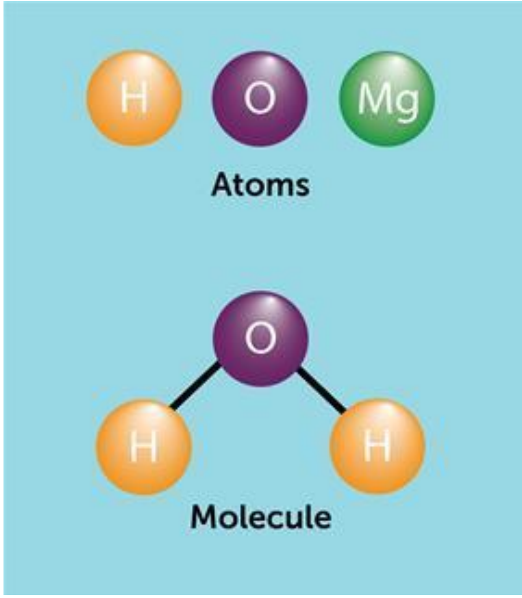
Principle of Electrical Engineering

LECTURE 2: UNIT 1

Prepared by Er. Bibek Dahal

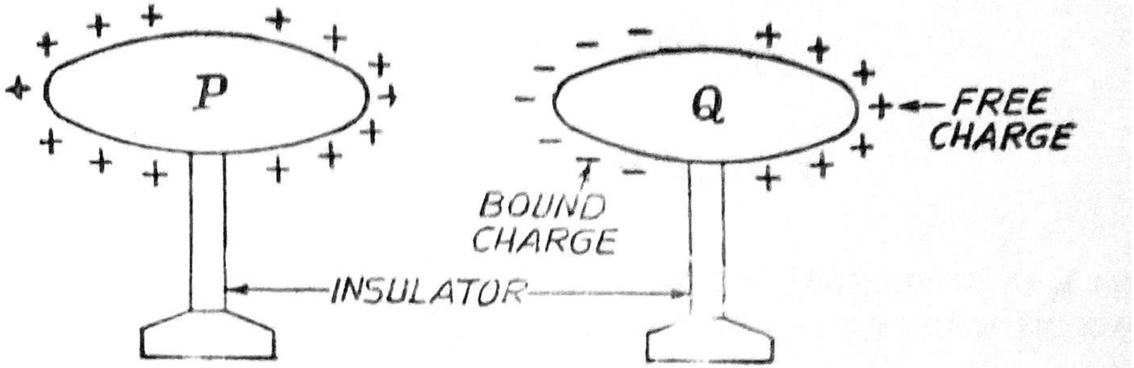
Basic Concept of Electricity

- **Matter:** it is defined as any things that occupies space and has mass such as air, water, iron, gold etc.
- **Atom:** Molecules can be subdivided into chemically still, minute particle known as atom. An atom may be regarded as the smallest particle of an element that can exists. Atoms are made up of three types of tiny particles. Protons (or positively charged particles) and neutrons (or particles that contain no charge) are found in the nucleus of an atom. Electrons (or negatively charged particles) are found outside the nucleus.
- **Molecule**: Matter is made up of extremely small particles known as molecules. When atoms combine, molecules are formed. For a few elements, when atoms of that element combine, a molecule of that element is formed eg H2 and O2. When atoms of some different elements combine, a molecule of a compound can form, eg H2O



Basic Concept of Electricity

- **Electric charge and current:**
  - The electric charge is the physical property of matter which experiences the force when placed in an electric field. Its SI unit is coulombs.
  - On the basis of nature it is divided into two parts:
    1. Positive charge: those particles which have more proton or more positive ions is called positive charge. Eg. Na^+ , Ca^+ , etc
    2. Negative charge: those particles which have more electron or more negative ions is called negative charge. Cl^- ,SO_4^- etc
  - On the basis of origin of charge, charge can be divided into three parts
    1. Free charge
    2. Bound charge
    3. Induced charge



Basic Concept of Electricity

- Current can be defined as the rate of flow of electric charge through conducting medium w.r.t time
- It is caused by drift off free electrons through a conductor to a particular direction.
- Its SI unit is ampere
- It is divided into two different types:
  1. Alternating current (AC)
  2. Direct current (DC)

Difference between AC and DC

Difference between dc current and ac current

===DC current	===AC current
> IN DC current, electric charge flow only in one direction.	> IN ac current, electric charge changes its direction periodicly.
> DC current can not transfer at long distance because of very large energy loss.	> Ac current safe travel at long distance.
> The frequencies of dc current is zero.	> The generating frequencies is 50 hz to 60 hz in ac current.
> The current of magnitude verying with time is constant.	> The current of magnitude verying with time.
> The source of availability is battery or cell.	> The source of availability is generator or mains.
> IN dc circuit have only resistance.	> IN Ac circuit have resistance with capacitor and inductor.
> Power factor is always 1.	> IN ac power factor laies between o to 1.
> Its wave form are pure and pulsating.	> Its wave are sinusoidal, tringular, square, quasi square wave.

