THE RADIANT EDUCATION POINT
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All matter is made up of atoms and each atom is made up of three subatomic particles named as electrons, protons and neutron. Electron and proton are being the charged particle.

Charge

The charge possessed by proton is called positive charge ($+1.6 \times 10^{-19}$ C) while the charge possessed by electron is called negative charge ($—1.6 \times 10^{-19}$ C). Neutron has the particle that has no charge.

• Like charges repel each other while unlike charges attract each other.

***Conductor*:** A substance which allows passage of electric charges through it easily is called a conductor. A conductor offers very low resistance to the flow of current. For example copper, silver, aluminium etc.

Insulator: A substance that has infinitely high resistance does not allow electric current to flow through it. It is called an insulator. For example rubber, glass, plastic, ebonite etc.

Electric current: The flow of electric charges across a cross-section of a conductor constitutes an electric current. It is defined as the rate of flow of the electric charge through any section of a conductor. Electric current is a scalar quantity.

Electric current = charge/Time or

$$I = Q/t$$

• SI unit of electric current is **ampere (A).**
• 1 Coulomb =1Ampere / 1 second
• 1 milliampere = 1 mA = 10^{-3} A
• 1 microampere = 1μA = 10^{-6} A
• If positive charge flows, direction of electric current is same as direction of flow of charge.
• If negative charge flows direction of electric current is opposite to direction of flow of charge.
• Electric current can't flow through insulator because in insulator, protons and electrons are fixed at their position.

Electric circuit: The closed path along which electric current flows is called an electric circuit.

Potential Difference

Potential difference between two points is the workdone per unit charge in taking the charge from one point to another.

Potential Difference between A&B (V) = Workdone (W) / Charge(q)
1 volt is the potential difference between two points if 1 J of work has to be done in taking 1 C charge from one point to another.

$$1V = 1J / 1C$$

As water flows from high level to low level similarly, electric current flows from high potential to low potential. Positive charges move from higher to lower potential regions. Electrons, being negatively charged, move from lower to higher potential regions.

***Cell:*-** The Difference of potential may be produced by a battery, consisting of one or more electric cells.
Potential difference across the terminals of the cell generated due to chemical reaction within the cell.When cell is connected to a conducting wire, current flows from high potential to low potential.

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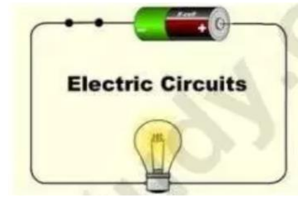
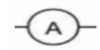
Electric circuit

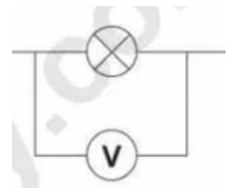


Electric circuit is a continuous and dosed path of electric current. For example figure given below shows a typical electric circuit comprising a cell, an electric bulb and a switch.
Note: current only flows if the electric circuit forms closed loop
We know that electric circuit is a continuous path consisting of cell, switch (plug key), electric components and connecting wires, Electric circuits can be represented conveniently through a circuit diagram.
A diagram which indicates how different components in a circuit have to be connected by using symbols for different electric components is called a circuit diagram.

Ammeter: An apparatus to measure the value of current. It is always connected in series in a circuit through which the current is to be measured.



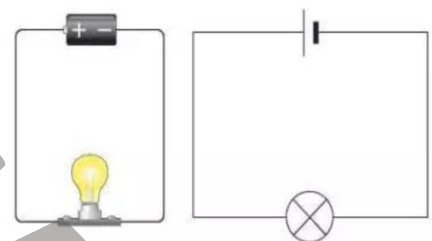
Voltmetor: An apparatus to measure the potential difference between two points in an electric circuit. It is always connected in parallel across the points between which the potential difference is to be measured.

