Basic Electrical Engineering ONESHOTS

Unit 6

Concept of Resistance

- It is used to resist the flow of current
- Denoted by R and unit is ohms
- Materials with large number of free electrons offer low resistance to flow of electric current.
- Low resistance materials are called conductors: gold, silver, copper aluminum
- High resistance materials are called insulators: glass rubber wood paper
- Semiconductor materials like: Silicon, germanium have moderate resistance

$$R = \rho \frac{l}{a}$$

Factors affecting the resistance:

- Length of Material
- Cross-section area
- Type of material
- Temperature

Resistance is the opposition that a circuit offers to the flow of electric current its unit is ohm.

A material's resistivity is a measure of how strongly it opposes the flow of current its unit is ohm meter.

Effect of temperature on Resistance of Materials

Insulator: In insulator the numbers of free electrons are less. With increase in temperature, vibration of ions will increase. But simultaneously the electrons from the atoms gain extra energy and get escaped from their parent atoms and become available for conduction. This reduces the resistance of insulating material.

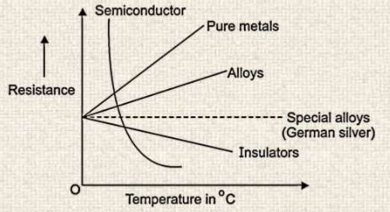


Fig. Variation of Resistance with respect to Temperature

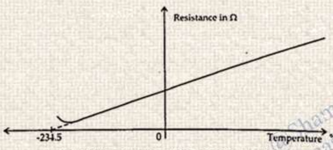
- **So in case of insulator, with increase in temperature, its resistance will decrease.**
- **The insulators have negative temperature coefficient of resistance.**

Examples: Carbon, Mica, Rubber, Plastic etc.

Effect of temperature on Resistance of Materials

Pure Metals (Conductors): The conductor has more number of free electrons. When such conductor is connected across some voltage, ions get formed inside it and the electrons which are moving randomly will get aligned in certain direction. At low temperature ions are stationery, but as soon as temperature increases, the unmovable ions gain energy and start oscillating about their mean position. More the temperature more will be the magnitude of oscillation. This will cause obstruction to flow of free electrons; which lead to increase in resistance.

- **So in case of conductor, the resistance will increase with increase in temperature.**
- **So the conductors have positive temperature coefficient of resistance**.
- Examples: Gold, Silver, Copper etc.



▲ Figure 3: Temperature vs Resistance Graph of Copper

Semiconductor: At low temperature, the resistance of semiconductor is high. But dominant increase in temperature gives additional energy to the electrons available in valency band. These electrons cross over the narrow energy gap and enters into conduction band.
So in case of semiconductor, after certain rise in temperature the resistance drastically reduces to small value and remains constant there after.
The semiconductors have negative temperature coefficient of resistance
Examples: Silicon, Germenium.

Alloy: The resistance of common alloys such as bronze, brass, steel increases as the temperature increases, but the rate of increase is very small. In special alloys an increase in temperature not only causes an obstruction to the electron movement but also compensates for this by increase in number of free electrons where the number of free electrons is about equal to the obstruction to the thermal energy gained. The temperature change may have very little effect on resistance. e.g. Manganin, Eureka show almost no change in resistance with change in temperature. So such types of alloys are used to make resistance boxes.

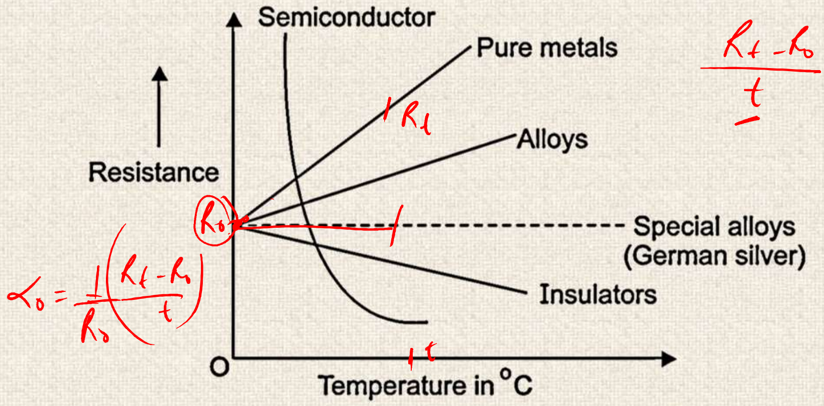
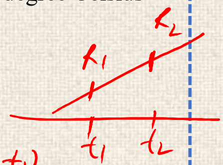


