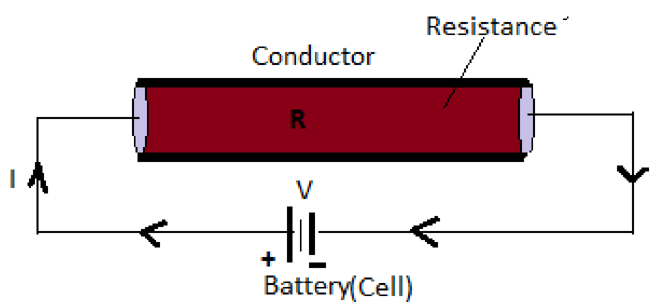
The electric current is life line of modern world. Every aspect of life is dependent of the electricity. TV, Mobile, Radio, Computer, Metro Railways etc. use electric current powered by cells, batteries and other source of electricity. The electric current is produced by power source and flow through a resistance as an application. Thus, main components of application of current electricity are; source of electricity and the resistance. The mathematical description of current electricity in use, apply following formulae listed here.

Formulae

Electric Current:

- The rate of flow of charge Q through a conductor is termed as the electric current I calculated with the formula $I = \frac{Q}{t}$.

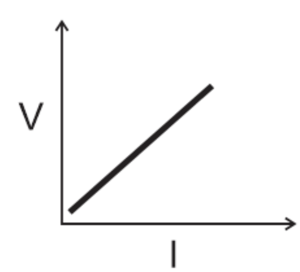


- As an application the current flowing through a conductor is calculated with the formula $I = \frac{V}{R}$, V (voltage in the unit volt) is the electric energy per unit charge delivered to the conductor that offers a resistance R to the electric current.

Ohm's Law

- It is observed by scientist G.S. Ohm that the current I flowing through a conductor depends on the voltage difference V across the ends of that conductor, i.e., $I \propto V$ so $I = kV$, the inverse of constant k is the characteristic of the material of the conductor called the resistance of the conductor. Thus, $V = R \cdot I$
- The unit of current is ampere that of resistance R volt/ampere known as Ohm denoted as Ω.

- The graph between V and I is a straight line.

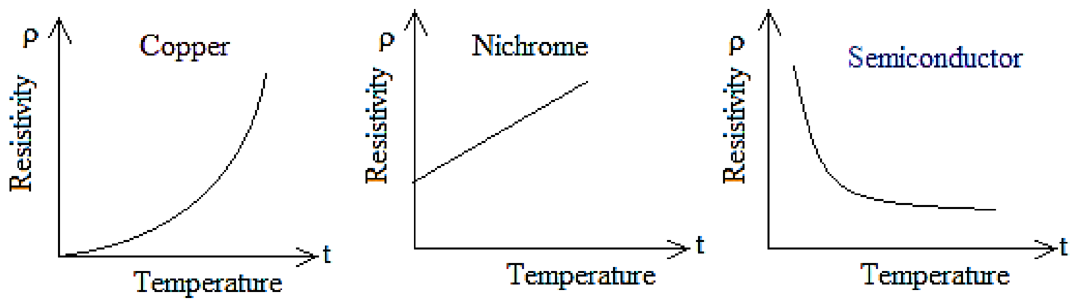


- A conductor with zero or negligible resistance is known as super conductor.

Resistance, Resistivity and Conductivity of a Conductor:

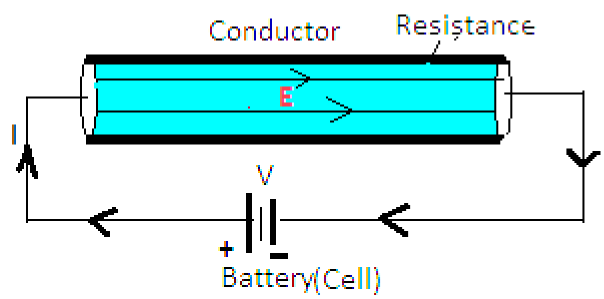
- The resistance R of a conductor of length L, area of cross-section A is given by $R = \rho L / A$, ρ is a constant for the material of conductor and is called the specific resistance (resistivity) of the material of the conductor.