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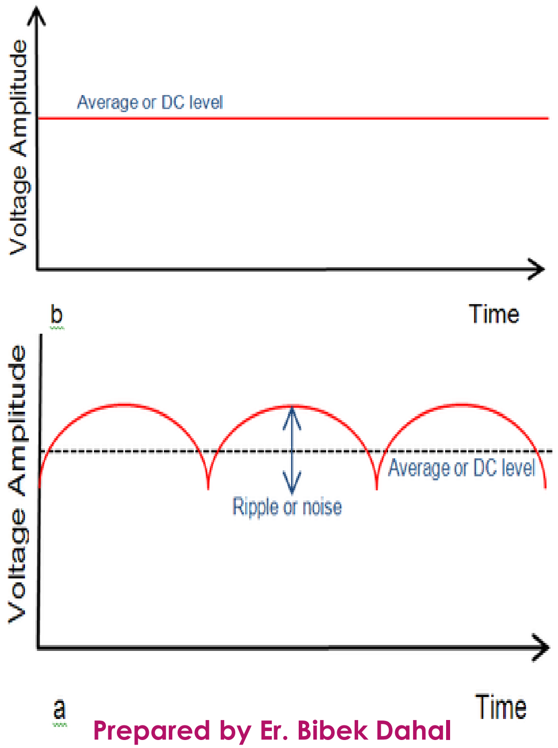
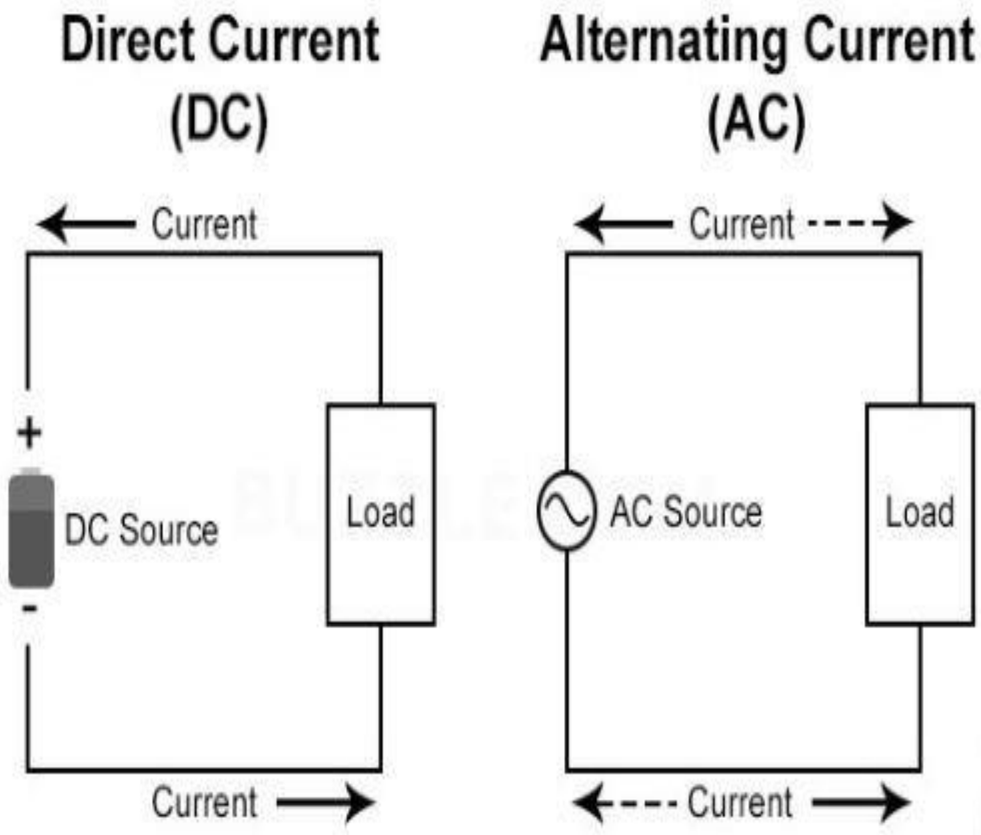
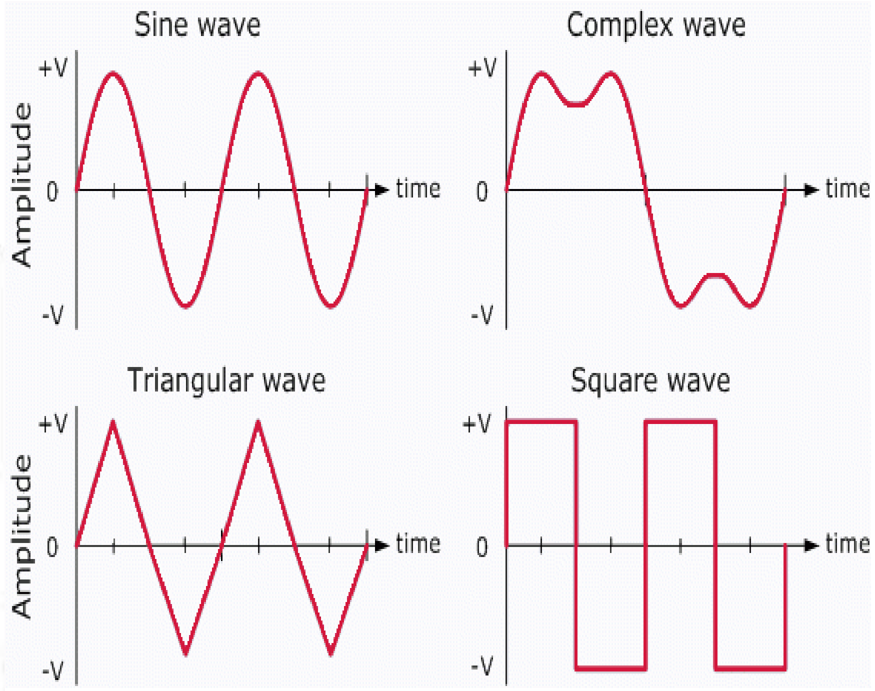
	Alternating Current	Direct Current
Amount of energy that can be carried	Safe to transfer over longer city distances and can provide more power.	Voltage of DC cannot travel very far until it begins to lose energy.
Cause of the direction of flow of electrons	Rotating magnet along the wire.	Steady magnetism along the wire.
Frequency	The frequency of alternating current is 50Hz or 60Hz depending upon the country.	The frequency of direct current is zero.
Direction	It reverses its direction while flowing in a circuit.	It flows in one direction in the circuit.
Current	It is the current of magnitude varying with time	It is the current of constant magnitude.
Flow of Electrons	Electrons keep switching directions - forward and backward.	Electrons move steadily in one direction or 'forward'.
Obtained from	A.C Generator and mains.	Cell or Battery.
Passive Parameters	Impedance.	Resistance only
Power Factor	Lies between 0 & 1.	it is always 1.
Types	Sinusoidal, Trapezoidal, Triangular, Square.	Pure and pulsating.

Difference between AC and DC

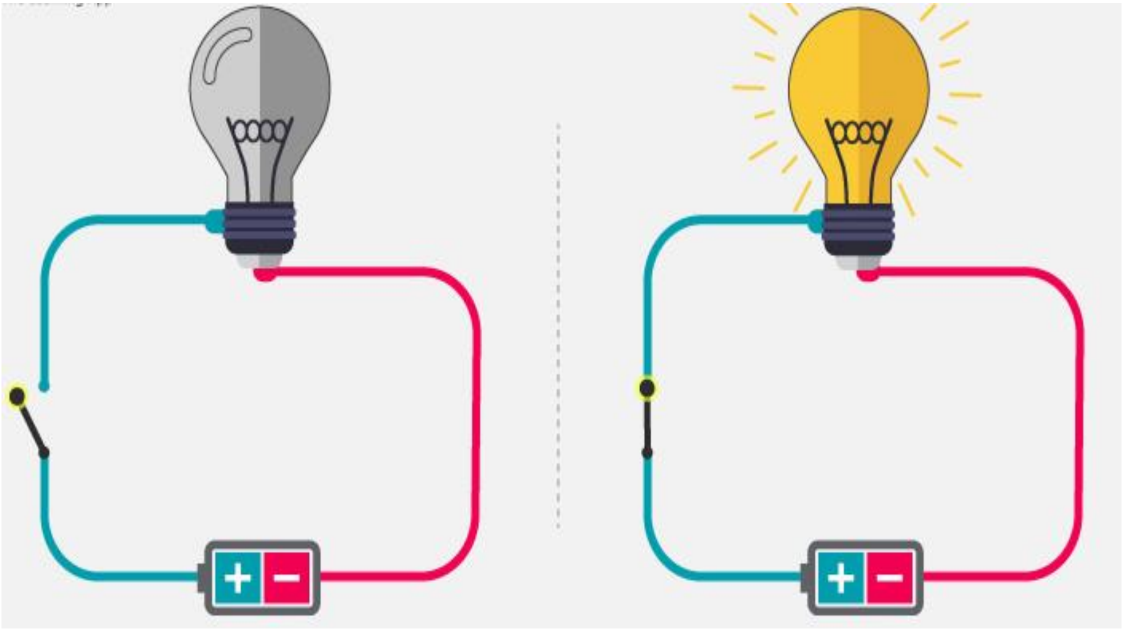






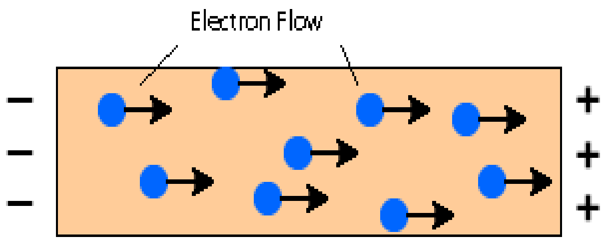
Basic Concept of Electricity

- Electric circuit: an electric circuit is formed when a conducting path is created to allow free electrons to continuously move.
- An electrical circuit is a path or line through which an electrical current flows. The path may be closed (joined at both ends), making it a loop. A closed circuit makes electrical current flow possible. It may also be an open circuit where the electron flow is cut short because the path is broken

