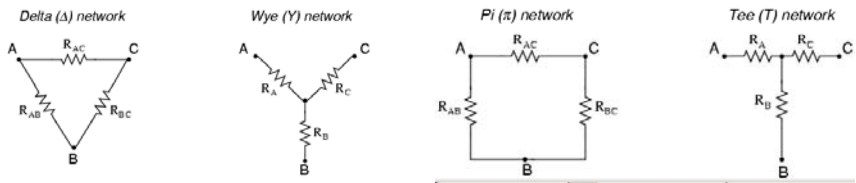
$$Current, (I) = \frac{Voltage, (V)}{Resistance, (R)} \text{ in Amperes, (A)}$$



Quantity	Symbol	Unit of Measure	Abbreviation
Voltage	V *or* E	Volt	V
Current	I	Amp	A
Resistance	R	Ohms	Ω

Electric Circuit Analysis/Kirchhoff

In complex circuits such as bridge or T networks, we can not simply use Ohm's Law alone to find the voltages or currents circulating within the circuit.



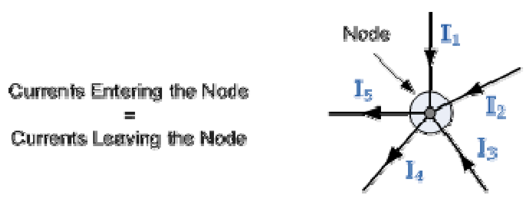
Kirchoff developed a pair or set of rules which deal with the conservation of current and energy within electrical circuits. The rules are commonly known as:

Kirchoffs Circuit Laws with one of these laws dealing with current flow around a closed circuit, **Kirchoffs Current Law, (KCL)** and

the other which deals with the voltage around a closed circuit, **Kirchoffs Voltage Law, (KVL)**.

Kirchoffs Current Law

Kirchoffs Current Law or KCL, states that the "*total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node*". (**Conservation of Charge**)

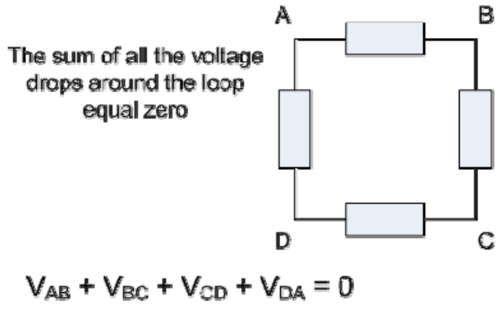


$$I_1 + I_2 + I_3 = I_4 + I_5 = 0$$

The term **Node** in an electrical circuit generally refers to a connection or junction of two or more current carrying paths or elements such as cables and components

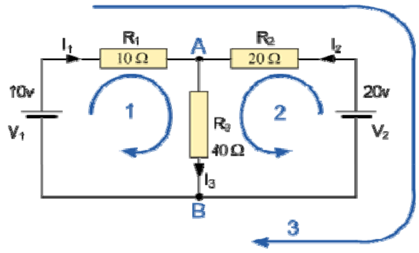
Kirchoffs Voltage Law

Kirchoffs Voltage Law or KVL, states that "*in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop*" which is also equal to zero.



In other words the algebraic sum of all voltages within the loop must be equal to zero.

Example



Using **Kirchoffs Current Law (KCL)** the equations are given as:

- At node A : $I_1 + I_2 = I_3$
- At node B : $I_3 = I_1 + I_2$

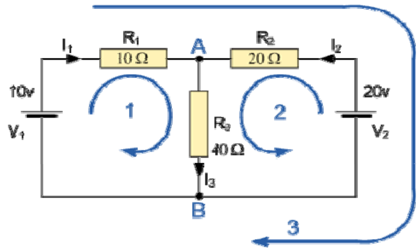
Using **Kirchoffs Voltage Law**, **KVL** the equations are given as;

- Loop 1 is given as : $10 = R_1 \times I_1 + R_3 \times I_3 = 10I_1 + 40I_3$
- Loop 2 is given as : $20 = R_2 \times I_2 + R3 \times I3 = 20I_2 + 40I_3$
- Loop 3 is given as : $10 - 20 = 10I_1 - 20I_2$

As I_3 is the sum of I1 + I2 we can rewrite the equations as;

- $10 = 10I_1 + 40(I_1 + I_2) = 50I_1 + 40I_2$
- $20 = 20I_2 + 40(I_1 + I_2) = 40I_1 + 60I_2$

Example



- I_1 =-0.143 Amps (Wrong Direction)
- I_2 = +0.429 Amps
- $I_3 = I_1 + I_2$
- At node B : $I_3 = I_1 + I_2$

-0.143 + 0.429 = 0.286 Amps

Using **Kirchoff's Circuit Laws** is as follows:

1. Assume all voltage sources and resistances are given.

2. Label each branch with a branch current.

3. Find Kirchoff's first law equations for each node.

4. Find Kirchoff's second law equations for each of the independent loops of the circuit.

5. Use Linear simultaneous equations as required to find the unknown currents.

videos

•Using Multimeter

•Using Oscilascope