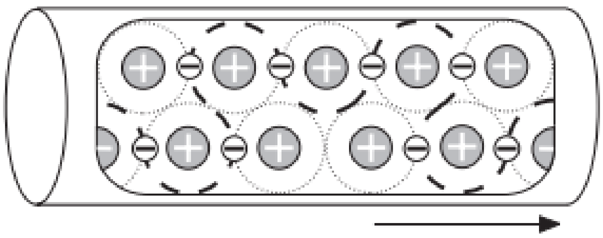
10-1 Current:

Electricity is the flow of free electrons in a conductor from one atom to the next atom in the same general direction. This flow of electrons is referred to as current and is designated by the symbol "I". Electrons move through a conductor at different rates and electric current has different values. Current is determined by the number of electrons that pass through a cross-section of a conductor in one second. We must remember that atoms are very small.

It takes about 1,000,000,000,000,000,000,000,000 atoms to fill one cubic centimeter of a copper conductor. This number can be simplified using mathematical exponents. Instead of writing 24 zeros after the number 1, write 10^{24}. Trying to measure even small values of current would result in unimaginably large numbers. For this reason, current is measured in amperes which is abbreviated "amps". The letter "A" is the symbol for amps. A current of one amp means that in one second about 6.24 x 10^{18} electrons move through a cross-section of conductor.



10-1-1 Units of Measurement:

The following chart reflects special prefixes that are used when dealing with very small or large values of current:

Prefix	Symbol	Decimal
1 kiloampere	1 kA	1000 A
1 milliampere	1 mA	10^{-3} A
1 microampere	1 μA	10^{-6} A

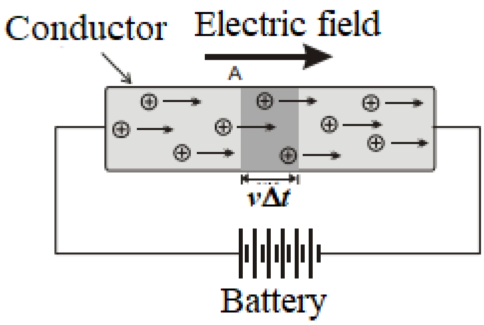
10-1-2 Definition of electric current in terms of drift velocity

The electric field produces electric force (F=q E), this force leads the free charge in the conductor to move in one direction with an average velocity called drift velocity.

Suppose there are ***n*** positive charge particle per unit volume moves in the direction of the field from the left to the right, all move in drift velocity ***v***. In time **Δ*t*** each particle moves distance ***v*Δ*t*,** the shaded area in the figure below, the volume of the shaded area in the figure is equal ***Av*Δ*t***, the charge **ΔQ** flowing across the end of the cylinder in time **Δ*t*** is

$$\Delta Q = nqvA\Delta t,$$

*where **q** is the charge of each particle.*



The current is defined by the net charge flowing across the area ***A*** per unit time. Thus, if a net charge **Δ*Q*** flow across a certain area in time interval **Δ*t***, the average current I_{av} across this area is

$$I_{av} = \frac{\Delta Q}{\Delta t} = nqvA$$

In general, the current I, is $$I_{av} = \frac{dQ}{dt}$$

Current is a scalar quantity and has a unit of **C/t**, which is called ampere **I**

10-1-3 Definition of the Current Density

The current per unit cross-section area is called the current density ***J***.

The current density $\vec{J}$ is a vector quantity.

$$\vec{J} = \frac{I}{A} = nqv$$

Example:

A copper conductor of square cross section 1mm^2 on a side carries a constant current of 20A. The density of free electrons is 8 ×10^{28} electron per cubic meter. **Find** the current density and the drift velocity.

