UTILIZATION OF ELECTRICAL ENERGY & TRACTION

(Diploma 5TH SEM)

Education for a World Stage

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Cp-1

Utilization Of Electrical Energy and Traction

Electro Deposition -:

* Electro Deposition is otherwise known as electroplating.
* The process of depositing a metal on the surface of some other metal by electrolysis is called electroplating.

Electrolyte -:

* The substance which decompose when an electric current is passed through them are called electrolyte.

Electrolytic process or electrolysis -:

* The process of decomposition of electrolyte by the passage of electric current through them is called electrolytic process or electrolysis.

Need of electroplating -:

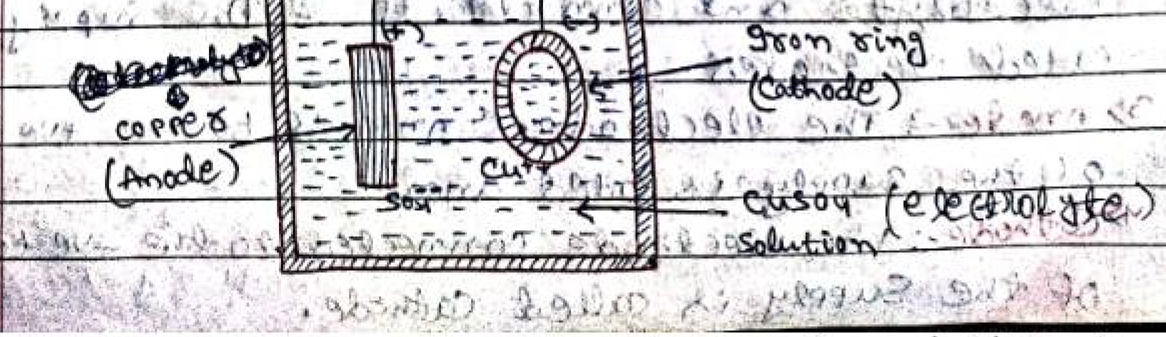
* The electroplating is used for

a) To protect the metals against corrosion. (କଳଙ୍କି)
b) To give shining appearance to the articles.
c) To give reflecting properties to the reflectors.
d) To replace worn out (ଘଷି ହୋଇଯିବା) material from a casting.
e) To repair a damaged casting.

Basic principles of electrodeposition -:

* If two electrodes are dipped in an electrolyte and potential is applied across them, the electrodes are named as +ve or anode (coating metal) and -ve or cathode (coated metal).
* When the molecules of the substance dissolved, they are broken up into two types of ions. (+ve or -ve)

Example -:



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* Let us consider a ring of iron to be coating with copper. And we used a solution of copper sulphate ($CuSO_4$).
* The soln breaks into +ve ion Cu^{++} & SO_4^{--} (-ve ion) by the help of water.
* When we gave D.C. supply the two electrodes from the bus bar, the -ve ions (SO_4^{--}) move towards the anode made of copper.
* Each SO_4^{--} ion after transfer of two electrons to the anode becomes SO_4 radical. It attracts the copper anode to form $CuSO_4$ molecule, which dissolves once again in water to maintain the electrolyte density at original level.
* The positive copper ions reach the -ve electrode i.e. the cathode (Fe) and receive two electrons ~~each~~ to become Cu atoms. These "Cu" then get deposited
* on the cathode surface.
* The copper deposited on the cathode surface is having the same mass as lost by the anode, in maintaining the electrolyte strength.

Eqn -: $CuSO_4 \rightleftharpoons Cu^{++} + SO_4^{--}$

At Anode :- SO_4^{--} lose two electron = SO_4 molecule

$SO_4^{--} + Cu^{++} \rightarrow CuSO_4$

At cathode :- Cu^{++} gain two electron = Cu molecule & deposite on the cathode surface.

* The whole process is called as electroplating or electrodeposition.

Some important terms regarding Electrolysis -:

1) Electrolyte -:
2) Electrodes -: The plates or rods immersed in an electrolyte and connected to D.C supply are called electrodes.
3) Anode -: The electrode connected to the +ve terminal of the supply is called anode.
4) Cathode -: The electrode connected to the -ve terminal of the supply is called cathode.

5> Ions-: When a d.c is passed through an electrolyte, it gets chemically decomposed into two parts known as +ve. and -ve ions.

6> Cations-: These are positively charged ions and they move towards the cathode.

7> Anions-: These are negatively charged ions and they move towards the anode.

8> Chemical equivalent weight-: Chemical equivalent weight of a substance may be defined as the ratio of its atomic weight and valency.

$\therefore$ Chemical Equivalent $= \dfrac{\text{Atomic weight}}{\text{valency}}$

9> Electro-Chemical Equivalent (ECE) -: Electro-Chemical equivalent of a substance is the amount deposited on passing a steady electric current of 1 ampere for one second through its sol^n.

10> Valency-: The valency of an atom or a group of atoms is the no. of Hydrogen-atoms with which it will react chemically. Valency is always an integer.

Ex-: CH_4

Faraday's laws of Electrolysis-:

1st law-: The weight of a substance liberated (मुक्त) from an electrolyte in a given time is proportional to the total quantity of electricity passed in that time.

* If w = weight of substance liberated in grams.

Q = the quantity of electricity passed. (charges)

then $w \propto Q$ $\qquad \boxed{I = \frac{Q}{T}}$

$\Rightarrow w \propto I.T$

$\Rightarrow \boxed{w = ZIT}$ $\qquad I$ = Strength of current (Ampere)

T = Time in second.

where Z = constant (electro-chemical equivalent of the substace)

If $I = 1$ Amp., $T = 1$ sec.

$\boxed{W = Z}$ Unit of ECE = milligramme per coulomb or gram per coulomb.

Second law :-

* If the same current flows for a given time through several electrolytes, the weights of substance liberated are proportional to their chemical equivalents.

$$\text{Chemical Equivalent} = \frac{\text{Atomic weight of substance}}{\text{Valency}}$$

* According to this law if we take the two electrolytes of copper sulphate and nickel sulphate in which same current flows for the same time, then

$$= \frac{\text{weight of copper deposited by given quantity of electricity}}{\text{weight of nickel deposited by same quantity of electricity}}$$

$$= \frac{\text{Chemical equivalent of copper}}{\text{chemical equivalent of nickel}}$$

$$\text{current efficiency} = \frac{\text{Actual quantity of substance liberated}}{\text{Theoretical quantity}}.$$

* It's value lies between 90 to 98%.
* Due to impurities, the quantity of a substance liberated is less than that calculated from Faraday's law.

$$\text{Energy efficiency} = \frac{\text{Theoretical energy}}{\text{Actual energy required}}$$

* Here the actual voltage required for the deposition or liberation of metal is higher than the theoretical value which increase the actual energy required.

Q1/ If a current of 10 amperes deposites 13.42 gm of silver from a silver nitrate Soln in 20 mins, calculate the electro-chemical equivalent of silver.

Ans :- $I = 10$ Amp.

$T = 20 \times 60 = 1200$ sec

$W = 13.42$ gm.

$$Z = \frac{W}{IT} = \frac{13.42}{10 \times 1200}$$

$= 0.001118$ gm/coulomb

Q) Calculate the quantity of electricity and the steady current required to deposit 5gm. copper from copper sulphate solution in one hour. Electro-chemical equivalent of copper is 0.3294 milligm/coulomb.

Ans:- $w = 5 gm.$

ECE of copper $(z) = 0.3294 \times 10^{-3}$ gm/coulomb.

$$Q = I.T = \frac{w}{z} = \frac{5}{0.3294 \times 10^{-3}} = 15180 \text{ coulomb}$$

$(\because w = zIT)$

$$\therefore I = \frac{Q}{T} = \frac{15180}{1 \times 60 \times 60} = \frac{15180}{3600} = 4.216 \text{ Amp (Ans)}$$

Factors effecting the amount of Electro-deposition-:

Time-: Time is directly proportional to the quantity of electrodeposition. So that more mass will be deposited in more
* time and less mass will be deposited in less time if the other condition remain same.

Efficiency-: Greater is the efficiency, greater is the quantity of metal deposited for a given time.

Current-: The value of current is also directly proportional to the mass of metal deposited.

* Greater is the current, greater is the quantity of metal deposited while other conditions remaining the same.
* But, if we increase the current beyond a certain limit which is fixed for different metals separately, the metal deposited will be of different colour such as blackish, which is known as burnt metal.

Strength of solution-: If the strength of solution is more, then the mass of metal deposited will be more as compared to the dilute solution of electrolyte if the other conditions remain the same.

* Dilute soln-: soln + water (More water) Ex-: H_2SO_4 (Sulfuric acid)
ex-: Mango juice.

classmate
Date
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Factors Governing the Better Electro-Deposition

a) current density -:

* current density = $\frac{\text{current}}{\text{Area}} = \frac{I}{A}$ (unit Amp/m^2)

* At low value of current density, the ions are released at slow rate, therefore the deposit will be coarse (ଘଣ) and crystalline (ସ୍ଫଟିକ) in nature.
* At higher values of current density, the quality of deposit become more uniform.
* If the current density is so high that it exceeds the limiting value for the electrolyte then a spongy and porous (ଛିଦ୍ର) deposit is obtained.
* current density for copper -: 33 to 44
  gold -: 110 to 330
  nickel -: 110 to 220
  silver -: 33 to 66

b) Electrolytic Concentration (ଏକାଗ୍ରତା) -:

* These factors depend upon the current density.
* Increase of concentration of the electrolyte tends to give better deposition at the cathode electrode.

c) Temperature -:

* The temperature of the electrolyte is different for different metals to have better deposit.
  Ex -: Chromium plating = 35°C.
  Copper plating = 50°C.
  Nickel plating = 50°C to 60°C.

d) Addition of Agents -:

* The quality of a deposit is improved by the presence of an addition agent which may be an organic compound (which contain carbon). Ex -: sugar ($C_{12}H_{22}O_{11}$), rubber (C_5H_8) etc.
* The additional agents are supposed to be absorbed by crystal nuclei and prevent their growth into large crystals.

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e) Nature of the electrolyte -:

* The smoothness of the deposit largely depends upon the nature of the electrolyte.

ex-: silver from silver nitrate ($AgNO_3$) solⁿ forms a rough deposit while that from cyanide (CN^-) solution forms a smooth deposit.

Types of electroplating	Electrolyte used
Copper plating →	$CuSO_4$ (copper sulphate)
Silver plating →	$Na[Ag(CN)_2]$ (sodium argnto cyanide)
Gold plating →	$Na[Au(CN_2)]$ (Sodium Auro cyanide)
Chrome plating →	$Cr_2(SO_4)_3$ (Chromium Sulphate)
Nickel plating →	$Ni(NH_4)_2(SO_4)_2 \cdot 6H_2O$ (Nickel ammonium Sulphate)

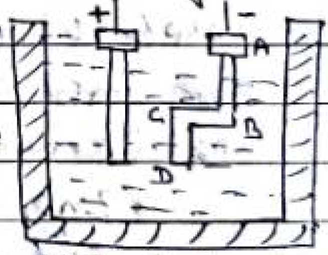
f) Nature of the metal deposit -:

* These factors influence the growth of crystals at the cathode side. ~~[illegible]~~

g) Throwing power -: * It is the ability of an electrolyte to deposit metal of a uniform thickness across a cathode surface.

* Throwing power used to produced a uniform deposit on a cathode, if the deposite having an irregular shape.

* In this fig. cathode (ABCD) is having an irregular shape.



* If we applied voltage betⁿ anode and cathode, we can find an uniform current at the anode side & ~~un~~ non-uniform current at the cathode side. (Due to the shape of cathode)

* Here, the surface AB is far away from the anode as compare to CD. Therefore resistance to the current path from anode to AB is more than that in case of anode to CD.

* Thus, the thickness of deposit on the surface of AB is smaller as compare to CD.

* Throwing power can be improved the deposit on two way
a) By increasing the distance between the object and the anode, so that the resistance between the anode and the different parts on the object is reduced.
b) By using cyanides soln in case of sulphates soln.

Application of electrolysis -:
1. Extraction of metal from their ores.
* There are two methods of extraction of metals from ores depending upon the physical state of the ore.
a) The ores is treated with a strong acid to obtain a salt and the soln of the salt is electrolysed to liberate the metal.
b) when the ore is in molten state it is electrolysed in the furnace (ভাটি) (lava)
* ore -: a naturally occurring solid material from which a metal or valuable mineral can be extracted profitably.

2. Extraction of zinc -:
* The zinc ore which has mainly zinc oxide (ZnO) is treated with concentrated sulphuric (H_2SO_4) acid and is passed through various chemical processes to get rid of impurities like cadmium (Cd), copper (Cu), etc. and formed zinc sulphate ($ZnSO_4$) soln.

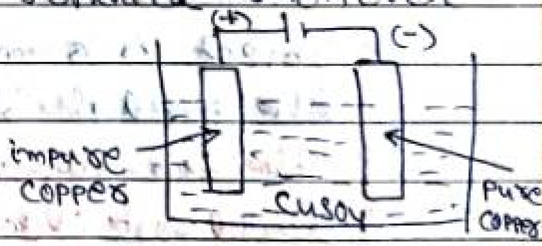
$ZnO + H_2SO_4 = ZnSO_4 + H_2O$

* Here the electrolysis process is carried out in wooden box & anode is lead (Pb) and cathode are of Aluminium. zinc deposited on the cathode side. (current density at cathode -: 1000 A/m², voltage drop = 3.5 V

3. Extration of Aluminium -:
* The ores of Aluminium are bauxite, cryolite, bauxite is treated chemically and reduced to aluminium (Al_2O_3) oxide and then dissolved in fused cryolite (Na_3AlF_6) and electrolysed. (An uncommon mineral)

* The furnace is lined with carbon & Aluminium metal gets deposited at the cathode.
* Temp. of furnace is about 1000°C & area of the furnace is 15 m^2. The voltage & current require for this process will be 8 volt and 45000 Amp. respectively.
* Since electrolytic process requires a great amount of power. So such plants are located near hydro electric power station.

