

Biyani's Think Tank

Concept based notes

Utilization of Electrical Power

(B.Tech)

Disha

Lecture

Deptt. of Information Technology
Biyani Girls College, Jaipur



Published by :

Think Tanks
Biyani Group of Colleges

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Sector-3, Vidhyadhar Nagar,

Jaipur-302 023 (Rajasthan)

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Edition : 2013

Price :

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Biyani College Printing Department

Preface

I am glad to present this book, especially designed to serve the needs of the students. The book has been written keeping in mind the general weakness in understanding the fundamental concepts of the topics. The book is self-explanatory and adopts the “Teach Yourself” style. It is based on question-answer pattern. The language of book is quite easy and understandable based on scientific approach.

Any further improvement in the contents of the book by making corrections, omission and inclusion is keen to be achieved based on suggestions from the readers for which the author shall be obliged.

I acknowledge special thanks to Mr. Rajeev Biyani, *Chairman* & Dr. Sanjay Biyani, *Director (Acad.)* Biyani Group of Colleges, who are the backbones and main concept provider and also have been constant source of motivation throughout this Endeavour. They played an active role in coordinating the various stages of this Endeavour and spearheaded the publishing work.

I look forward to receiving valuable suggestions from professors of various educational institutions, other faculty members and students for improvement of the quality of the book. The reader may feel free to send in their comments and suggestions to the under mentioned address.

Note: A feedback form is enclosed along with think tank. Kindly fill the feedback form and submit it at the time of submitting to books of library, else NOC from Library will not be given.

Author

7 SEM, EEE**UTILIZATION OF ELECTRICAL POWER**

Unit-1 (i) Electric Heating: Different methods of electric heating. Principle of high frequency induction and di-electric heating. Construction, operation, performance and applications of arc furnace and induction furnace. (ii) Electric Welding: Welding process, welding transformer, Classification of Electric Welding: arc welding, resistance welding, welding of various metals.

Unit-2 Illuminations: Definitions, laws of illuminations, polar curves, luminous efficiency, photometer, incandescent lamps: filament materials, halogen lamp. Electric discharge lamps: sodium vapour lamp mercury vapour lamp and fluorescent lamp. Light Calculations: commercial, industrial, street and flood lighting.

Unit-3 Electrolytic Process: Principles and applications of electrolysis, electrodeposition, manufactures of chemicals, anodizing, electro polishing electro-cleaning, electroextraction, electrorefining, electro-stripping (parting) power supplies for electrolytic process.

Unit-4 Electric Traction & Means of Supplying Power: Systems of Electric Traction: DC & AC Systems, Power Supply for Electric Traction System: Comparison and application of different systems. Sub-station equipment and layout, conductor rail & pantograph.

Unit-5 Traction Methods: Types of services, speed time and speed distance curves, estimation of power and energy requirements, Mechanics of train movement. Co-efficient of adhesion, Adhesive weight, effective weight. Traction Motor Controls: DC and AC traction motors, Series parallel starting. Methods of electric braking of traction motors.

Reference/Suggested Books:

1. H. Partab, "Art and Science of Electrical Energy" Dhanpat Rai & Sons
2. H. Partab, "Modern Electric Traction" Dhanpat Rai & Sons.
3. C.L. Wadhwa – Utilization of Electric Traction Electric Power.
4. G.K.Dubey, "Fundamentals of Electric Drives" Narosa Publishing House.

Unit 1

Q1. Define electric heating? What are the advantages of heating?

Ans:

Heating is required for domestic purposes as well as industrial purposes. Industrial applications include

- Melting of Metals
- Hardening
- Tempering
- Case Hardening
- Drying
- Melting

Electric heating is any process in which electrical energy is converted to heat. Common applications include heating of buildings, cooking, and industrial processes.

An electric heater is an electrical appliance that converts electrical energy into heat. The heating element inside every electric heater is simply an electrical resistor, and works on the principle of joule heating: an electric current flowing through a resistor converts electrical energy into heat energy.

A heat pump uses an electric motor to drive a refrigeration cycle, drawing heat from a source such as ground water or outside air and directing it into the space to be warmed. Such systems can deliver two or three units of heating energy for every unit of purchased energy.

Main Advantages of Electric Heating are:

1. Economy
2. Cleanliness
3. Absence of Flue Gases
4. Ease of Control
5. Automatic Protection
6. Upper Limit of Protection

- 7.Special Heating Requirement
- 8.High Efficiency of Utilization
- 9.Better Working Conditions
- 10.Safety

Heat can be transfer by any one of these modes:

Modes of Transfer of Heat

- 1.Conduction
- 2.Convection
- 3.Radiation

1. Conduction:

In this mode of transfer of heat, one molecule of the substance gets heated and transfer the heat to the adjacent and so on.

Rate of conduction of heat along a substance depends upon temperature gradient.

$$Q = \frac{kA}{t}(T_1 - T_2)T$$

2. Convection

Convection is the movement of molecules within fluids (i.e. liquids, gases).

It cannot take place in solids, since neither bulk current flows nor significant diffusion can take place in solids.

3. Radiation:

Radiation is a process in which energetic particles or energy or waves travel through a medium or space.

Q2. What are the types of electric heating? Describe resistance heating.

Ans:

Classification of Electric Heating:

It can be classified as:

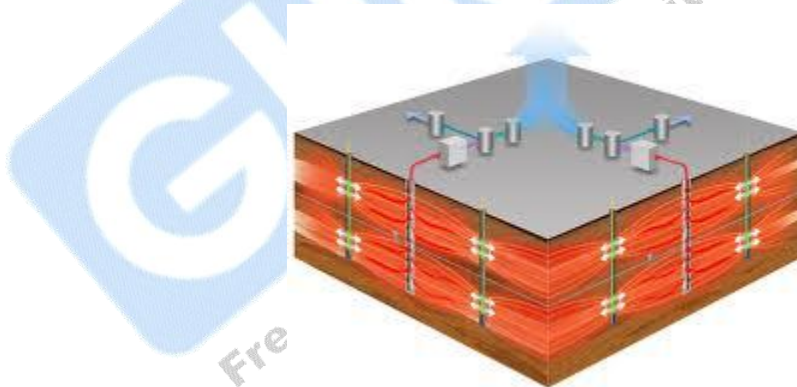
- Direct Resistance Heating
- Indirect Resistance Heating
- Infra-red or Radiant Heating
- Arc Heating
- Direct Induction Heating

- Indirect Induction Heating
- Dielectric Heating

Resistance heating:

Electric heating is any process in which electrical energy is converted to heat. Common applications include space heating, cooking, water heating and industrial processes. An **electric heater** is an electrical appliance that converts electrical energy into heat. The heating element inside every electric heater is simply an electrical resistor, and works on the principle of Joule heating: an electric current through a resistor converts electrical energy into heat energy. Most modern electric heating devices use nichrome wire as the active element. The heating element, depicted on the right, uses nichrome wire supported by heat resistant, refractory, electrically insulating ceramic.

Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, drawing energy from a source such as the ground or outside air and directing it into the space to be warmed.



Electrical resistance heating is used by the environmental restoration industry for remediation of contaminated soil and groundwater. ERH consists of constructing electrodes in the ground, applying alternating current (AC) electricity to the electrodes and heating the subsurface to temperatures that promote the evaporation of contaminants. Volatilized contaminants are captured by a subsurface vapor recovery system and conveyed to the surface along with recovered air and steam. Similar to Soil vapor extraction,

the air, steam and volatilized contaminants are then treated at the surface to separate water, air and the contaminants. Treatment of the various streams depends on local regulations and the amount of contaminant.

Q3. Write a short note on induction heating.

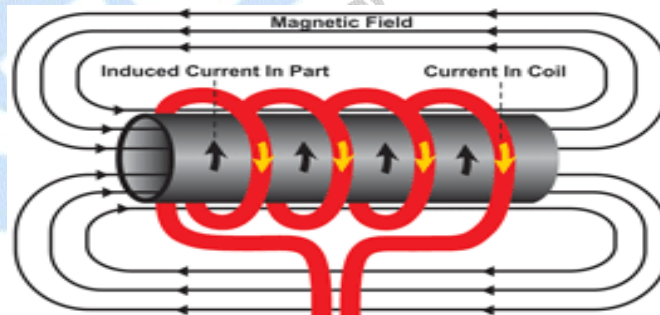
Ans:

Induction heating:

Induction heating is a process which is used to bond, harden or soften metals or other conductive materials. For many modern manufacturing processes, induction heating offers an attractive combination of speed, consistency and control.

Induction heating is a non-contact heating process. It uses high frequency electricity to heat materials that are electrically conductive. Since it is non-contact, the heating process does not contaminate the material being heated. It is also very efficient since the heat is actually generated inside the workpiece. This can be contrasted with other heating methods where heat is generated in flame or heating element, which is then applied to the workpiece. For these reasons Induction heating leads itself to some unique applications in industry.

It helps to have a basic understanding of the principles of electricity. When an alternating electrical current is applied to the primary of a transformer, an alternating magnetic field is created. A source of high frequency electricity is used to drive a large alternating current through a coil. This coil is known as the work coil. See the picture opposite.



In a basic induction heating setup shown at right, a solid state RF power supply sends an AC current through an inductor (often a copper coil), and the part to be heated (the workpiece) is placed inside the inductor. The inductor serves as the transformer primary and the part to be heated becomes a short circuit secondary. When a metal part is placed within the

inductor and enters the magnetic field, circulating eddy currents are induced within the part.

The passage of current through this coil generates a very intense and rapidly changing magnetic field in the space within the work coil. The workpiece to be heated is placed within this intense alternating magnetic field.



Q4. Write a note on dielectric heating.

Ans:

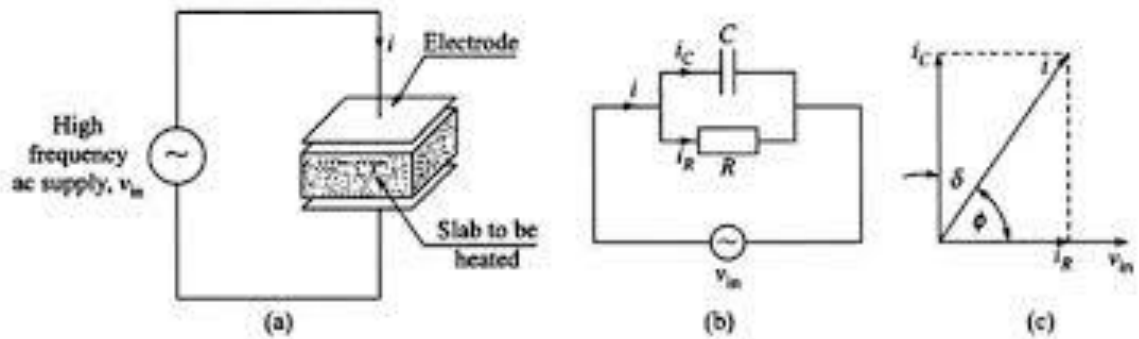
Dielectric heating which is known as electronic heating, RF heating, high-frequency heating is the process in which a high-frequency alternating electric field, or radio wave or microwave electromagnetic radiation heats a dielectric material. At higher frequencies, this heating is caused by molecular dipole rotation within the dielectric. At lower frequencies in conductive fluids, other mechanisms such as ion-drag are more important in generating thermal energy.

Molecular rotation occurs in materials containing polar molecules having an electrical dipole moment, with the consequence that they will align themselves in an electromagnetic field. If the field is oscillating, as it is in an electromagnetic wave or in a rapidly oscillating electric field, these molecules rotate continuously aligning with it. This is called dipole rotation, or Dipolar Polarisation. As the field alternates, the molecules reverse direction. Rotating molecules push, pull, and collide with other molecules (through electrical forces), distributing the energy to adjacent molecules and atoms in the material. Once distributed, this energy appears as heat.^[2]

Temperature is the average kinetic energy (energy of motion) of the atoms or molecules in a material, so agitating the molecules in this way increases the temperature of the material. Thus, dipole rotation is a mechanism by which energy in the form of electromagnetic radiation can raise the temperature of an object. There are also many other mechanisms by which this conversion occurs.

Dipole rotation is the mechanism normally referred to as dielectric heating, and is most widely observable in the microwave oven where it operates most efficiently on liquid water, and much less so on fats and sugars. This is because fats and sugar molecules are far less polar than water molecules, and thus less affected by the forces generated by the alternating electromagnetic fields. Outside of cooking, the effect can be used generally to heat solids, liquids, or gases, provided they contain some electric dipoles.

Dielectric heating involves the heating of electrically insulating materials by dielectric loss. A changing electric field across the material causes energy to be dissipated as the molecules attempt to line up with the continuously changing electric field. This changing electric field may be caused by an electromagnetic wave propagating in free space (as in a microwave oven), or it may be caused by a rapidly alternating electric field inside a capacitor. In the latter case there is no freely propagating electromagnetic wave, and the changing electric field may be seen as analogous to the electric component of an antenna near field. In this case, although the heating is accomplished by changing the electric field inside the capacitive cavity at radio-frequency (RF) frequencies, no actual radio waves are either generated or absorbed. In this sense, the effect is the direct electrical analog of magnetic induction heating, which is also near-field effect (and also does not involve classical radio waves

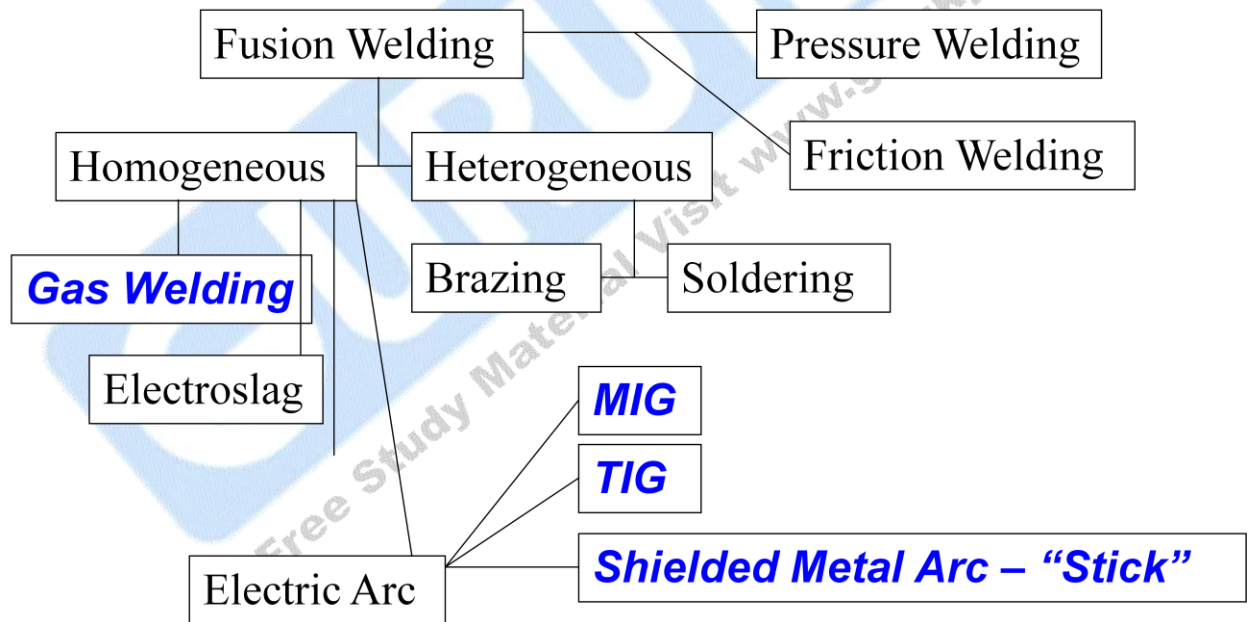


Q5. Define welding and describe its types.