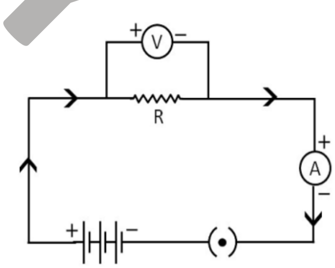


Some points to note

- The direction of current is from positive to negative end (though in reality it is the opposite (link)
- The longer end of the battery is the positive end, and the shorter end of the battery is the negative end.
- The positive end of the ammeter is connected to the positive end of the battery, while the negative end of the ammeter is connected to the negative end of the battery.
- The positive end of the voltmeter is connected to the positive end of the battery, while the negative end of the voltmeter is connected to the negative end of the battery.

Sl. No.	Components	Symbols
1	An electric cell	
2	A battery or a combination of cells	
3	Plug key or switch (open)	
4	Plug key or switch (closed)	
5	A wire joint	
6	Wires crossing without joining	
7	Electric bulb	or
8	A resistor of resistance *R*	
9	Variable resistance or rheostat	or
10	Ammeter	
11	Voltmeter	
12	Galvanometer	





Ohm's Law

- Ohm's Law gives a relationship between Potential Difference and Electric Current
- As per Ohm's Law, Current flowing through a conductor is directly proportional to potential difference across its ends provided physical conditions like temperature remains the same

$$V \propto I$$
$$V = RI$$

Where R is constant for the given conductor and called resistance. Resistance is the property of conductor which resists the flow of electric current through it. Component that is used to resist the flow of electric current in a circuit is called resistor. SI Unit of resistance is Ohm. Ohm is denoted by Greek letter Ω

1 ohm (Ω) of resistance (R) is equal to the flow of 1A of current through a conductor between two points having potential difference equal to 1v.

$$1\ \Omega = 1\ V/1\ A$$

Factors on which Resistance Depends

Resistance in a conductor depends on following factors.
Length of conductor: Resistance R is directly proportional to the length of the conductor. This means, Resistance increases with increase in length of the conductor. This is the cause that long electronic wires create more resistance to the electric current.

$$R \propto l$$

Ares of cross section: Resistance R is inversely proportional to the area of cross section (A) of the conductor. This means R will decrease with increase in the area of conductor and vice versa.
More area of conductor facilitates the flow of electric current through more area and thus decreases the resistance. This is the cause that thick copper wire creates less resistance to the electric current.

$$R \propto 1/A$$

$$R = \rho\ (l/A)$$

This constant (ρ) is called resistivity.

It is denoted by ρ (rho)

Nature of material: Wire used in electronic circuit is made up of different materials and different materials have different value of resistivity (p). It is the properly of material. As resistivity depends upon nature of material therefore resistance R also depends upon nature of material.
Resistance R is directly proportional to resistivity p of material.
NOTE: Resistance also depends upon on temperature. Resistance increases with increase in temperature and decreases with decrease in temperature.

Electrical Resistivity

Resistivity is the characteristic property of the material by which it resists the amount of current through it.
SI Unit of resistivity is ohm meter.
Factors on which resistivity depends
Resistivity is a characteristic property of the material.
It depends upon

- Nature of material

- Physical conditions, like temperature

On the basis of resistivity of material, different materials can be categorized into

- **Conductors -** Those materials which have very low resistivity and allow the current to pass through them easily. Eg- copper.
- **Insulators -** Those materials which have very high resistivity and do not allow the current to pass through them easily. Eg-plastic.

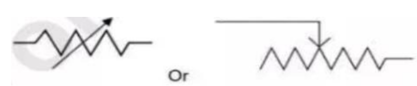
There are some materials whose resistivity lies between that of conductors and insulators.
They are called alloys.
Alloys are made up with one or more than one metals. (Eg- Nichrome)

	Material	Resistivity (Ω m)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of Cu and Ni)	49×10^{-6}
	Manganin (alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn and Fe)	100×10^{-6}
Insulators	Glass	$10^{10} - 10^{14}$
	Hard rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

Materials having resistivity in the range of 10-18 Ω m to 10-6 Ω m mare considered as very good conductors.
Silver has resistivity equal to 1.60 X 10 Ω m and copper has resistivity equal to 1.62 X 10-8 Ωm.
Rubber and glass are very bad conductors or very good insulators. They have resistivity in the order of 10-12 Ω m to 10-17 Ω m.