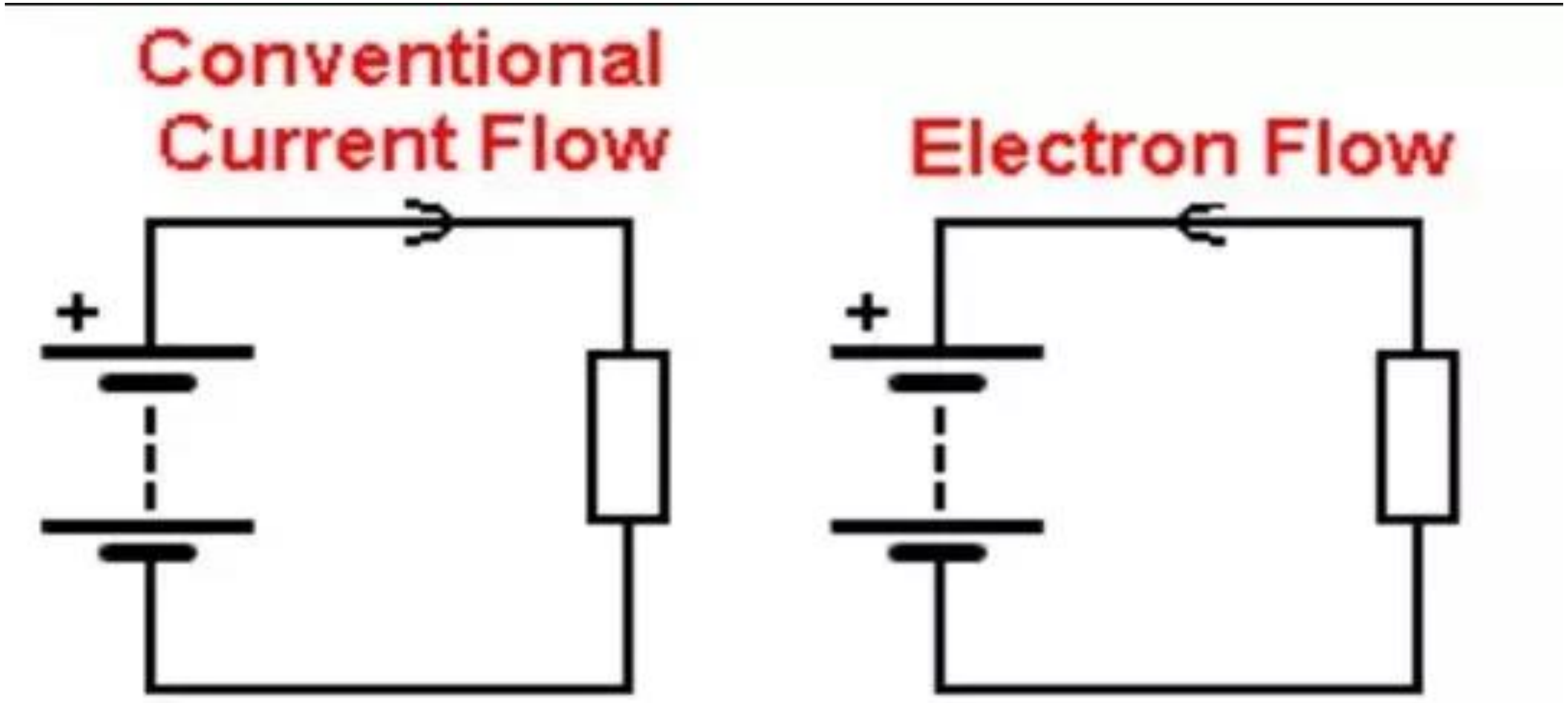


Why does the current flow?

- The electron repelled by the negative charge at the negative terminal of the battery and attracted by positive charge at a positive terminal.
- Therefore the electron drifts away from the negative terminal and towards positive terminal
- When the electrons reaches positive terminal a chemical reaction transform them across the battery and back to negative terminal



Conventional and Real Current Flow



Conventional and Real Current Flow

- The electron is repelled by the negative charge at the negative terminal of the battery and attracted by the positive charge of a positive terminal .
- Therefore the electron drift away from negative terminal and towards the positive terminal
- As stated above the moment of electron and therefore a direction of current flow are from negative terminal of battery to positive terminal as shown in figure
- However before the true nature of electricity was known, scientists assumed the current was the result of movement of positively charged particles.
- Therefore the current flowed from positive to negative terminal. This convention is still used today and it is conventional current flow
- Conventional current flow assumes current flow out of the positive terminal through the circuit and into the negative terminal of the source. This was convention chosen during the discovery of electricity
- Real current flow is what actually happens and electrons flow out of the negative terminal through the circuit and moves to the positive terminal of the source

Conservation of charge

- Law of conservation of charge says that the net charge of an isolated system will always remain constant.
- This means that any system that is not exchanging mass or energy with its surroundings will never have a different total charge at any two times.
- For example, if two objects in an isolated system have a net charge of zero, and one object exchanges one million electrons to the other, the object with the excess electrons will be negatively charged and the object with the reduced number of electrons will have a positive charge of the same magnitude. The total charge of the system has not and will never change.

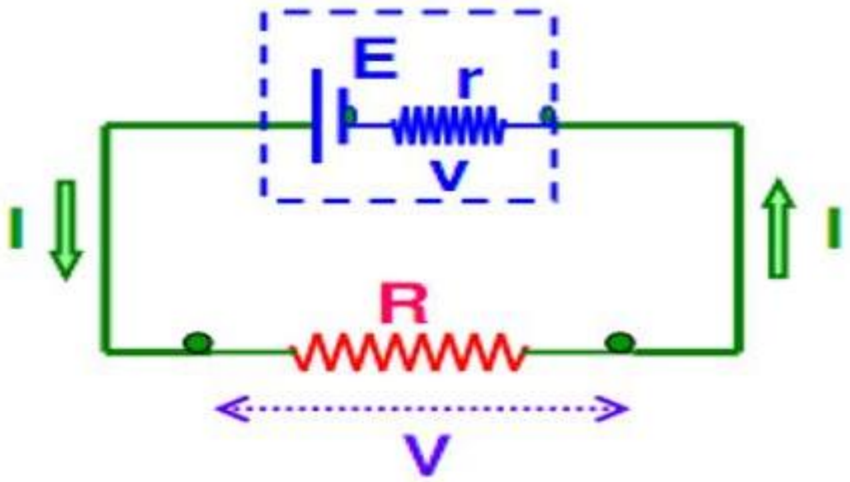
Electromotive Force and Potential Difference

- **The emf (electromotive force**) is the potential difference between the terminals of a battery when no current is flowing through an external circuit when the circuit is open
- It is the maximum voltage that can be attained by a specific circuit
- **Potential difference** is the voltage across the terminals of the battery when the current is being drawn from it to an external.