- The resistivity of a conductor (rather of material of the conductor) changes with temperature according to formula, $\rho(t) = \rho_{20°C}(1+\alpha t)$, here $\rho_{20°C}$ is the resistivity of conductor at $20°C$, α the temperature coefficient of resistivity. Some standard temperature coefficients are: $\alpha_{Aluminum} = 0.00427 / °C$, $\alpha_{Silver} = 0.00380 / °C$, $\alpha_{copper} = 0.00386 / °C$, $\alpha_{Nichrome} = 0.0004 / °C$ Nichrome is [Ne, Fe, Cr alloy] and $\alpha_{Iron} = 0.00651 / °C$.
- The temperature coefficient of resistivity of Carbon (graphite), Germanium, and Silicon that are semiconductors, is negative.
- The Graphs (curves) of resistivity of some materials are shown here:



- From Ohm's law $I = \frac{V}{R} = \frac{V}{\rho(L/A)} \Rightarrow \frac{I}{A} = \frac{1}{\rho}\frac{V}{L}$ or $j = \frac{1}{\rho}E$ here j=I/A is called the current density and E the electric field induced inside the conductor.

- The charge flow in a conductor is the flow of free electrons available in the conductor. The average velocity of electrons inside a conductor is known as the drift velocity dented as v_d given by $v_d = \frac{eE}{m}\tau$, e charge on electron, m mass of electron, E the electric field induced by power source across the conductor and τ relaxation time (the average time between successive collision of an electron with the core of atom of the conductor.)

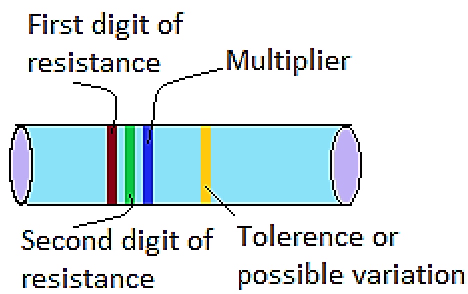


- The relation between j and E is $j = \frac{1}{\rho}E$ or $j = \sigma E$. Here, $\sigma = 1/\rho$ and $\sigma = \frac{ne^2}{m}\tau$, is called the conductivity of the material of the resistance.

- The mobility (or ease of flow) of electron is denoted as μ and is given by $\mu = \frac{v_d}{E} = \frac{e \cdot \tau}{m}$.

Resistors and Colour Codes: [Deleted]

- **Resistor**: A that can offer some resistance to the current passing through it is called the resistor. The resistors are coded with colours so that the values of resistance offered by then can be calculated. The two digits resistance of a resistor of codes (3+1 strips on a resistor) is calculated as follows:



The

Here, codes of first two colours are Red (2), Green (5) and Multiplier of 3rd colour Blue is 10^6. Colour of 4the strip is golden so tolerance is 5%. Hence, the resistance of shown resistor is $\left(25 \times 10^6 \pm 5\%\right)\Omega$.

The table for colour codes is given below:

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9
1	10^1	10^2	10^3	10^4	10^5	10^6	10^7	10^8	10^9
Gold- multiplier 10^{-1}, tolerance 5%. **Silver**- multiplier 10^{-2}, tolerance 10%.									

Note: If there is no colour then tolerance is 20%.

- The resistance of a conductor increases with temperature and at temperature t the resistance $R(t)$ of a conductor is $R(t) = R_0(1 + \alpha t)\Omega$, R_0 resistance at 0°C and α coefficient of resistance of material of the resistor.
- The electrical conductivity of a substance decreases with temperature because $\rho = \frac{1}{\sigma} = \frac{m}{\rho e^2 \tau} \Rightarrow \sigma \propto \tau \Rightarrow \boldsymbol{\sigma} \propto \frac{\mathbf{1}}{\mathbf{T}}$ as temperature T increases relaxation time τ decreases.