Fig. Variation of Resistance with respect to Temperature

Resistance Temperature Coefficient (RTC)

RTC is defined as the ratio of change in resistance of material per degree Celsius to its resistance at t° C.

$$\alpha_o = \frac{R_t - R_o}{R_o t}$$



$$\alpha_1 = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$$

Effect of Temperature on RTC:

$$R_2 = \alpha_1 R_1 (t_2 - t_1) + R_1$$

Change in temperature changes RTC. Let us consider a conducting material whose initial resistance is $\mathbf{R_1}$ at temperature $\mathbf{t_1}$**° C** i.e. at point A.
Now, if the temperature of the material is gradually increased by heating process up to temperature $\mathbf{t_2}$**° C** i.e. at point B, then it's resistance will be $\mathbf{R_2}$.

The expression for R_2 ,

$$R_2 = R_1 \left[1 + \alpha_1 \cdot (t_2 - t_1)\right] \quad \dots (1)$$

Where α_1 is T.C.R. at t_1°C

Now if the material is having resistance R_2 at t_2°C and if the material is gradually cooled down up to initial temperature t_1°C i.e. up to point A, then

$$R_1 = R_2 \left[1 + \alpha_2 \cdot (t_1 - t_2)\right] \quad \dots (2)$$

where α_2 is T.C.R. at t_2°C.

From eq1 and 2 finding

$$\frac{R_1}{R_2} = 1 + \alpha_2 (t_1 - t_2)$$

$$\frac{R_1}{R_2} = \frac{1}{1 + \alpha_1 (t_2 - t_1)}$$

$$\alpha_2 (t_1 - t_2) = \frac{1}{1 + \alpha_1 (t_2 - t_1)} - 1 = \frac{1 - 1 - \alpha_1 (t_2 - t_1)}{1 + \alpha_1 (t_2 - t_1)} = \frac{-\alpha_1 (t_2 - t_1)}{1 + \alpha_1 (t_2 - t_1)}$$

$$\alpha_2 = \frac{\alpha_1}{1 + \alpha_1 (t_2 - t_1)}$$

$$\boxed{\alpha_1 - \alpha_2 = \alpha_1 \alpha_2 (t_2 - t_1)}$$

Insulation Resistance:

If we consider

t_1 = 0°C and t_2= t° C, $\alpha_1 = \alpha_o$ and $\alpha_2 = \alpha_t$ then,

$$\alpha_t = \frac{\alpha_0}{1 + \alpha_0 t}$$

The **insulation resistance** is defined as the resistance offered by an insulating material to the flow of leakage current.
It is denoted by Ri and its unit is Ω.

$$R_i = V/I_l$$

V = Voltage measured between conductor and earth

I_l = Leakage current and R_i = Insulation resistance.

Factors affecting value of Insulation Resistance

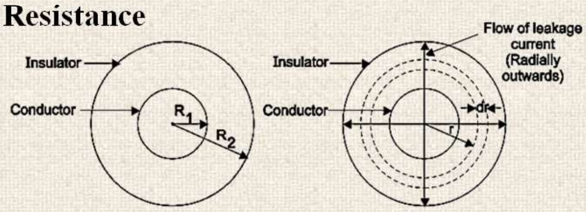
1) **Resistivity of the material:** Ri depends on type and nature (resistivity) of the material

2) **Temperature:** As temperature of insulating material increases Ri decreases and vice versa

3) **Length:** Ri is inversely proportional to the length of the cable

4) **Moisture:** Ri decreases when the moisture content in insulating material increases.

Derivation of Insulation Resistance



- Due to finite insulation resistance of the insulating material used, some leakage current flows from the conductor in radially outward direction.
- Therefore, to obtain the expression for R_i, a small section with thickness as "dr" at a distance of "r" meters from the center of the cable is considered.
- Where, R_1 = Radius of conductor, R_2 = Radius of cable including conductor and insulator Length offered by insulation layer = dr, Cross-sectional area = $2\pi rl$

The resistance offered by small section is

$$dR_i = \rho \times \frac{dr}{2\pi rl}$$

The total insulation resistance R_i can be obtained by integrating "dR_i" over the entire radius of insulating material i.e. from R_1 and R_2.