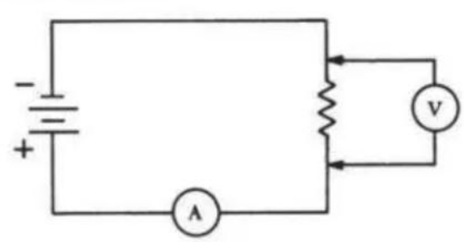
Variable Resistance (Rheostat)

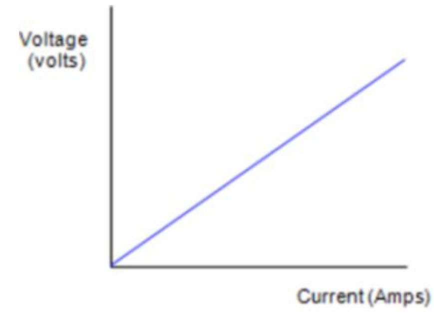
The device which is used to vary the resistance in an electronic circuit; without changing the voltage from the source; is called Rheostat and that resistance is called variable resistance.
Symbol of Variable Resistance -



VERIFICATION OF OHM'S LAW

Set up a circuit as shown above. Note reading in the ammeter and voltmeter at different values of potential (by changing the battery). Every time you will find different values of current I and potential difference V in ammeter and voltmeter.
Plot these values on graph and observe the nature of the graph. The graph of V (potential difference) versus 'i' (electric current) is always a straight line.



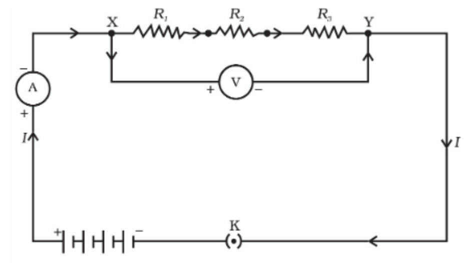


From above, it is clear that current is directly proportional to voltage.

Resistance in series:

When resistors are joined from end to end, they are said to be in series combination.
Value of current in the ammeter is same irrespective of its position in the circuit, So we conclude that in a series combination of resistors the current is same In every part of the circuit or same current (i) flow through each resistor.
If we add potential difference across each one of resistors (R1, R2 and R3) then we get

$$V = V1 + V2 + V3$$
$$iR = iR1 + iR2 + iR3 \qquad (\text{as } V = iR)$$
$$R = R1 + R2 + R3$$



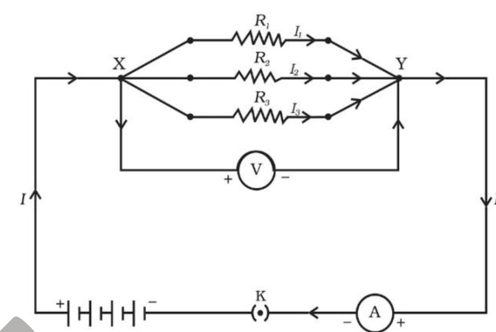
So in this case, the total resistance of the system is equal to the sum of the resistance of all the resistors in the system.
If n resistors are connected in series combination then.

$$R = R1 + R2 + R3 + \dots\dots\dots\dots + Rn$$

Resistance in parallel:

When resistors are joined in parallel, they are said to be in parallel combination
In parallel combination, the potential difference across each resistor is equal to the voltage of the battery applied.
When resistors are connected in parallel, the sum of the currents flowing through all the resistances is equal to total current flowing in the circuit.

$$i = i1 + i2 + i3$$
$$V/R = V/R1 + V/R2 + V/R3 \qquad (\text{As } I=V/R)$$
$$1/R = 1/R1 + 1/R2 + 1/R3$$