Electrical Energy and Power:

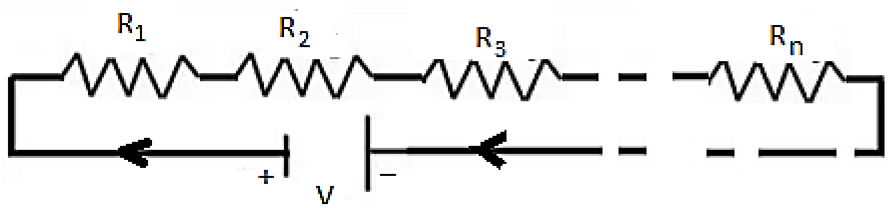
- When charge (free electrons) flow through a conductor, due to their collisions with the core of atoms of the conductor the energy is dissipated in the form of heat. This energy equals the amount of energy supplied by the external power source (battery or cell) to maintain flow of electrons (I) and is calculated with the formula $E = V \cdot I \cdot t$, V voltage, t the time charge flow is maintained.

- From the Ohm's law $E = V \cdot \frac{V}{R} \cdot t = \frac{V^2}{R} t$ or $E = I^2 \cdot R \cdot t$.

- The power consumed in the resistance is $P(\text{watt}) = \dfrac{E(\text{joule})}{t(\text{second})} = V \cdot I = I^2 \cdot R = \dfrac{V^2}{R}$.
- If power P is to be delivered by a transmission cable of resistance R_{cable} at voltage V then the wasted power in the cable is $P_{wasted} = \dfrac{P^2}{V^2} R_{cable}$.

Equivalent Resistance of two or more Combined Resistances:

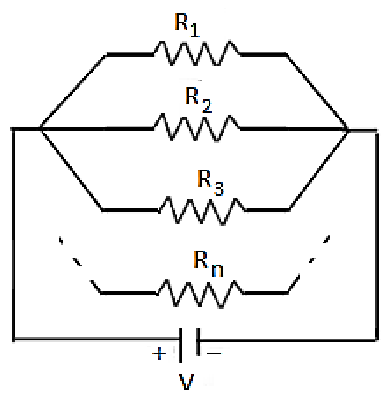
- There can be three types of combination of resistances: (1) Series Combination, (2) Parallel Combination, and (3) Mixed Combinations.
- The series combination of n resistances is shown in Fig here:



Series Combination of n resistances

The equivalent resistance $R_{eq(series)} = R_1 + R_2 + R_3 + \cdots + R_n$ in series combination is greater than the greatest resistance of all resistances $R_1, R_2, R_3, \cdots, R_n$, and current flowing in each resistance is same.

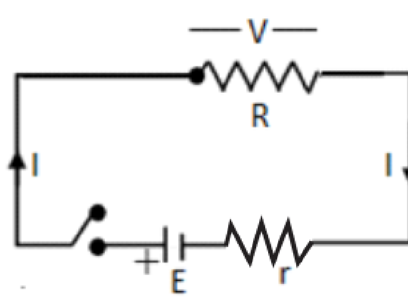
- The parallel combination equivalent resistance is $\dfrac{1}{R_{eq(parallel)}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \cdots + \dfrac{1}{R_n}$. The equivalent resistance in parallel combination is less than the minimum resistance of all resistances $R_1, R_2, R_3, \cdots, R_n$, and voltage across each resistance is same.



- The equivalent resistance in mixed combination is calculated by using only two formulae discussed above.