4. Refining of Metals -:
* The metal extraced from its ore is not that much pure which would be used for electrical application.
Ex-: The purity of copper obtained from its ore is about 98%. But copper to be used in electrical applications must have a purity of 99.95%. This purity of copper is obtained by electrolysis.
* For copper, we generally used electrolytic sol^n copper ~~sulphide~~ ($CuSO_4$) (~~sulphide~~) sulphate
* The anodes are of impure copper extracted from its ore and the cathode are of pure copper.
* At regular intervals, the copper deposit is removed from the cathode and anode is replaced whenever required.
* Energy consumption for this process = 150 to 300 kWh per tonne of the refined copper.



5. Production of chemicals -:
* Many chemicals such as caustic soda (KOH), chlorine gas, amonium sulphate, hydrogen, oxygen etc. are produced by electrolysis on a large scale.

6. Separating metal from their compounds -:
* Many metals are separated from their compounds by electrolysis.
Ex-: an ore of aluminium contains about 70% aluminium oxide, silica and iron oxide.

* First pure aluminium oxide is obtained by suitable treatment and pure aluminium is obtained by electro-lytic process.

7. Electrotyping -:
* In this process wood cuts are reproduced in copper by the process of electroplating.
* First the mould is made of the type in wax, then it is coated with black lead to give it a metallic surface and then coating a layer of copper on that surface.

8. Electroforming -:
* The production or reproduction of an article by electrodeposition is known as electroforming.
→ Ex:- In the production of coins, models etc. mould is first made on wax surface by waxing material then it coated with graphite in order to make it conducting.
* Then the mould is then dipped in a electroforming cell as a cathode.
* After obtaining coating of desired thickness the object is removed and the wax is melted out of the metal shell.

9. Electro-deposition -:

10. Electro-cleaning -:
* Electro-cleaning process is used before every electro-deposition process.
* By this process we will remove some unwanted ~~material~~ things like grease, oil, ~~etc~~ soil, corrosion etc.

CP-2 Electric heating

* Electric heating is based on the principle that when electric current passes through a medium (soild, liquid or gas) heat is produced.
* whenever current (I) is made to flow through any circuit, having a resistance (R), power dissipated in that circuit is I^2R watts & the time of current flows for 't' seconds, energy consumed is I^2Rt Joules/watt-secs.
* This energy is being converted into heat and can be worked out as, $H = \frac{I^2Rt}{4.2}$ calories $= 0.24\, I^2Rt$ Calories.

where 4.2 is a constant called mechanical equivalent of heat.

* There are three modes of transmission of heat.

a) conduction (Solid) b) convection (Liquid or gas) c) Radiation (distant object)

Domestic Application of Electric Heating-:

1. Room heater for heating the room.
2. Immersion heaters for water heating.
3. Hot plates for cooking.
4. Electric kettles.
5. Electric Toasters.

Industrial Application of Electric heating-:

1. Melting of metals.
2. Electric welding.
3. Making of Plywood.
4. Moulding of glass for making glass appliances.
5. Moulding of plastic components.

Advantages of Electric Heating over other Methods of Heating-:

1. clean & Neat Atmosphere-:

* ~~During this process, coal dust is not required. Thus smoke is not generated.~~
* There is no coal dust or smoke generate and operators hand do not go black while operating

an electrical heating appliance.

2. No pollution-:

* In electrical heating process, no smoke or flue gases will be generate because the absence of flue channel or a pipe. (a channel or pipe in a chimney for carrying flame and smoke to the outer air) * No heat loss occurs in this process.

3. Controlled temperature-:

* The temperature can be controlled with in ±5°c, which is not possible in non-electrical heating process.

4. Ease of control-:

* The heating can be started instantaneously or stopped at a required time keeping a time gap betn switching off and cooling of the heating circuit.
* Here automatic switching controls are possible.

5. Localised Application-:

* In this process, a workpiece can be heated up to a particular depth for heat treatment whereas the piece as a whole receives heat in non-electrical heating process.

6. Low Ambient Temperature-:

* The temperature around an electrical furnace is much lower as compared to that around non-electrical furnace which is troublesome for the workers.

7. Uniform Heating-:

* The heating can be generated from within the workpiece resulting in uniform heating through induction heating. (the process of heating an electrically conducting object by electromagnetic induction)

8. Heating of Bad Conductor of Heat and Electricity-:

* wood, plastic and bakery items can be uniformly and suitably heated with dielectric heating process.
* Dielectric heating or high frequency heating is the process in which a radio frequency alternating electric field a dielectric material (insulator)

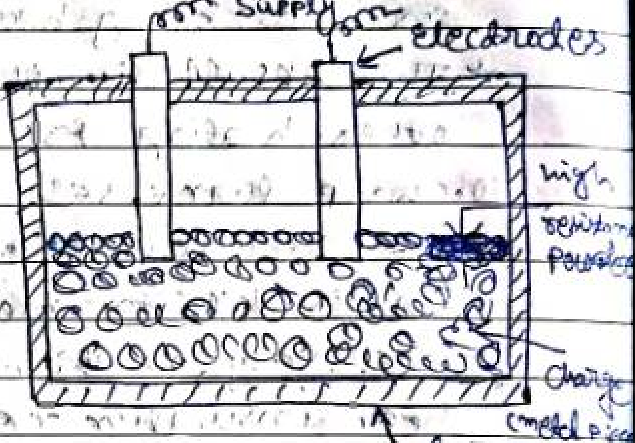
9. Highest efficiency of Utilisation-:
* Heat produced electrically does not go waste through chimney and other by-products.
* Most of the heat produced is utilised by the material being heated electrically.
* This results in the highest efficiency as compared to other heating processes.

10. Cheap furnaces-:
* The electrical furnaces do not require big space for installation, no storage of coal and fire wood is necessary, no chimney to be constructed, no extra heat insulation necessary.
* Due to all the above reason, this process is cost effective as compared to non-electrical heating method.

Resistance heating-:
* This method is based upon the I^2R loss. whenever current is passed through a resistive material, heat is produced because of I^2R loss.
* Resistance heating are of two types.
a) Direct resistance heating.
b) Indirect resistance heating.

Direct resistance heating-:
* In this method of heating, the material or charge to be heated is taken as a resistance and current is passed through it.
* The charge may be in the form of powder, pieces or liquid.
* The two electrodes are immersed in the charge & connected to the supply.
* In case of D.C or single phase AC, two electrodes are required but there will be three electrodes in case of three phase supply.

* when metal pieces are to be heated, a powder of high resistivity material is sprinkled over the surface of the charge to avoid direct short circuit.
* Here, The current flows through the charge and heat is produced.
* This method has high efficiency since heat is produced in the charge itself.
* Automatic temp. control is not possible in this method but it gives uniform heat & high temp.

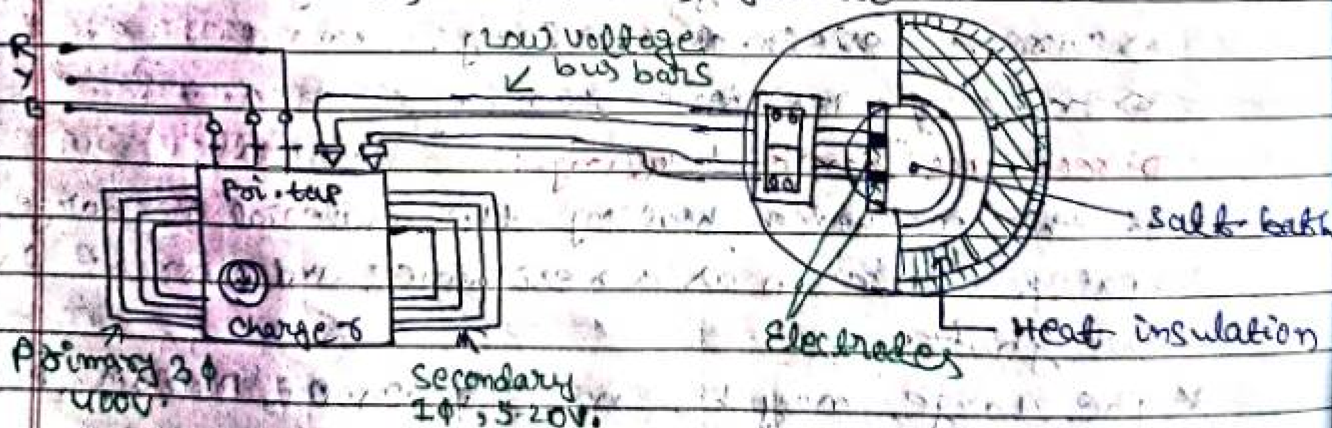


(Direct resistance heating)

* One of the major application of the process is Salt bath furnances having an operating temp. betn 500°C to 1400°C.

((*⇒ Salt bath furnance is basically a metal container filled with salt such as nitrates, nitrites, caustic soda, chlorides, carbonates, cyanide.))

ex-:



* The bath makes use of a supply voltage across two electrodes varying betn 5 to 20V.
* For this purpose a special double wound transformer is required which makes use of 3-ϕ primary and a 1-ϕ secondary. This speaks of an unbalance load.

→ selection of variable turn.

* tapping used ~~for~~ to regulate the vtg.

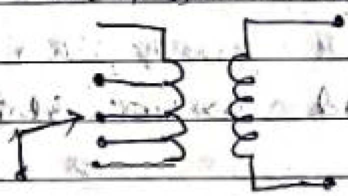
* The variation in the secondary voltage is done with the help of an off load tapping switch on the primary side. This is necessary for starting & regulating the bath load.

* ⇒ Double would transformer is a device that transfers energy from one ckt to another by magnetic coupling. For that matter this could be an AC voltage, even at a different frequency & transformer will isolate it from primary side.

* → The change of voltage is affected by changing the no. of turns of the t/F provided with taps, for controlling purpose: taps are usually provided on the high vtg. windings of the T/F.

a) OFF load tap changing T/F :- T/F is disconnected from the main supply when the tap setting is to be changed.

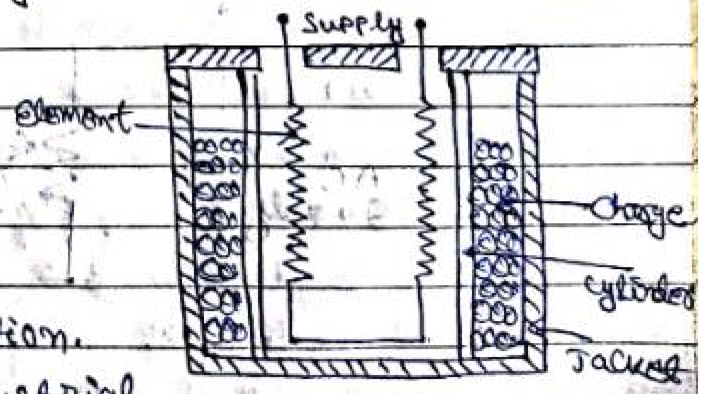
* tapping is done manually



b) on-load tap changing T/F :- Supply may not be interrupted.

Indirect Resistance heating :-

* In this method, the current is passed through a highly resistance element which is either placed above or below the oven depending upon the nature of the job to be performed.



* The heat proportional to I^2R losses produced in heating element delived to the charge either by radiation or by convection.

* Sometimes in case of industrial heating the resistance is placed in a cylinder which is ~~so~~ surround by the charge placed in the jacket.

~~____~~ outer covering of tank, pipe etc.

* ferrous -: Metal contain iron (magnetic) iron + carbon
* non-ferrous: Metal don't contain iron (non-magnetic) Al, Cu

~~Here~~

* Automatic temperature control is possible & this process provides ~~tem~~ uniform temp.
* Both A.C & D.C supplies can be used for this purpose & the voltage is depending upon the design of heating elements.

Ex-: Resistance furnance or oven.

Arc furnances

* The furnances used for melting/extraction of ferrous and non-ferrous metals need a high temp. operation.
* One of the method is through production of electric arc which gives an arc temp. betn 3000°C to 3500°C.
* Arc is the flow of current through an air gap betn two conducting bodies.

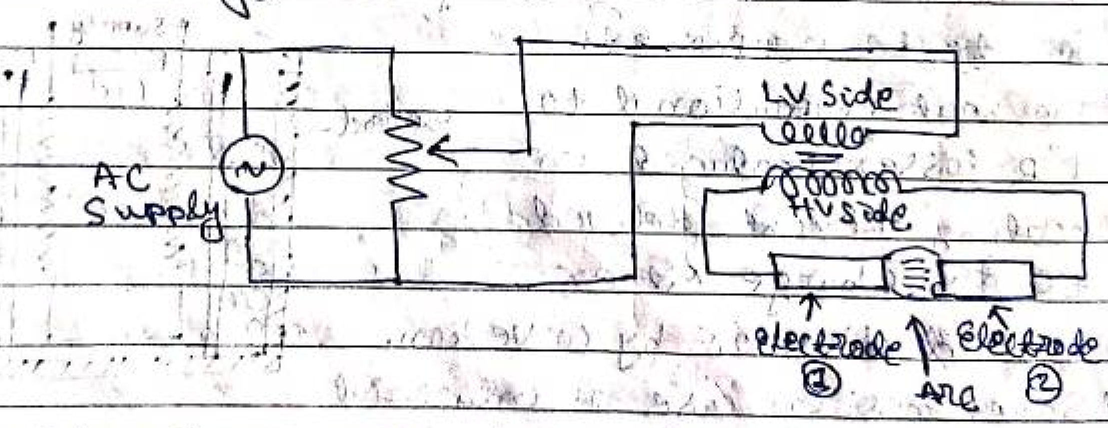
Methods of striking Arc -:

* It is of two type.

a> H.T strike method b> L.T. strike method.