Ans:

It is a process of joining two or metals metals together by means of current or any how.

Types of Welding



Fusion Welding Principles:

In this type of welding the Base metal is melted and the Filler metal may be added.

The Heat is supplied by various means

- Oxyacetylene gas
- Electric Arc
- Plasma Arc
- Laser

During fusion welding, the molten metal in the weld “puddle” is susceptible to oxidation. And it must protect weld puddle (arc pool) from the atmosphere. This can be done by any one of these methods:

- Weld Fluxes
- Inert Gases
- Vacuum

The flux used in this process are : SiO_2 , TiO_2 , FeO , MgO , Al_2O_3 .

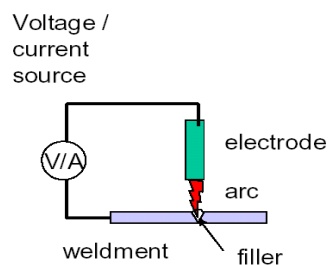
This will produces a gaseous shield to prevent contamination and will act as scavengers to reduce oxides. This flux also add alloying elements to the weld.

Inert Gases used in fusion welding are: Argon, helium, nitrogen, and carbon dioxide. These gases form a protective envelope around the weld area. These gases can be used in

- MIG
- TIG
- Shield Metal Arc

Electric Arc Welding

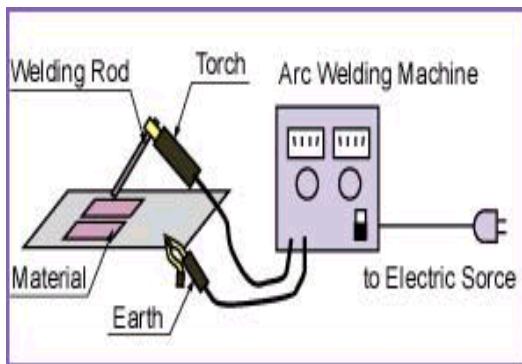
The heat for fusion is supplied by an electric arc. Arc is formed between electrode and work this melts and fuses the joint edges .



Types of Electric Arc Welding :

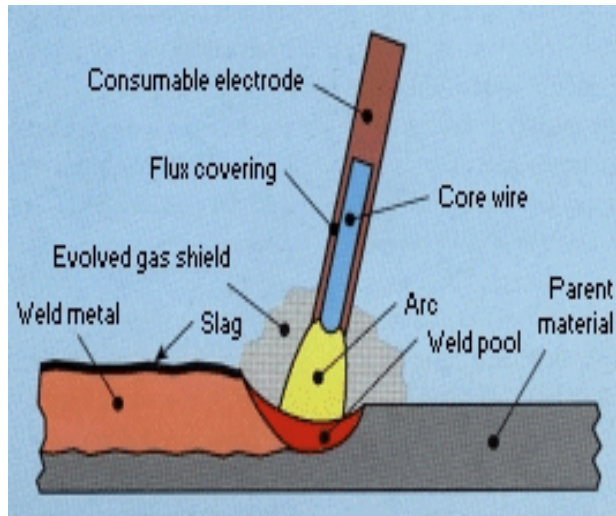
- Manual Metal Arc (MMA)
- Metal Arc Gas Shielded (MAGS) *MIG*
- Tungsten Arc Gas Shielded (TAGS) *TIG*
- Submerged Arc Welding (SAW)
- Manual Metal Arc (MMA)

The most widely used of all the arc welding processes is commonly called “stick” welding .

**Working:**

Touch the electrode against work withdraw electrode to establish arc. Heat of arc melts base metal, the electrode's metal core, and any metal particles in electrode's covering.

Heat also melts, vaporises, or breaks down chemically non-metallic substances in covering for arc shielding. Mixing of molten base metal and filler metal from electrode produces coalescence required to effect joining.



The Electrode and Coating used:

Coating is a combination of chemicals

- Cellulosic electrodes contain cellulose
- Rutile electrodes titanium oxide (rutile)
- Basic electrodes contain calcium carbonate (limestone) and calcium fluoride (fluorspar)

The Function of Electrode Coating is to Produce gas to shield weld pool from oxidising effects of atmosphere and the fluxing elements help weld pool to form. It also helps slag to form-removes impurities it can contain alloying elements or additional filler metal .

In this process we can use both ac and dc supply. In AC power source it takes power directly from mains power supply. It use a transformer to supply the correct voltage to suit the welding conditions.

DC power source can be used as two types:

DC generator

Transformer-rectifier

DC Generator

An electricity generator is driven by a motor. The motor can be electric, petrol or diesel. The generator provides DC current for the arc .

Transformer-rectifier :

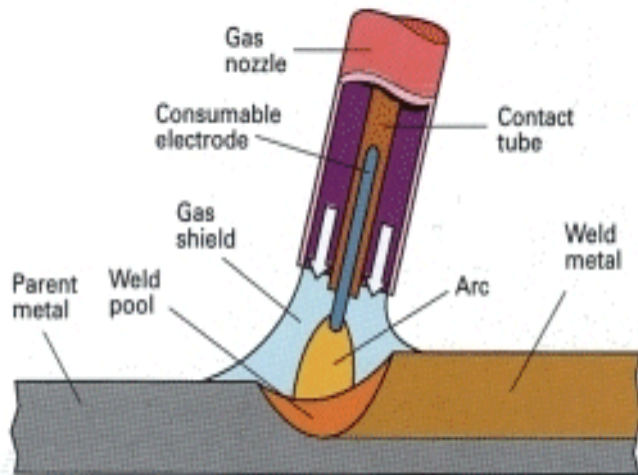
A transformer with an electrical device to change AC to DC, this is known as a rectifier. It has the advantage of being able to supply both DC and AC.

Applications:

repair work, structural steelwork.

- Metal Arc Gas Shielded (MAGS) *MIG*

MIG is similar to MMA in that heat for welding is produced by forming an arc between a metal electrode and the workpiece the electrode melts to form the weld bead. The main difference is that the metal electrode is a small diameter wire fed from a spool and a shielding gas is used. As the wire is continuously fed, the process is often referred to as semi-automatic welding.



Three major elements used in this welding are :

- Welding torch and accessories
- Welding control & Wire feed motor
- Power Source
- Shielding gas

The welding torch guides the wire and shielding gas to the weld zone. Brings welding power to the wire also major components/parts of the torch are the contact tip, shielding gas nozzle, gas diffuser, and the wire conduit. Its main function is to pull the wire from the spool and feed it to the arc. This also controls wire feed speed and regulates the starting and stopping of wire feed .

Power source used in this process are:

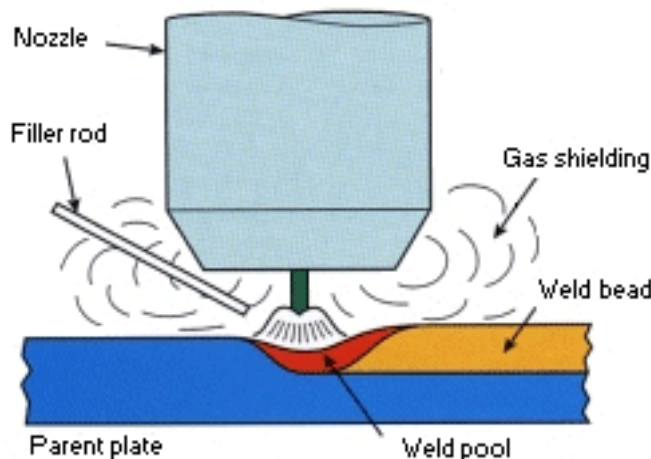
Positive (+) lead is connected to the torch

Negative (-) lead is connected to the work piece

The purpose of shielding gas is to protect the weld area from the contaminants in the atmosphere. The Gas used can be Inert, Reactive, or Mixtures of both. Argon, Helium, and Carbon Dioxide are the main three gases used in MAGS .

- **Tungsten Arc Gas Shielded (TAGS) TIG**

TIG is similar to MMA in that heat for welding is produced by forming an arc between a metal electrode and the workpiece . In the TIG process the arc is formed between a pointed tungsten electrode and the work piece in an inert atmosphere of argon or helium. The small intense arc provided by the pointed electrode is ideal for high quality and precision welding.



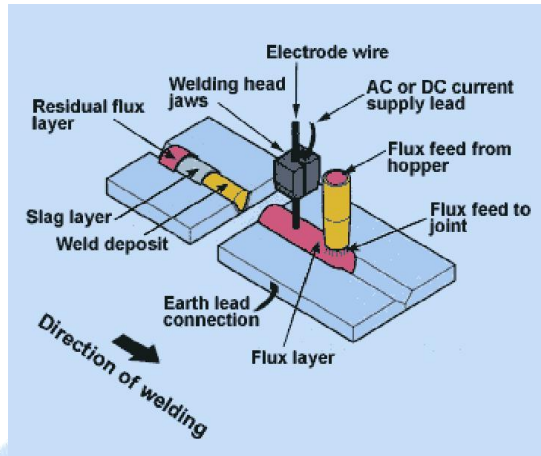
The electrode is not consumed during welding. When filler metal is required, it must be added separately to the weldpool. There are two currents one for starting the arc the other switched on using a trigger or foot pedal, this is a high frequency current to maintain the arc, this is generated by a separate unit.

TIG must be operated with a constant current power source - either DC or AC. Electrodes for DC welding are normally pure tungsten. In AC welding, as the electrode will be operating at a much higher temperature, It should be noted that because of the large amount of heat generated at the electrode, it is difficult to maintain a pointed tip and the end of the electrode assumes a spherical or 'ball' profile.

Shielding gas is selected according to the material being welded. Argon , Argon + Hydrogen, Argon/Helium. Helium is generally added to increase heat input (increase welding speed or weld penetration). Hydrogen will result in cleaner looking welds and also increase heat input, however, Hydrogen may promote porosity or hydrogen cracking.

- **Submerged Arc Welding (SAW)**

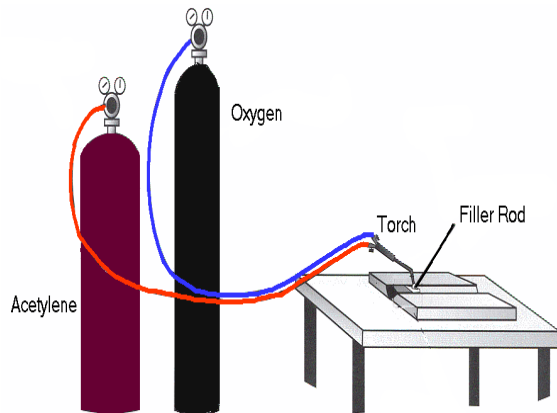
Similar to MIG welding, SAW involves formation of an arc between a continuously-fed bare wire electrode and the workpiece. This process uses a flux to generate protective gases and slag, and to add alloying elements to the weld pool. A shielding gas is not required. Prior to welding, a thin layer of flux powder is placed on the work piece surface. The arc moves along the joint line and as it does so, excess flux is recycled via a hopper. Remaining fused slag layers can be easily removed after welding. As the arc is completely covered by the flux layer, heat loss is extremely low. There is no visible arc light, welding is spatter-free and there is no need for fume extraction.



- **Gas Welding (Oxy-acetylene)**

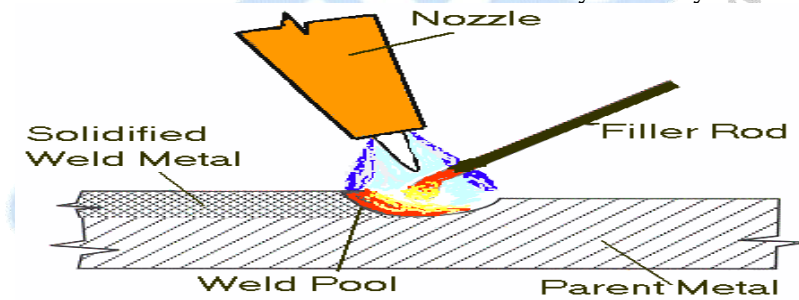
A number of welding processes use a flame produced by burning a mixture of *fuel gas* and *oxygen*. The gas usually used is *Acetylene* but other gases are also used.

Separate cylinders and a hose pipe from each cylinder transports the gases to a torch. Gas and fuel mix in the torch burns @ 3100°C.



During the welding heat from the flame is concentrated on the joint edges until the metal melts and starts to flow. When the molten metal from both sides melts it starts to fuse, when the metal cools down the two parts become *Permanently* joined . Additional *Filler Metal* is fed in by hand into the weld pool, at regular intervals where it becomes molten and joins with the parent metal.

Oxygen extracted from air and compressed into cylinders at high pressure. Cylinder is black. Oil should never be brought into contact and should not be used on fittings . Acetylene (C_2H_2) is a fuel gas. Cannot be compressed directly as explodes at high pressures. Cylinders are packed with porous material which is filled with acetone Acetone absorbs acetylene. Cylinder colour coded maroon .



- **Resistance welding**

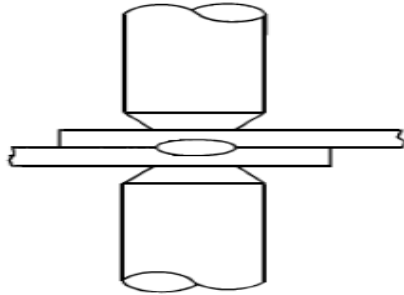
Resistance welding uses the application of electric current and mechanical pressure to create a weld between two pieces of metal. Weld electrodes conduct the electric current to the two pieces of metal as they are forged together. The welding cycle must first develop sufficient heat to raise a small volume of metal to the molten state. This metal then cools while under pressure until it has adequate strength to hold the parts together. The current density and pressure must be sufficient to produce a weld nugget, but not so high as to expel molten metal from the weld zone.

It can be of following types:

- Spot welding
- Seam Welding

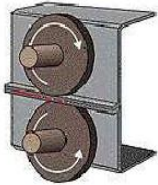
Spot welding :

It is ideal for joining light sheet metal. The electrodes are made from copper. Pressure is applied to the electrodes and an electric current is passed through the circuit. The high resistance between the joint faces causes rapid heating and fusing of a small globule of metal from both faces.



Seam welding :

In this type of welding the rollers allow the workpiece to move through the welder continuously. A stream of electrical pulses pass through the rollers and welds the joint .



Friction welding:

In this process one part is held stationary while the other part is rotated. When the parts are hot enough the rotation is stopped and the parts forged together.

Unit :2

Q1. What is illumination? Describe the law of illumination.

Ans: Sun is a prime natural source of light but artificial lighting plays almost main role in our daily life. These artificial lights are produced by mechanical lamps and electrical lamps. That part of radiant energy from a hot body which produced the visual sensation on human eye is called light.

When light falls on a surface, it becomes visible, the phenomenon is called as illumination.