	EMF	Potential Difference
1	EMF is the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell i.e. when the circuit is open.	P.D is the difference of potentials between any two points in a closed circuit.
2	It is independent of the resistance of the circuit.	It is proportional to the resistance between the given points.
3	The term 'emf' is used only for the source of emf.	It is measured between any two points of the circuit.
4	It is greater than the potential difference between any two points in a circuit.	However, p.d. is greater than emf when the cell is being charged.

Electromotive Force and Potential Difference

- When a battery is in use/or the circuit is closed a small portion of the **emf** is spent in overcoming the internal resistance of the battery. This energy per unit charge is called **potential difference.**
- If 'E' is the emf of the battery used in the circuit and 'r' is the internal resistance of the specific battery and the external resistance of the circuit is 'R' in circuit of 'I' current then,



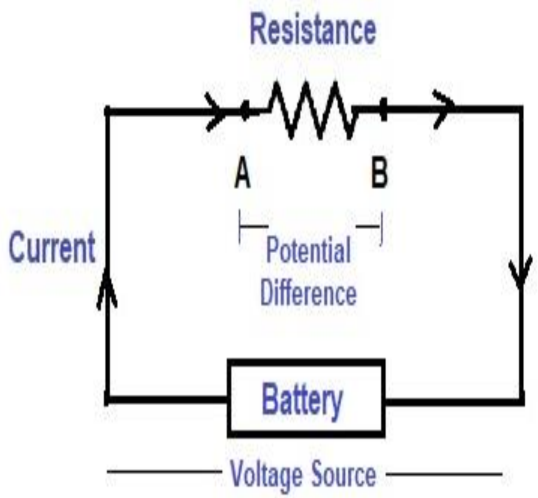
E= I*r +I*R

Or, I*R= E - I*r

  - Here 'E - I*r' is regarded as the potential differences between the terminal of the battery which is also known as terminal voltage

Electromotive Force and Potential Difference

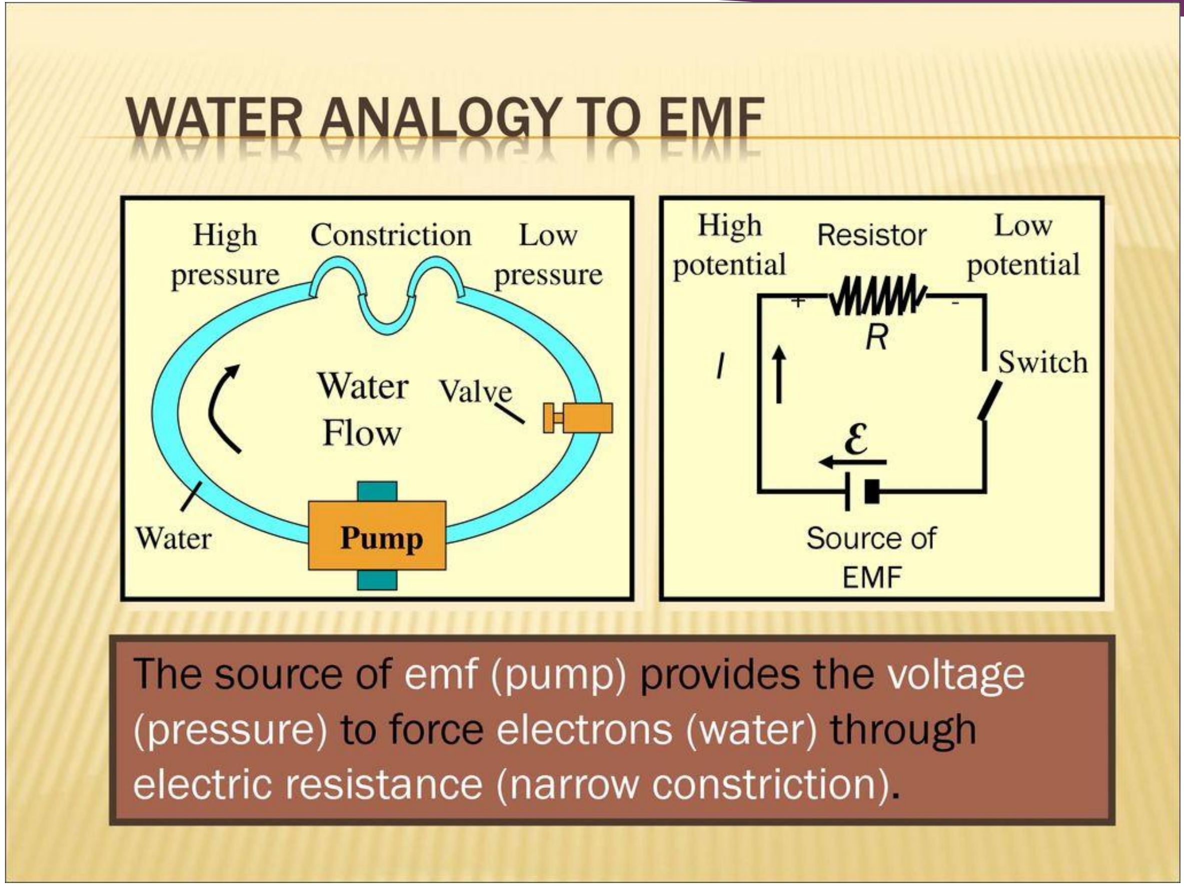
- The potential difference across the two points of a conductor causes the dissipation of electrical energy into other forms of energy as charges flow through the circuit.
- When one end A of a conductor is connected to the positive terminal and its other end B is connected to the negative terminal of the battery, then the potential at A becomes higher than the potential at the B.
- This causes a potential difference between the two points of the conductor. The flow of current continues as long as there is a potential difference. The agency which provides the potential difference for the steady flow of current in the copper wire is the battery. As the current flows from higher potential to the lower potential through the conductor, the electrical energy (due to the current) is converted into other forms (heat and light, etc.).
- When current flows through the conductor, it experiences resistance in the conductor by collisions with an atom of the conductor. This energy supplied by the battery is utilized in overcoming this resistance and is dissipated as heat and other forms of energy. The dissipation of this energy is accounted for by the potential difference across the two ends of the light bulb.