H.T strike Method

* Here a constant gap is maintained across a pair of electrodes say made of carbon.
* The electrodes are connected across the secondary side of step-up transformer & the primary is fed with variable A.C voltage.



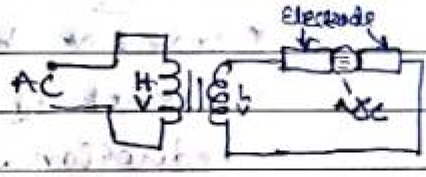
* To strike an arc the primary i/p vtg. is gradually increased, thus increasing the high tension voltage across the secondary/electrodes.

L.T = Low tension. (खींचाव)
H.T = High tension

* A stage comes when the medium betn the two electrodes is ionised & becomes conducting. At that time arc is formed betn the two electrodes.
* After the striking of the arc the potential difference across the electrodes has to be reduced from H.T to L.T. Since the conducting gap betn the two electrodes has now negligibly resistance as compared to the gap resistance before striking of the arc.

L.T Strike

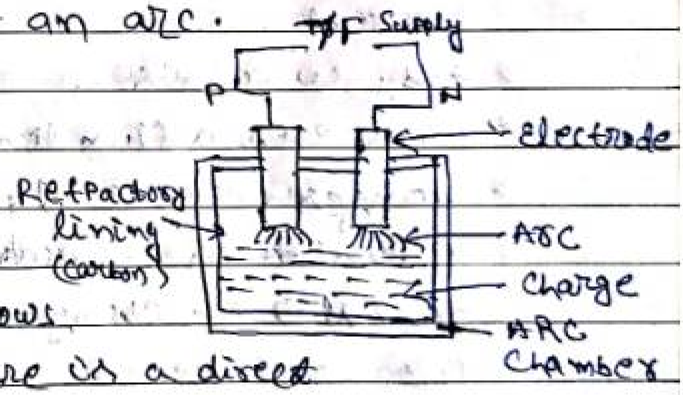
* In the second case a low voltage is enough to strike the arc.
* In this case the electrodes are connected to the lower voltage side of a transformer.



* These are momentarily short circuited and immediately separated. resulting in production of an arc.

(2) Direct arc furnaces

* When the arc is struck betn electrodes and the charge to be heated, so that the arc current flows through the charge and there is a direct contact betn the arc & the charge.

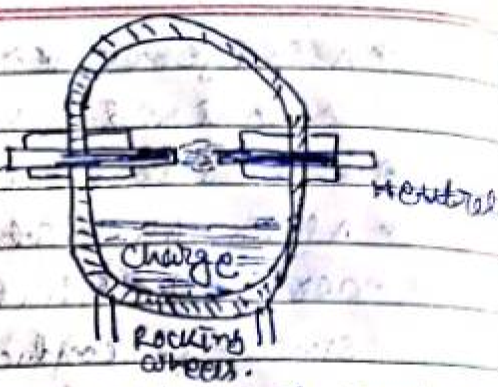


* The heating process is faster in this case, heating efficiency is too high and in addition to arc heat, additional heat is produced by the current passing through the charge undergoing heating.

In Direct Arc furnaces

* In this case a low vtg. A.C Single phase is applied across the electrodes.
* The arc is struck by short circuiting the electrodes for a moment and withdrawing these apart.

* The heat from by the arc is transferred to the charge top layer and refractory lining through radiation and from top layers of the charge to other portion of the charge through conduction.



* To distribute the heat, the furnance is rocked properly.
* Special motors with reduction gears and reversing directions are used for rocking.

Induction heating :-

* Induction heating is the process of heating an electrically conducting object (usually a metal) by electromagnetic induction, through heat generated in the object by eddy currents.

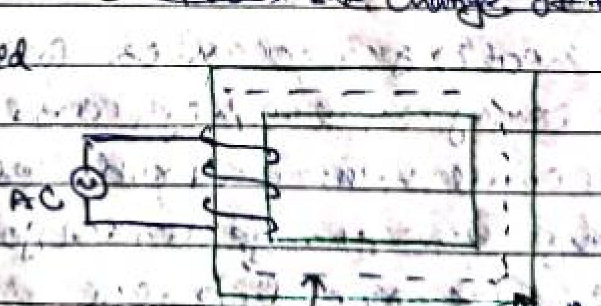
Eddy currents :-

* when ever a flux linking with any conduction body changes, the result is an emf induced which is a function of rate of change of flux ($e = -N\frac{d\phi}{dt}$) or rate of change of current ($e = -L\frac{di}{dt}$).

(emf is induced in such a dirn which opposite to the change of flux, change of cur)

add

* 1st law → conductor placed in magnetic field → emf induced.
* emf ∝ rate of change of flux linkage.



→ Since the core is a complete circuit single coil turn, any induced emf will result in circulation of current through this core. This current is known as eddy current.

* Here the magnitude of current depends upon the magnitude of induced emf & the resistance offered by the core material to the flow of this current.
* If i amperes is the magnitude of current and R ohms the resistance of the core material, then i^2R watts will be the power dissipated by the core. This power will be utilised in heating the core.
* Here induced emf is depends upon the rate of change of flux.
* Eddy current $\propto$ frequency ($f = \frac{1}{T}$) $\propto$ rate of change of flux.

b) * flux density (B) $\propto$ reluctance (S), so greater is relative permeability higher will be the flux density (B).

$B = \underbrace{\mu_0 \mu_r}_{\mu} . H$ & $\underset{\text{magnetic field intensity}}{H} = \frac{NI}{l}$ A/m

$\boxed{B = \phi / A}$

N = no. of turns on the coil μ_r = relative permeability.

i = current through the coil

l = length of the magnetic ckt.

* greater is the no. of turn's on the coil, greater will be the magnetic flux. Thus eddy current heating is a function of N.
* Larger is the current flowing through the coil greater will be the flux produced & higher will be the eddy current.
* $W_e = K B_{max}^2 f^2$

W_e = Power dissipated through eddy current

K = constant.

B_{max} = flux density.

f = frequency

Hysteresis:-

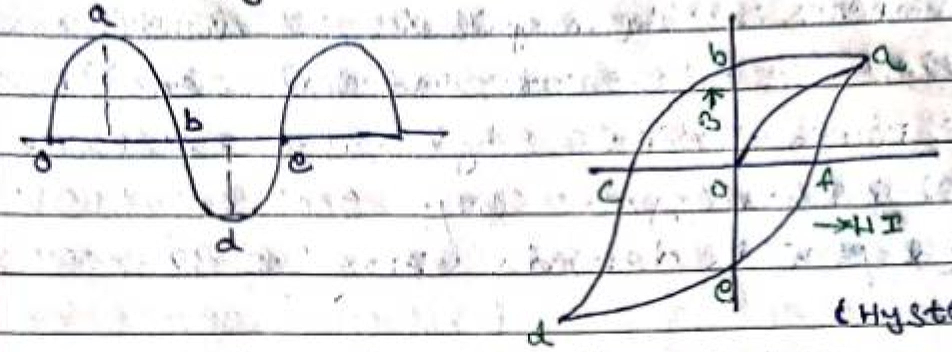
* when ever a piece of magnetic material is magnetised de-magnetised and re-magnetised again & again, energy will be loss. This losses so occurring in

residual flux :
the magnetic flux density that remains in a material when the magnetizing force is zero.

any electromagnetic device are named as hysteresis losses.

* The energy loss is then converted into heat.

*



(Hysteresis loss)

* During +ve half cycle, the core is magnetised to maximum value (+ve peak value 'a').
* when the sinusoidal current becomes zero, the magnetic flux density is not reduced to zero due to residual flux. (Remanence is the magnetization left behind in a ferromagnetic material (such as iron) after an external magnetic field is removed.
* During -ve half cycle, some coercive force is necessary to reduce the residual flux to zero (At point 'c')
* At point 'd', the core is having maximum reversed flux, to be demagnetised & remagnetised by the coming +ve half cycle.
* The configurations are termed as hysteresis loops.
* Greater is the area covered by one such loop, larger is the magnitude of hysteresis loss & more is the heat produced.
* $\boxed{W_h = K B_{max}^{1.6} f}$

W_h = power dissipated in a core due to hysteresis

B_{max} = Max^m flux density.

f = frequency

K = Constant.

* coercive force : the ability of a ferromagnetic material to withstand an external magnetic field without becoming demagnetized.

flux passing per unit area

Low frequency Induction heating -:

* Induction heating processes make use of currents induced by electromagnetic action in the material to be heated.
* It based upon the principle of T/F.
* There is a primary winding through which an A.C current is passed.
* Here the coil is magnetically coupled with the metal to be heated.
* An electric current is induced in this metal when the A.C current is passed through the primary coil.
* For melting or refining metals various types of induction furnances are available.

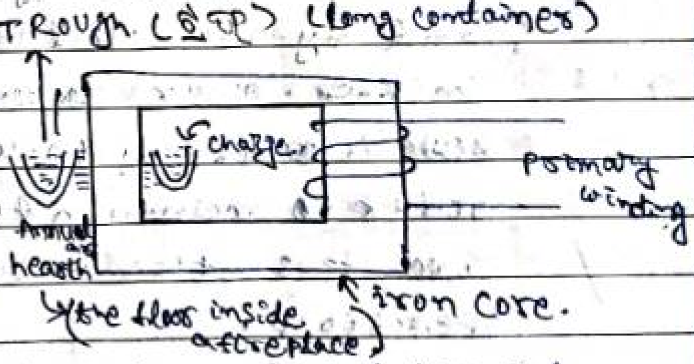
Type of induction furnaces -:

1> Core type -: a> Direct core type b> vertical core type c> Indirect core type.

2> Coreless type -:

Direct core type induction furnance -:

* It is like a transformer.
* The charge forms the secondary winding and consists of one turn only formed by the metal to be melted.



* Here the current in the charge is very high (several thousand amperes).
* The charge is magnetically coupled to the primary winding.
* Here the electromagnetic forces are set-up by the high current for the molten metal.
* When there is no molten metal, no current will flow in the secondary.
* To start the furnance molten metal is poured in the annular hearth or a sufficient quantity is left over from the previous charge.

reactance -: oppose the change in voltage or current.

Draw backs -)

a) Leakage reactance is high, power factor is low due to poor magnetic coupling.

b) Low freq. supply is required.

c) Furnace can't function if the secondary circuit is open. It must be closed.

vertical core-type induction furnace -: (Ajax-wyatt vertical core type f.)

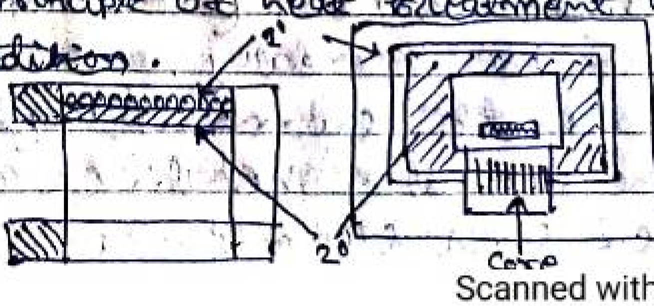
* It is an improved version of core type furnace.
* ~~Its size is vertical~~
* Here the magnetic coupling in this furnace is better than core type, leakage reactance is low & power factor is high. & it can operate in normal freq. (50Hz)
* The tendency of the circuit to rupture (breakdown) due to the pinch effect, is counteracted by the weight of the charge in the main body of the crucible. (metal contain)

construction of plasma through which a large electric current is flowing.

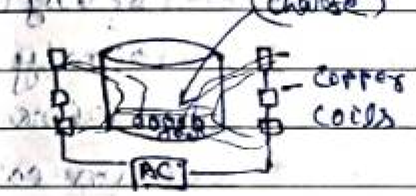
* The circulation of molten metal is kept up round the vee portion by convection currents (current in fluid), as indicated and by the electromagnetic forces betn the currents in the lower values of vee.
* It is necessary to keep the vee full of metal in order to maintain the continuity of the secondary circuit so this furnace is suitable for continuous operation.
* The top is covered with insulated cover which can be removed for charging.
* Hydraulic tilting arrangement is there to take the molten metal out. (By using pressure)

Indirect core type induction furnace -:

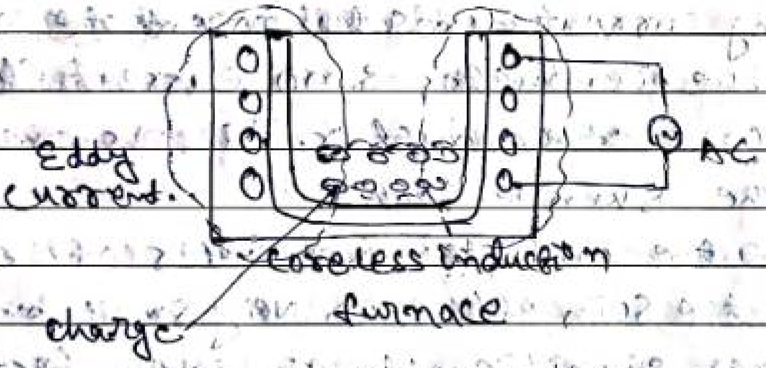
* based on the principle of heat treatment of metals. ~~charge by radiation.~~



* The 2° windings forms the walls of a metal container and the iron core links the primary as well as 2° winding
* It has poor power factor (0.8)
* used for temp. control. (without the used of external control equip.)
* The part AB of the magnetic cut. is ~~situated~~ situated in the oven chamber and made from a special alloy which looses its magnetic properties at a perticular temp. & regains them when cooled approximately to the same temp.
* temp range 400°C to 1000°C



Coreless Induction Furnace



* The flux produced by the primary winding set up eddy currents in the charge. The eddy current developed in any magnetic field $\boxed{\text{Eddy current} \propto B^2 \times f^2}$
* The Eddy currents are sufficient to heat the metal to melting point.
* The artifical cooling of primary coil is necessary because of high amount of copper losses and of high temp.
* The coil is constructed in the form of hollow tube through which cold water is circulated.
* Yoke – provide a path for flux, protection of the structure.