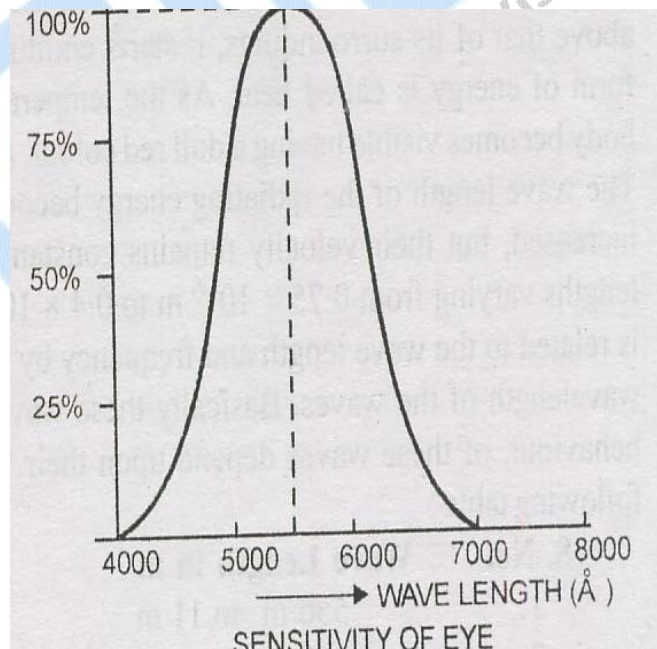
It is defined as luminous flux falling on a surface per unit area. It is denoted by E and measured in lumen per square meter or meter- candle.

$$E = \Phi / A \text{ lux}$$

But due to poor performance the mechanical light are totally replaced by electrical lights. The electrical lighting are mainly used for decorative purpose, advertising, traffic control , medical field and street lighting etc.

Natural light consists of seven colors having different wavelengths. The average human eye is most sensitive to a wave length of 5500 \AA .

The relative sensitivity of eye for a particular wave length is the visual effect produced by the light on the average human eye as compared with the effect of light having wave length 5500 \AA on human eye.



Sensitivity of Human eye

This is also known as Relative luminosity Factor.

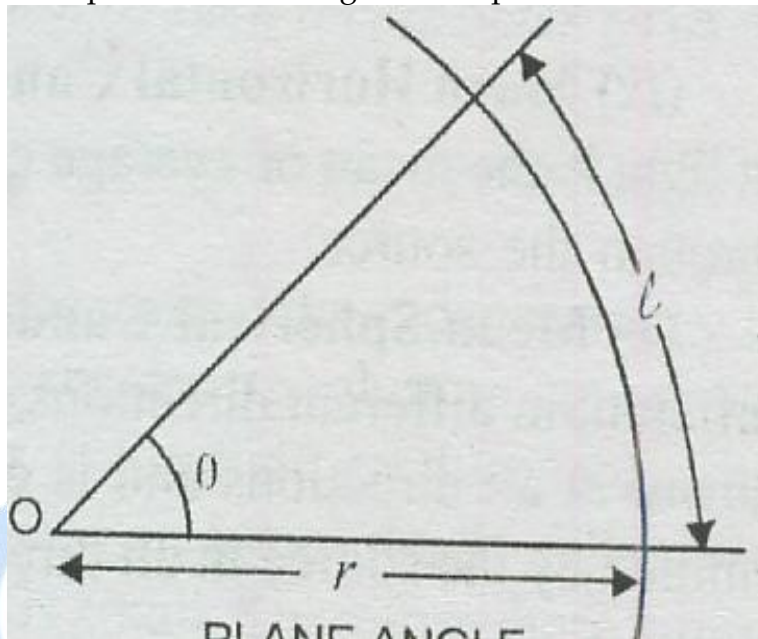
Terms used in Illumination:

Luminous Flux:

The total quantity of radiant energy per second responsible for visual sensation from a luminous body is called Luminous Flux. It is represented as Φ and measured in lumens.

Lumen:

It is the unit of luminous flux. One lumen is defined as the luminous flux emitted per unit solid angle from a point source of one candle power.



The angle subtended at a point by two converging lines lying in the same plane is called plane angle. It is measured in radians and equal to the ratio of the length of the arc to its radius,

$$\theta = \text{arc} / \text{radius} = l / r \text{ radians}$$

Luminous Intensity:

Luminous intensity in any particular direction is the luminous flux emitted by the source per unit solid angle in that direction. It is denoted by I and its unit is candela or candle power (CP).

Luminous intensity of source in a particular direction, $I = \Phi / \omega$

Lux:

One meter candle or lux is defined as the illumination produced by a uniform source of one CP on the inner surface of a sphere of radius one meter.

Lamp Efficiency:

It is defined as the visible radiations emitted by it in lumens per watt. Usually, the light sources do not radiate energy only in the visible spectrum. The radiant energy is also accompanied with infrared and ultra violet radiations. Sun light produces majority of radiations in the visible spectrum. The tungsten lamp produces small radiations so its efficiency is very poor.

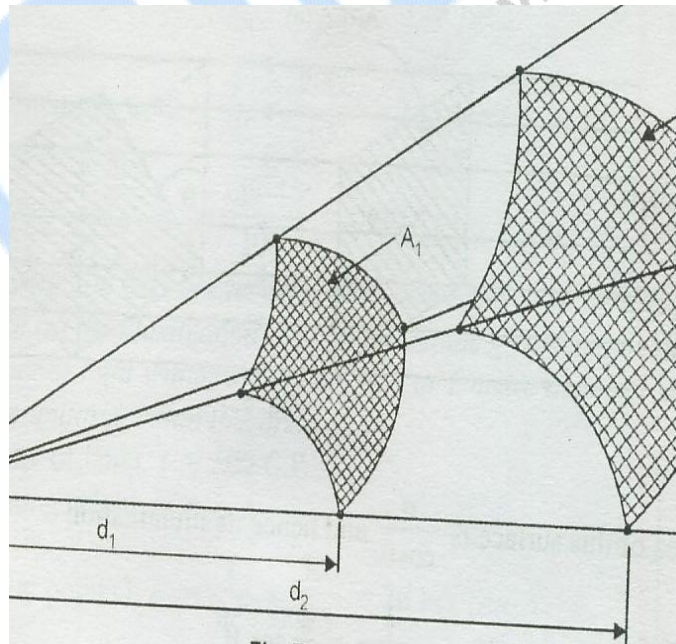
Law of Illumination:

The illumination on a surface depends upon the luminous intensity, distance between the source and surface and the direction of rays of light. It is governed by following laws :

- Inverse square law
- Lambert's cosine law

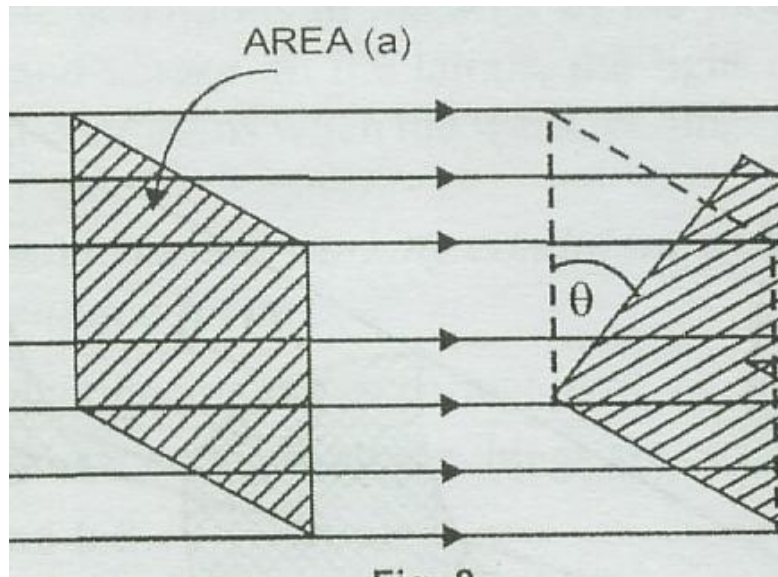
Inverse Square Law:

It states that the illumination of a surface is inversely proportional to the square of the distance of the surface from the source. $E \propto 1/d^2$



Lambert's Cosine Law:

This law states that the illumination on any surface is proportional to the cosine of angle between the direction of the incident flux and perpendicular to the area. $E = 1/d^2 \cos \theta$



Q2. Describe in detail the electric arc lamp.

Ans:

The principle of an arc lamp is that when two electrodes carrying current are separated through a small distance, an arc is struck between them. The arc lamps were used in the past for street lighting purposes but now a day these are used when extreme brightness is required.

Most commonly use arc lamp is Carbon Arc Lamp.

This is the oldest type of lamp and is still being employed in cinema projectors and search lights. It consists of two hard carbon rods (Electrodes). The diameter of +ve electrode is double to that of -ve electrode. The -ve electrode is generally fixed and +ve electrode is placed in adjustable holder and the process is manually or automatic. The arc consists of carbon vapors surrounded by orange red zone of burning carbon and pale green flames.

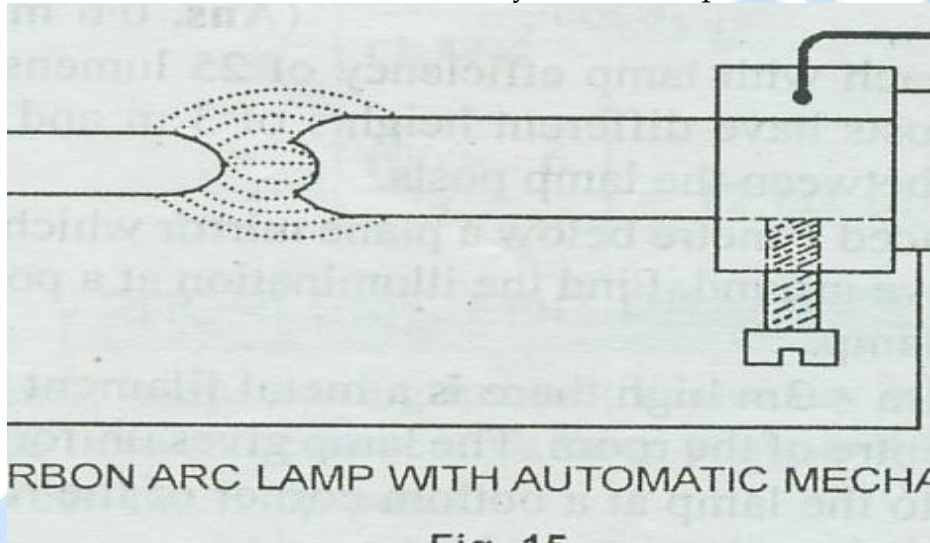
When the lamp is OFF, the two electrodes are touching each other due to spring pressure on +ve electrode. When the supply is ON a large current is

flow through electrodes. The temperature of carbon electrode is increased and thus the +ve electrode is pulled away against its spring pressure through a small distance by coil and thus an arc is struck between electrodes. This arc is maintained by transfer of carbon particles from one electrode to other electrode.

These particles travel from +ve electrode to -ve electrode, thus after sometime of operation +ve electrode become hollow and -ve become pointed.

That's why +ve electrode is made double than -ve electrode.

In carbon arc lamp 85 % of light is given by +ve electrode which produces high intensity light and only 10 % by -ve electrode and 5 % by air. The temperature of +ve electrode is 4000 °C and that of -ve electrode is about 2500 °C. The luminous efficiency of such lamps is about 9 lumen/watt.



For maintaining the arc, a minimum voltage required is given by : $V = (39 + 28 L)$, where L is length of arc in centimeter.

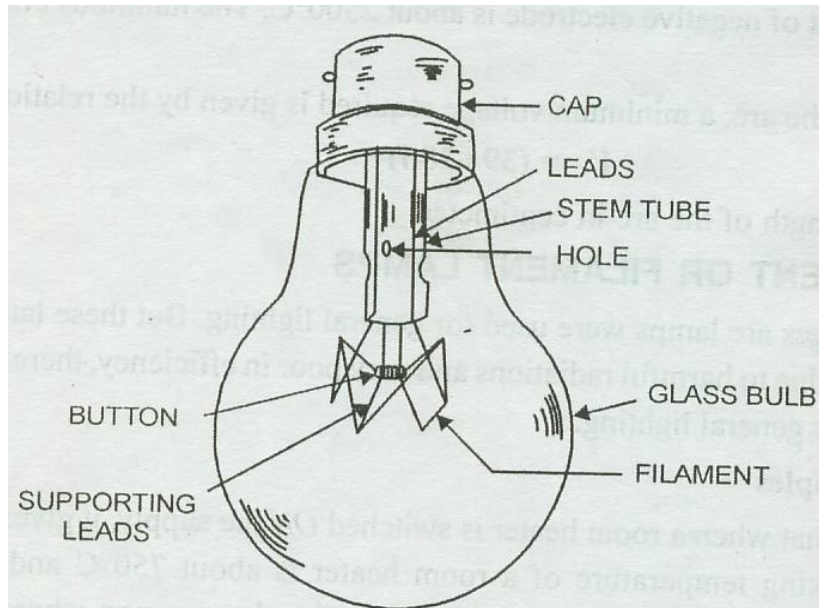
Q3. Describe in detail the working of incandescent lamp/filament lamp.

Ans:

When a room heater is switched On , it gives out red light with heat at the working temperature of 750 °C and at this temperature the radiations are mostly in infra red regions. This working principle is used to develop the filament lamp.

When an electric current is passed through a fine metallic wire , it raises the temperature of wire. At low temperature only heat is produced but at higher temperature light radiations goes on increasing. As filament lamp consists of

fine wire of high resistive material placed in an evacuated glass bulb. This type of lamps are operated at the temperature of 2500 °C .



A tungsten filament is enclosed in evacuated glass bulb but to improve its performance some chemical like argon or nitrogen gas are filled.

Properties of Metal for Filament:

- High melting point : so that it can be operated at high temperature.
- High specific resistance : so that it produces more heat.
- Low temperature coefficient : so that filament resistance may not change at operating temperature.
- Low vapor pressure ; so that it may not vaporize.
- High ductile : so that it may withstand mechanical vibrations.

Q4. Write the types of electric discharge lamps. And describe them.

Ans:

There are 2 types of discharge lamps.

Type 1:

Those lamps in which color of light is the same as produced by the discharge through the gas or vapour.

e.g. sodium vapor lamps, mercury vapor lamps, neon gas lamps.

Type 2:

Those lamps which use the phenomenon of fluorescence, they are known as fluorescent lamp. In these lamps, the discharge through the vapour produces ultra violet waves which causes fluorescence in certain materials called as phosphor. The inside of the fluorescent lamp is coated with a phosphor which absorbs invisible ultra violet rays and radiate visible rays.

e.g. fluorescent mercury vapor tube.

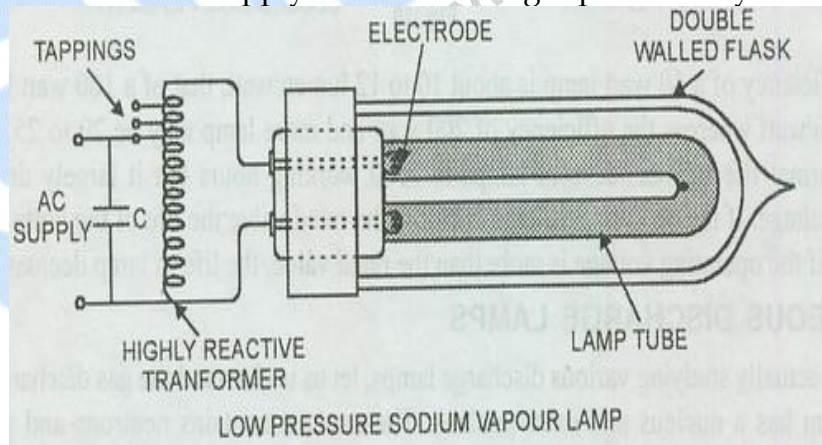
sodium vapor lamp:

Construction of sodium vapor lamp:

This lamp consists of discharge tube made from special heat resistance glass, containing a small amount of metallic sodium, neon gas and two electrodes. Neon gas is added to start the discharge and to develop enough heat to vaporised sodium. A long tube is required to get more light. To reduce overall dimensions of the lamp, the tube is generally bent into U-shape .