$$R_i = \int_{R_1}^{R_2} dR_i = \int_{R_1}^{R_2} \frac{\rho\, dr}{2\pi rl} = \frac{\rho}{2\pi l}\int_{R_1}^{R_2} \frac{dr}{r} = \frac{\rho}{2\pi l}\left[\log_e r\right]_{R_1}^{R_2}$$

$$R_i = \frac{\rho}{2\pi l}\left[\log_e R_2 - \log_e R_1\right] = \frac{\rho}{2\pi l}\, l_n\left(\frac{R_2}{R_1}\right)\ \Omega$$

$$\boxed{R_i = \frac{\rho}{2\pi l}\log_e\left[\frac{R_2}{R_1}\right]}\ \Omega$$

CELL

A cell is a DC source, which converts chemical energy into electrical energy.

An electrochemical cell has two metal plates, which act as electrodes.

One of the plate is positively charged and is called anode.

The other plate is negatively charged and is called cathode.

These electrodes are immersed in a conducting liquid or a paste, which is a chemical compound, called as electrolyte.

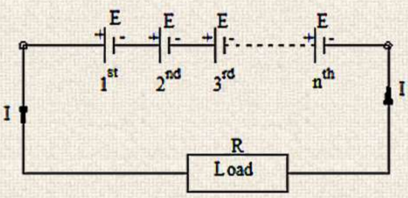
The chemical reactions between the electrodes and the electrolyte create a potential difference across the two electrodes.

Types of Cells:

Primary Cells	Secondary Cells
The chemical change is irreversible.	The chemical change is reversible.
It can be used only once.	It can be used many times.
It is used for small applications like calculator, remote clocks, wireless mouse etc.	It is used for large applications like inverter, ups, solar lighting etc.
Voltaic cell, Daniel cell, Alkaline, zinc chloride cell, mercury cell etc. are the examples of primary cells	Lead Acid battery, Nickel metal hydride, Nickel chloride etc. are the examples of secondary cells

Grouping of cells.

Series Grouping

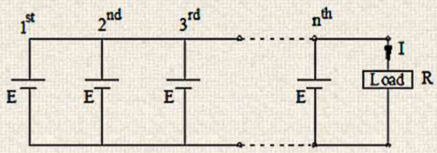


If n= no. of cells,
r = Internal resistance of the cell
E= EMF of each cell
R= Resistance of the load

Total EMF of the battery = n × E
Total internal resistance of battery = n × r
Total resistance of circuit = R + n r
Current delivered by battery

$$I = nE/(R + nr)$$

Parallel Grouping



Equivalent resistance all cells

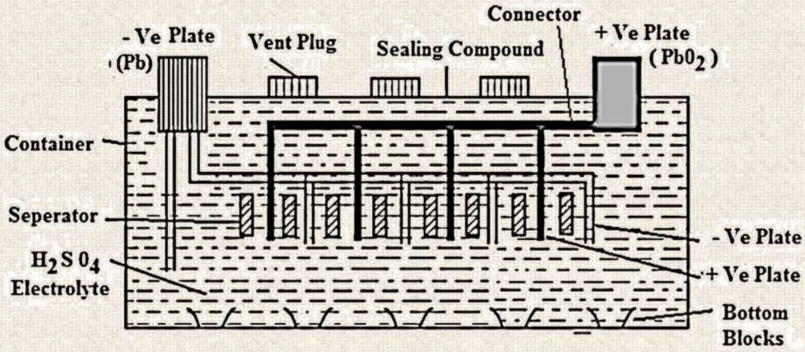
$$R_{eq} = \frac{1}{\frac{1}{r}+\frac{1}{r}+\frac{1}{r}+\text{........}+\frac{1}{r}(n\ times)} = \frac{1}{\left(\frac{n}{r}\right)} = \frac{r}{n}$$