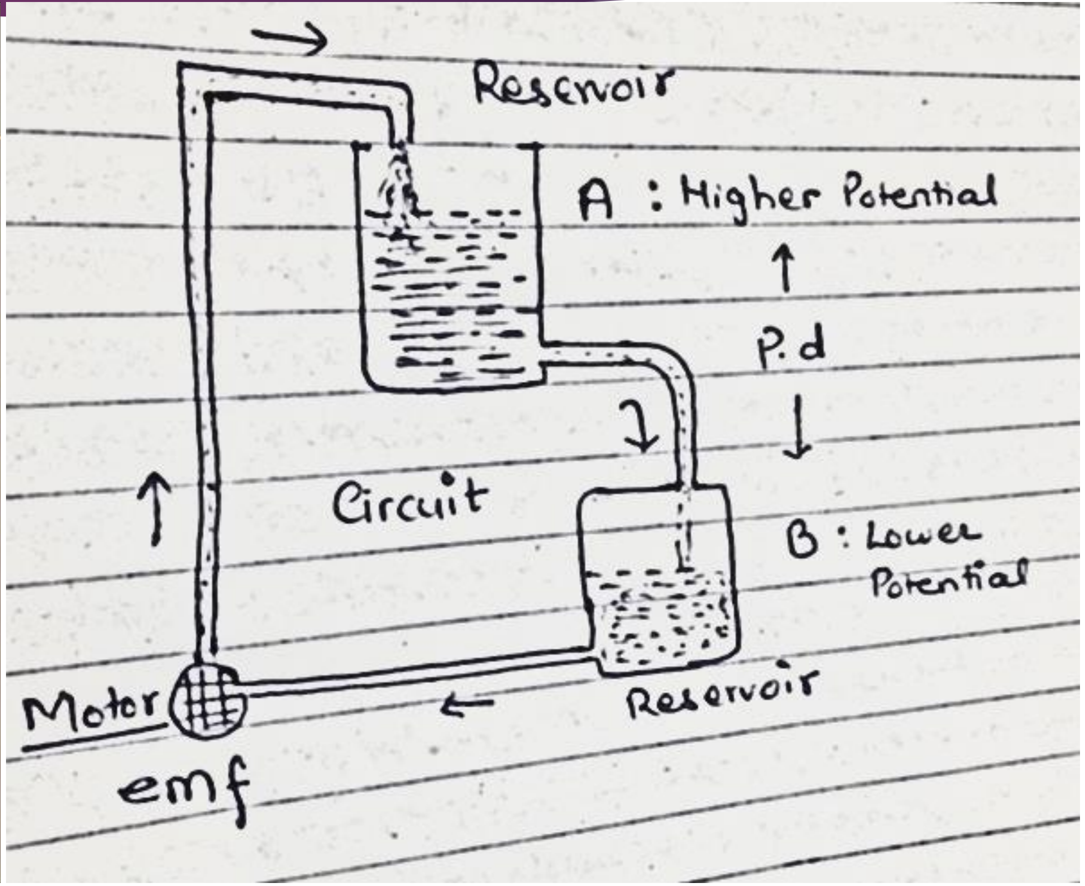


Electromotive Force and Potential Difference

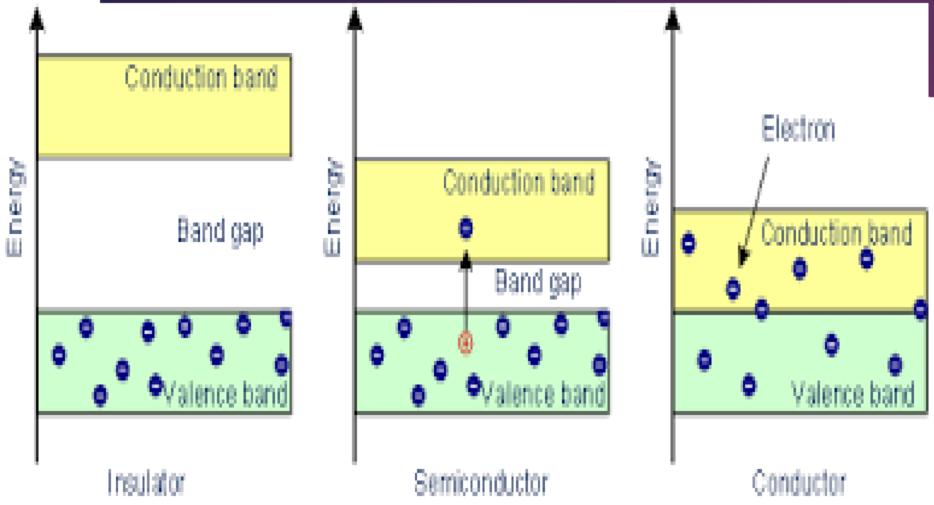
Electromotive force (emf)	Potential Difference (Pd)
E.m.f is the energy supplied to the unit charge by the cell.	Potential difference is the energy dissipated as the unit charge passes through the components.
E.m.f is the cause.	Potential difference is the effect.
The emf is also present even when no current is drawn through the battery.	Potential difference across the conductor is zero in the absence of current.
Its unit is volt.	Its unit is volt.
It remains constant.	It does not remain constant.
It is always greater than potential difference.	It is always less than emf.
It transmits current both inside and outside of the cell.	Potential difference transfer current between two points in the cell.
Its symbol is E.	Its symbol is V.
Its formula is E = I (Rtr) Rtr = total external and internal resistance.	Its formula is V = E – Ir
It does not depend on circuit resistance.	It directly depends on the resistance between two points of measurement.

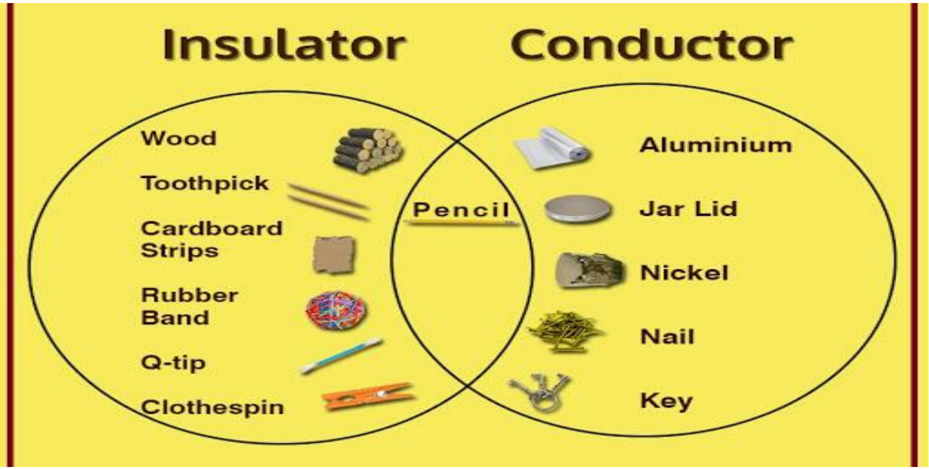
Electromotive Force and Potential Difference

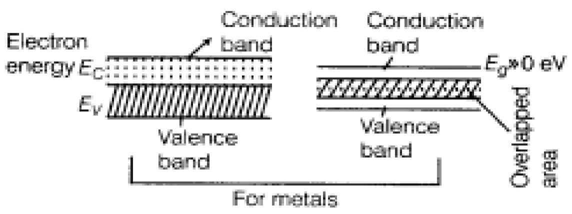
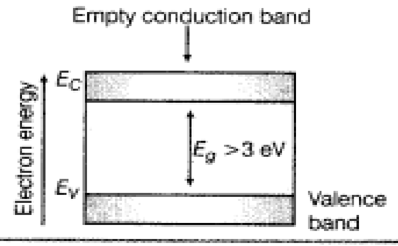
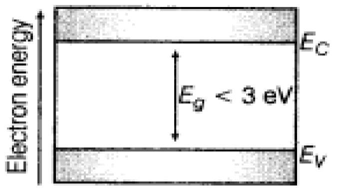