Advantages :

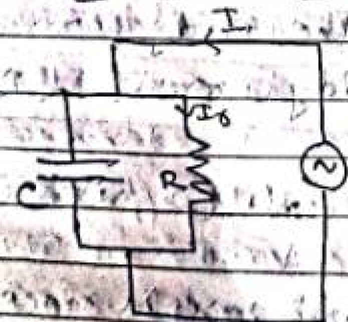
* The time taken to reach the melting temp. is less in this furnace.
* operating cost is low.
* There is no dust, smoke or noise.
* Charging and pouring is simple.
* Crucible of any shape can be used.

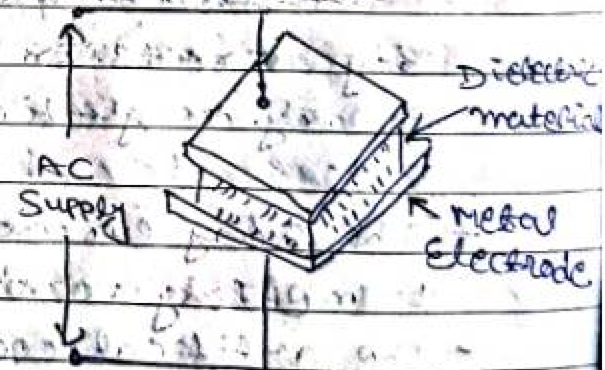
Skin effect :-

* The steady (D.C) [Direct Current] when flowing through a conductor distributes uniformly over the whole the whole x-section of a conductor.

* But in case of A.C, the distribution is not uniform.
* The alternating current tends to concentrate near the surface of the conductor & no current flows through the core of conductor. This phenomenon is called as the skin effect.
* Resistance of the conductor ∝ diameter of the conductor
* At low freq. the skin effect is very small but its effect becomes significantly at higher freq.

Dielectric Heating :-





(Dielectric heating)

* This is also called high frequency capacitive heating and is employed for heating of insulating materials like wood, plastic etc.
* The supply freq. applied for this type of heating is 10 - 30 mega cycles per second (hertz) & the applied voltage up to 20 kv.

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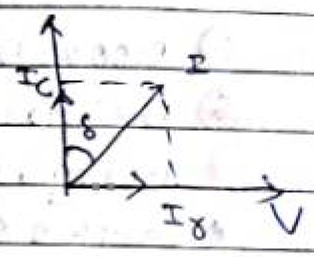
* The principle of operation of dielectric heating is that when a capacitor is subjected to a sinusoidal voltage, the current drawn by it is never leading the voltage exactly by 90°.
* The angle betn. voltage and current is slightly less than 90° (δ)

$$\left(\delta = \frac{1}{2\pi} \sqrt{\frac{\rho \times 10^7}{\mu_r \cdot f}}\ m \right)$$



where δ = loss angle.
ρ = Resistivity
μ_r = Relative permeability $\boxed{\mu = \mu_0 \mu_r}$ ($4\pi \times 10^{-7}$ H/m)
f = frerequency.

* Here a small component of current which is inphase with the applied voltage and in turn produces a power loss in the dielectric.
* At 50 Hz = Power loss is small.
* At high freq. ((10-30 MegaHz)), the loss become so large that it is sufficient to heat the dielectric material.
* Thus, the material to be heated is placed betn two sheet type conducting electrodes across which alternating voltage of high freq. is applied.
* Capacitor value $\boxed{(C) = K K_0 A/d}$ farads

K = Relative permittivity
K_0 = Permittivity in ~~sp~~ free space (8.854×10^{-12})
A = Surface area of electrode (m^2)
d = distace betn two electrode.

* Permeability (μ) = The measure of the resistance of a material against the formation of a magnetic field.
(cability to permit flow of magnetic flux)

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Some application of Dielectric heating -:
① Ply wood industry -: (assemblies with glue line for joining)
② plastic industry -: (used for moulding plastic)
③ Tombacco industry -: (Drying of tombacco in cigarette)
④ Bakeries -: (Dielectric heating required for baking biscuits, cakes & etc)
⑤ Book Binding -: (Drying the glue in 5-10 sec.)
⑥ Dehydration of food -: (used for long time, air tight containers)

Microwave heating -:
* In this system electricity is converted into electromagnetic waves, which generates energy and this energy is used to cook the food.

(electro magnetic radiation)

* These waves are high frequency radio waves, which is used by radio, TV, x-ray etc.
* The wavelength of these waves is very short & also called as microwaves.
* When a microwave energy comes into contact with some substance, it is reflected, transmitted or absorbed.
* These waves are reflected by metals, transmitted through paper, glass, plastic etc. and absorbed by water/moisture present in the food.
* When this energy is absorbed, heat is produced and cooking take place.
* The microwaves are attracted to water, fat & sugar molecules.

Applications -:
a) Drying of paper and textiles.
b) Food processing / kitchen work.
c) Treatment of diseases like cancer etc.
d) Manufacture of plastics.
e) Processing of cement etc.

Advantages -:

i) It has Neat and clean system.

ii) It provides uniform heating to the substance.

iii) The system provides quick heating.

iv) within the material, the heat is generated directly which gives much faster temp. rise.

Microwave oven

Micro wave generator → Applicator → Substance to be heated

* This oven basically converts the microwave energy ~~to~~ into thermal energy and supplies to the substance which is to be heated.
* Domestic ovens -: 1kw rating capacity.
* Industrial ovens -: several kilowatts rating capacity.
* Micro wave generator -: It generates microwaves energy to be supplied to the substance.
* Applicator -: This is a linking block betn. Microwave generator and the substance to be heated.

C> Electric welding

* Welding is a process in which two metal parts are joined by heating.
* Here the metal parts are heated up to the melting point for proper joining (with or without the application of pressure and filler metal)
* Electric welding -:
* The welding in which electric current is used to produce heat required for joining purpose of metals are called Electric welding.
* It is used in many purpose

a> Construction of ships d> ~~boiler~~ tanks

b> bridges steel frames e> pipe lines etc.

c> Structures.

Arc -: flow of current through an air gap betⁿ two conducting bodies.

* It is of two types
a) Arc welding -: (heat is produced either by striking an arc betⁿ an electrode)
b) Resistance welding -: (heat is produced by passing a heavy current through the metallic joint)

Arc welding -:

* An electric arc is produced by bringing two conductors connected to a suitable source of electric current, momentarily in contact and then separating by small distance.
* Here the current continuous to flow across the small gap and gives intense heat. This heat is utilised for melt the part of a work piece.
* Welded joint -: The welded joint is a union of metal parts made by localised heat without any pressure.
* For welding operation -: (for successful welding)

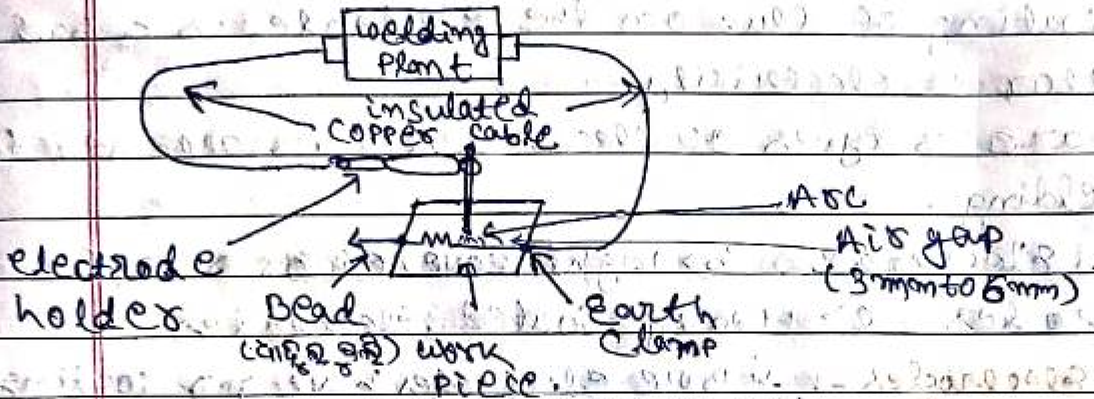
→ Maxᵐ voltage specified = 100V; AC (80-100)V, DC (60-80)V.
→ Current range = 30 to 500A (manually operated)
→ Current range = 75 to 600A (Automatic operated)
→ Temperature = 3000°C.

* The electric welding is widely used for joining the metal parts to repair fractured castings [illegible] and the fillings by the deposition of new metal on the worn parts.
[illegible]

Principle of Arc welding -:

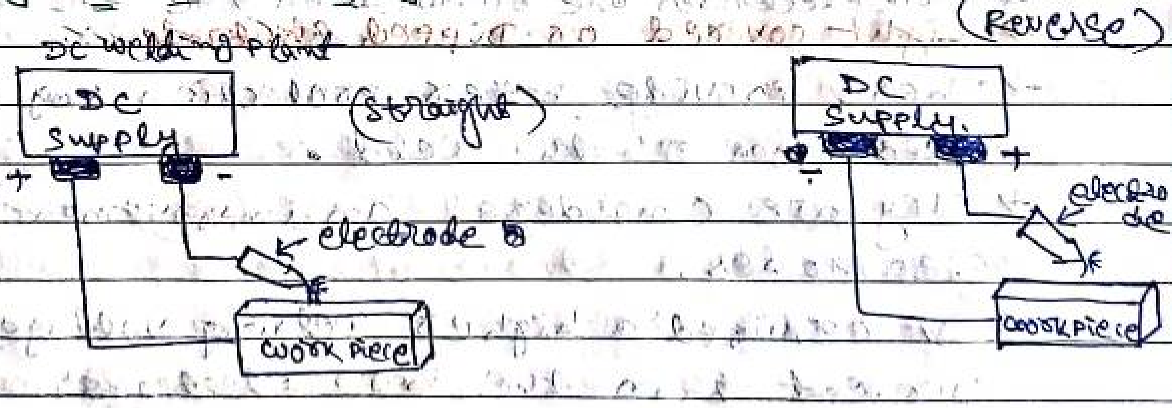
* In Arc welding we used both (AC & DC) source.
* Here two terminals are their. One terminal is connected to the electrode and the other to the work piece and the circuit is completed through air gap.
* The gap is provided betⁿ the tip of the

electrode and the surface of work piece by keeping the electrode at a distance of about 3mm to 6mm from the surface of the work piece.
* Due to the interruption by the air gap, heat is produced
* Here electrical energy is converted at the arc into heat energy.



(***) welding is affected by the length of arc being maintained. A long arc requires a higher voltage than a short arc but a good operator will maintain the correct length of arc.

Polarity in D.C. welding



* when an electrode is connected with -ve pole of DC welding plant, it is called straight polarity.
* when an electrode is connected with +ve pole of DC welding plant, it is called Reverse polarity.
* In A.C welding, no such polarity is their.
* Around 65 to 75% of heat produced in the arc is collected on the positive pole & the rest

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fluxing -: used to remove oxides from the contacts of the parts of electrode.

from the -ve poles.

Electrodes for metallic arc weldings -:

* An electrode is made of a metallic wire called core wire coated uniformly with flux material.
* During fluxing the electrodes about 20mm. of its length is left bare at one end for inserting it into electrode holder.
* The coating of flux on the electrode is a bad conductor of electricity.
* There are 3 types of electrodes, which are used for arc welding.

a) Bare electrode b) Light covered or Dipped electrodes c) Heavy coated electrodes.

a) Bare electrodes -: * Bare electrodes have no coating flux material on them.

* These electrodes are used for lower welding voltage
* welding current ranges from 60 to 310 amperes according to the size of electrode are used.
* Here the duration to start the arcing is more as compared to other electrodes.
* Bare electrodes are operated on the -ve pole. (Straight Polarity)

b) Light covered or Dipped electrodes -:

* These provide better protection ~~any~~ against oxidation of the weld.
* They are considered an improvement version as compared to bare electrodes.
* It required a higher welding voltage and lower current than the bare electrodes.
* Light covered electrodes are operated on the -ve pole. (Straight polarity).

Heavy coated electrodes -:

* These are coated with a material of substantial thickness and solidity.
* Heavily coated electrodes are operated on the +ve pole. (Reversed polarity)

mineral-: the substance that is naturally fromed under the ground.
Ex-: coal, petroleum product etc.)

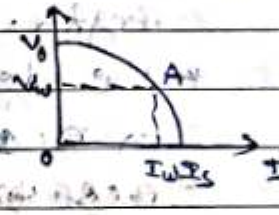
* ~~Here~~ This types of electrodes have in general a spiral winding of asbesto ~~material~~ mineral on the basis of covering. (~~[illegible]~~ → (A soft gray mineral that does not burn).

Electric arc welding Equipments -:

a) D.C welding equipment -:

* consists of a motor / generator set. ← (compound generator) (Squirrel cage induction motor)

* ~~Here~~ compound generator give drooping characteristics. Here the terminal voltage falls automatically with the increase in load current.



where V_0 = open circuit voltage.
V_w = welding voltage.
I_w = welding current.
I_s = Short Ckt. current.