Solution

The current density is: $J = \frac{I}{A} = 20 \times 10^{6}\ A/m^2$

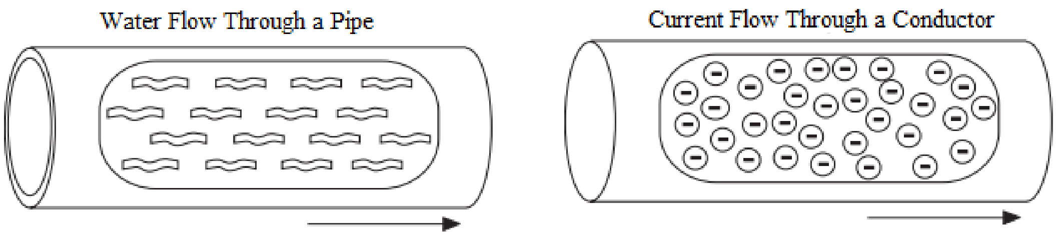
The drift velocity is:

$$v = \frac{J}{nq} = \frac{20\ \text{x}10^6}{(8\text{x}10^{28})(1.6\text{x}10^{-9})} = 1.6\text{x}10^{-3} m/s$$

This drift velocity is very small compare with the velocity of propagation of current pulse, which is 3×10^{8} m/s. The smaller value of the drift velocity is due to the collisions with atoms in the conductor.

10-2 Voltage:

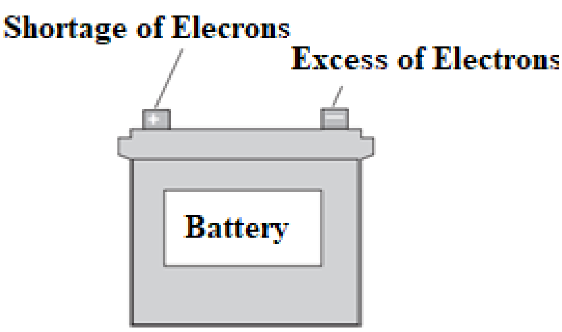
Electricity can be compared with water flowing through a pipe. A force is required to get water to flow through a pipe. This force comes from either a water pump or gravity. Voltage is the force that is applied to a conductor that causes electric current to flow.



Electrons are negative and are attracted by positive charges. They will always be attracted from a source having an excess of electrons, thus having a negative charge, to a source having a deficiency of electrons which has a positive charge. The force required to make electricity flow through a conductor is called a difference in potential, electromotive force (emf), or more simply referred to as voltage. voltage is designated by the letter "E", or the letter "V". The unit of measurement for voltage is volts which is also designated by the letter "V".

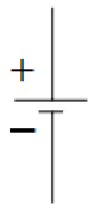
10-2-1 Voltage Sources:

An electrical voltage can be generated in various ways. A battery uses an electrochemical process عملية الكهروكيميائية A car's alternator and a power plant generator utilize a magnetic induction process. All voltage sources share the characteristic of an excess of electrons at one terminal and a shortage at the other terminal. This results in a difference of potential between the two terminals.



10-2-2 Voltage Circuit Symbol:

The terminals of a battery are indicated symbolically on an electrical drawing by two lines. The longer line indicates the positive terminal. The shorter line indicates the negative terminal.



10-2-3 Units of Measurement:

The following chart reflects special prefixes that are used when dealing with very small or large values of voltage:

Prefix	Symbol	Decimal
1 kilovolt	1 kV	1000 V
1 millivolt	1 mV	10^{-3} V
1 microvolt	1 μV	10^{-6} V

10-4 Resistance and Resistivity Ohm's low

A third factor that plays a role in an electrical circuit is resistance. All material impedes the flow of electrical current to some extent. Resistance is designated by the symbol "**R**". The unit of measurement for resistance is ohms (**Ω**).

The resistance ***R*** of a conductor is defined as the ratio ***V/I***, where ***V*** is the potential difference across the conductor and ***I*** is the current flowing in it. Thus, if the same potential difference ***V*** is applied to two conductors **A** and **B**, and a smaller current ***I*** flows in **A**, then the resistance of **A** is greater than **B**, therefore we write,

$$R = \frac{V}{I} \quad \text{Ohm's law}$$

This equation is known as Ohm's law, which show that a linear relationship between the potential difference and the current flowing in the conductor. Any conductor shows the lineal behavior its resistance is called <u>*ohmic resistance*</u>.