Conductor and Insulator





Conductor (Metal)	**Insulator**	**Semiconductor**
In conductor, either there is no energy gap between the conduction band which is partially filled with electrons and valence band or the conduction band and valence band overlap each other.	In insulator, the valence band is completely filled, the conduction band is completely empty and energy gap is quite large that small energy from any other source cannot overcome it.	In semiconductor also, like insulators the valence band is totally filled and the conduction band is empty but the energy gap between conduction band and valence band, unlike insulators is very small.
Thus, many electrons from below the fermi level can shift to higher energy levels above the fermi level in the conduction band and behave as free electrons by acquiring a little more energy from any other sources.	Thus, electrons are bound to valence band and are not free to move and hence, electric conduction is not possible in this type of material.	Thus, at room temperature, some electrons in the valence band acquire thermal energy greater than energy band gap and jump over to the conduction band where they are free to move under the influence of even a small electric field and acquire small conductivity.
		

Conductor and Insulator

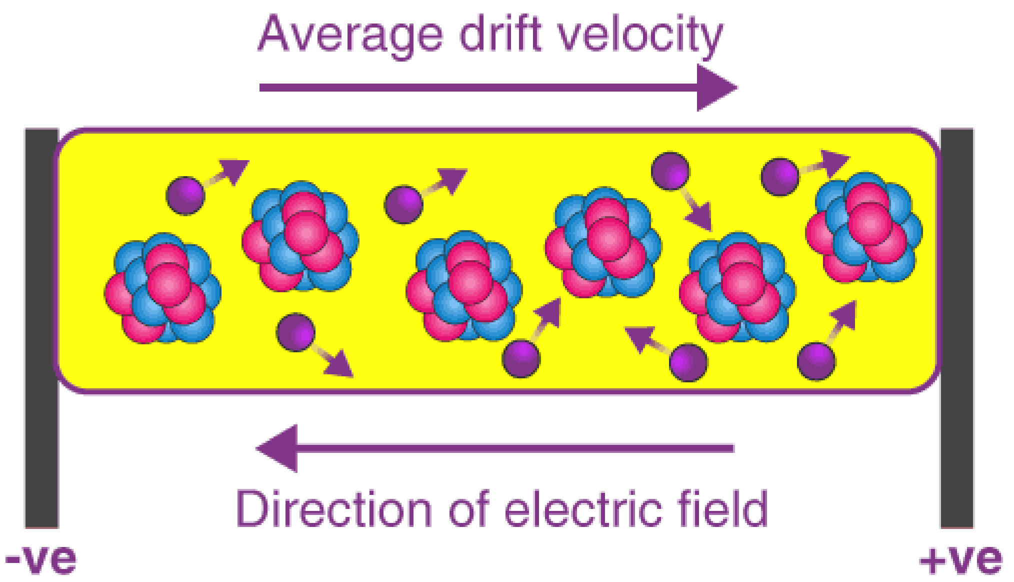
- **Conductors** are materials that permit electrons to flow freely from particle to particle
- An object made of a conducting materials will permit charge to be transferred across the entire surface of the object
- If charge is transferred to the object at a given location then charge is quickly distributed across the entire surface of the object
- The distribution of charge is result of electron movement since conductors allow for electron to be transported from particle to particle
- A charged object will always distribute its charge until the overall repulsive forces between excess electrons is minimized
- If a charged conductor is touched to another object, the conductor can even transfer its charge to that object
- The transfer of charge between objects occurs more readily if the second object is made of conducting material
- Conductors allow for charge transfer through the free movement of electrons

Conductor and Insulator

- **Insulators** are the materials that block the free flow of electron from atom to atom and molecule to molecule
- if charge is transferred to an insulator at a given location the excess charge will remain at the initial location of charging
- The particles of the insulator do not permit the free flow of electrons and also charge is not distributed evenly across the surface of an insulators
- While insulators are not useful for transferring charge, they do serve a critical role in electrostatic experiments and demonstrations
- Conductive objects are often mounted upon insulating object
- This arrangement of a insulator on top of a conductor prevents charge from being transferred from the conductive object to its surrounding

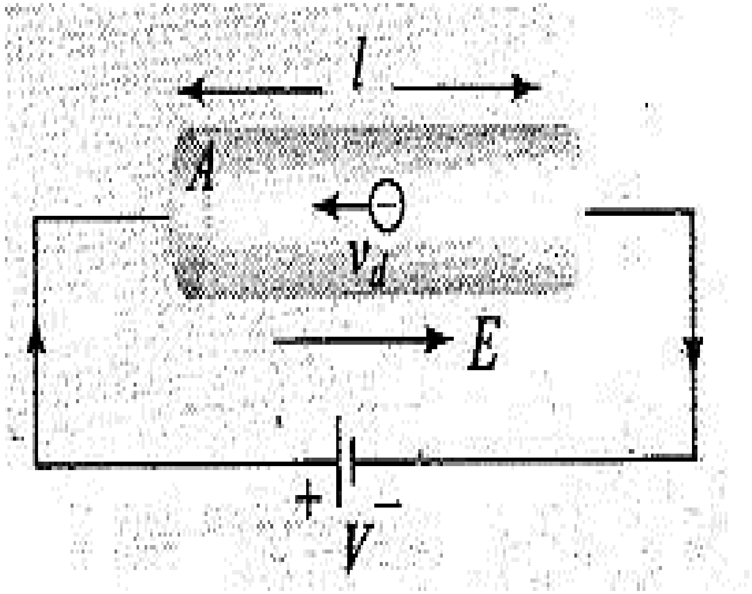
Electron flow/ Electron drift velocity

- Subatomic particles like electrons move in random directions all the time. When electrons are subjected to an electric field they do move randomly, but they slowly drift in one direction, in the direction of the electric field applied. The net velocity at which these electrons drift is known as **drift velocity.**
- **It is the average velocity attained by charged particles, (e.g. electrons) in a material due to an electric field.**



Electron flow/ Electron drift velocity

- Let us suppose a conductor having cross sectional area 'A' is applied potential of 'V' volt. Since conductor carries many number of free electrons, whenever we apply potential, electron will migrate towards the positive terminal of a battery.
- This result current 'I' in the conductor in opposite direction as shown in figure



Let,

N= number of free (mobile electrons per m^3)

V_d = drift velocity by which the electron move towards positive terminal of battery in small time '**dt**'

ds = small elementary length carrying small charge 'dq'

dl = change in length

e = electron charge = 1.602×10^{-19} coulombs

Electron flow/ Electron drift velocity

- Distance travelled by charge **(ds) = V_d* dt**
- Volume of small element of conductor **= A* ds**
- Total no. of electron in small elementary section **= N *A* ds**
- Total charge in small elementary section **dq = e* N *A * ds**
- **Current =** $\frac{dq}{dt} = \frac{e*N*ds*A}{dt} = e*N*A*Vd$
  - **I = V_d * e * N *A**
  - **I/N = V_d * e * N**
  - **J = V_d *e * N**
  - Where ,