Total resistance of circuit $= R + \frac{r}{n}$

Current delivered by battery (I) $= \frac{E}{R+\frac{r}{n}}$

$$I = \frac{nE}{nR + r}$$

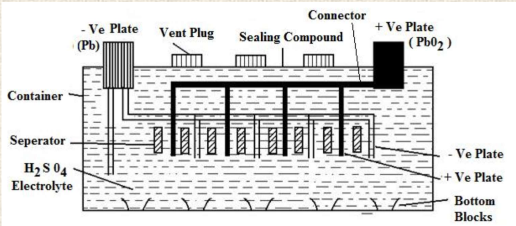
Construction of Lead acid battery



1. **Plates:**
   The plates, which are actually electrodes are of two types:
   a) **Anode:** Lead Peroxide (PbO2) of Chocolate brown color

   b) **Cathode:** Spongy Lead (Pb) with slate grey color

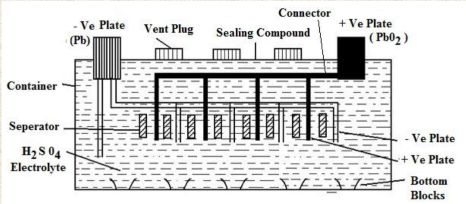
2. Electrolyte:
Aqueous solution of Sulphuric acid (H2SO4).



3. Separators:
The separators are used to separate positive and negative plates, preventing them to come in contact with each other. These are made of either specially treated wood or perforated rubber. The common separator is wood, since it is the cheapest of all separators.

4. Container
The container is made of vulcanized rubber, or glass. Glass containers are normally used for light duty work and rubber container for portable work. Entire assembly of plates along with the solution is placed in the container.

5. Bottom Blocks
These are fitted at the bottom of the container to prevent short circuiting of cell due to the active material fallen from the plates



6. Plate connector
Separate connectors are used to connect all positive plates to one bar and negative plates to another common bar.

7. Cover with vent Plug
The covers are generally of vulcanized rubber. A hole is provided for pouring the electrolyte and this can be closed by a screwed cap. The cap is provided with minute holes for gases to escape. This is also known as 'Vent Cap'. The function of the vent cap is to allow the escape of the gases.

Indications of fully charged battery

1) Voltage **2) Specific Gravity of Electrolyte**

3) Color of the electrodes **4) Gassing**

1. Voltage: When the cell is fully charged its terminal potential will be approximately **2.6 volts.**

2. Specific Gravity: When the cell is fully charged, the specific gravity of the electrolyte will be **approximately 1.21.**
When the cell is fully **discharged** its value **falls to 1.17.**

3. Color of Electrodes: When the cell is **fully charged**, the lead sulphate **anode** gets converted into lead per oxide (PbO2) **dark chocolate brown in color** and lead sulphate **cathode** gets converted into lead (Pb), grey in color.

4. Gassing: When the cell is fully charged, the hydrogen and oxygen gases are liberated at the cathode and anode respectively. Liberation of gases (hydrogen and oxygen), known as gassing, on the electrodes indicates that the cells are fully charged.

Maintenance of Lead Acid Battery:

1. The battery should be recharged immediately after discharge i.e., when output voltage is lowered from the permissible value.
2. The electrolyte level in the cells must always be kept above top of the electrodes (plates). Any loss of level (due to evaporation and decomposition) must be compensated by adding pure and distilled water. The ordinary tap water must not be used.
3. The specific gravity of electrolyte must be checked during each charging. If the electrolyte is to be added, it should be pure.
4. The battery should not be left in the discharged condition for longer period, as it reduces the life of battery.

5. The discharged battery should be protected from low temperatures to prevent the electrolytes from freezing and bursting the cell container.
6. The battery should not be overcharged as it can weaken the plate structure of the cells.
7. A battery like a lead-acid battery contains sulfuric acid. Such a battery should be handled and transported carefully as the leakage of acid can cause damage to skin or eyes.
8. A battery should be charged in a well ventilated space free from flames or sparks, as the gases released during charging are explosive.
9. The terminals of the battery should be kept clean to avoid corrosion and to prevent increase in contact resistance. A thin layer of Vaseline or petroleum jelly should be applied over the terminals.
10. A battery should be overcharged after every 3 to 4 months to wipe out the traces of impurities on the electrode plates. If this is not done, the internal resistances of the cells increase

Precautions to be taken for lead acid battery

1. Store or recharge lead-acid batteries in a well-ventilated area away from sparks or open flames.
2. Wear acid-resistant goggles/face shield, gloves, and if available, an apron, when recharging or handling lead-acid batteries.
3. Keep lead-acid battery vent caps securely in place.
4. Never overcharge a lead-acid battery and only refill fluid with distilled water.
5. Never attempt to short-circuit a battery. Doing so can damage the product and generate heat that can cause burns.
6. Never attempt to charge a battery which has been physically damaged
7. Do not keep any inflammable liquid like Petrol near the battery.
8. Do not place any metal objects like screwdriver or spanner on the battery. This may cause shorting of terminals.
9. Do not wear metal bangle / metal wear in hand to prevent shorting/burning.
10. The connectors should be firmly attached to the battery terminals.