Working Principle :

An electric discharge lamps require a high voltage at starting and low voltage during operation. So at starting a voltage of 450 V is applied across the lamp to start the discharge. After 10 to 15 minutes, the voltage falls to 150 V because of low power factor. To improve the power factor a capacitor is connected across the supply. The color of light produce is yellowish.



Mercury vapor lamp:

On the basis of pressure inside the discharge tube, the mercury vapor lamps are classified as high pressure Mercury Vapor Lamp and low pressure Mercury Vapor Lamp.

High pressure M.V. Lamps are of following types :

M.A. type : these are operated at 220 -250 V A.C. main and made in 250 W and 400 W.

M.A.T. type : these are made in 300 and 500 W and operated at 200 -250 V A.C. as well as D.C.

M.B. type : This is operated at 200 - 250 V A.C. and made in 80 W and 125 W.

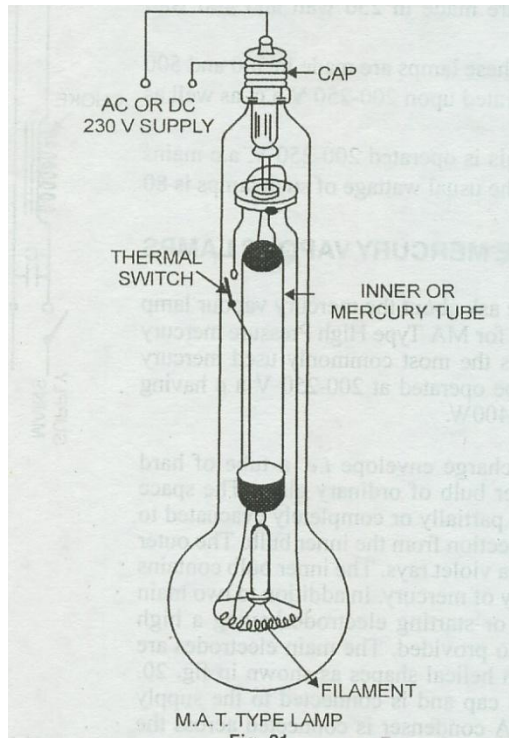
Construction :

It consists of hard glass tube enclosed in outer bulb of ordinary glass. The space between two bulbs are completely evacuated to prevent heat loss by convection from inner bulb. The outer bulb absorbs harmful ultra violet rays. The inner bulb contains argon gas with certain quantity of mercury. In addition with two electrodes on starting electrode having high resistance in series also provided. The main electrodes are made of tungsten wire in helical shape. The lamp has screwed cap and connected to supply with choke. A capacitor is connected across supply to improve power factor.

Working Principle :

When the supply is switched ON, full voltage is applied across main and starting electrodes. This voltage breaks down the gap and discharge through argon gas takes place. As the lamp warms up, mercury is vaporized , which increase the vapor pressure. This discharge takes the shape of intense arc. After 5 minutes, the lamp gives full light.

It gives greenish blue color light . this lamp is always suspended vertically, other wise inner glass tube may break due to excessive heat.



Neon Lamp:

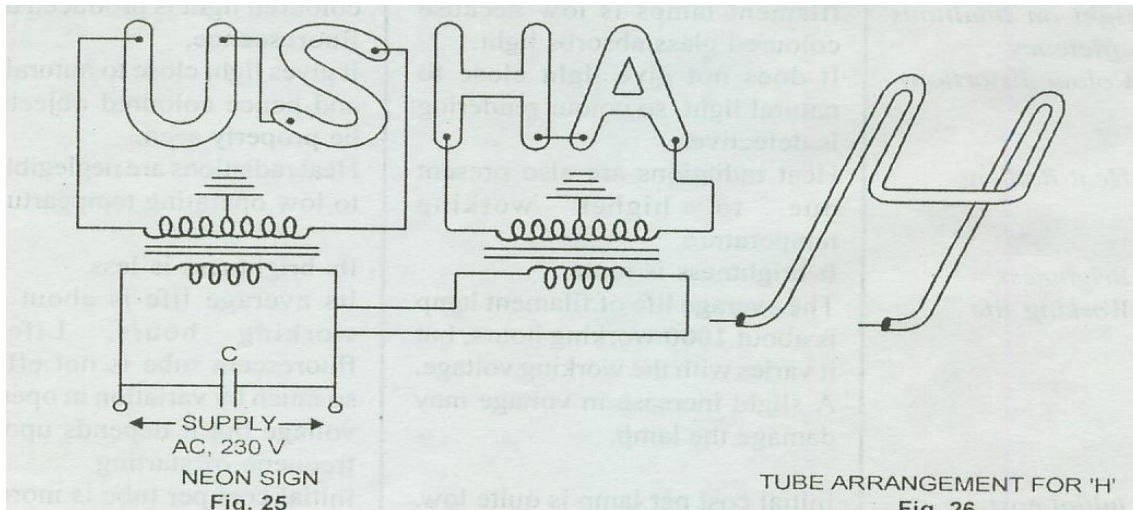
These lamps are operated at a very low temperature of about $200\text{ }^{\circ}\text{C}$ that's why these are called cold cathode discharge lamps.

Two electrodes are housed at the two ends of the tube which contain neon gas. The electrodes are made of iron or nickel cylinder without any coating and practically they do not emit electrons. It gives red light whereas with mixture of mercury and argon it gives bluish green color. Voltage require for starting and operation is 10000 V . This high voltage is obtained from transformer.

Working :

When the supply is switched ON at primary side of transformer, a voltage of 10000 V develops across secondary side which come across two electrodes. At this voltage a discharge occurs in neon gas.

Different colors can be obtained by changing the constituents of gases and mercury filled in the tubes.



Applications :

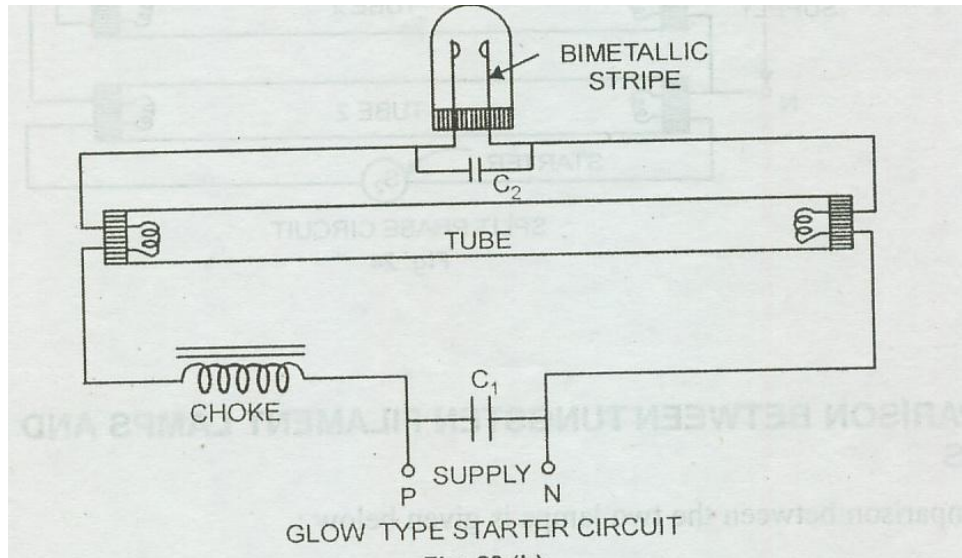
Neon lamps are generally used for advertising. Most of letters having two ends at which electrodes are placed. In letter having more than two ends , the tube path is repeated for some portion.

Fluorescent Tube:

it is a low pressure mercury vapor lamp. It consists of a glass tube 25 mm in diameter and 0.6 m, 1.2 m and 1.5 m in length. The tube contains argon gas at low pressure about 2.5 mm of mercury. At the two ends, two electrodes coated with some electron emissive material are placed.

The colors produce by this tubes are as :

Material	Color
Zinc silicate	Green
Calcium tungsten	Blue
Cadmium borate	Pink
Calcium Holo phosphate	White or day light
Magnesium tungsten	Bluish white

**Working :**

A choke is connected in series with the tube which act as a blast and provide a high voltage at starting glow in the tube. During running condition the same choke absorbs some supply voltage and remain a voltage of 110 V across the tube. A capacitor is connected to improve the power factor.

Advantages of Fluorescent Tube:

1. Voltage fluctuation has very small effect on light output.
2. The luminous efficiency is more as length of rod is more.
3. It gives light close to natural light.
4. Heat radiations are negligible.

Disadvantages of Fluorescent Tube:

1. Its brightness is less.
2. Initial cost is more
3. Overall maintenance cost is high.

Q5. What is photometer? Write the working principle of a photometer.

Ans:

The candle power of a source in any given direction is measured by comparing it with a standard or substandard source with the help of an optical instrument called PHOTOMETER.

The branch of optics which deals with the measurement of light is known as 'Photometry'. Photometers are mostly based on inverse square law of illumination and may be classified as stationary and portable photometers.

The stationary photometers are usually installed in a dark room with dead black walls and ceiling in order to eliminate error due to reflected light.

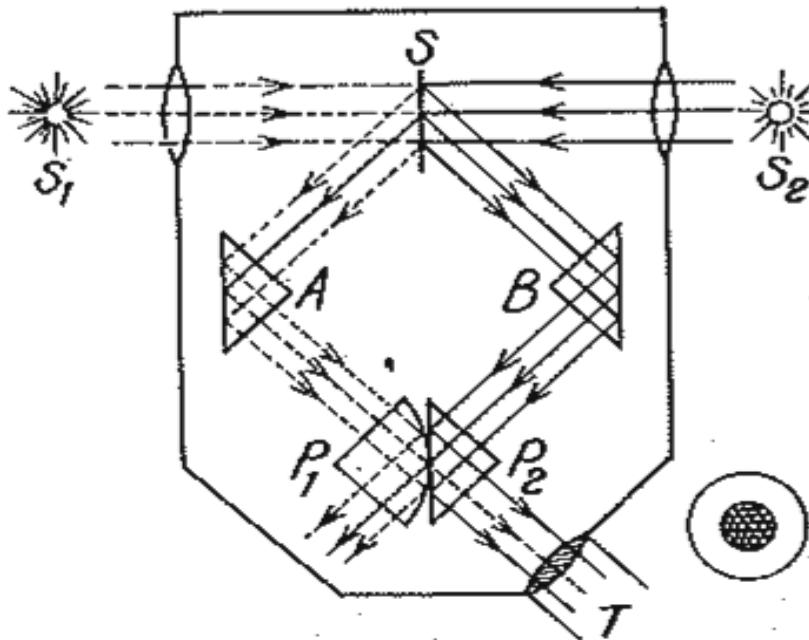
The portable photometers are direct reading instruments used to measure illumination in houses, offices, commercial and industrial places.

LUMMER - BRODHUN PHOTOMETER :

This is one of the most accurate photometers used for comparing the luminous intensities of two sources.

Screen 'S' : This is a specially prepared screen made of some white diffusing material of high reflecting power such as plaster of paris or magnesium carbonate.

The light rays from the two sources are incident on the two sides of this screen.



Totally reflecting prism P_1 and P_2 :

P_1 and P_2 are two isosceles right angled prisms whose angles are 45° , 90° and 45° . The light rays scattered from the screen 'S', fall normally on one face of the prism, enter into the prisms without any change in their direction, undergo total internal reflection and emerge normally from the other face of these prisms.

Lummer Brodhun Cube A and B :

It consists of two right-angled isosceles prisms A and B in contact with each other. The edges of prism A are cut in such a way that it is slightly curved at the outer edge while flat in the central part. The prisms are cemented together at the central part with Canada Balsam, whose refractive index is the same as that of the material of the prisms. The two prisms are in optical contact with each other at the central part and enclose an air film between them at other parts.

Telescope T :

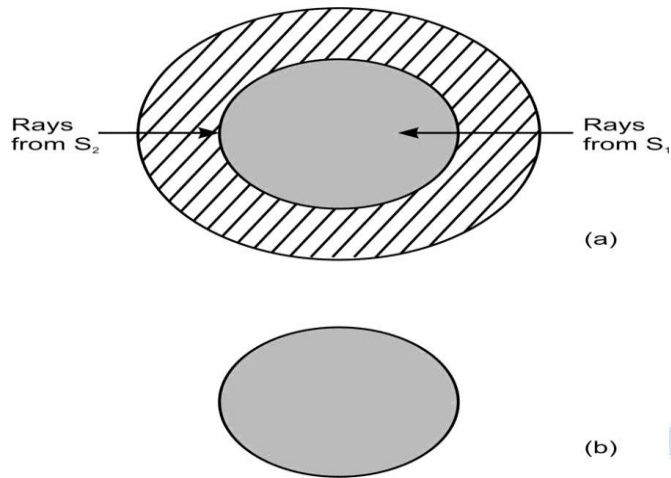
The telescope (T) is used to receive the light coming from Lummer - Brodhun cube. The whole apparatus is enclosed in a metallic box blackened from inside.

Working :

S_1 and S_2 are two sources whose luminous intensities are to be compared. These sources can be moved along an optical bench. They are placed on the opposite side of the screen 'S' at equal distances and illuminate the screen normally. The light rays reflected diffusively from each side of screen are incident on the prisms P_1 and P_2 . These light rays undergo total internal reflection from the prisms and fall on Lummer Brodhun cube.

The outer rays from the source S_1 undergo total internal reflection at prism 'A', while the middle ray passes into the prism 'B' through the point of contact of the prisms A and B without any deviation. The outer rays from S_2 undergo total internal reflection at 'B', while the middle ray passes into the prism 'A' through the point of contact without any deviation.

In this way, middle ray from source S_1 and outer rays from source S_2 enter into the telescope. Since the luminous intensities of the two sources are different, the field of view of the eyepiece of the telescope consists of a central part illuminated by light from S_1 and an outer part illuminated by light from S_2 of different brightness. Now the distances of S_1 and S_2 are adjusted in such a way that the field of view appears equally bright.



Q6. Classified the lighting schemes and describe them in detail.

Ans:

Lighting schemes are classified according to the location, requirement and purpose etc. are as under :

1. Direct lighting
2. Indirect lighting
3. Semi direct lighting
4. Semi indirect lighting
5. General lighting

Direct Lighting:

in this system almost 90 to 95 % light falls directly on the object or the surface. The light is made to fall upon the surface with the help of deep reflectors. Such type of lighting scheme is most used in industries and commercial lighting. Although this scheme is most efficient but it is liable to cause glare and shadows.

Indirect Lighting:

In this system, the light does not fall directly on the surface but more than 90 % of light is directed upwards by using diffusing reflectors. Here the ceiling acts as a source of light and this light is uniformly distributed over the surface and glare is reduced to minimum. It provides shadow less illumination which is useful for drawing offices and composing rooms. It is also used for decoration purposes in cinema halls, hotels etc.

Semi direct Lighting:

This is also an efficient system of lighting and chances of glare are also reduced. Here transparent type shades are used through which about 60 % light is directed downward and 40 % is directed upward. This also provides a uniform distribution of light and is best suited for room with high ceilings.

Semi indirect Lighting:

In this system about 60 to 90 % of total light is thrown upward to the ceiling for diffused reflection and the rest reaches the working plane directly. A very small amount of light is absorbed by the bowl. It is mainly used for interior decoration.

General Lighting:

This system employs such type of luminaries, shades and reflectors which give equal illumination in all the directions.