    J= current density A/m^2

    Unit= ampere /$meter^2$

Electron flow/ Electron drift velocity

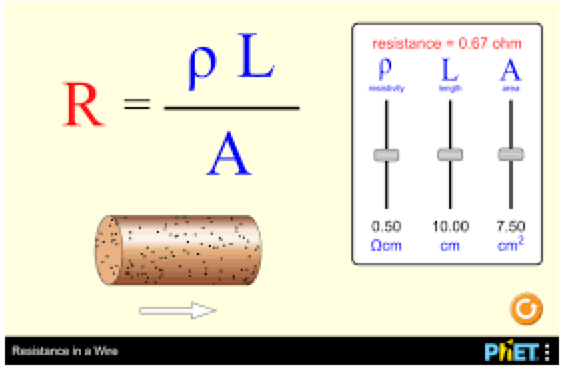
- Numerical:
- Find the velocity of charge leading a 1A current which flow in a copper conductor of cross sectional area 1 cm^2 and length 10 km. number of free electron of copper is 8.5×10^{28} per m^3 . How long will it take electric charge to travel from one end of the conductor to another end?

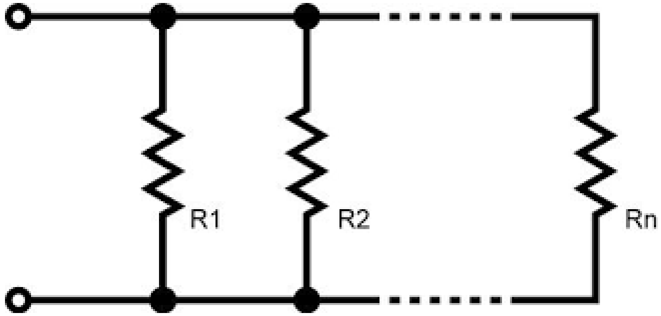
Electron Mobility

- the electron mobility characterizes how quickly an electron can move through a metal or semiconductor, when pulled by an electric field.
- When an electric field E is applied across a piece of material, the electrons respond by moving with an average velocity called the drift velocity $\mathbf{V_d}$, Then the electron mobility **μ** is defined as
- $\mathbf{V_d = \mu * E}$

Resistance

- The property of matter or substances by virtue of which it opposes the flow of charge or current is called resistance
- The substances or matter which poses the resistance is called resistor
- Its unit is ohm





Effect of temperature on Resistance

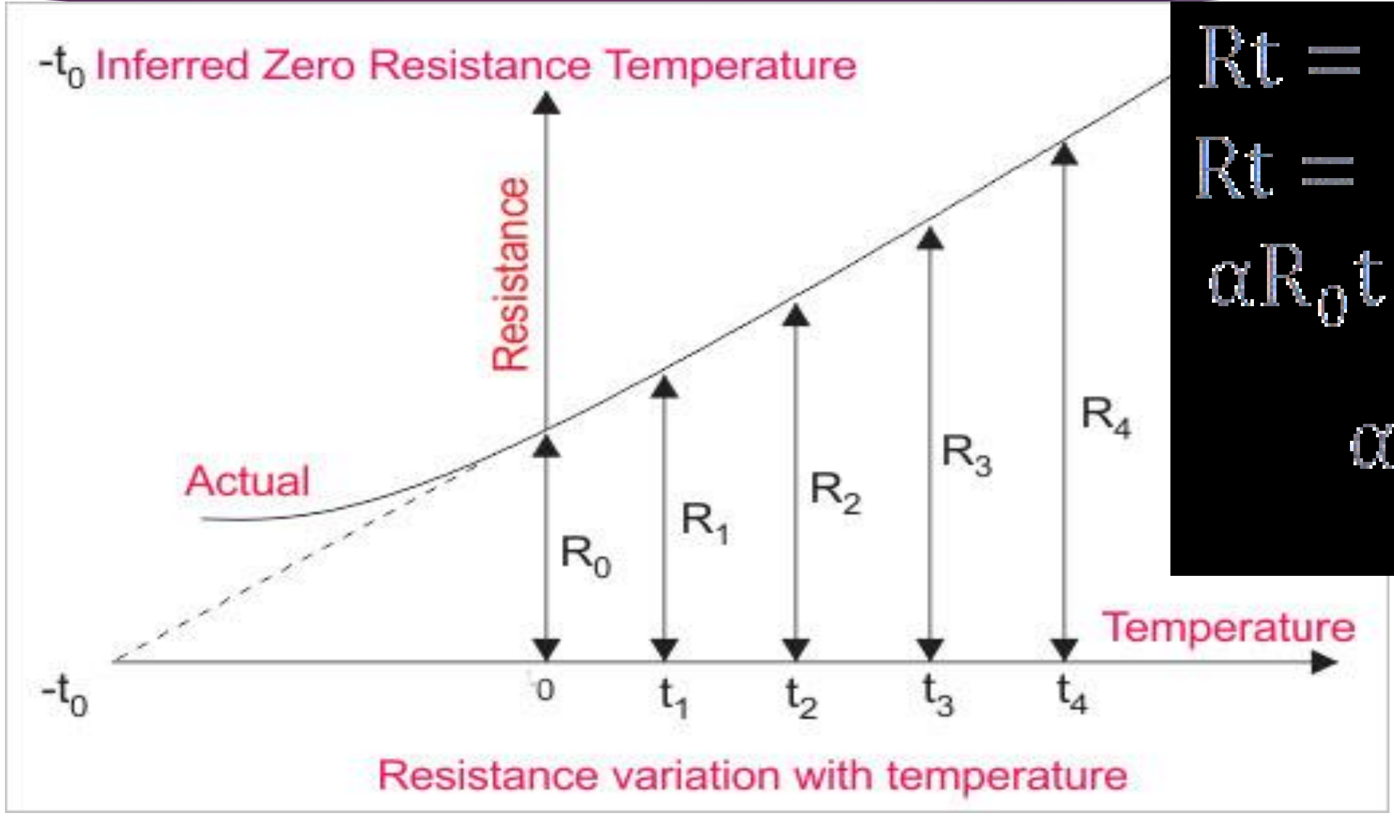
- As the temperature increases resistance of the conductor increases resistance of the conductor increases because as we hear conductor it gets expanded and hence its free path decreases. So resistance increase i.e.

$$\text{Resistance } \alpha \text{ temperature}$$

- The resistance of all pure metallic conductor increases with the increase in temperature but the resistance of the insulator and non metallic material generally decreases with the increase in temperature
- If the resistance of any pure metal is plotted temperature base, it is found that over the wide range of temperature the graph is practically a straight lines as illustrated in figure

Effect of temperature on Resistance

Material	°C
Silver	−243
Copper	−234.5
Gold	−274
Aluminum	−236
Tungsten	−204
Nickel	−147
Iron	−162
Nichrome	−2,250
Constantan	−125,000



$$Rt = R_0(1 + \alpha t)$$

$$Rt = R_0 + \alpha R_0 t)$$

$$\alpha R_0 t = Rt - R_0$$

$$\alpha = \frac{\Delta R}{R_0 t}$$

Effect of temperature on Resistance

- There are some materials mainly metals, such as silver, copper, aluminum, which have plenty of free electrons. Hence this type of materials can conduct current easily that means they are least resistive. But the resistivity of these materials is highly dependable upon their temperature. Generally metals offer more electrical resistance if temperature is increased. On the other hand the resistance offered by a non-metallic substance normally decreases with increase of temperature.
- If we take a piece of pure metal and make its temperature 0o by means of ice and then increase its temperature from gradually from 0oC to to 100oC by heating it.
- During increasing of temperature if we take its resistance at a regular interval, we will find that electrical resistance of the metal piece is gradually increased with increase in temperature. If we plot the resistance variation with temperature i.e. resistance Vs temperature graph, we will get a straight line as shown in the figure below. If this straight line is extended behind the resistance axis, it will cut the temperature axis at some temperature, – t0oC. From the graph it is clear that, at this temperature the electrical resistance of the metal becomes zero. This temperature is referred as inferred zero resistance temperature.

