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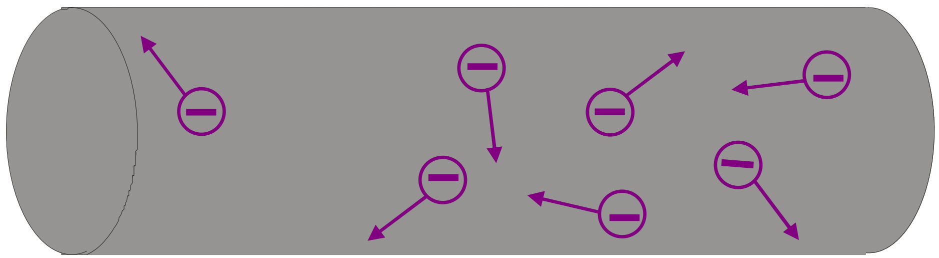
ELECTRIC CURRENT

Electric current is a motion of charge from one region to another.

In metals some of the electrons are free to move within material. In the absent of electric field they move randomly in all directions with speed of the order of 10^6 m/s and undergo frequent collisions with the positive ions of the material. There in no net flow of charge in any direction.

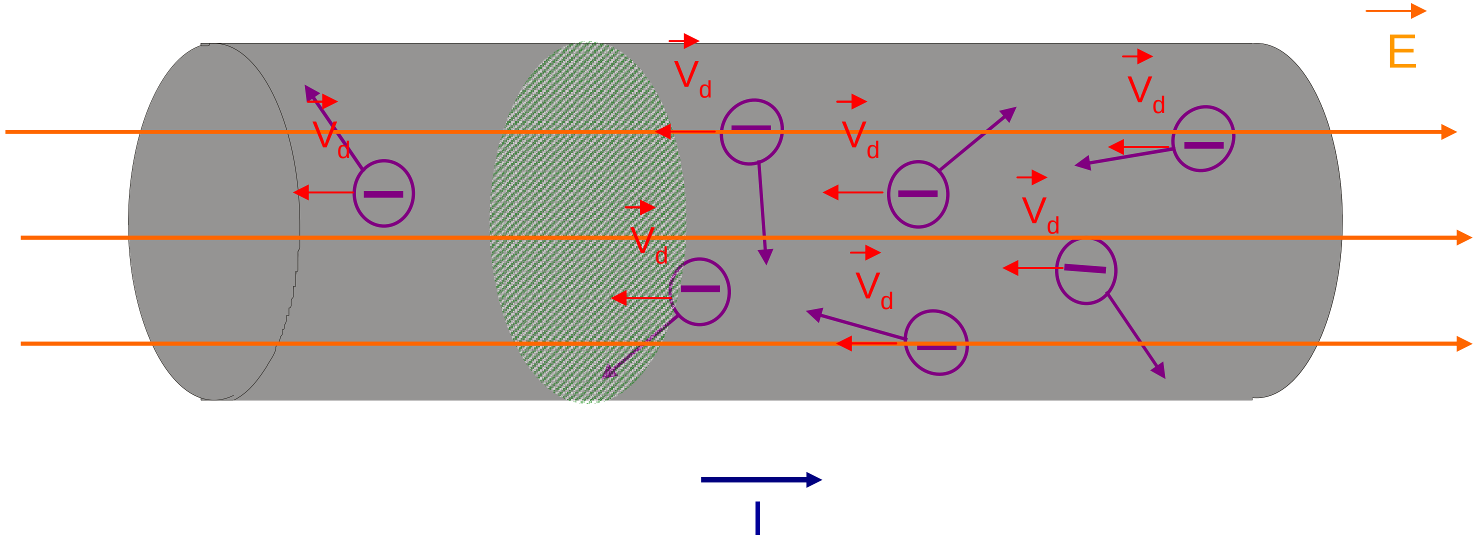


When steady electric field is established inside a conductor there is a net motion or drift of charge in the direction of electric force,

$$\vec{F} = q\vec{E}$$

The drift velocity $\vec{V}_d$ of electrons in metal is very slow in comparison to their average speed (~10^6 m/s).