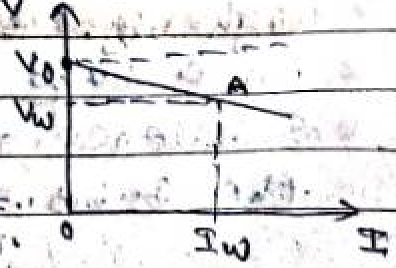
* If supply from existing system is used for welding then a ballast ~~resistance~~ resistor is connected in series with the equipments and control is obtained by variation of the external resistance.

* This method is suitable when a no. of operators are working on the same supply ~~sy~~ system. In such cases each operator is provided with separate ballast.

(*) Ballast resistor -: It is a special type of resistor.
→ when we increase the current flowing through it, its resistance value is also increase & vice versa.

b) A.C welding Equipments -:

* A transformer reduces the voltage from that of the supply drawn to about 100 V ito regulate the current and produce the drooping charactersties for required of a resistance.



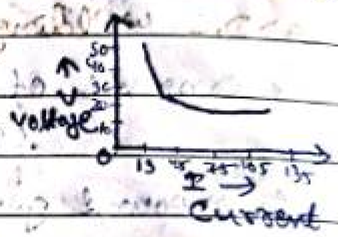
I_w = welding current.
V_0 = open ckt vtg.
V_w = welding vtg

Electrical properties of an Arc -: (D.C & A.C arc Phenomena

Arc Stability -:

* Electric arc has negative resistance characteristics.
* As the arc current increase, the voltage across it decreases, i.e. resistance of the arc decreases.
* form ohm's law, we can find out ~~to~~

$$I = \frac{V}{R} \text{ or } \boxed{R = \frac{V}{I}}$$



* It is not possible in manual arc welding for welder to hold a constant arc weld length.
* The decrease in arc length will result in the decrease in arc resistance and hence building up of arc current. This will further reduce the arc resistance.
* In this way, effect & cause help each other till arc will be out of control.
* similary increase in the arc length will bring about increase in resistance of arc which will reduce the arc & its diameter resulting in further increases This will further increase the resistance of arc.
* From the above two cases, we ~~get to~~ know that arcing is a difficult job for the operator to maintain a stable arc.
* Arc stability is achived in A.C by putting choke in the supply line which gives drooping characteristic

Choke :- The function of choke is to provide high vtg. enough for ionization to take place in a tube light & after establishment and substence of ionizations limit the voltage across the tube.

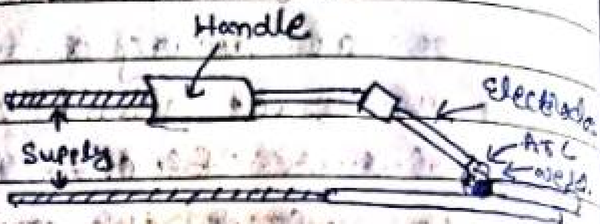
ionize-: covert into ion or ions, by removing one or more electrons.

Arc blow-: Arc blow is the unwanted or deflection of the arc during arc welding.

* The space round the arc & in the adjacent metal is always effected by magnetic fields which tends to deflect the arc.
* Here the intensity of magnetic field is proportional to the square of the current. $\underset{(A/m)}{H} \propto I^2$
* The magnetic field deflects the arc when it is not uniformly distributed.
* The distribution of field depends upon the position & shape of workpiece & air-gap.
* To avoid arc blow and get good quality of weld, an A.C welding machine is used because in A.C, the flow of current changes direction rapidly and with that the magnetic field will also change directions very rapidly.
* This change will cancel the arc blow effect & stabilize the arc.
* Sufficient voltage is required to strike an arc than to maintain it. This is because some voltage is required to ionize the air-gap.
* when electrons leave the cathode, they hit the anode after attaining certain velocity, where their momentum is destroyed. This is how more heat is produced at anode as compare to cathode.
* As we are interested to heat the work piece to be welded, it is always connected to positive terminal of dc supply welding & electrode is connected to -ve terminal (straight polarity)

Types of electric Arc welding :-

a) Metallic arc welding :-



* In metallic arce system a metal rod is used as an electrode & the arc is struck betn this electrode and work piece.
* AC Supply = ~~secondary winding of~~ welding T/F
* DC supply = welding generator.
* Due to welding two pieces to be welded & fuse together
* After complete the welding process, remove the electrode. At the time weld metal be cools & solidifies to give a strongly welded joint.
* Arcing temp. = 3500°C.
* Used short arc, voltage = 20V to 25V.
* In no case, voltage exceed to 30V, (proper welding is not done)
* Different current is used for different type of joint.
* Lap joint will require more current than the butt joint for a same material.

Carbon arc welding :-

* This method is normally used for welding copper and its alloys.
* DC supply :- carbon = -ve, work piece = +ve (Alloys)
* DC supply :- carbon = +ve, work piece = -ve, the carbon particles have a tendency to go into the welded joint and cause brittleness. (ভঙ্গুর)
* Only DC used in this type of welding.
* Carbon welding are of two type.

a) no flux is used ~~on~~ (Non-ferrous metals)

b) flux is used (either in the form of powder or paste to prevent the weld from oxidation. (Ferrous metal)

Alloys-: Combination of metals of one or more elements.

Non-ferrous metal-: doesn't contain iron.
ex-: Aluminum, aluminum alloys, copper etc.
ferrous metal -: contain iron
ex-: iron, iron alloys etc.

Helium or argon arc welding-:
* This method is used for welding aluminium alloys, magnesium and magnesium alloys.
* An arc is struck between electrode of tungsten (W) and the work piece & helium or argon is used to give an inert (inactive) atmosphere, so that oxidation of the welded joint does not take place. Chemically inactive
* Both AC & DC welding equipment is used for this type of welding.
* AC (open ckt. voltages) = 100 volt.
* DC (open ckt. voltage) = 70 volt.

Atomic hydrogen arc welding-:
* For the atomic hydrogen arc welding process, two tungsten electrodes are used.
* The source of power could be either D.C or A.C but we commonly used A.C. (commonly available).
* To strike and maintain the arc, an open ckt voltage of 300 volt is necessary & current range - 50 Amp.
* In this type of welding the arc is struck betn two tungsten electrodes & hydrogen is passed through the arc.
* Due to the high temp. (about 4000°C), the hydrogen changes to its atomic form.
* When the atomic hydrogen travels to cooler regions (away from the arc), it regains its molecular form.
* In doing so, it gives up the energy which it had received from the arc.
* Thus a very intense heat is generated which is

used to melt the job to be welded.

* After cooling the two parts of the job are welded together.
* A filler rods may be used if additional metal is needed for making a joint.
* This method is used for welding Stainless Steel & non-ferrous metals.

Resistance welding

→ Discovered :- Prof. Elihu Thompson (1885)

* The principle of resistance welding is the generation of heat in the joint by passing a heavy current through the parts & applied mechanical pressure which welds the metal.
* Here a resistance welding machine must be capable of supplying an electric current of the required value to produce the necessary heat for welding process.

Advantages :-

* It is a quick method of joining two pieces.
* There is very little wastage of the metal.
* The process can be accurately controlled.
* The welds are consistently uniform.

Generation of Heat :-

$\boxed{H = I^2Rt}$ where H = heat generated

I = current in Amp.

t = time in sec.

R = electrical resistance of the joint.

* The temp. depends on the quantity & is affected by heat losses.
* A.C = 4400 to 5000 Amp/sq.cm of area to be welded
* Pressure = 280 to 565 kg/sq.cm.
* This operation will be conduct at low voltage and high current.

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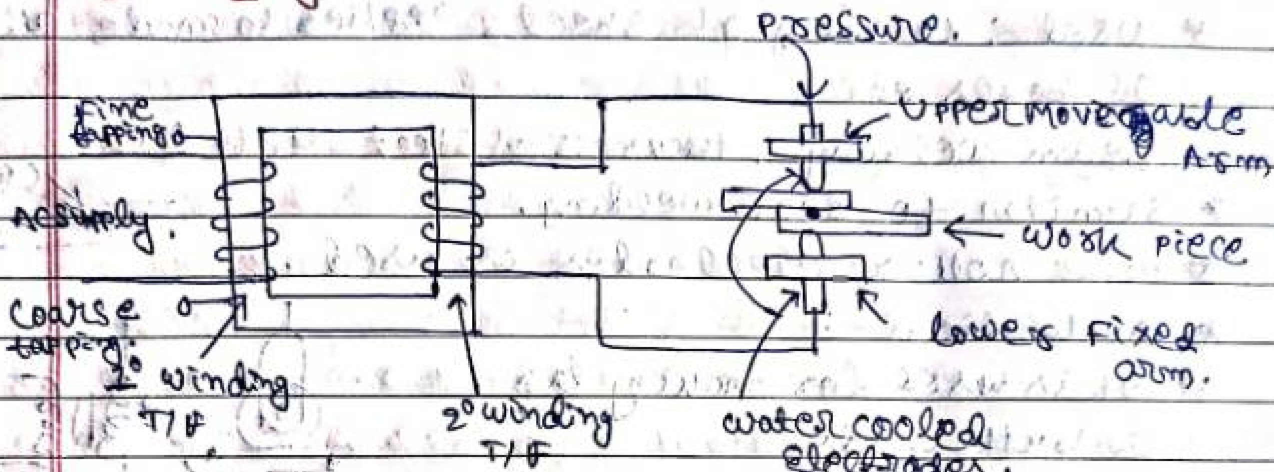
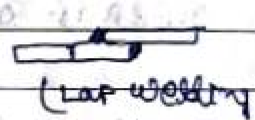
tapping -: the action of striking against Something with a quick light blow or blow.

* It is of several type.
a) Butt welding b) Flash welding c) spot welding
d) seam welding e) projection welding.

Spot welding



* This is the simplest & most common method which is used for lap welding.
* thin sheets thickness = 12.7 mm (maximum).



* The spot welding machine consists of a T/F to produce high current at low voltage.
* Electrodes are connected to the ends of the secondary winding for leading the current to the work and to apply the necessary mechanical pressure.
* In addition, there must be a mechanical arrangement to bring the electrodes in to contact with the work.
* It is used to provide tapping on the primary winding of the T/F to regulate the secondary voltage.
* The materials to be welded are overlapped & pressed betn two water cooled electrodes & current is passed through it.
* The metals in the zone of pressure get heated up to fusion and joint. After that it cooled under pressure.
* For spot welding current = 5000 Amp.
* Vtg. betn the electrodes = less than 3 volt.
* Open ckt Vtg = less than 12 Volt.

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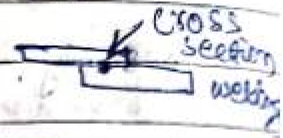
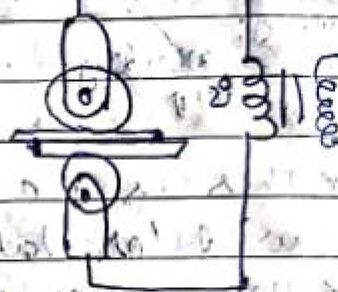
* The spot weld is affected by the value of current flow, the pressure betn the electrode tips (made by copper or copper alloy) & the time of current flow.
* Used -: welding of sheet, applied to made all types of boxes etc.

Seam welding -: thickness of sheet = up to 10mm.



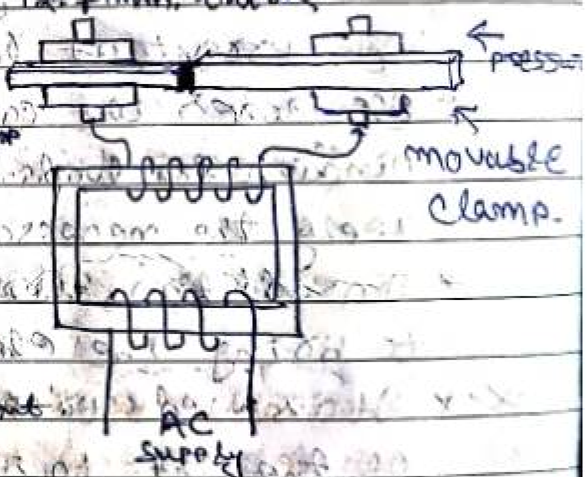
* Similar to spot welding.
* Here roller electrodes is used.
* Application -:
* It is used for making lap & butt welds.
* It is quicker than spot welding operation.



Butt welding (mm)-:

* thickness of sheet = up to 12.7mm thick
* components -:

T/F, two clamps (fixed clamp & movable clamp)



* In this process, heat is generated by the contact resistance betn two component
* Here the two parts are brought together & the pressure is applied along the axial direction.
* A heavy current is passed from the welding T/F which create necessary heat at the joint.

Application -:

a) The parts are joined end to end or edge to edge.
b) Used for welding pipes, wires & rods

$$\boxed{\underset{\text{density}}{\rho} = \frac{\text{mass} - kg}{\text{volume} - m^3}}$$

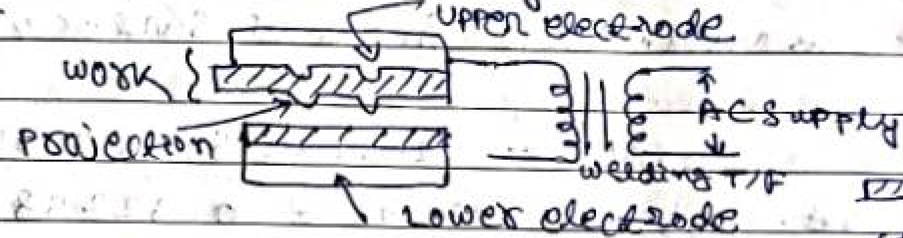
Flash welding -:

* This is similar to butt welding except for the difference that in this case current is applied to the parts before they are brought together.