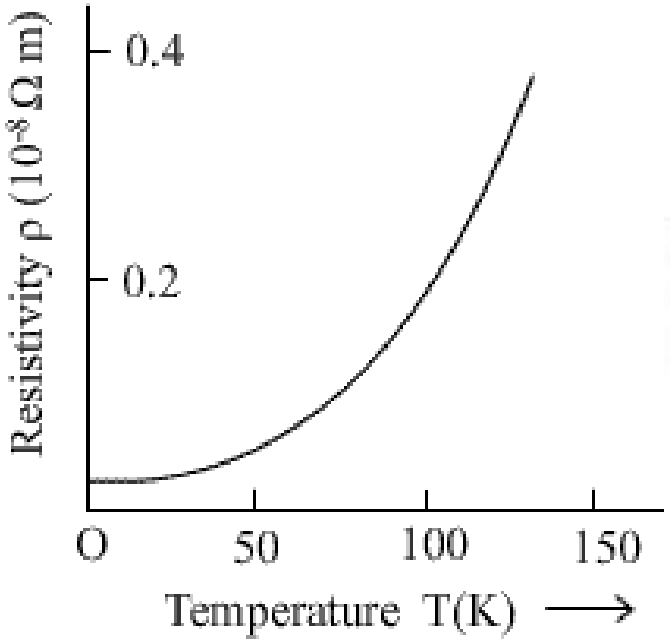
Effect of temperature on Resistance

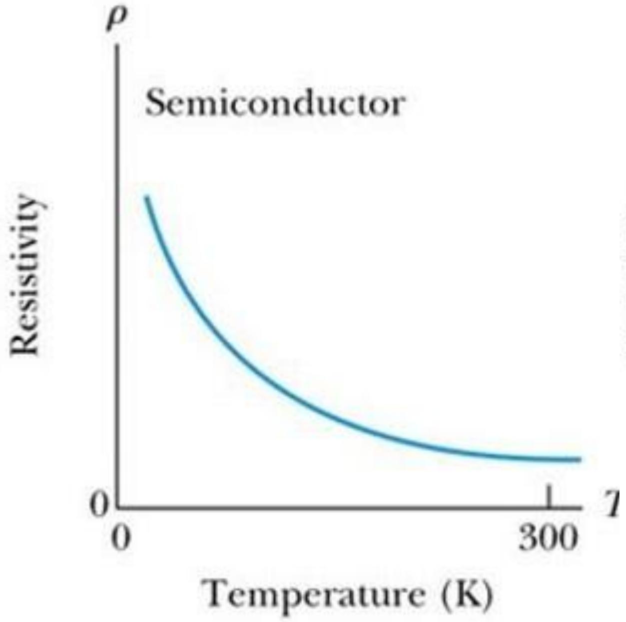
- Although zero resistance of any substance cannot be possible practically. Actually rate of resistance variation with temperature is not constant throughout all range of temperature.
- Let's R1 and R2 are the measured resistances at temperature t1oC and t2oC respectively. Then we can write the equation below,

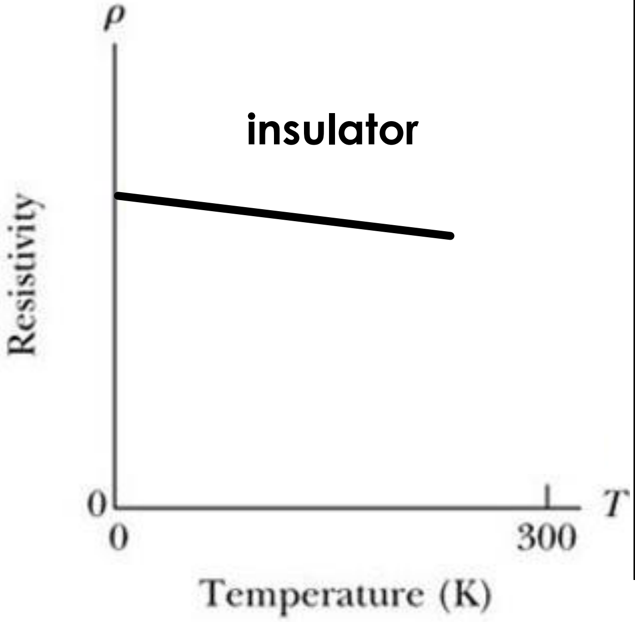
$$\frac{R_2}{R_1} = \frac{t_0 + t_1}{t_0 + t_2}$$

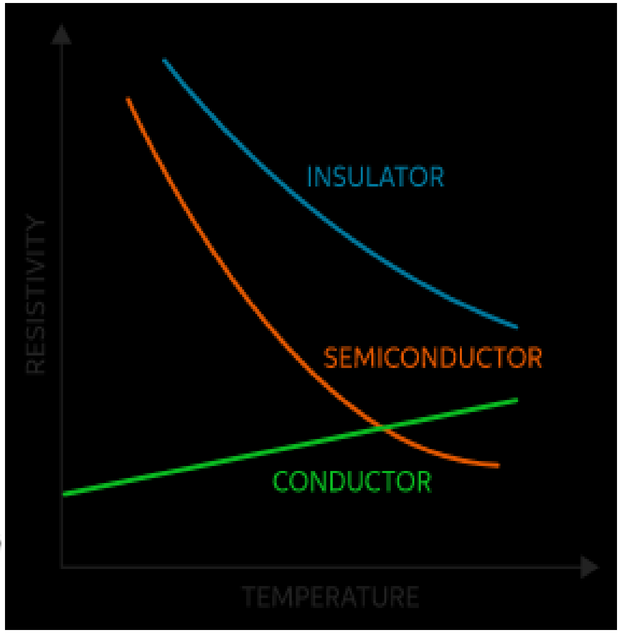
- From the above equation we can calculate resistance of any material at different temperature. Suppose we have measured resistance of a metal at t1oC and this is R1.
- If we know the inferred zero resistance temperature i.e. t0 of that particular metal, then we can easily calculate any unknown resistance R2 at any temperature t2oC from the above equation.

Effect of temperature on Resistance









$\alpha = +$ve
Al, Cu, Zn, Ag

$\alpha = -$ve
Germanium, silicon AND GRAPHITE

$\alpha = 0$
Insulators, alloys constantan, manganin

Thank You!!