ELECTRIC CURRENT



A current arrow indicates the direction in which positive charge carriers would move.
The current (I) is defined as the net charge flowing through the area per unit time:

$$I = \frac{dQ}{dt}$$

$$[I] = \frac{C}{s} = A$$

coulomb

second

ampere

ELECTRIC CURRENT

Electric current density in a conductor

If all charge move with V_d then during the time interval dt all particles move a distance $V_d$dt. They can cross the area A during the time interval dt if they are within the cylinder of the volume:

$$dV = A\,V_d\,dt$$

The total charge of moving charge particles in the volume dV is:

$$dQ = q\,n\,A\,V_d\,dt$$

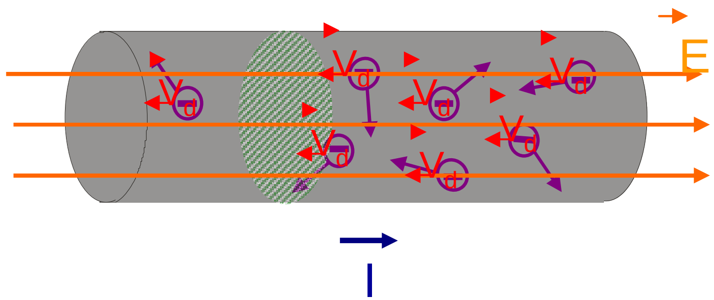
where n- number of moving charge particles per unit volume.

So, the current is

$$I = q\,n\,A\,V_d$$

The current per unit cross-section area is called current density:

$$j = \frac{I}{A} = q\,n\,V_d$$

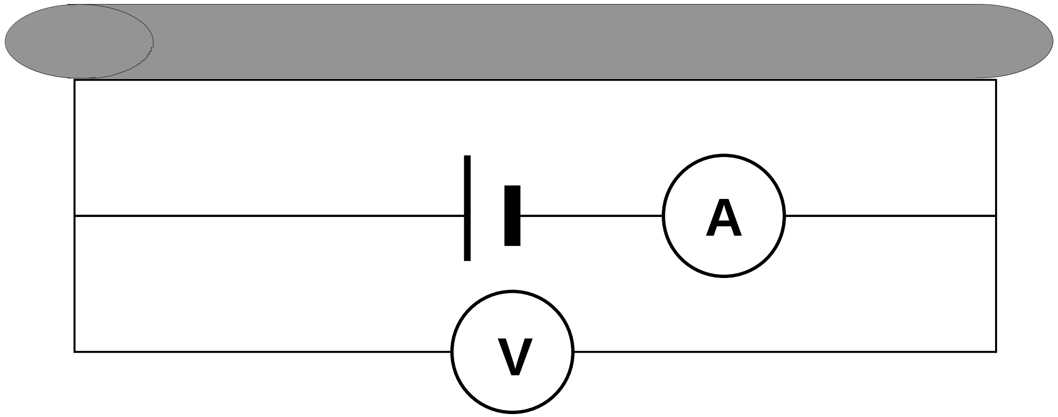


The current density is a vector quantity and its vector definition takes the form:

$$\vec{j} = q\,n\,\vec{V}_d$$

Resistors and their resistance

In the case of metal the electric current at a given temperature is nearly directly proportional to an electric potential difference applied between any two points of metal.