→ when the two pieces ~~to be~~ are brought together, they creat a arcing or flashing.

Projection welding -:

* Modified form of Spot welding




(After welding)

* In projection welding, upper electrode consists of forming slight projections on the sheet of metal.

Advantages

* More than one spot or weld are done at a time. Therefore, more O/P is obtained
* Due to low current density & low pressure, the electrode life is increased.
* Good finished product ~~would be~~ is obtained.
* It locates the welds automatically at certain desired points by the position of projection.

Problem of CP (1), CP (2), CP (3)

Ex:- Calculate the time taken to deposit a coating of nickel 0.05 cm thick on a metal surface by means a current of 20A per sq. inch of surface. Nickel is a divalent metal of atomic weight 59 and density of 9 gm/cc (gm/cubic cm.) Silver has an atomic weight of 108 and ECE of 1.118 mg/col. (valency of silver - 1)

valency ②

Ans. silver (Ag) atomic weight = 108 $\boxed{1\,inch = 2.54\,cm}$

Electro Chemical equivalent (ECE) = 1.118 mg/col.

chemical equivalent of silver (CE) = $\frac{\text{Atomic weight}}{\text{valances}}$

$= \frac{108}{1} = 108$

Chemical equivalent of Nickel $= \frac{\text{weight}}{\text{valency}} = \frac{59}{2} = 29.$

Density of Nickel $= \frac{\text{mass of Nickel}}{\text{volume of Nickel}}$

$\Rightarrow$ Mass of Nickel = Density of Nickel $\times$ volume of Nickel

$\Rightarrow$ volume (V) = (area of surface) $\times$ Thickness of coating

$\Rightarrow V = 2.54 \times 2.54 \times 0.05 = 0.32258$

Mass of Nickel $= 0.32258 \times 9 = 2.90322$

Now $\frac{\text{E.C.E of Ni}}{\text{E.C.E of Ag}} = \frac{\text{CE of Ni}}{\text{CE of Ag}}$

$\Rightarrow$ E.C.E of Ni $= \frac{\text{CE of Ni}}{\text{CE of Ag}} \times$ E.C.E of Ag.

$= \frac{59/2}{108} \times 1.118 \times 10^{-3}$

$= 3.05537 \times 10^{-4}$ gm/coul

We know $W = ZIT$ (m)

$\Rightarrow 2.903 = 3.0537 \times 10^{-4} \times 20 \times T$

$\Rightarrow t = \frac{2.903}{3.0537 \times 10^{-4} \times 20} = 475.3 \simeq 475$ sec. (Ans)

Q) A steady current of 40 Amp. is passed through a solⁿ of copper sulphate for 1 hr. Find the weight of copper deposited. The chemical equivalent for the copper is 31.8 and ECE of hydrogen is 0.01044 mi. gm/coulomb.

Ans: $\frac{\text{E.C.E of Cu}}{\text{E.C.E of } H_2} = \frac{\text{Chemical Equivalent of Cu}}{\text{Chemical Equivalent of } H_2}$

$\Rightarrow \text{E.C.E of Cu} = \frac{\text{C.E of Cu}}{\text{C.E of } H_2} \times \text{E.C.E of } H_2$

$= \frac{31.8/1}{1/1} \times 0.01044 \times 10^{-3}$

$= 3.31992 \times 10^{-4} = 0.000331992 \text{ gm/Col}$

$W = ZIT$

$\Rightarrow W = 0.000331992 \times 40 \times 60 \times 60 = 47.80 \text{ gm. (Ans)}$

Q) An ammeter connected in series with a silver electrolytic cell reads 0.60 Amp and it is found that 0.322 gm of metal deposite in a run lasting 10 min. What is the error of ammeter to this point of its range? ECE of silver = 1.118 milligm/col.

Ans: m or $w = 0.322$ gm

$T = 10 \times 60 = 600$ sec

$Z = 1.118 \times 10^{-3}$ gm/col

w or $m = ZIT$

$\Rightarrow 0.322 = 1.118 \times 10^{-3} \times I \times 600$

$\Rightarrow I = \frac{0.322 \times 10^{3}}{1.118 \times 600} = 0.48 \text{ Amp.}$

But the actual ammeter reading = 0.60 Amp

So error = Actual value − Measured value

$= 0.60 - 0.48 = 0.12 \text{ Amp.}$

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CP-4 Illumination

* Illumination is different form light. Light is cause and illumination is the result of the light on the surface of which it falls.
* Thus the illumination makes the surface look more or less bright with a certain colour and it is this brightens and colour which the eye sees.

Terms used in illumination

Light -: Light is defined as the radiant energy from a hot body causing visual sensation upon the human eye.

Flux -: It is also known as luminous flux.
* It is defined as the total quantity of light energy radiated or emitted per second from a luminous body in the form of light wave.
* It is measured in lumens & denoted by F or ϕ.

$$\boxed{\phi \text{ or } F = Q/t \text{ lumens}}$$

Q = the luminous output of source of light (lumen/hrs)

t = time (hours)

Light energy -: (Q)
* It is the energy obtained in visual radiations in a given time & is expressed in lumen hour

Luminous efficiency or Radiant efficiency -:
* It is defined as the output in lumens per watt of the power consumed by the source of light.
* Luminous efficiency $= \frac{\text{luminous flux } (\phi)}{\text{Power } (P)}$ (lumens/watt)

Ex -: Bulb rating = 500 watt

Voltage = 250 volt.

luminous efficiency = 13 luman/watt

ϕ = ?

Ans -: ϕ = luminous efficiency × power

= 13 × 500 = 6500 lumens (Ans)

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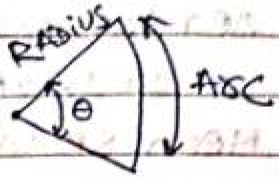
Luminous Intensity :-

Plane angle :- Plane angle is subtended at a point in the same plane by two converging lines.

Unit :- radians or degrees.

$$\theta = \frac{Arc}{radius}$$

$$= \frac{l}{r} \text{ radians}$$



$$1 \text{ Radians} = \frac{180}{\pi} \text{ degree}$$

* The largest plane angle subtened at a point may be 2π radians.

Solid angle :- (ω)

* Solid angle is the angle generated by the line passing through the point in space and the periphery of the area.

related to

or A solid angle enclose a volume by an infinite no. of lines lying on a surface and meeting at a point.

Unit :- Steradian.

$$\omega = \frac{Area}{(Radius)^2} \text{ steradian.}$$

$$\text{Plane angle } (\theta) = \frac{Arc}{Radius} = \frac{Circumference}{Radius} = \frac{2\pi r}{r}$$

$$= 2\pi \text{ radians}$$

$$\text{Solid angle}(\omega) = \frac{\text{Area of Sphere surface}}{(\text{Radius of Sphere})^2}$$

$$= \frac{4\pi r^2}{r^2} = 4\pi \text{ steradians.}$$

Luminous Intensity :-

$$\boxed{I = \frac{F}{\omega} = \frac{\phi}{\omega}} \text{ lumens/steradians or Candla}$$

where F/Φ = luminous flux

ω = Solid angle.

* Lumens = candle power x solid angle = C.P x ω
* $C.P = \frac{\text{lumens}}{\omega}$
* candle power (C.P) -: candle power is the light rendering capacity of a source in a given direction.
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Mean spherical candle power (M.S.C.P) -:

$$M.S.C.P = \frac{\text{total flux (lumens)}}{4\pi} = \frac{\phi}{4\pi}$$

~~Mean hemi spherical candle power (M.H.S.C.P)~~

* It is defined as the average of candle powers in all directions and in all plans from the source of light.

Mean hemi-spherical candle power (M.H.S.C.P) :

* It is defined as the average of candle powers in all directions above or below the horizontal plane passing through the source of light.

Mean horizontal candle power (M.H.C.P)

* It is average of all the candle powers in all dir in the horizontal plane containing the source of light.

Reduction factor -: $\frac{M.S.C.P}{M.H.C.P}$ = $\frac{\text{Mean Spherical candle power}}{\text{Mean horizontal candle power}}$

Q1// Calculate the total flux from the lamp having mean spherical candle power of 35.

Soln -: M.S.C.P = 35

$M.S.C.P = \frac{\text{Total flux}}{4\pi}$ => Total flux = M.S.CP x 4π

$= 35 \times 4 \times \frac{22}{7}$

$= 440$ lumens

Q// A 250 volt ~~lamp of~~ lamp has a total flux of 3000 lumens and takes a current of 0.8 amp. Calculate (i) lumens/watt (Ans) (luminous efficiency)
(ii) MSCP

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solⁿ :- wattage of lamp or power(P) = VI = 250 × 0.8 = 200 watts
total flux(Φ) or (F) = 3000 lumens

Luminous efficiency $= \frac{\text{lumens}(\Phi)}{\text{watt}(P)} = \frac{3000}{200} = 15$ lumens/watt

M.S.C.P $= \frac{\Phi}{4\pi} = \frac{3000}{4\pi} = 238.7$ lumens

Light spectrum :-
* The light spectrum consists of seven colours.
a) violet b) Indigo c) Blue d) Green e) yellow
f) orange g) Red. (VIBGYOR)
* These light radiations have different frequency and wave length.

$\boxed{v = \lambda f}$ v = velocity (m/s)
λ = wave length (m)
f = frequency (Hz) or $\frac{1}{sec}$

wave length of different colour:-
* 1 meter = 10^{10} Angstrom Unit (Å) (A.U)
* 1 meter = 10^{6} micron (μ)
* violet = 4100 Å, Green = 5500 Å, Blue = 4700 Å
* orange = 6100 Å, Yellow = 5800 Å, Red = 6000 Å

Q// calculate the wave length of light, if its frequency is 6×10^{14} Hz.

Ans :- $v = \lambda f$ velocity of light = 3×10^{8} m/s

$$\Rightarrow \lambda = \frac{v}{f} = \frac{3 \times 10^{8}}{6 \times 10^{14}} = 0.5 \times 10^{-6} \text{ meter} \times 10^{10}$$
or = 5000 Å (Ans)

Electro magnetic waves spectrum :-

frey.	wavelength	Nature of wave
3×10^{22}	10^{-14}	cosmic Rays (A highly energetic Atomic nucleus move the high space.)
3×10^{20}	10^{-12}	γ-Rays
3×10^{18}	10^{-10}	x-Rays
3×10^{16}	10^{-8}	Ultraviolet Rays
3×10^{14}	10^{-6}	visible light

$3 \times 10^{12} \rightarrow 10^{-4} \rightarrow$ Infrared Rays
$3 \times 10^{10} \rightarrow 10^{-2} \rightarrow$ Short wave Radiowaves
$3 \times 10^{6} \rightarrow 10^{2} \rightarrow$ Long wave Radiowaves

Illumination -: (E) :

* when the light falls upon any surface, the phenomenon is called illumination.

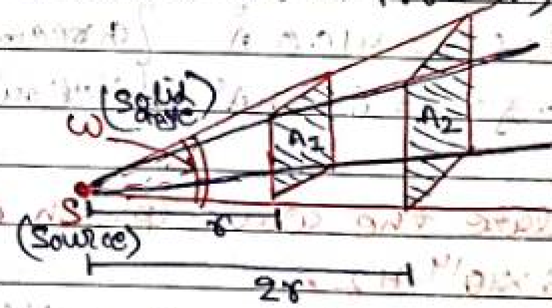
$$\boxed{E = \frac{\phi}{A}}$$ Unit = lumens/m^2 or lux ~~or~~

* one Phot $= 10^4$ lux

Laws of Illumination -:

First law -: (inverse square law)

* According to this law, the illumination of a surface is inversely proportional to square of distance from the source. ~~and the surface~~
(condn -: The distance betn the surface & the source is sufficiently large, so that the source can be consider as a point.)