Design of Indoor Light Scheme:

While designing a good lighting schemes, the following points must be kept in mind :

1. It should provide adequate illumination.
2. It should provides uniformly distributed light all over working plane.
3. It should avoid glare and shadows as far as possible.
4. It should provide light of suitable colors.

Factors required for Light Scheme:

The following factors are required to be considered while designing the lighting scheme :

1. Illumination level
2. Quality of light
3. Co efficient of utilization
4. Depreciation factor
5. Space height ratio

Illumination Level:

This is the most vital factor in deciding the number and wattage of luminaries so that we are able to see and recognize the object properly. Colors of the body have the property of reflecting the light in different proportions, degree of illumination, its distance from the viewer, contrast between the object to be seen and its surroundings.

<u>Type of work</u>	<u>recommended illumination level</u>
Offices	100-400 lumens/ meter square
Schools	250-400 lumens/ meter square
Industry	1000 lumens/ meter square
Shops	250-500 lumens/ meter square
Hotels	80-100 lumens/ meter square
Hospitals	250-3500 lumens/ meter square

Quality of Light:

This means that the illumination should not be harmful to the viewers. It should be glare free, shadow less and contrast free. Direct glare from the source of light is most common factor. Presence of polished and glassy surface will cause indirect glare unless diffused light is used. Hard and long shadows can be avoided by using a large number of lamps and adjusting the mounting height.

Co-efficient of Utilization:

A surface to be illuminated receive light either directly from the lamps or reflected from the ceiling and walls or both. In this case, the total flux reaching the surface will never be equal to the flux emitted by the lamp, due to absorption by reflectors, ceiling and walls.

Utilization factor = $\frac{\text{lumens reaching at the working place}}{\text{total lumens emitted by the source}}$

Usually it varies from 0.5 to 0.8.

Depreciation Factor:

The total flux emitted by the source and its fitting may be reduced due to deposition of dust upon the surfaces. Similarly quantity of light reflected from the ceiling and walls also decreases with the passage of time. This is called as depreciation factor.

Usually it varies from 1.3 to 1.6.

Space Height Ratio:

The ratio of space (horizontal distance) between the two adjacent lamps to the vertical height of the lamps above the working plane is called space height ratio.

So the distance between the lamps is not too much. An ideal scheme could be when there is large number of small size lamps are used also it increases the cost of installation. So the space height ratio is 1 to 1.5.

Unit 3

Q1. Write the basic principle of electrolytic process and applications of electrolysis. Also write down the laws of electrolysis.

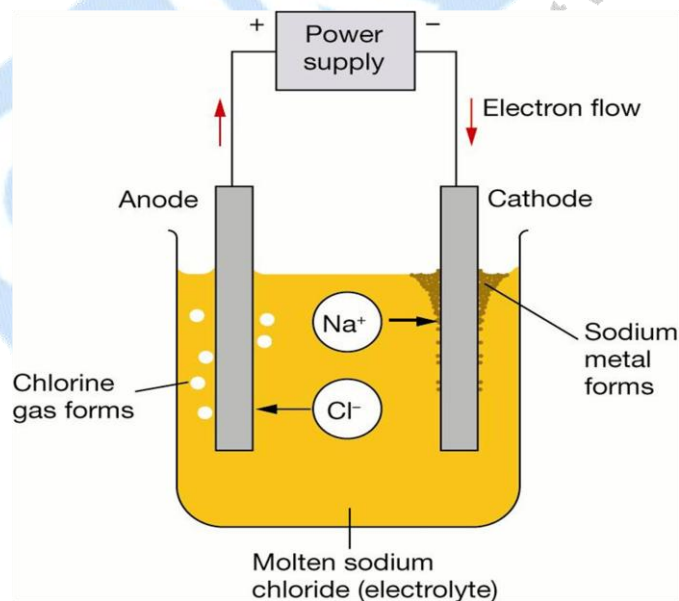
Ans:

An ionic compound conducts electricity when it is molten or in solution. The current causes the ionic compound to split up and form new substances. This process is called electrolysis, a word which comes from Greek and means "splitting by electricity".

In electrolysis, the substance that the current passes through and splits up is called the electrolyte. The electrolyte contains positive and negative ions. Negative ions move to the positive electrode and lose electrons. This is oxidation.

Positive ions move to the negative electrode and gain electrons. This is reduction.

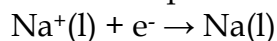
Because of the electrode the ions are attracted to, negative ions are called anions and positive ions are called cations.



Sodium is extracted from molten sodium chloride by electrolysis. A simple cell of molten salt is shown above. The electrodes are made of an unreactive conducting material such as graphite or platinum. The reaction occurring here is the reverse of the reaction that occurs spontaneously between sodium and chlorine to form sodium chloride. Electrical energy from the power supply has caused a non-spontaneous reaction to occur.

- **At the cathode (-)**

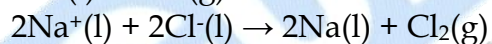
The power supply pushes electrons towards this electrode. Positive sodium ions accept electrons and become sodium atoms:



Sodium is solid at room temp, but is liquid at the temperatures required to melt NaCl. It is less dense than molten NaCl and floats to the top of the cell.

- **At the anode (+):**

Electrons are withdrawn from this electrode by the power supply. Since the electrode is made of unreactive material, the electrode itself will not participate in an oxidation reaction to supply electrons. Instead Cl^- ions in the electrolyte give up electrons and form chlorine atoms. These atoms quickly form molecules of Cl_2 and bubbles of chlorine gas form at the electrode.



Since Cl_2 is a strong oxidant and Na is a strong reductant, there must be no contact between them; otherwise they will reform sodium chloride and the products from the electrolysis will be lost. This will certainly occur in the simple cell.

Electrical energy is converted into chemical energy. The reactions that occur in electrolytic cells are essentially the opposite to those occurring in galvanic cells. Reactions in electrolytic cells would not normally happen without the application of electrical energy, and so they are called non-spontaneous reactions. Chemicals formed by electrolysis are often difficult to obtain by other means.

Important applications of electrolysis:

- Plating a thin film of metal on surfaces of other metals to improve the appearance or prevent corrosion.
- Extraction of reactive metals such as sodium and aluminium from their ores.
- Industrial production of sodium hydroxide, copper, chlorine and hydrogen
- Recharging of car batteries and other rechargeable cells, such as lithium batteries
- Increasing the thickness of the surface oxide layer on aluminium metal to improve its resistance to corrosion.

Faraday's Laws - The first law of electrolysis:

It states that the mass of substances liberated from an electrolyte in a given time is proportional to the quantity of electricity passing through the electrolyte that is

$$m \propto Q \text{ and } Q = I \times t$$

$$m = Zit$$

where, Z = a constant called electro chemical equivalent

I = steady current in amp

t = time for which the current flow the electrolyte

The second law of electrolysis:

It states that when the same quantity of electricity is passed through several electrolytes, masses of the substances deposited are proportional to their respective chemical equivalent weights.

Q2. Describe the process of electro-deposition and electro plating with neat and clean diagram.

Ans:

The deposition of a layer of metal on the surface of another metal by electrolysis is called electro-deposition. It is performed in an electrolytic cell such as the simplified one used for tin plating as shown. The object to be

plated is connected by a wire to the negative terminal of a power supply. This is the negative electrode of the cell. It is immersed in a solution, such as tin nitrate solution, which contains ions of the metal that is to form the plating. This is the electrolyte. An electrode of tin metal is connected to the positive terminal of the power supply. Typical steps in the electroplating of metals:

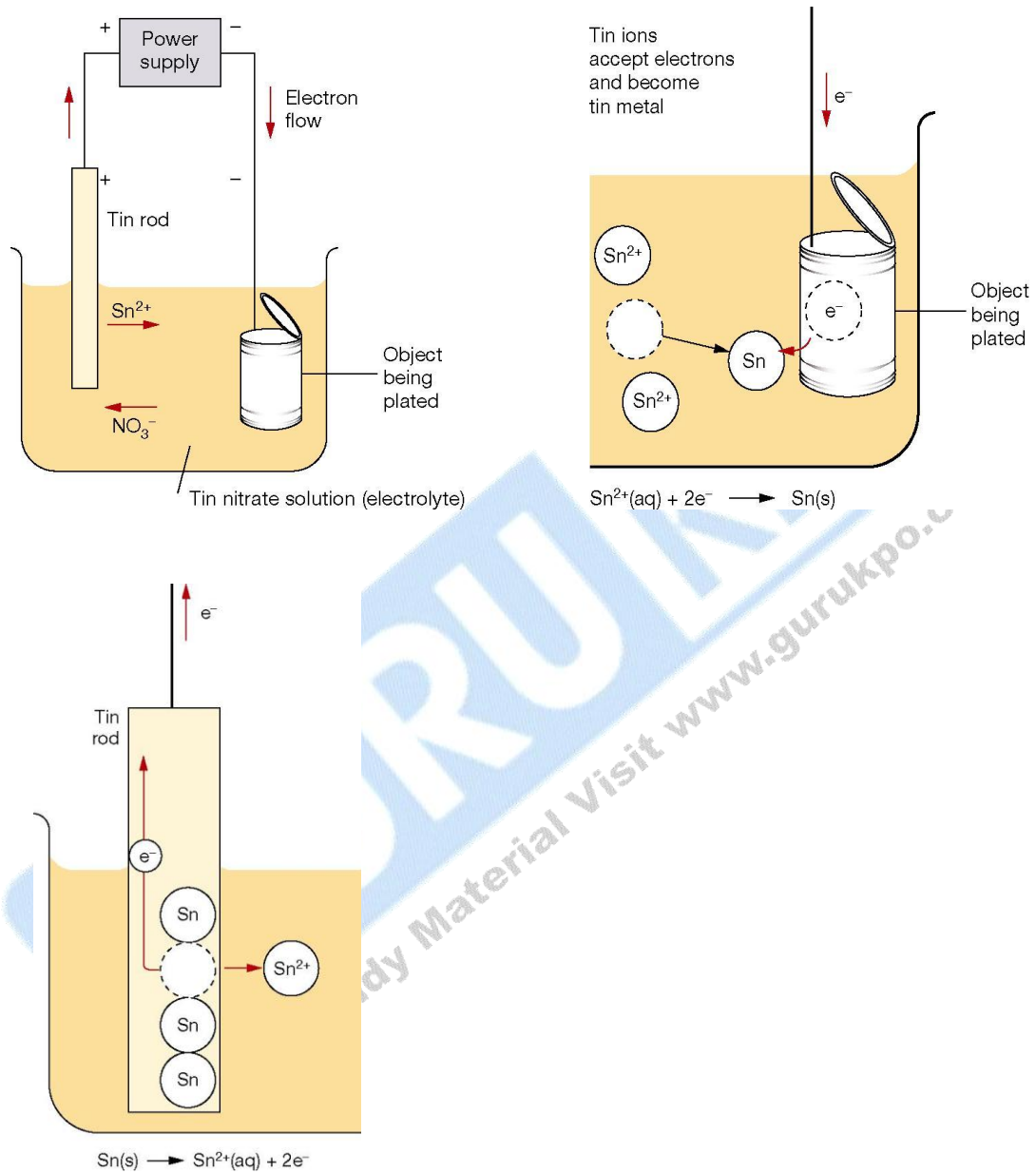
1. Cleaning with organic solvent or aqueous alkaline; to remove dirt or grease.
2. If the surface is covered by oxides as a result of corrosion, clean with acid.
3. Rinse with water to neutralise the surface.
4. Electroplate metals under controlled condition.
5. Rinse with water and dry.
6. Additional step: heat treatment in air or vacuum environment

Parameters that may influence the quality of electrodeposits:

- Current density (low to high current)
- The nature of anions/cations in the solution
- Bath composition, temperature, fluid flow
- Type of current waveform
- the presence of impurities
- physical and chemical nature of the substrate surface

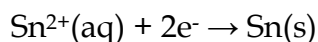
Working of electroplating:

When the cell is in operation the power supply acts as an 'electron pump' pushing electrons onto the negative electrode and removing electrons from the positive electrode.



- **At the negative electrode:**

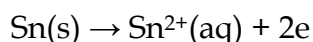
The negative terminal of the power supply pushes electrons along the wire to the electrode. Tin ions are attracted to the electrode, accept electrons and are converted to tin metal:



A coating of tin forms on the object. Since reduction of the tin ions has occurred, the negative electrode is acting as a cathode.

- **At the positive electrode:**

The positive terminal of the power supply withdraws electrons from the tin electrode. A reaction that released electrons must occur. Tin metal slowly dissolves as Sn^{2+} ions are formed:



This reaction replaces the Sn^{2+} ions in solution that were consumed by the reaction at the negative electrode. Since an oxidation reaction has occurred the positive electrode is the cathode.

The excess of positive charge caused by the production of Sn^{2+} ions at the anode will be balanced by movement of NO_3^{-} ions in the electrolyte to that region and by movement of Sn^{2+} ions away from it. At the cathode, loss of positive charge causes cations to migrate towards it and anions away from it. It is still cations towards the cathode and anions away from it.

Examples of electroplating:

- Iron is widely used because it is cheap and strong. Electroplating with iron improves their resistance to corrosion.
- Electroplating jewellery makes an object more attractive.
- Chromium is used for decoration, non-tarnishing and hard-wearing.

Q3. Explain with neat and clean diagram the term 'anodizing' and anodizing of aluminium.

Ans:

The purpose of anodizing is to grow an aluminum oxide layer on the aluminum so it can be dyed and to increase Corrosion and wear resistance.

Anodizing of aluminium:

Working:

The Aluminum part that to be anodized, immersed in acid electrolyte . then Apply electrical current, DC, ~12V. This part will work as a anode (+) (thus the name).by doing this there will be Electrolysis and chemical reaction occurs. The Porous aluminum oxide layer grows on the aluminum. Up to 3000 times thicker than naturally occurring Al_2O_3 layer will grow. The Dye will goes into pores, thus results in bright colors. This should be Placed in boiling water to seal pores.

The Electrolyte in Solution is Free ions and conductive. The electrolyte used is Sulfuric, oxalic, or phosphoric acid . in above procedure 15% solution of sulfuric acid (H_2SO_4) is used.

The chemical reaction will takes place as:

At Anode:

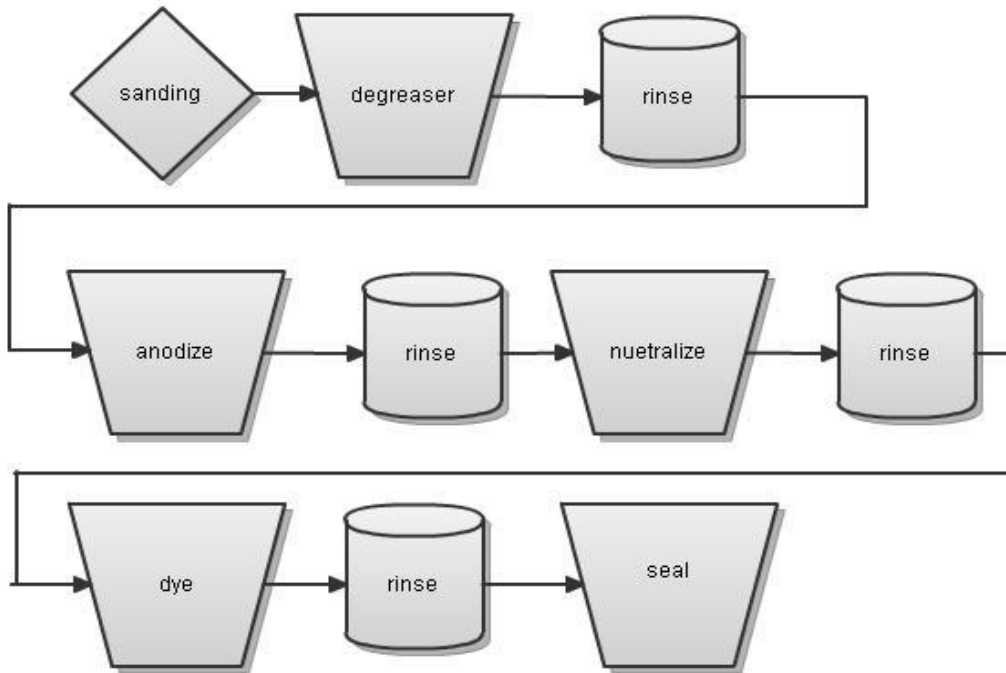
- Evolution of oxygen
- $2\text{Al} + 3\text{H}_2\text{O} \rightarrow \text{Al}_2\text{O}_3 + 6\text{H}^+ + 6\text{e}^-$

At Cathode:

- Evolution of hydrogen
- $6\text{H}_2\text{O} + 6\text{e}^- \rightarrow 3\text{H}_2(\text{g}) + 6\text{OH}^-$

The Materials used in this process:

- Aluminum item (anode)
- Aluminum wire
- Aluminum sheet (cathode)
- Sulfuric Acid 15%
- Non-metal container
- Power supply
- Distilled/ de-ionized water
- Dye (RIT clothes dye)
- Baking soda



Other metals can be anodized e.g. Titanium, magnesium, niobium, tantalum, tungsten, zirconium. Ti utilizes interference property of oxide film instead of dye for color.