The ratio of a potential difference to the electric current is then called resistance R:

$$R = \frac{V}{I}$$

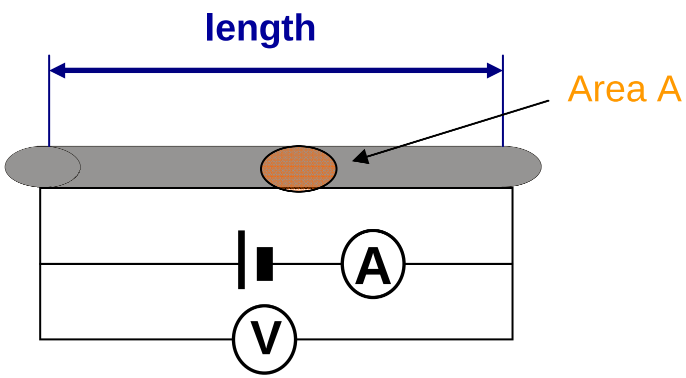
$$[R] = \frac{V}{A} = \Omega$$

George Simon Ohm (1787-1854)

ELECTRIC CURRENT

The resistance of a metal wire is proportional to its length (l) and inversely proportional to its cross-section area (A):

$$R = \rho \frac{l}{A} \qquad [R] = \Omega m$$



where ρ is the resistivity of the material.

Using ρ we can write vector relation between $\vec{E}$ and $\vec{j}$ for resistor:

$$\vec{E} = \rho \vec{j}$$

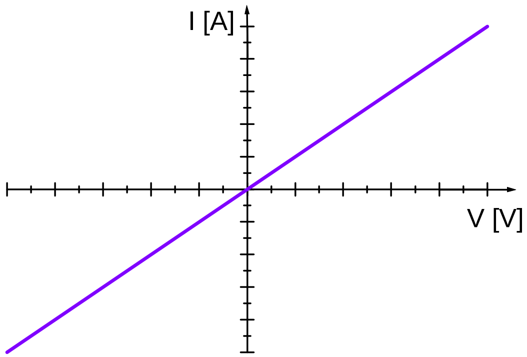
The reciprocal of resistivity is know as conductivity (σ):

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

material	***resistivity at room temperature***
Silver	$1.62\times10^{-8}\,\Omega$ m
Copper	$1.69\times10^{-8}\,\Omega$ m
Gold	$2.35\times10^{-8}\,\Omega$ m
Aluminum	$2.75\times10^{-8}\,\Omega$ m

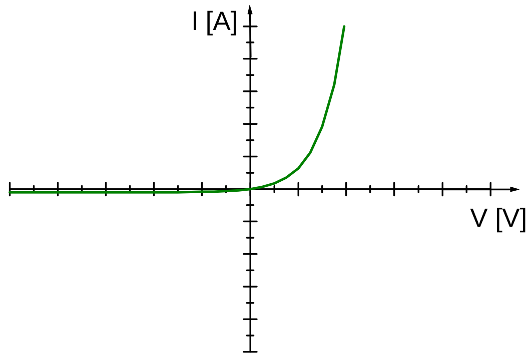
Current versus potential difference applied to:

a) a resistor,



A resistor obeys Ohm's Law

b) a diode



A diode does not obey Ohm's Law

Electromotive force

An electromotive (emf) device is a device which maintains a potential difference between a pair of terminals by doing work on the charge carriers.
Electromotive force (ε) is defined as:

$$\varepsilon = \frac{dW}{dq}$$

$$[\varepsilon] = \frac{J}{C} = V$$

joule per coulomb

volt

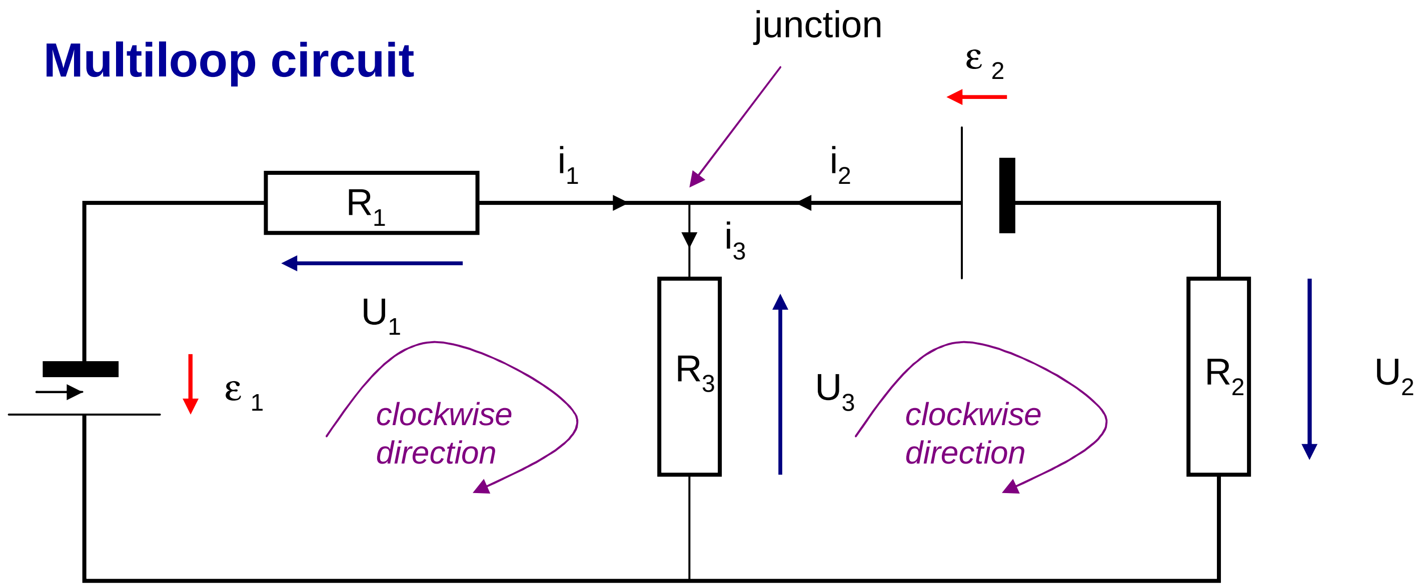
dW – work done on the charge dq in moving it from low-potential terminal to high-potential terminal.

Emf devices:

- battery,
- electric generator,
- solar cells,
- fuel cells.

An emf device does work on the charge carriers to force them to move form low-potential end to high potential end.

Multiloop circuit



Kirchhoff's junction rule

At any junction the algebraic sum of the currents must be zero.

$$i_1 + i_2 - i_3 = 0$$

currents approaching the junction ($i_1 + i_2$) — *current leaving the junction* (i_3)

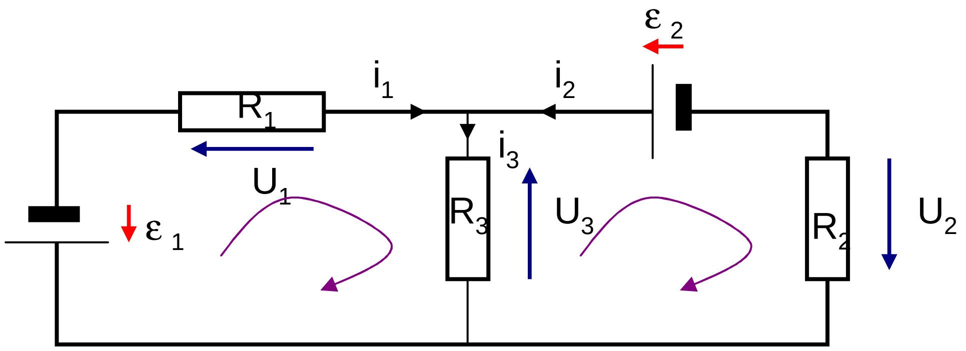
Kirchhoff's loop rule

The algebraic sum of the potential differences in any loop must equal zero.

$$-\varepsilon_1 - U_1 - U_3 = 0$$

$$U_3 - \varepsilon_2 + U_2 = 0$$

for clockwise direction



$$\begin{cases} i_1 + i_2 - i_3 = 0 \\ -\varepsilon_1 - R_1 i_1 - R_3 i_3 = 0 \\ R_3 i_3 - \varepsilon_2 + R_2 i_2 = 0 \end{cases}$$

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