Methods of charging the storage batteries

a) Constant Voltage Charging

In this method the charging voltage is kept constant so the current is high in the beginning when a battery is in discharged condition, and it gradually decreases as the battery picks up charge and its back emf is increased.

The batteries are connected in Parallel.

charging time is almost reduced to half, capacity is increased by 20% but efficiency is reduced by 10% (approx)

a) Constant Current Charging

In this method the batteries are connected in series.

The charging current is kept constant throughout the charging period by reducing the resistance in the circuit as the battery voltage goes up.

Usually employed for initial charging of lead-acid batteries and for charging portable batteries in general.

Applications of Lead Acid battery.

1. Used in automobiles for starting and lighting
2. Used in generating stations and Substations to operate protective devices and emergency lighting
3. Used Un-interrupted Power Supply (UPS)
4. Used in Emergency Lighting
5. Used in telephone exchange

Applications of Lithium Ion Battery.

1. Used in mobile phones, Laptops
2. Used in cameras and calculators
3. Used in Electric vehicles
4. Used in toys and rechargeable flash lights
5. Used in aerospace applications.

@ShameemSir
Sarcastic Teacher

Comparison of Lead Acid and Lithium ion battery

	Lead Acid	Lithium Ion
Anode	PbO_2	$LiCoO_2$
Cathode	Pb	Carbon
Electrolyte	H_2SO_4	Lithium salt with organic solvent
Specific power	180 W/kg	340 W/kg
Specific Energy	50 Wh/kg	265 Wh/kg
Energy density	50-100 Wh/m^3	690 Wh/m^3
Cycle life	200-300 cycles	1200 Cycles
Cost	Low cost	Costly
Rated Voltage	2.2 Volt	3,6 Volt

Comparison of Lead Acid and Lithium ion battery

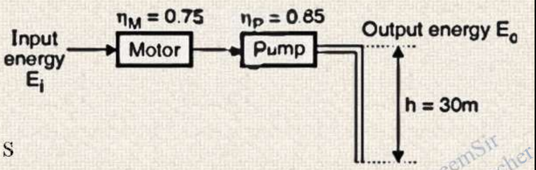
	Lead Acid	Lithium Ion
Maintenance	Maintenance required	Maintenance free
Charging	Slow and inefficient	Fast charging
Handling	Difficult	Easy
Use	Car, motorcycle, UPS, Emergency lighting	Mobile phone, Laptop, Camera, Electric vehicles

Finding the power Bill

- Motor pump
- Appliances power and operation time

Ex. 10.6.22 : An electric pump lifts 80 m^3 of water per hour to a height of 30 m. The pump efficiency is 85% and the motor efficiency is 75%. If the pump is used for 4 hours daily, calculate the energy consumption per month and energy charges at rate of ` 10/kWhr. **May 09, 8 Marks**

m = 80 x 1000 = 80000 kg
h = 30 m,
η_P=0.85, η_M=0.75,
t =4 hours = 4 x 3600 = 14400 s
Rate = 10/kWhr



Calculate output energy E_o :

$$E_o = m \times g \times h = 80 \times 10^3 \times 9.81 \times 30$$

$$= 23.544 \times 10^6 \text{ J} \qquad ...(1)$$

Input energy :

$$E_i = \frac{E_o}{\eta_M \eta_P} = \frac{23.544 \times 10^6}{0.75 \times 0.85} = 36.93 \times 10^6 \text{ J} \qquad ...(2)$$

This is the input energy per hour.

But $E_i = V \times I \times t$

$$\therefore \quad V \times I = \frac{E_i}{t} = \frac{36.93 \times 10^6 \text{ J}}{3600 \text{ sec}} = 10258.82 \text{ W}$$

Energy charges per month
= 1231.06 Wh x10/kWh
=12310.6/-

Energy consumption per month = Vx I x t
= 10258.82 W x 4h x 30 days
= 1231058.8 Wh = 1231.06 kWh

Pyq

- phase sequence
- balanced and unbalanced load
- emf equation of 1-phase transformer.
- laminations used in transformer core
- losses ? How to minimize?
- relation between phase values and line values of voltage and current in case of balanced star connected 3-ph inductive load.
- RYB. phasor diagram.