Q4. State and explain the term electro extraction and electro-extraction of zinc.

Ans:

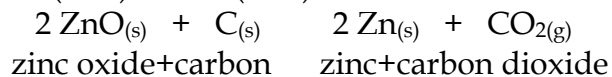
The method used to extract a metal from its ore is guided by the position of the element on the Reactivity Series. Metals high up on the series are strongly bonded in their compounds. Electrolysis is the only method strong enough to extract these.

Example: Na(sodium), Mg(magnesium) and Al(aluminium)

Metals in the middle of the series are less strongly bonded in their compounds. Their oxides can be reduced by carbon to give the metal.

Example:

Zn(zinc) and Fe(iron)



Metals at the bottom of the series can be found uncombined in nature. They simply need to be purified of unwanted materials. When they do occur in ores, example copper sulphide, heating is strong enough to displace the metal from the ore.

Example: Cu(copper), Ag(silver) and Au(gold)

The Reactivity Series is a list of metals arranged in order of reactivity. Potassium is the most reactive metal and thus is on top of the series. Hydrogen is a non-metal but is placed in this series to show that the metals below it do not react with acids to produce Hydrogen gas.

Major ores of Zinc are :Sphalerite (ZnS), Zincite (ZnO), Franklinite [$ZnO(Fe, Mn)_2O_3$], Calamine [$Zn_2(OH)_2SiO_3$], Smithsonite ($ZnCO_3$). Sphalerite (ZnS).

The Processes of Zinc extraction is Horizontal Retort, Vertical Retort Electrothermic, Electrolytic, Imperial Smelting. The principal processes by which zinc is extracted from its ores can be categorized under :

- pyro-metallurgical processes and hydro-metallurgical processes.
- Pyro- metallurgical processes
- Horizontal Retort Vertical Retort, Electro- thermal, Imperial Smelting
- Hydro- metallurgical processes
- Roast leach electrowin, Pressure leaching, Electrolytic

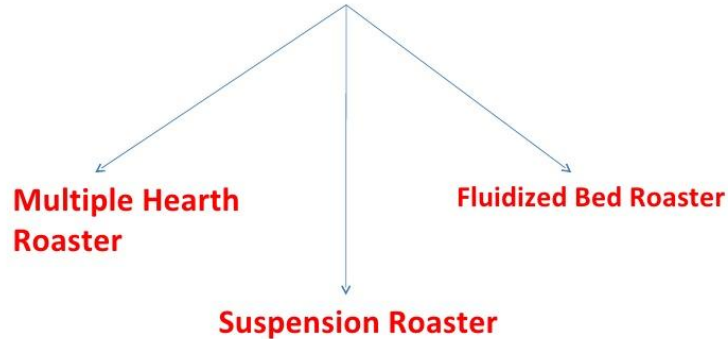
Presently about 15 - 20% of the world's zinc production comes from pyrometallurgical route.

Both of the processes (pyro+ hydro- metallurgy) share the same first step: roasting.

Roasting is a process of oxidizing zinc sulfide concentrates at high temperatures into an impure zinc oxide, called "Zinc Calcine". The chemical reactions taking place during the process are: Approximately 90% of zinc in concentrates are oxidized to zinc oxide, but at the roasting temperatures around 10% of the zinc reacts with the iron impurities of the zinc sulfide concentrates to form zinc ferrite.

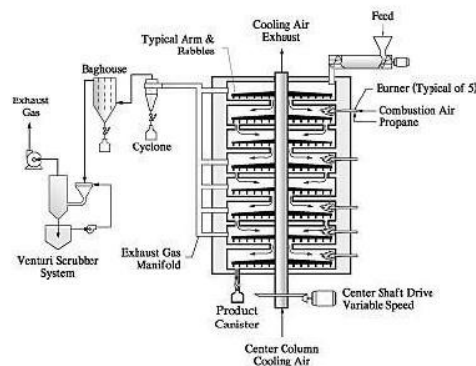
Types of roasting Multiple Hearth Roaster Suspension Roaster Fluidized Bed Roaster.

Types of roasting



Multiple Hearth Roaster Schematic diagram depicting a Multiple Hearth Roaster:-

Multiple Hearth Roaster



Schematic diagram depicting a Multiple Hearth Roaster

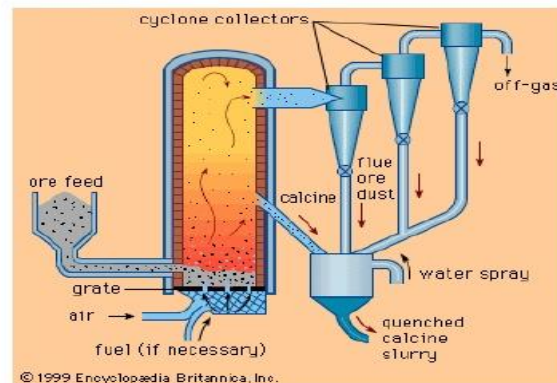
In a multiple-hearth roaster, the concentrate drops through a series of 9 or more hearths stacked inside a brick-lined cylindrical column. Working: As the feed concentrate drops through the furnace, it is first dried by the hot gases passing through the hearths and then oxidized to produce calcine. **Reaction Conditions:** The reactions are slow and can be sustained only by

the addition of fuel. Pressure and Time requirements: Multiple hearth roasters are unpressurized and operate at about $690\text{ }^{\circ}\text{C}$ ($1,270\text{ }^{\circ}\text{F}$). Operating time depends upon the composition of concentrate and the amount of the sulfur removal required. Limitations/ Advantages: Multiple hearth roasters have the capability of producing a high-purity calcine. Suspension Roaster Engineering Design: The roaster consists of a refractory-lined cylindrical steel shell, with a large combustion space at the top and 2 to 4 hearths in the lower portion, similar to those of a multiple hearth furnace.

Working: In a suspension roaster, the concentrates are blown into a combustion chamber very similar to that of a pulverized coal furnace. Additional grinding, beyond that required for a multiple hearth furnace, is normally required to ensure that heat transfer to the material is sufficiently rapid for the desulfurization and oxidation reactions to occur in the furnace chamber. Pressure and Temperature requirements: Suspension roasters are unpressurized and operate at about $980\text{ }^{\circ}\text{C}$ ($1,800\text{ }^{\circ}\text{F}$).

Fluidized Bed Roaster Schematic diagram depicting a Fluidized Bed Roaster :

Fluidized Bed Roaster



Schematic diagram depicting a Fluidized Bed Roaster

Working: In a fluidized-bed roaster, finely ground sulfide concentrates are suspended and oxidized in a feedstock bed supported on an air column.

Reaction Conditions: As in the suspension roaster, the reaction rates for desulfurization are more rapid than in the older multiple-hearth processes.

Pressure and Temperature requirements: Fluidized-bed roasters operate under a pressure slightly lower than atmospheric and at temperatures averaging 1,000 °C (1,830 °F). In the fluidized-bed process, no additional fuel is required after ignition has been achieved.

Advantages: The major advantages of this roaster are greater throughput capacities, greater sulfur removal capabilities, and lower maintenance.

Hydro-metallurgical extraction of Zinc About 80% of world's total zinc output is produced through conventional hydrometallurgical route i.e. Roast-leach-electrowin (RLE) route. The three out of the four plants installed in India are operating on hydrometallurgical process route. The pre-requisite condition for zinc metal extraction from sulphide concentrate through a hydro-metallurgical route is the elimination of its sulphur content in order to make it amenable to further treatment by leaching.

Leaching: The basic leaching chemical formula that drives this process is: This is achieved in practice though a process called double leaching.

Double Leaching: The calcine is first leached in a neutral or slightly acidic solution (of sulfuric acid) in order to leach the zinc out of the zinc oxide. The remaining calcine is then leached in strong sulfuric acid to leach the rest of the zinc out of the zinc oxide and zinc ferrite. The result of this process is a solid and a liquid; the liquid contains the zinc and is often called leach product.

Economic considerations: The solid obtained after double leaching is called leach residue and contains precious metals (usually lead and silver) which are sold as a by-product.

Iron removal: There is also iron in the leach product from the strong acid leach, which is removed in an intermediate step.

The main purpose of roasting of zinc sulphide concentrate is to convert it into a product, which is amenable to further treatment through hydrometallurgical process for extraction of zinc. Secondly, to fix the sulphide contents into sulphur dioxide gases for subsequent economical recovery as sulphuric acid.

Roasting reaction: $2\text{ZnS} + 3\text{O}_2 = 2\text{ZnO} + 2\text{SO}_2$ These rich gases are cleaned and cooled to recover dust content as zinc calcine and to remove the various harmful impurities such as Hg, Se, F, Cl, As, etc. The dead roasted product, zinc calcine, is subjected to leaching with recycled electrolyte to extract zinc content. The enriched zinc sulphate solution is further subjected to purification with zinc dust to eliminate impurities like copper, cadmium, cobalt, nickel etc. before being subjected to electrolysis.

Electrolysis: Zinc is extracted from the purified zinc sulfate solution by electrowinning, which is a specialized form of electrolysis. Working: The process works by passing an electric current through the solution in a series of cells. This causes the zinc to deposit on the cathodes (aluminum sheets) and oxygen to form at the anodes. By Products: Sulfuric acid is also formed in the process and reused in the leaching process. Limitations in maintenance: Every 24 to 48 hours, each cell is shut down, the zinc-coated cathodes are removed and rinsed, and the zinc is mechanically stripped from the aluminum plates.

Pyro- metallurgical extraction of Zinc Presently about 15 - 20% of the world's zinc production comes from pyrometallurgical route. The horizontal and vertical retort processes and electrothermal process were used in the past for zinc production but have become obsolete due to high power consumption and low recovery. The only pyrometallurgical process of importance presently is Imperial Smelting Process (ISP).

Unit: 4

Q1. Define electric traction and write down the types of electric traction.

Ans:

Driving forward of vehicle is called Traction and the system, which employs this type of mechanism is called Traction system.

Electric traction means a locomotion in which the driving force is obtained from electric motors. Electric traction will co environmentally antique to play a dominant role in the Railway since it is a clean technology compared to diesel traction and also its running cost is low. There are many advantages of electric traction over other forms of locomotion. Maximum tractive effort should be exerted at starting Equipment should be capable of overloads for short periods The wear caused on the track should be minimum Braking should be possible without excessive wear on the brush.

Major classification of traction:

Non-electric traction:

Examples: Steam engine drive , Ic engine drive

Electric traction:

Examples: Diesel electric drive , Gas turbine electric drive

Advantages:

- Cheapness: electric traction is cheap as compare to other traction system.
- Acceleration & Braking: in case of electric traction system regenerative braking is used which feeds back 80% of the energy required during ascent back and descent.
- Cleanliness: electric traction is free from smoke and flue gases etc.
- Maintenance Cost: maintenance cost of electric traction is 50% of that of steam traction.

- Starting time: the motors used in this system has a very high starting torque. High starting torque makes the acceleration rate high.
- Saving in high-grade coal: high grade coal is quite deficient in our country but use of electric traction save high grade coal. As there is no need for coal to drive electric locomotive.
- Better co-efficient of adhesion: co efficient of adhesion is more in case of electric traction system, due to absence of unbalanced forces produced by the reciprocating masses.

Disadvantages :

- High initial expenditure : the capital cost of the electric traction is quite high.
- Failure of supply is a problem : Electrically operated vehicles have to move only on electrified track For braking & control, additional equipments required India with its large railway network and the growth of large metropolitan centers is building up a large market for railway transport equipment. Clean technologies due to environmental considerations. Energy conservation to minimise wastage of power. Faster/reliable railway transportation. The success of space, defence and atomic energy can be replicated by the Railways also.

Different types of electric traction:

- Direct steam engine drive
- Direct IC engine drive
- Steam electric drive
- IC engine electric drive
- Petrol electric traction
- Battery electric drive
- Electric drive

Track System Classification: In general following electric traction systems exist :

- AC 3 phase 3.7 kV system
- AC single phase 15/16 kV -161/25 Hz
- AC single phase 20/25 kV - 50/60 Hz
- DC 600 V
- DC 1200 V
- DC 1.5 kV
- DC 3 kV.

Q2. Differentiate between ac and dc traction system.**Ans:****Dc traction system:**

DC traction units use direct current drawn from either a conductor rail. The most popular line voltages for overhead wire supply systems - 1500VDC and 3000V DC. And 600V DC-750V DC volt range used. for third rail systems (a means of providing electric power to a railway train, through a semi-continuous rigid conductor placed along side or between the rails of a railway track and that additional rail is called conductor rail.

Disadvantages:

- Expensive substations are required at frequent intervals and the overhead wire or third rail must be relatively large and heavy.
- The low-voltage, series-wound, direct-current motor is land. well suited to railroad traction, being simple to construct and easy to control.

Ac traction system:

AC Traction units draw alternating current from an overhead line.

Typical Voltages Used are:-

- 15 kV AC, 16 $\frac{2}{3}$ Hz (16.7 Hz)
- 25 kV AC, 50 Hz
- 25 kV AC, 60 Hz

Fewer substations are required in this system and the lighter overhead current supply wire can be used. In this system the reduced weight of AC support structure can be used. The capital cost of electrification is also reduced.

Specification:

- WAG-9
- Rated Power-5000 HP
- Traction System- 25KV AC
- Speed- 140 Km/hr
- Traction Motor- DC Motor.