Cells / Battery EMF and Combinations of Cells:

- The EMF equation of a cells connected with a resistance is given by $E = V + I \cdot r$, r is the internal resistance of the battery and V the voltage across resistance R.
- For charging of cells V = E + ir
- For discharging of cells V = E – ir



- For open cell V = E
- Power will be maximum if r = R and P_{max} = $\frac{E^2}{4R} OR \frac{E^2}{4r}$

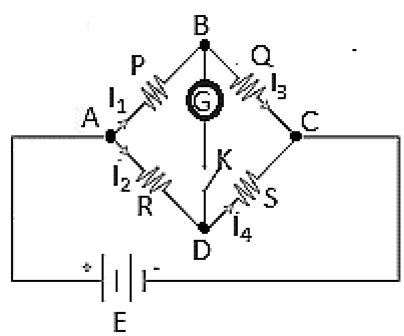
- If n cells of EMF's $\varepsilon_1, \varepsilon_2, \varepsilon_2, \cdots$ are connected end to end in series as +- +-, +- … then the equivalent EMF is $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \cdots + \varepsilon_n$ and $r_{eq} = r_1 + r_2 + \ldots + r_n$
- If n cells of EMF's $\varepsilon_1, \varepsilon_2, \varepsilon_2, \cdots$ are connected end to end in parallel such that all positive terminals at one end and all negative terminal at other end and their internal resistances $r_1, r_2, r_3, \ldots, r_n$ are then the equivalent EMF $\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \frac{\varepsilon_3}{r_3} + \cdots + \frac{\varepsilon_n}{r_n}$, where $\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \ldots\ldots + \frac{1}{r_n}$

Kirchhoff's Rules:

- The **Kirchhoff's Rules** are used to find particular currents or voltage across any resistance when large number of cells, resistances are connected in combinations.
- The **Kirchhoff's Junction Rule** states that at any junction the sum of all currents entering at any point of the circuit equals the sum of all currents leaving from that junction. If entering currents are $I_1, I_3, I_5, \cdots, I_{2m+1}$ and current leaving junction are $I_2, I_4, I_6, \cdots, I_{2m}$, then $I_1 + I_3 + I_5 + \cdots + I_{2m+1} = I_2 + I_4 + I_6 + \cdots + I_{2m}$
- The **Kirchhoff's loop Rule** states that the algebraic sum of change in potential around any closed loop (path) must be zero, i.e. $\sum V = 0$.

Wheatstone bridge:

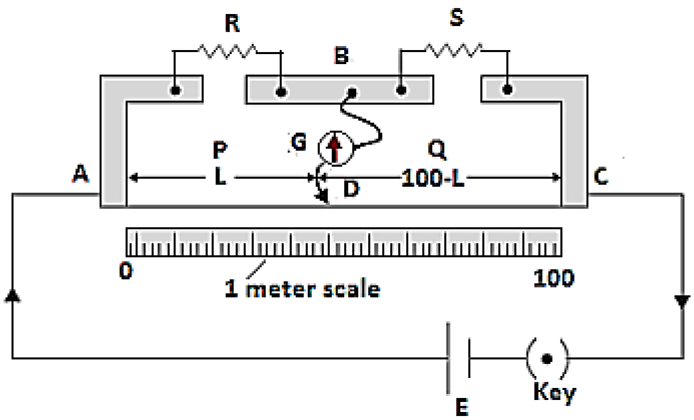
- Wheat stone bridge is a specific circuit having various applications in current electricity. The circuit of Wheatstone bridge is shown in Fig. here. The Wheatstone bridge is said to be balanced when current flowing through Galvanometer G is zero and in that condition the resistance P, Q, R and S follow the condition $P/Q = R/S$.



Meter bridge:

- A meter bridge is another combinations of cells and resistors use to compare and determine specific resistance of a given specimen wire (conductor). Here, the ration P/Q is replaced by L, and 100-L.

- The equation of Meter Bridge is $\frac{R}{S}=\frac{L}{100-L}$, R is known resistance and S unknown resistance. Therefore, the unknown resistance or its specific resistance can be determined using relation $S=\rho L_s/A$, L_s is the length of unknown resistance S, A the area of cross-section and ρ the specific resistance.



Potentiometer: [Deleted]

- The potentiometer is another combinations of cells and resistors use to compare emf of two cells and to determine internal resistance of a given a cell.
- The equation of potentiometer to compare emf of two cells is $\frac{E_1}{E_2}=\frac{L_1}{L_2}$.
- The equation of potentiometer to determine internal resistance of a cell is $r=R\left(\frac{L_1}{L_2}-1\right)$