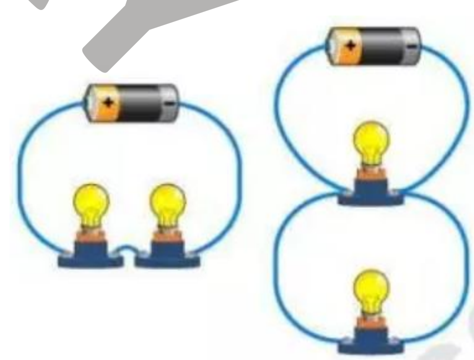


So in this case, the reciprocal of total resistance of the system is equal to the sum of reciprocal of the resistance of resistors.
If n resistors are connected in parallel combination then,

$$1/R = 1/R1 + 1/R2 + 1/R3 + \dots\dots\dots + 1/Rn$$

Note: When numbers of resistors are connected in parallel then their combined resistance is less than the smallest individual resistance. While in series combination, equivalent resistance is always greater than any individual resistance.

Devices in Series and Parallel



There are 2 ways to connect multiple devices to a power source, series and parallel.

Series and Parallel Connection

Advantages of Parallel connection

1. In series connection, either all devices are ON or all are OFF. But in parallel connection, devices can be selectively switched ON or OFF.
2. In series connection, if one device fails, all devices will turn OFF. But in parallel connection, if one device fails, rest all work fine.
3. In series connection, all devices will get same current. But in parallel connection, different devices need different current for proper working.

Heating Effect of Electric Current

Let I current flowing through a resistor of resistance R and potential across the resistor is V. When charge Q moves against the potential difference V in time t, the amount of work is

W = Q x V

W= V x Q/T x T

W = ViT

Thus workdone by battery for moving the charge in electric circuit (W) ViT

Battery has chemical energy due to which it can do work. As battery does work, it's chemical energy decreases. But total energy is always conserved. Chemical energy of battery is converted to heat energy in the resistor.

Therefore**, heat produced in resistor (H) = Vit**

This heating of resistor is commonly known as Heating Effect of Electric Current.

By using Ohms law

H= (iR)it= i^2Rt

This is known as **Joules Law of Heating**. It states that heat produced in a resistor is directly proportional to the square of current given to the resistor, directly proportional to the resistance for a given current and directly proportional to the time for Which the current is flowing through the resistor.

Practical Application of Heating Effect

For application of the heating effect, the element of appliances must have high melting point to retain more heat. The heating effect of electric current is used in the following applications:

electric bulb : When electric energy is supplied to an electric bulb, the filament gets heated because of which it gives light. The heating of electric bulb happens because of heating effect of electric current. The filament of bulb is generally made of tungsten metal having melting point equal to 3380°C.

electric iron : When an electric iron is connected to an electric circuit, the element of electric iron gets heated, which heats the electric iron.The element of electric Iron is made of alloys having high melting point.

Electric fuse : Electric fuse Is used to protect the electric appliances from high voltage. Electric fuse is made of metal or alloy of metals, such as aluminium, copper, iron, lead. etc. In the case of flow of higher voltage than specified, fuse wire melts and protects the electric appliances.

Electric power:

The rate of doing work is called power

$$\text{As work} = \text{heat energy} = vit = (ir) \times (i) \times (t) = i^2 r\, t$$

$$\text{power} = \text{heat energy} / \text{time}$$

$$P = i^2 r\, t / t = i^2\, r = vi$$

SI unit of electric power is watt (W).

1W= 1 volt x l ampere = 1Vx1A

1 kilo watt or 1kW = 1000W

Unit of energy is kilo watt hour (kWh)

1 kWh = 1000 watt X 1 hour = 1000 W x 3600 s

l kWh = 3.6 x l0 watt second = 3.6 x 108 J

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Rating of Devices

Rating **of** device **is** the **value of** electric power **and** potential **of that** electric device. **If we know** the **rating of any** electrical device we can **easily find** the **value of resistance.**

For example, an electric bulb is rated 220V and 100W. I
device.

Given,

Voltage rating = 220 V

Power rating = 100 W

As we know,

$$\text{Power } P = \frac{V^2}{R}$$

$$\Rightarrow \quad R = \frac{V^2}{P}$$

$$\Rightarrow \quad \text{Resistance of device} = \frac{(\text{Voltage rating})^2}{\text{Power rating}}$$

$$= \frac{(220)^2}{100} = 484\Omega$$