Advantages of atraction system:

- i. High power-to-weight ratio than forms of traction such as diesel or steam that generate power requiring on board prime mover. higher power-to-weight ratio resulting in :
 - Faster acceleration
 - Fewer locomotives
 - Higher limit of speed
 - Higher practical limit of power
 - Higher hauling capability
- ii. No exhaust fumes or carbon emission.
- iii. Less noise pollution (quieter operation)
- iv. The maintenance cost of an electric locomotive is nearly 50% of that for a steam locomotive. Moreover, maintenance time is also much less .
- v. An electric locomotive can be started at a moment's notice whereas a steam locomotive requires two hours to heat up.
- vi. The motors used in electric traction have a very high starting torque. Hence, it is possible to achieve higher acceleration of 1.5 to 2.5 km/h/s as against 0.6 to 0.8 km/h/s in steam traction.
- vii. It is possible to use regenerative braking in electric traction system. It leads to the following advantages:
 - About 80% of the energy taken from—the supply during ascent is returned to it during descent. And presently this returned energy is not sent back to public network but made available for other vehicles within the network
 - Goods traffic on gradient become safer and speedier.
- viii. Since height of an electric locomotive is much less than that of a steam locomotive, its centre of gravity is comparatively low. This fact enables an electric locomotive to electric negotiate curves at higher speeds quite safely.
- ix. Electric trains may be powered from a number of different sources of energy (e.g. hydroelectricity, nuclear, natural gas, wind generation etc.) as opposed to diesel trains that are reliant on oil.
- x. Electric trains do not have to carry around the weight of their fuel unlike diesel traction.
- xi. A electrified railway has no need to switch between methods of traction thereby making operations more efficient. One country that approaches this ideal is Switzerland.

Disadvantages of ac traction system:

- i. capital cost of electrification is Significant .
- ii. it increases maintenance cost of the lines.
- iii. Overhead wires further limit the clearance in tunnels.
- iv. Upgrading brings significant cost, especially where tunnels and bridges have to be altered for clearance.
- v. Railway Traction needs immune power, with no cuts, warranting duplication of Transmission and Distribution systems, which obviously comes at a Premium Price.

Q3. Describe the working of ac locomotive.**Ans:**

ELECTRIC LOCOMOTIVES: An electric locomotive is a locomotive powered by electricity from overhead lines , a third rail or an on-board energy storage device such as a chemical battery or fuel cell .

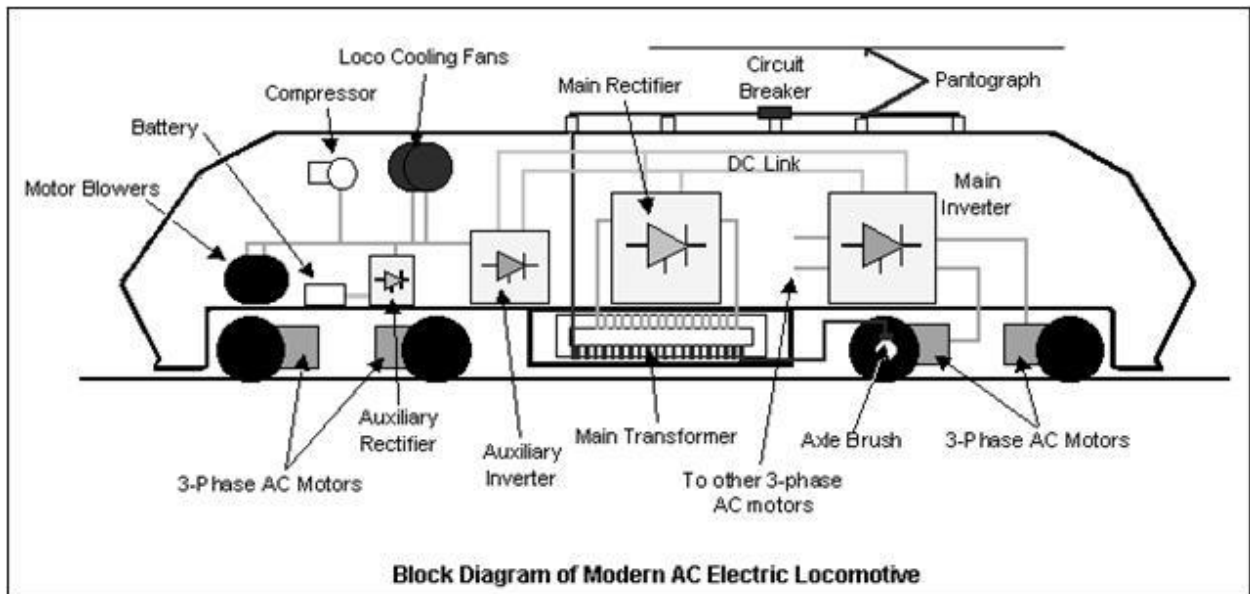
An electric locomotive can be supplied with power from

- Rechargeable energy storage systems, such as battery or ultracapacitor-powered mining locomotives.
- A stationary source, such as a third rail or overhead wire.

A diesel-electric locomotive combines an onboard diesel engine with an electrical power transmission or storage (battery, ultracapacitor) system.

The distinguishing design features of electric locomotives are:

- The type of electrical power used, AC or DC.
- The method of storing (batteries, ultracapacitors) or collecting (transmission) electrical power.
- The means used to couple the traction motors to the driving wheels (drivers



A **pantograph** (or "**pan**") is an apparatus mounted on the roof of an electric train or tram to collect power through contact with an overhead catenary wire. Typically a single wire is used, with the return current running through the track. The term stems from the resemblance of some styles to the mechanical pantographs used for copying handwriting and drawings.

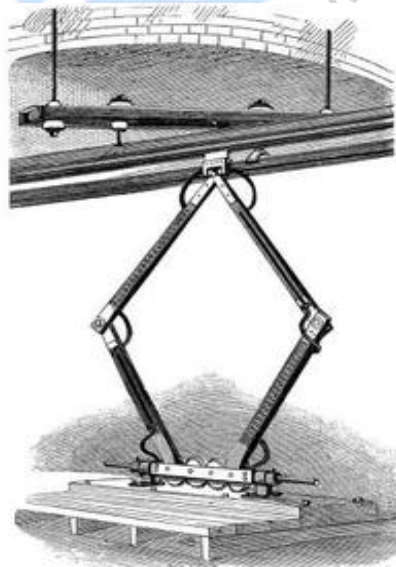
The most common type of pantograph today is the so-called half-pantograph (sometimes 'Z'-shaped), which has evolved to provide a more compact and responsive single-arm design at high speeds as trains get faster. The half-pantograph can be seen in use on everything from very fast trains (such as the TGV) to low-speed urban tram systems. The design operates with equal efficiency in either direction of motion.

The electric transmission system for modern electric rail systems consists of an upper weight carrying wire (known as a catenary) from which is suspended a contact wire. The pantograph is spring-loaded and pushes a contact shoe up against the underside of the contact wire to draw the electricity needed to run the train. The steel rails of the tracks act as the electrical return. As the train moves, the contact shoe slides along the wire and can set up acoustical standing waves in the wires which break the contact and degrade current collection. This means that on some systems adjacent pantographs are not permitted.

Pantographs are the successor technology to trolley poles, which were widely used on early streetcar systems. Trolley poles are still used by trolleybuses, whose freedom of movement and need for a two-wire circuit makes pantographs impractical, and some streetcar networks, such as the Toronto Streetcar System, which have frequent turns sharp enough to require additional freedom of movement in their current collection to ensure unbroken contact.

Pantographs with overhead wires are now the dominant form of current collection for modern electric trains because, although more fragile than a third-rail system, they allow the use of higher voltages.

Pantographs are typically operated by compressed air from the vehicle's braking system, either to raise the unit and hold it against the conductor or, when springs are used to effect the extension, to lower it. As a precaution against loss of pressure in the second case, the arm is held in the down position by a catch. For high-voltage systems, the same air supply is used to "blow out" the electric arc when roof-mounted circuit breakers are used.



Bow collector:

A **bow collector** is one of the three main devices used on tramcars to transfer electric current from the wires above to the tram below. While once very common in continental Europe, it has now been largely replaced by the pantograph.

The bow collector is one of the simplest and most reliable methods of current collection used on tramways. The very earliest versions were simply very heavy-gauge wire or steel bars bent into a rectangular shape and mounted long-side-down on the tramcar roof. The height of the collector was such that its top edge would scrape along the wire above. The top section is made of a 1 inch broad (or thereabouts) steel rod, machined to have a bow-shaped cross section, hence the name. This bow shaped rod is referred to as the 'collector plate', and in later models may be up to several inches wide. Unlike many trolley poles, the bow collector does not normally have a revolving base (one exception was in Rome, where the entire assembly could be revolved), but is rather fixed centrally to the tramcar roof.

Properly the bow collector should be mounted in such a way so that the top edge of the collector plate would rise several inches above the wire when the collector frame is standing straight up. Thus the collector usually leans opposite to the direction of travel; when the time comes to travel in the opposite direction, the collector must be swung over. To allow this to happen, the overhead wire must be raised by several inches at places where the bows are swung over, such as terminals and turn-outs. This operation is usually achieved by ropes and pulleys. The collector is folded down to a horizontal position when the car is not in use.

Some early cars had no means to swing the bows over. It was thought that this would happen automatically when the tramcar started travelling the other way, but collectors such as these were a failure.

Most Soviet trams (of which some are still in use in ex-USSR) had no means to swing the bows over. These trams were not designed to travel two ways. Another example is KTV-55-2 tramcar which had two bow collectors for the two directions of travelling.

third rail is a method of providing electric power to a railway train, through a semi-continuous rigid conductor placed alongside or between the rails of a railway track. It is used typically in a mass transit or rapid transit system, which has alignments in its own corridors, fully or almost fully segregated from the outside environment. Third rail systems are always supplied from direct current electricity.

Third-rail:

Third rail is a method of providing electric power to a railway train, through a semi-continuous rigid conductor placed alongside or between the rails of a railway track. It is used typically in a mass transit or rapid transit system, which has alignments in its own corridors, fully or almost fully segregated from the outside environment. Third rail systems are always supplied from direct current electricity.

The third-rail system of electrification is unrelated to the third rail used in dual-gauge railways. The conductor rail is placed on the sleeper ends outside the running rails, but in some cases a central conductor rail is used. The conductor rail is supported on ceramic insulators (known as "pots") or insulated brackets, typically at intervals of around 10 feet (3 metres).

The trains have metal contact blocks called "shoes" (or "contact shoes" or "pickup shoes") which make contact with the conductor rail. The traction current is returned to the generating station through the running rails. The conductor rail is usually made of high conductivity steel, and the running rails are electrically connected using wire bonds or other devices, to minimize resistance in the electric circuit.

The conductor rails have to be interrupted at level crossings and at crossovers, and ramps are provided at the ends of the sections to give a smooth transition to the train shoes.

The position of contact between the train and the rail varies: some of the earliest systems used top contact, but later developments use side or bottom contact, which enabled the conductor rail to be covered, protecting track workers from accidental contact and protecting the conductor rail from snow and leaf fall.

Q4. What are substation equipment used in traction system.**Ans:**

These are the basic required equipments used in traction system:

- High Voltage Aerial Lines and Underground Cables
- Substations
- 1500V dc Traction System
 - Overhead Wiring
 - Traction Return
- Power Supply for signalling operation, communication equipment, station and buildings, etc
- LV installations in Railway Tunnels and Yards

The High Voltage A.C. Distribution System require following Standard voltage

- Standard Voltages
 - 11kV
 - 33kV
 - 66kV
 - 132 kv

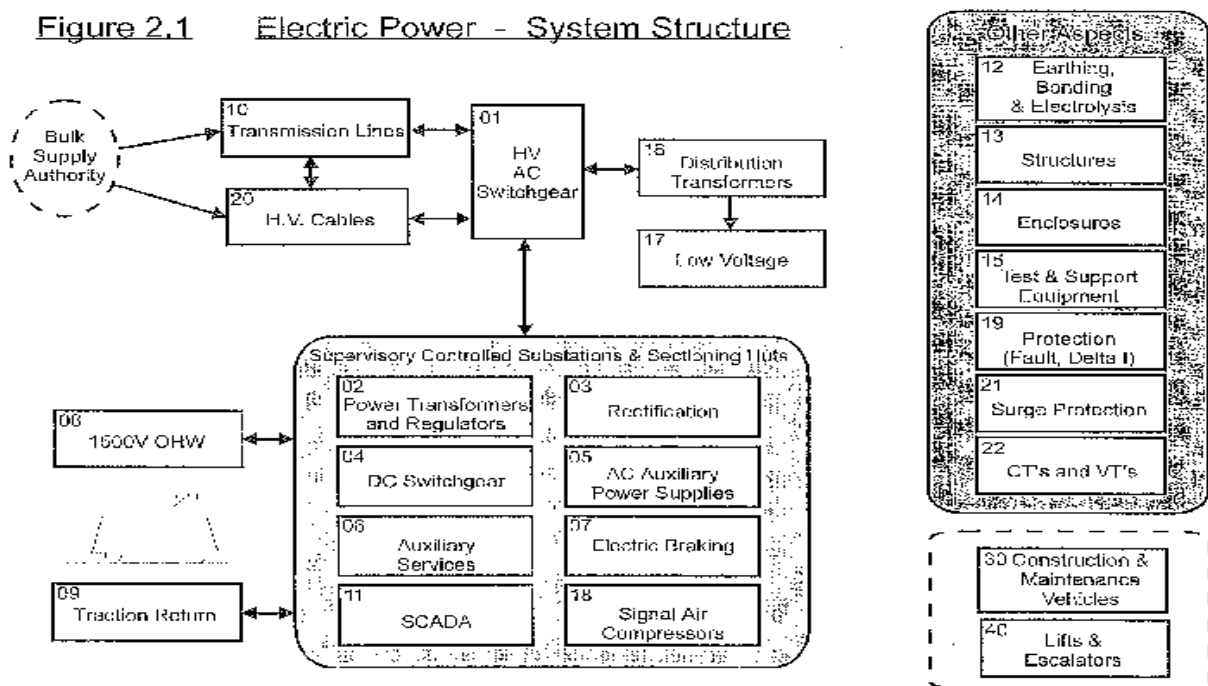
These voltages can be transferred either by Overhead Transmission Lines or by Underground Cable. The conductors used for hv arial lines are made up of Copper or Aluminium (AAC or Aluminium Alloy). And these conductors are supported by Wood Poles and Steel Poles.

Following are the Traction sub station :

- Switchgear
 - AC Circuit Breaker
 - DC Circuit Breaker

- Transformers & Rectifiers
 - Convert the high voltage ac supply to 1500V dc
- Control and Monitoring
 - SCADA (Supervisory Control and Data Acquisition)

Figure 2.1 Electric Power - System Structure



Free St.

UNIT 5

Q1. Describe typical speed time curve for different services.

Ans:

A train is to be run between two stations optimally as far as possible. The movement of trains and their energy consumption can be conveniently studied by means speed-time and speed distance curve. Speed-time curve show the speed at various times after the start of run whereas the speed - distance curve shows the speed at various distances from starting point of the two i.e. speed - time and speed - distance curve is generally more useful as the slope of the curve represents the acceleration and the area under the curve ($\int V dt$) represents the distance travelled.

A curve plotted with time in seconds or minutes as abscissa and speed in Km/hr as ordinate is known as speed - time curve. This curve gives the complete information of motion of train - slope of the curve at any point gives the magnitude of acceleration or retardation. The upward slope indicates retardation.

SPEED -TIME CURVE FOR MAIN LINE SERVICE:

In the service, the distance between two stations is more than 10 Kms.

Speed - time curve mainly consists of

- (i) Initial acceleration
- (ii) Constant speed run or free run
- (iii) Costing
- (iv) Retardation

Typical speed time curve for main line service is shown.

(i)Acceleration:

With electric trains using d.c series motors the period of acceleration consists of two parts namely:

- (a) constant acceleration or acceleration while notching up
- (b) decreasing acceleration.

(a) Constant Acceleration:

The acceleration of the electric train is maintained constant during starting period which is achieved by supplying approximately constant current. The voltage across the motor is gradually increased by cutting out the starting resistance with the help of starter by moving the starter handle period (0 - t_1) and acceleration is known as rheostatic acceleration. The typical value of acceleration varies between 0.6 - 0.8 Km phps.