* consider a point of source (S) having an intensity (I) (lumens/steradian or candla).
* Let two surfaces having areas A_1 & A_2 be placed at distances 'r' and '2r' meters away from the source respectively.
* The two surfaces are enclosed in the same solid angle 'ω'.
* we know $I = \frac{\phi}{\omega}$ I = luminous intensity
$\Rightarrow \phi = I . \omega$ ϕ = luminous flux
ω = Solid angle

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so flux for area(A_1) = $I \cdot \omega$

but $\omega = \frac{\text{Area}}{(\text{radius})^2} = \frac{\text{Area}}{(\text{Distance})^2} = \frac{A_1}{r^2}$ steradian

then ~~so~~ total flux for area(A_1) = $\frac{I \cdot A_1}{r^2}$

& ~~but~~ illumination (E_1) on the surface area(A_1) :-

$$E_1 = \frac{\phi}{A_1} = \frac{I \cdot \cancel{A_1}}{r^2} \times \frac{1}{\cancel{A_1}} = \frac{I}{r^2} \quad \text{—(i)}$$

similarly flux for area(A_2) = $I \cdot \omega$

but $\omega = \frac{\text{Area}}{(\text{Distance})^2} = \frac{A_2}{(2r)^2}$ steradian

then total flux for area(A_2) = $\frac{I \cdot A_2}{(2r)^2}$

& illumination (E_2) on the surface area (A_2) :-

$$E_2 = \frac{\phi}{A_2} = \frac{I \cdot \cancel{A_2}}{(2r)^2} \cdot \frac{1}{\cancel{A_2}} = \frac{I}{(2r)^2} \quad \text{—(ii)}$$

By divided eqn (i) & (ii), we get

$$\frac{E_1}{E_2} = \frac{I/r^2}{I/2r^2}$$

or $\boxed{E_1 : E_2 :: \frac{I}{r^2} : \frac{I}{(2r)^2}}$

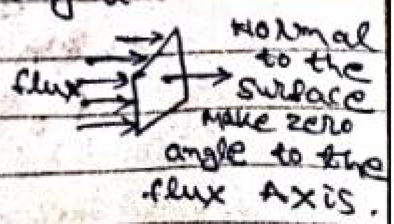
2nd law

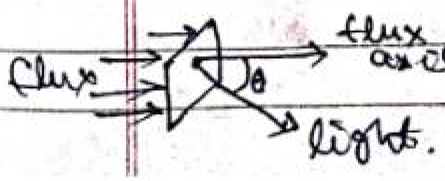
Lambert's ~~law~~ cosine law :-

* According to this law, illumination of a surface is directly proportional to the cosine angle betn the flux & the direction of ~~area~~ light.

i.e. $E \propto \cos\theta$

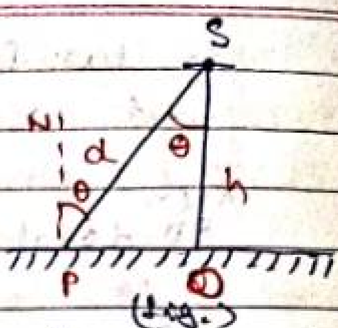
* For normal surface, $E = \frac{\phi}{\text{Area}}$





* For inclined surface, $E = \frac{\phi}{\text{Area}} \times \cos\theta$

Illumination at a point -:



* Let 'P' be the point on a plane surface at a distance of 'd' meter from a source of light 'S'.
* The source is at a height of 'h' meters from the surface & its luminous intensity (I)
* From 1st law of illumination,
  Illumination at point 'P',

$$E_P \propto \frac{I}{d^2} \quad \text{--- (i)}$$

& from 2nd law of illumination,

$$E_P \propto \cos\theta \quad \text{--- (ii)}$$

Now by combining Eqn (i) & (ii)

$$E_P = \frac{I}{d^2}\cos\theta \quad \text{--- (iii)}$$

But from the above fig.

$$\cos\theta = \frac{OS}{PS} = \frac{h}{d}$$

$$\Rightarrow \boxed{d = \frac{h}{\cos\theta}} \quad \text{--- (iv)}$$

Put Eqn (iv) in Eqn (iii)

$$E_P = \frac{I}{(h/\cos\theta)^2}\cdot\cos\theta = \frac{I}{h^2}\cos^3\theta$$

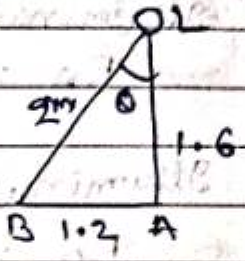
Therefore, illumination at a point 'P',

$$E_P = \frac{I}{d^2}\cos\theta = \frac{I}{h^2}\cos^3\theta$$

similarly, if we consider $\cos\theta = 1$ at point 'O'.
then illumination at point 'O'.

$$E_O = \frac{I}{d^2} = \frac{I}{h^2} \quad (\because \text{Here } d = h)$$

Q// The illumination at a point on a working plane directly below the lamp is to be 100 lumens/m². The lamp gives 256 C.P uniformly below the horizontal plane. Determine the height at which the lamp is suspended and find illumination at a point on the working table 1.2 meters away from the vertical axis of the lamp.



Ans :- Luminous intensity (I) of lamp $= 256$ C.P

Illumination at a point directly below the lamp $E_A = 100$ lumens/m² or lux

∴ Illumination at point (A)

$$E_A = \frac{I}{d^2} = \frac{I}{h^2}$$

$$\Rightarrow 100 = \frac{256}{h^2} \Rightarrow h^2 = \frac{256}{100} \Rightarrow h = \sqrt{\frac{256}{100}} = \frac{16}{10} = 1.6\text{m.}$$

Illumination at point 'B'

$$E_B = \frac{I}{h^2} \cos^3\theta$$

$$= \frac{256}{1.6} \times (0.8)^3$$

$$= 51.2 \text{ lumens/m}^2$$

or 51.2 lux (Ans)

$$LB = \sqrt{(AB)^2 + (AL)^2} = \sqrt{(1.2)^2 + (1.6)^2} = 2\text{m.}$$

$$\cos\theta = \frac{b}{h} = \frac{1.6}{2} = 0.8$$

Q// A source of light has an output of 500 C.P in all directions below the lamp level. It is suspended at 3m above the ground. Calculate

a) illumination at point 'A' on ground directly below the lamp.

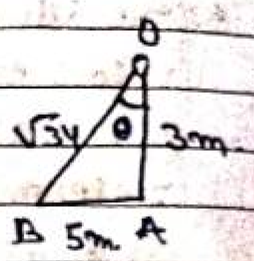
b) illumination at point 'B', 5 m. Away from 'A'.

Answer -: luminous intensity = 500 C.P

(OA) h = 3 m.

(AB) d = 5 m.

$$(OB) = \sqrt{(AB)^2 + (OA)^2}$$
$$= \sqrt{(5)^2 + (3)^2}$$
$$= \sqrt{34}$$



Illumination at point 'A'

$$E_A = \frac{I}{h^2} = \frac{500}{3^2} = 55.55 \text{ lumens/m}^2 \text{ or lux.}$$

Illumination at point 'B'

$$E_B = \frac{I}{d^2}\cos\theta$$

$$\boxed{\cos\theta = \frac{OA}{OB} = \frac{3}{\sqrt{34}}}$$

$$= \frac{500}{(\sqrt{34})^2} \times \frac{3}{\sqrt{34}} = 7.56 \text{ lux (Ans)}$$

Q// A lamp of 200W having an MSCP of 400 is suspended 2 m. above a working surface. Calculate
(i) Illumination directly below the lamp.
(ii) Lamp efficiency (Luminous efficiency) lumens/watt
(iii) Total luminous flux in a radius of 0.20m. of a circle.

Ans-: a) $E = \frac{I}{h^2} = \frac{400}{2 \times 2} = 100$ lux

b) $MSCP = \frac{\phi}{4\pi} \Rightarrow \phi = MSCP \times 4\pi$
$= 400 \times 4\pi = 5024$ lumens

$\therefore$ Lamp efficiency $= \frac{\text{lumens}}{\text{watts}} = \frac{5024}{200} = 25.12$ lumens/watt

c) Area of circle $= \pi r^2$
$= \pi \times (0.2)^2 = \frac{\pi}{25} \text{ m}^2$

We know $E = \frac{\phi}{\text{Area}}$

or $\phi = E \times \text{Area} = 100 \times \frac{\pi}{25} = 12.5$ lumens (Ans)

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Calculation of a lighting scheme -:

* output of ~~the~~ a source = $\frac{\text{Lumens required}}{\text{Depreciation factor} \times \text{coeff. of utilisation}}$

Depreciation factor -: = $\frac{\text{illumination under normal working cond}^n}{\text{illumination when everything is clean.}}$

* (Dust, smoke)

* It's average value is 0.8.

* wattage of lamps = ϕ/η ← output of a source; ← efficiency of lamp.

Design of lighting scheme -:

Space-height ratio = $\frac{\text{The horizontal distance bet}^n\text{ lamps}}{\text{Mounting height of lamps}}$

Utilization factor - $\frac{\text{total flux (lumens) utilised on working planes}}{\text{Total flux (lumens) radiated by lamp.}}$

* It is depends upon

a) Area to be illuminated

b) height at which the lamps are fitted.

c) The colour of surrounding walls.

d) The type of lighting - direct ~~to~~ or indirect light.

* Direct light -: 0.25 to 0.5

* indirect light -: 0.1 to 0.3

Q/ A room of 30×20 is to have direct lighting. The avg. illumination is 200 lux. The lamps are to be fitted 4m. from ground floor. Find the no. of lamps and wattage/lamp for the lighting scheme. Given efficiency of the lamps available as 25 lumens/watt, depreciation factor 0.8 and coefficient of utilisation 0.75. (Taking 200W lamp)

Ans -: $E = 200$ lux or lumens/m^2

Area $= 30 \times 20 = 600\,m^2$

$E = \frac{\phi}{A} \Rightarrow \phi = E \times A = 200 \times 600 = 12000$ lumens

Desired light O/P $= \frac{\phi}{D.F \times C.U}$

$= \frac{120000}{0.8 \times 0.75} = 200000$ lumens.

Wattage of lamps $= \frac{O/P}{\eta} = \frac{200000}{25} = 8000$ watts

No. of lamps $= \frac{\text{wattage of lamps}}{\text{lamp power}}$

$= \frac{8000}{200} = 40$

Sources of light -:

* various sources of light can be divided into two groups.

a) Natural sources. (sun, stars etc)

b) Artificial sources
- Non-electrical sources of light (candles, kerosine lamps etc)
- Electrical sources of light (incandescent lamps, mercury vapour lamps, fluorescent lamp, Sodium vapour lamps etc.

Electrical sources of light -:

Incandescent - lamps -:

Filament materials -:

* The material used for filament is carbon, osmium tantalum and tungsten.

* But now-a-days we prefer tungsten as a filament because of the following reason.

a) It has high melting point. (3500°C)

b) It has high resistivity

c) It has low temp. co-efficient.

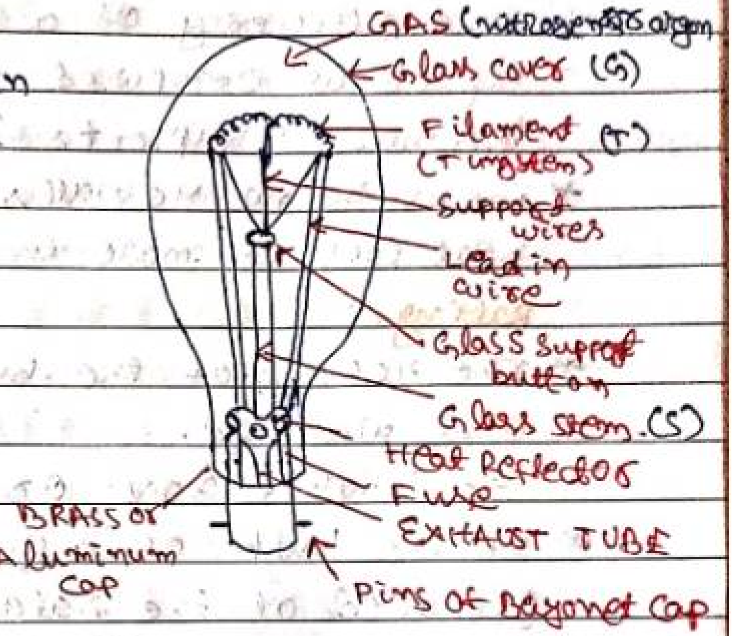
d) It is ~~sufficiently~~ strong mechanically to withstand vibrations during normal use.

e) It has higer efficiency than other filament molecule.

Convection: It is the heat transfer due to the bulk movement of molecules with fluids in gas or liquid.

* For finding the resistance of the filament we used the formula, $\boxed{R = \frac{V}{I} = \frac{4 \rho l}{\pi d^2}}$ d = diameter of filament.
ρ = sp. resistance.
l = length of the filament.

CONSTRUCTION OF LAMP



* It consists of a tungsten filament (T) placed in a glass cover (G)
* Here the filament is ~~capa~~ capable of being operated for a long periods of time at a high temperature.
* Tungsten satisfied all the necessary condn of filament, so we used Tungsten as a filament.
* In case of tungsten filament light output $\propto E^n$ where n = 4 or 5 and power input $\propto E^n$ where n = 1.8. E = voltage.
* During manufacture of filament all air is pumped out of glass cover to prevent filament burning up when operating condn.
* Lamps larger than 40 watts are filled with inert gas (argon (Ar) and ~~neg~~ nitrogen (N))
* These gases are used to reduce the rate of evaporation (By reduce the heat) & to avoid deterioration due to oxidation. Hence the life span of the filament increase.
* The filament is supported on wire hooks fixed on a glass stem (S) and is normally in the helical / ~~spiral~~ spiral / coiled coil form. (filament)

* This reduces the surface area of the filament exposed to gas and thereby reduces the heat loss due to convection.
* It also reduces space requirement for the large length of filament.
* The efficiency of a ~~coil~~ ~~spherical~~ spiral coil lamp is higher as compared to single coil lamps & it required less no. of supports for the filament.
* Lamps below 40 watts are not filled with gas. So heat loss is more in this type of bulb.

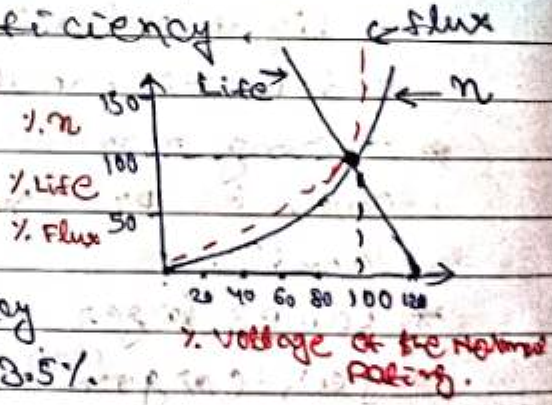
Rating -:

* The rating of the bulbs is specified in volts and wattage.

  Ex -: 60W, 230V or 100W, 250V etc.
* If the bulbs of a given voltage rating are not operated at the rated voltage, there is direct influence on the a) lumens output.

  b) Life span.

  c) Efficiency.



* 5% increase operating vtg. → 50% reduces the life span
* 2% change in vtg. → 1.5% change in wattage, 2% in efficiency & output by 3.5%.