The resistance ***R*** has a unit of volt/ampere (***v/A***), which is called Ohm (Ω).

$$V = IR \qquad \text{and} \qquad I = \frac{V}{R}$$

10-4-1 Resistance Circuit Symbols

Resistance is usually indicated symbolically on an electrical drawing by one of two ways. An unfilled rectangle is commonly used. A zigzag line may also be used.

Each material has different resistance; therefore, it is better to use the resistivity ρ, it is defined from

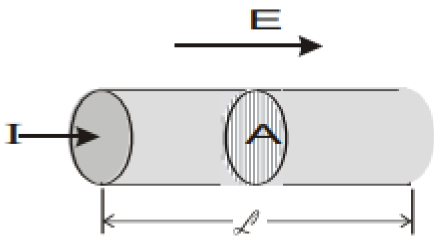
$$\rho = \frac{E}{J}$$ The resistivity has unit of Ω.m

The inverse of resistivity is known as the conductivity **σ.**

$$\sigma = \frac{1}{\rho} = \frac{J}{E}$$

10-4- 2 Evaluation of the Resistance of Conductor

Consider a cylindrical conductor as shown in the figure, of cross-sectional area ***A*** and length, carrying a current ***I***. If a potential difference ***V*** is connected to the ends the conductor, the electric field and the current density will have the values



$$E = \frac{V}{\ell} \text{ and } J = \frac{I}{A}$$

The resistivity ρ is $$\rho = \frac{E}{J} = \frac{v/\ell}{I/A} = \frac{V}{\ell} \times \frac{A}{I}$$

But the $\frac{V}{I}$ is the resistivity *R* This leads to, $R = \rho\frac{\ell}{A}$

Therefore, the resistance ***R*** is proportional to the length l of the conductor and inversely proportional the cross-sectional area ***A*** of it

The amount of resistance depends upon composition, length, cross-section and temperature of the resistive material. As a rule of thumb, resistance of a conductor increases with an increase of length or a decrease of cross-section.

Notice that the resistance of a conductor depends on the geometry of the conductor, and the resistivity of the conductor depends only on the electronic structure of the material.

10-4-3 Units of Measurement:

The following chart reflects special prefixes that are commonly used when dealing with values of resistance:

Prefix	Symbol	Decimal
1 kilohm	1 kΩ	1000 Ω
1 megohm	1 MΩ	1,000,000 Ω

Example1:

Calculate the resistance of a piece of aluminum that is 20cm long and has a cross-sectional area of 10^{-4}m^2. What is the resistance of a piece of glass with the same dimensions? $\rho_{Al}=2.82\times10^{-8}\Omega$.m, $\rho_{glass}=10^{10}\Omega$.m.

Solution:

The resistance of aluminum $R_{Al} = \rho\frac{\ell}{A} = 2.82\times10^{-8}\left(\frac{0.1}{10^{-4}}\right) = 2.82\times10^{-5}\ \Omega$

The resistance of glass $R_{glass} = \rho\frac{\ell}{A} = 10^{10}\left(\frac{0.1}{10^{-4}}\right) = 10^{13}\ \Omega$

Notice that *the resistance of aluminum is much smaller than glass*.

Example2:

A 0.90V potential difference is maintained across a 1.5m length of tungsten wire that has a cross-sectional area of 0.60 mm^2. What is the current in the wire?

Solution:

From Ohm's law

$$I = \frac{V}{R} \quad \text{where} \quad R = \rho\frac{\ell}{A}$$

Therefore,

$$I = \frac{VA}{\rho\ell} = \frac{(0.90)(6.0x10^{-7})}{(5.6x10^{-8})(1.5)} = 6.43\ A$$

Q)

(a) Calculate the resistance per unit length of a 22-nichrome wire of radius 0.321mm. (b) If a potential difference of 10V is maintained cross a1m length of nichrome wire, what is the current in the wire. $\rho_{\text{nichromes}} = 1.5\times10^{-6}\Omega$.m