(b) Decreasing Acceleration:

During speed curve running (t_1 to t_2) the voltage acting across the motor remains constant and current starts decreasing with increase in speed according to the characteristics of the motor and finally the current taken by the motor becomes constant. During this period though the train accelerates but acceleration decreases with the increase in speed and finally becomes zero at the speed at which the tractive effort developed by the motor becomes exactly equal to the resistance to the motion of train.

(ii) Free Run or Constant Speed Run:

At the end of speed curve running i.e., at t_2 the train attains maximum speed. During this period the train runs with constant speed attained at t_2 and thus the power drawn from the supply is constant.

(iii) Coasting:

At the end of free running period (i.e., at t_3) power supply is cut off and the train will start running due to its momentum. Due to the frictional resistance to the motion, the speed of that train starts decreasing or in other words there will be a retardation during this period and this retardation is known as coasting retardation.

(iv) Retardation or Braking:

At the end of coasting period (i.e., at t_4) the brakes are applied to bring the train to rest. During this period the speed decreases rapidly and finally reduces to zero.

SPEED - TIME CURVE FOR URBAN SERVICE:

In city service electric trains the distance between two stations is nearly between 0.75Km and 1 Km. The typical speed - time curve for urban service is as shown:

This curve essentially consists of (i) Acceleration (ii) Coasting or Running without power (iii) Retardation due to braking.

(i) Acceleration:

Same as above for main line service.

The acceleration required for this service is high so that high average speed and short time of run is obtained as the distance between the two stops is comparatively very short. The typical value of acceleration required ranges between 1.5 Kmphps - 4 Kmphps.

(ii) Coasting or Running without Power:

Same as above for main line service.

The coasting period is small and coasting retardation is about 0.15 Kmphps.

(ii) Retardation:

Same as above for main line service.

The retardation required for urban service is high so that high average speed and short time of run is obtained. The typical value of retardation varies 3 - 4 Kmphps.

SPEED - TIME CURVE FOR SUB - URBAN SERVICE:

The speed time curve for suburban service consists of: (i) Acceleration (ii) Coasting or Running without Power (iii) Retardation due to braking.

(i) Acceleration:

This will work as urban service.

(ii) Coasting or Running without Power:

This will work as for main line service.

The coasting period is comparatively longer as the distance between two stations is longer than of urban service.

(iii) Retardation:

This will work as urban service.

CHARACTERISTICS OF VARIOUS TYPES OF SERVICES:

Main Line Service	Urban service	Sub urban Service
1.The distance between two stations in this service is more than 10 Km.	1.The distance between two stations in this service is between 0.75 to 1 Km.	1.The distance between two stations in this service varies between 1 - 8 Km.
2. The speed-time curve of main line comprises of free running and coasting periods which are long whereas the acceleration and braking periods are comparatively small.	2. The speed-time curve of urban service consists of acceleration, retardation and coasting (small period) whereas there is no free running period.	2.The speed-time curve of suburban consists of acceleration, retardation And comparatively long coasting period but no free running period.
3.The maximum speed that can be attained in this service is 160 Kmph.	3.The maximum speed that can be attained in this service is 120 Kmph.	3.The maximum speed that can be attained in this service is 120 Kmph.
4.The typical value of acceleration varies between 0.6 - 0.8 Kmphps.	4.The typical value of acceleration varies between 1.5 - 4.0 Kmphps.	4.The typical value of acceleration varies between 1.5 - 4.0 Kmphps.
5.The typical value of retardation is 1.5 Kmphps.	5.The typical value of acceleration varies between 3 - 4 Kmphps.	5.The typical value of retardation varies between 3 - 4 Kmphps.

In any calculations of train motion the following factors are considered:

1. **CREST SPEED:** It is the maximum speed attained by a train during run.

2. **AVERAGE SPEED:** It is the mean speed maintained by a train during a run. It is given as:

$$\text{Avg. speed} = \text{Distance between stops in km} / \text{Actual time of run in hr}$$

3. **SCHEDULE SPEED:** It is the ratio of the distance between the stops and total time taken including time for stops to cover this distance i.e.,

$$\text{Schedule speed} = \text{distance between stops in km} / \text{Actual time of run in hr.} + \text{stop time in hr.}$$

The following factors affect the schedule speed of a train:

- (a) crest speed or maximum speed
- (b) acceleration
- (c) retardation
- (d) duration of stops.

(a) Crest speed:

For a constant run and with fixed acceleration and retardation the actual time of run will decrease with the increase in crest speed. The effect of variation in crest speed on schedule speed is considerable in case of long distance run i.e., if the distance between two stations is more, the high crest speed will reduce the time drastically.

(b) Acceleration:

If the distance between two stations and crest speed are constant then increase in acceleration will reduce the running time of the train. The increase

in acceleration will increase the schedule speed .If the distance between two stations is small then increase will be considerable.

(c) Retardation:

With high braking retardation, the schedule speed of the train also increase. This effect will be considerable if the distance between stations is small.

(d) Duration of stop:

If the duration of stop is more, then the total running time will be more and thus the schedule speed will be low. Thus for high schedule speed duration of stop should be less. There it is recommended to have stop time of 15 to 20 seconds for small service to have a fairly good schedule speed whereas it is negligible in main line service.

Q2. Describe the methods of electric braking of traction motors.

Ans:

Field coils in two series and parallel groups assume unsaturated magnetic operation.

Electric Braking: A motor and its load may be brought to rest quickly by using either (i) Friction Braking or (ii) Electric Braking. Mechanical brake has one drawback: it is difficult to achieve a smooth stop because it depends on the condition of the braking surface as well as on the skill of the operator. The excellent electric braking methods are available which eliminate the need of brake lining levers and other mechanical gadgets. Electric braking, both for shunt and series motors, is of the following three types:

- (i) Rheostatic or dynamic braking
- (ii) Plugging i.e., reversal of torque so that armature tends to rotate in the opposite direction.
- (iii) Regenerative braking.

Obviously, friction brake is necessary for holding the motor even after it has been brought to rest.

- (a) Rheostatic or Dynamic Braking: In this method, the armature of the shunt motor is disconnected from the supply and is connected across a variable resistance R . The field winding is left connected across the supply. The braking effect is controlled by varying the series resistance R . Obviously, this method makes use of generator action in a motor to bring it to rest.
- (b) Plugging or Reverse Current Braking: This method is commonly used in controlling elevators, rolling mills, printing presses and machine tools etc. In this method, connections to the armature terminals are reversed so that motor tends to run in the opposite direction. Due to the reversal of armature connections, applied voltage V and E start acting in the same direction around the circuit. In order to limit the armature current to a reasonable value, it is necessary to insert a resistor in the circuit while reversing armature connections.
- (c) Regenerative Braking: This method is used when the load on the motor has over-hauling characteristic as in the lowering of the cage of a hoist or the downgrade motion of an electric train. Regeneration takes place when E becomes greater than V . This happens when the overhauling load acts as a prime mover and so drives the machines as a generator. Consequently, direction of I_a and hence of armature torque is reversed and speed falls until E becomes lower than V . It is obvious that during the slowing down of the motor, power is returned to the line which may be used for supplying another train on an upgrade, thereby relieving the powerhouse of part of its load.

Electric Braking :

- (a) Rheostatic (or dynamic) Braking: The motor is disconnected from the supply, the field connections are reversed and the motor is connected in series with a variable resistance R . Obviously, now, the machine is running as a generator. The field connections are reversed to make sure that current through field winding flows in the same direction as before (i.e., from M to N) in order to assist residual magnetism. In practice, the variable resistance employed for starting purpose is itself used for braking purposes.
- (b) Plugging or Reverse Current Braking: As in the case of shunt motors, in this case also the connections of the armature are reversed and a variable resistance R is put in series with the armature.

- (c) **Regenerative Braking:** This type of braking of a series motor is not possible without modification because reversal of I_a would also mean reversal of the field and hence of E_b . However, this method is sometimes used with traction motors, special arrangements being necessary for the purpose.

Starter of DC Motors: the current drawn by a motor armature is given by the relation where V is the supply voltage, the back emf and R the armature resistance. When the motor is at rest, there is no back emf developed in the armature. If, now, full supply voltage is applied across the stationary armature, it will draw a very large current because armature resistance is relatively small. This excessive current will blow out the fuses and, prior to that, it will damage the commutator and brushes etc. To avoid this happening, a resistance is introduced in series with the armature (for the duration of starting period only, say 5 to 10 seconds) which limits the starting current to a safe value. The starting resistance is gradually cut out as the motor gains speed and develops the back emf which then regulates its speed. Very small motors may, however, be started from rest by connecting them directly to the supply lines.

Regenerative:

By this method, full-load test can be carried out on two shunt machines, preferably identical ones, without wasting their outputs. The two machines are mechanically coupled and are so adjusted electrically that one of them runs as a motor and the other as a generator. The mechanical output of the motor drives the generator and the electrical output of generator is used in supplying the greater part of input to the motor. If there were no losses in the machines, they would have run without any external power supply. But due to these losses, generator output is not sufficient to drive the motor and vice-versa. The losses are supplied either by an extra motor which is belt-connected to the motor-generator set, or by electrically from the supply mains. The two shunt machines are connected in parallel. They are, to begin with, started as unloaded motors. Then, the field of one is weakened and that of the other is strengthened so that the former runs as a motor and the latter as a generator. The usual method of procedure is as follows: Machine M is started up from the supply mains with the help of a starter (not shown) whereas main switch S of the other machine is kept open. Its speed is adjusted to normal value by means of its field regulator. Machine M drives machine G as a generator and its

voltage is read on voltmeter V. The voltage of G is adjusted by its field regulator until voltmeter V1 reads zero, thereby showing that its voltage is the same, both in polarity and magnitude as that of the main supply. Thereafter, S is closed to parallel the machines. By adjusting the respective field regulators, any load can now be thrown on to the machines. Generator current I_1 can be adjusted to any desired value by increasing the excitation of G or by reducing the excitation of M and the corresponding values of different ammeters are read. The electrical output of the generator plus the small power taken from the supply, is taken by the motor and is given out as a mechanical power after supplying the motor losses.

Q3. What are the estimation of energy requirement for traction system.

Ans:

Energy output is the energy required for the propulsion of a train or vehicle is mainly for accelerating the rest to velocity ' V_m ', which is the energy required to overcome the gradient and track resistance to motion.

Energy required for accelerating the train from rest to its crest speed ' V_m '

The energy required for accelerating the train = power \times time

$$\begin{aligned}
 &= \frac{\text{work done}}{\text{time}} \times \text{time} \\
 &= \text{tractive effort} \times \text{velocity} \times \text{time} \\
 &= F_t \times \frac{V_m}{3,600} \times t_1 \text{ N-km/h-sec} \\
 &= F_t \times \frac{1}{2} \times \frac{V_m}{3,200} \times \frac{t_1}{3,600} \text{ N-km (or) kW-hr} \\
 &= \frac{1}{2} \times \frac{V_m^2}{(3,600)^2 \alpha} F_t \text{ kW-hr} \left[\because t_1 = \frac{V_m}{\alpha} \right] \\
 &= \frac{1}{2} \times \frac{V_m^2}{(3,600)^2 \alpha} [277.8W_g \alpha + 98.1 WG + W_r] \text{ kW-hr.} \\
 &[\because F_t = 277.8W_g \alpha + 98.1 WG + W_r].
 \end{aligned}$$

Energy required for overcoming the gradient and tracking resistance:

$$\begin{aligned} &= \text{tractive effort} \times \text{velocity} \times \text{time} \\ &= F_t' \times \frac{V_m}{3,600} \times \frac{t_2}{3,600} \text{ kW-hr} \\ &= \frac{V_m t_2}{(3,600)^2} [W_r + 98.1 WG] \text{ kW-hr,} \end{aligned}$$

where F_t' is the tractive effort required to overcome the gradient and track resistance, W is the dead weight of train, r is the track resistance, and G is the percentage gradient.

Total energy output = energy required for acceleration + energy required to overcome gradient and to resistance to motion.

$$\begin{aligned} &= \frac{V_m^2}{2(3,600)^2 \alpha} [277.8 W_e \alpha + 98.1 WG + W_r] + \frac{V_m t_2}{(3,600)^2} [W_r + 98.1 WG] \text{ kW-hr} \\ &= \frac{V_m^2 (1,000)}{2(3,600)^2 \alpha} [277.8 W_e \alpha + 98.1 WG + W_r] + \frac{V_m t_2 \times 1,000}{(3,600)^2} [W_r + 98.1 WG] \text{ W-hr} \\ &= \frac{V_m^2 (1,000)}{2\alpha (3,600)^2} [27.8 W_e \alpha] + \left[\frac{V_m^2 (1,000)}{2\alpha (3,600)^2} + \frac{V_m t_2 \times 1,000}{(3,600)^2} \right] [W_r + 98.1 WG] \text{ W-hr} \\ &= 0.01072 W_e V_m^2 + \frac{1,000}{(3,600)^2} [W_r + 98.1 WG] \left[\frac{V_m^2}{2\alpha 3,600} + \frac{V_m t_2}{3,600} \right] \text{ W-hr} \\ &= 0.01072 W_e V_m^2 + 0.2778 [W_r + 98.1 WG] [D_1 + D_2] \text{ W-hr,} \end{aligned}$$

$$\text{where } D_1 = \frac{V_m^2}{2\alpha 3,600} = \frac{V_m^2}{7,200\alpha}$$

$$D_2 = \frac{V_m t_2}{3,600}$$

$$\therefore \text{The specific energy output} = \frac{\text{energy output in Whr}}{\text{weight of train in tons} \times \text{distance of running}}$$

Multiple Choice Questions

1. What is formed at the cathode in the electrolysis of aqueous rocksalt?
 - A. Sodium
 - B. Chlorine
 - C. Hydrogen
 - D. Sodium chloride
2. What is formed at the anode in the electrolysis of aqueous rocksalt.
 - A. Sodium
 - B. Chlorine
 - C. Hydrogen
 - D. Sodium hydroxide
3. What is left in the solution as a result of the electrolysis of aqueous rocksalt?
 - A. Sodium
 - B. Chlorine
 - C. Hydrogen
 - D. Sodium hydroxide
4. What is chlorine gas *NOT* used in the manufacture of?
 - A. Alkali
 - B. Hydrochloric acid
 - C. P.V.C.
 - D. Bleach
5. What is sodium hydroxide *NOT* used in the manufacture of:
 - A. Textiles
 - B. Aluminium
 - C. Soap
 - D. Cable insulation
6. Overall efficiency of steam locomotive system is close to
 - A. 5 to 10%
 - B. 25 to 30%
 - C. 55 to 60%
 - D. 75 to 80%.

Ans: a

2. In a steam locomotive electric power is provided through

- (A) battery system
- (B) diesel engine generator
- (C) overhead wire
- (D) small turbo generator.

Ans: d

3. The efficiency of diesel locomotives is nearly

- (A) 20 - 25 percent
- (B) 35 - 40 percent
- (C) 50 - 55 percent
- (D) 70 - 75 percent.

Ans: a

4. The advantage of electric traction over other methods is

- (A) no pollution problems
- (B) faster acceleration
- (C) better braking action
- (D) all of the above.

Ans: d

5. Steam Engine provided on steam locomotives is

- (A) Single acting condensing type
- (B) double acting condensing type
- (C) double acting non - condensing type
- (D) single acting non condensing type.

Ans: c

6. Which locomotive has the highest operational availability

- (A) Diesel
- (B) Electric
- (C) Steam
- (D) All have same availability.

Ans: b