Effects of Glass Cover -:

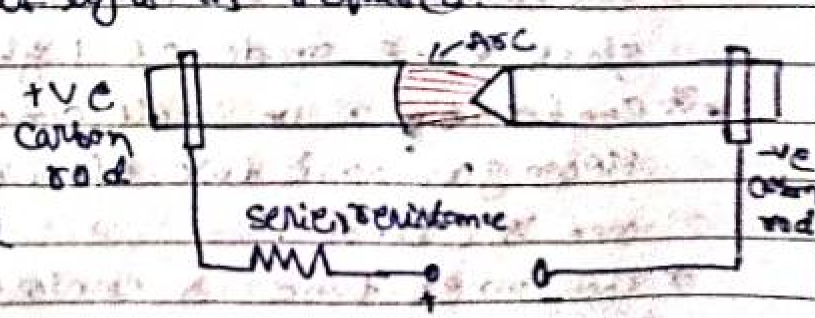
* Green, yellow, Red glass covers → signalling purpose
* Bluish glass cover → Moon light effect
* Milky glass cover → day light effect
* Miscellaneous colour glass cover → decorative lighting purpose

Neon lamps-: (low pressure gas discharge lamp)

* Neon lamp consists of a glass bulb filled with neon gas with a small percentage of helium.
* The two electrodes in the glass bulb are of pure iron spaced few mm apart.
* These lamps are operated on 110 volt a.c or 150 volt d.c supply.
* Neon lamps give orange pink colour light and its size is very small as compared to incandescent lamps.
* Its luminous efficiency is 15 to 40 lumens/watt and consumption is about 5 watts.
* These lamps are used as indicator lamps and night lamps.
* Neon gas = orange colour or pink
* hydrogen gas = Red colour
* Helium gas = Yellow color
* CO_2 = white * Mercury = blue.
* Gas discharge lamps-:
* Gas discharge lamps produce light by sending electricity through an ionized gas. (Use noble gas or combination of noble gas).

Carbon arc lamp (Arc lamp)

* Used in cinema projectors and search lights when a very bright point source of light is required.
* In this lamp two hard carbon rods are placed end to end and connected to D.C supply.



* The voltage of DC supply should not be less than 45 volt.
* When current passed through the carbon rods

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they become incandescent due to high resistance.
* ~~are~~ Here the two carbon rods are separated apart by a small distance of 2 or 3 mm.
* when the two carbon rods struck with each other an arc is produced betn the two rods & hence white light will be produced.
* The arc is maintained by transfer of carbon particles from +ve rod to -ve rod.
* So positive rod becomes hollow after some time and -ve rod becomes pointed like a pencil.
* The rate of burning of +ve rod is twice than that of -ve rod. (DC supply)
* In case of AC supply, consumption of both the carbon rods are equal.
* In this lamp, about 85% light is given by the +ve carbon rod, 10% by -ve carbon rod and 5% by the air.
* The temp. of +ve carbon rod is betn 3500°C to 4000°C and that of -ve rod is 2500°C.
* Luminous efficiency = 9 lumens/watt.
* Here a series resistance is used for stabilising the arc.

Sodium vapour lamp :-
* Sodium vapour lamp consists of an inner U-shaped glass tube made of high resistance glass. ~~and~~
* It contains a small amount of metallic sodium, Neon gas and two electrodes, one is anode & other one is cathode.
* The inner tube is enclosed with an outer glass tube of U-shape and the space betn them is ~~...~~ to minimise the heat losses from the inner tube.

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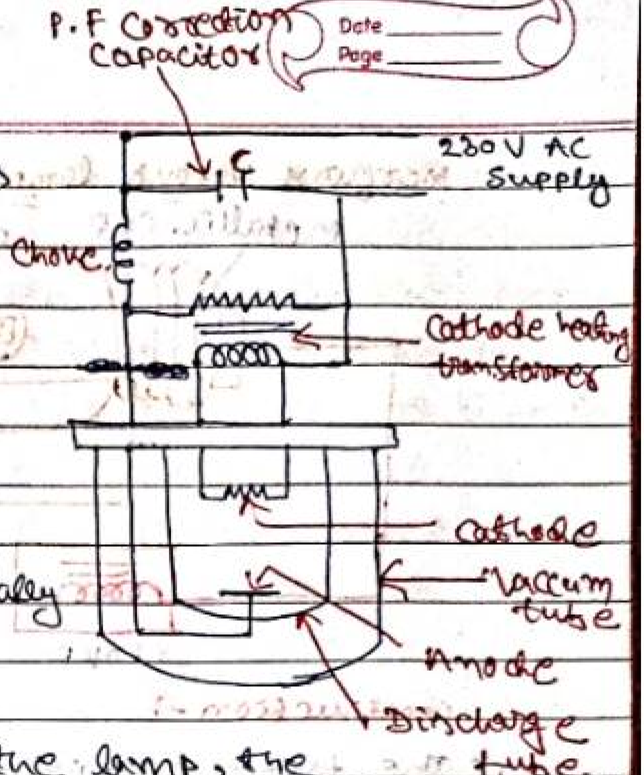
* The presence of neon gas serves to vaporise the sodium by producing sufficient heat.
* The glass tube is used of 'U'-shape because long discharge ~~path~~ paths are necessary.
* This lamp is used horizontally to help the sodium when spread along the tube.



* When supply is given to the lamp, the discharge take place in the neon gas first and orange or pink glow produces.
* The metallic sodium then gradually vaporises and producing a light of yellow colour.
* wave length of yellow colour light is 5900 Å.
* The lamp takes about 5 to 6 minutes for starting and takes about 15 minutes to reach its full capacity.
* luminous efficiency = 50 lumens/watt.
* Avg. life = 3000 working hours.
* operating temp. = 300°C
* Lamps rating = 40W, 60W, 85W, 140W
* Here the cathode heating T/F is used to send a high voltage of above 480 volts at the time of starting the lamp.
* The function of choke is to limit the current which tends to increase due to -ve temp. resistance characteristics. (R↓ with temp↑)
* The capacitor is used to improve the power factor about (0.3).
* These lamps are operated only on AC supply & used for general outdoor lighting (Street light).

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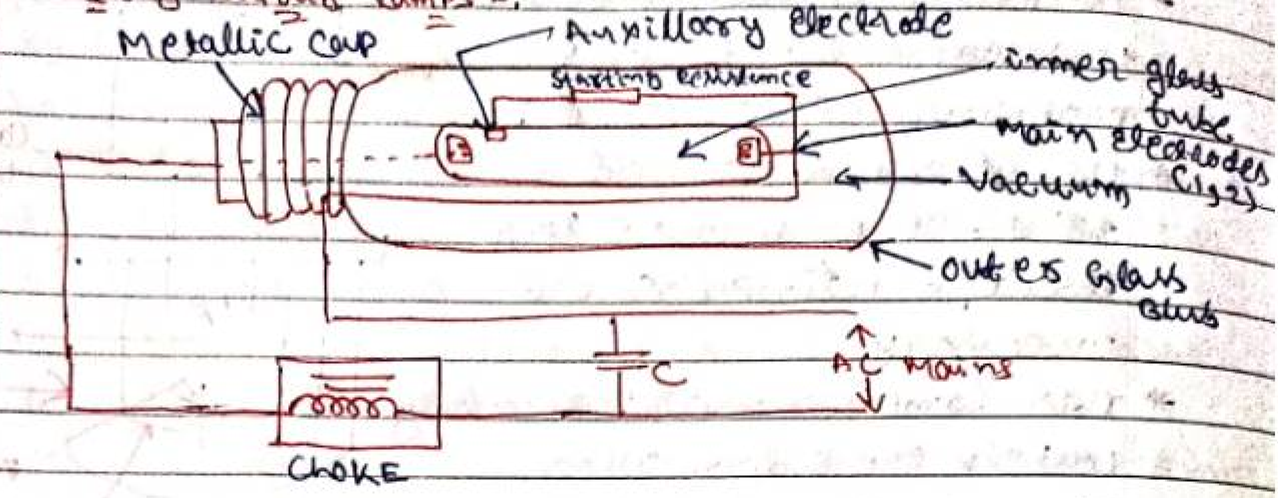
Mercury vapour lamps -:



Construction -:

* The tube containing mercury vapour is made of hard glass.
* The outer glass cover protects the inner tube from coming into direct contanct with atmospheric temp.
* It also absorbs the ultra-violet radiations emitted from the lamp during working.
* The inner tube consists of a small percentage of argon. Besides mercury
* There are two main electrodes made of tungsten wire and a starting electrode which is ~~spaced~~ located quite close to one of the main electrodes
* During connections to the supply mains, the auxillary electrodes through a high series resistance along with the main electrode (2) is connected to neutral of the supply.
* The phase comes to the first main electrodes through the insulated part of the metallic cap.

Working -:

* ~~when~~ Here the supply vtg. appears betn the main electrode (1) & the starting or auxillary electrode.
* The argon coming betn these two electrodes is immediately ionised because distance betn

* Ignitors -: provide the high striking voltage needed to ignite a UV lamp.

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these two electrodes is very small & a glow appears between the electrodes.

* A small current starts flowing through the starting resistor in series with the auxillary electrode.
* This results in building up of pressure due to heating up of mercury.
* Ultimately, the medium betⁿ the main electrodes is ionised & the current starts flowing betⁿ the two.
* It is no longer controlled by the high resistance in the starting ckt, but by the choke in the main ckt.
* capacitor -: power factor improved.
* Rating 250-400W. for AC mains voltage (230V.)
* Mercury lamp -: Blue color, Avg. life span -: 24000hr.
* temp = 658°C, η = 40 lumens/watt

Electric drives ce-5

Group Drive -:

* In this case, one motor is used as a drive for two or more than two machines.
* The motor is connected to a long shaft, on which belt and pulleys are connected to run other machine.
* It is also called line shaft Drive.

Adv -:

* This type of electric drive is economical, as a single motor of large capacity costs less than the costs of a no. of small motor of the same total capacity.

Disadv -:

* In case of fault in the motor, all the connected machines to this motor will not work properly.
* It is not possible to install a new machine in this type of Drives.

Individual Drive -:

* In this type of electric drive a single electric motor is used to Drive one individual machine.
* It's cost is more as compare to group drives but each operator has complete control on his machine. (either increase or decrease the speed of motor or to stop it)
* Adv -: If there is a fault in one motor, this will not effect the production of the industrial product.

Multi-motor Drive -:

* It consists of several individual drives, each performs different funⁿ and are a part of big, complicated machinery.
* This type of drives are used in paper-making machines, cable manufacturing units, metal-cutting machines etc.

Advantages of Electric Drive -:

* cost is too low as compared to other systems of drives.
* The system is more simple & clean.
* The control is very easy and smooth.
* Facility for remote control.
* It's maintenance cost is quite low.
* It can be started at any time without delay in time.

Disadvantages -:

* Electric drives system is restricted to the electrified area.
* During short ckt condⁿ & power supply failure, it will not work properly. ~~so the system~~

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Q) Comparison betⁿ Individual Drive & Group drive.

Points	Individual	Group
1. Initial cost	More	less
2. Power factor	High p.f	Low p.f
3. Efficiency	High	Low
4. Reliability	More Reliable	less Reliable
5. Flexibility	Machines may be fitted wherever convenient.	Such arrangement is not possible in group drives.
6. Speed	More useful where constant speed is required	Does not give constant speed.
7. Space utility	Space can be fully & conveniently utilized	More space is required in group drives

Choice of Electrical Drives -:

* Some of the important factors to choose an electrical drive are -:

a> Requirements related to the source -: Type of source & its capacity, magnitude of voltage, voltage fluctuations power factor, harmonics and their effects on loads.

b> Steady state operation requirements -: Nature of speed torque characteristics, speed regulation, speed range, efficiency, duty cycle, speed fluctuation and rating.

c> Transient requirement -: Starting, breaking, value of acceleration & de-acceleration, reversing performance.

d> Capital and running cost, maintenance cost.

e> Environment & location.

f> Reliability

g> Space & weight restrictions.

Starting & running characteristics of D.C motor

* In all d.c motors, the torque eqⁿ is

$$\boxed{T = \frac{\phi \times Z \times P \times I_a}{2\pi A}}$$

ϕ = flux Z = no. of conductors
P = No. of Pole
I_a = Armature current.
A = No. of parallel paths.

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If π, Z, P, A = constant the $\boxed{T \propto \phi I_a}$

If π, Z, P, A = constant

then $T \propto \phi I_a$

and back emf eqn $E_b = \frac{\phi Z N P}{60A}$

$$\Rightarrow N = \frac{E_b}{\phi Z} \times \frac{60A}{P} \quad (\because E_b = V - I_a R_a)$$

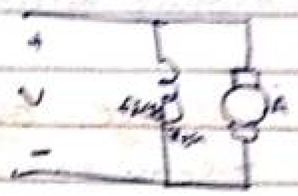
$$\Rightarrow N = \frac{V - I_a R_a}{\phi Z} \times \frac{60A}{P}$$

* R_a = armature resistance

If Z, A, P = constant.

$$\boxed{N \propto \frac{V - I_a R_a}{\phi}} \quad \text{or} \quad \boxed{N \propto \frac{E_b}{\phi}} \quad -(2)$$

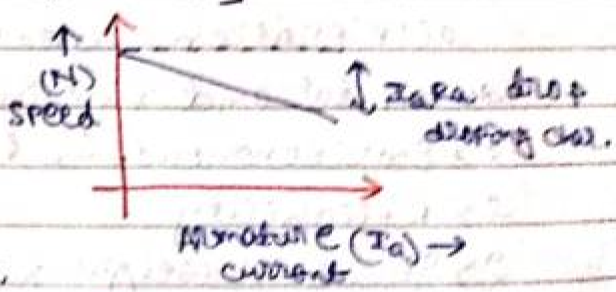
D.C Shunt motor -:



* In DC shunt motor field winding is connected in parallel with the armature.
* from eqn (2), it is clear that speed is directly proportional to back emf (E_b) & inversely proportional to flux (ϕ).

Speed vs Armature current characteristics:

* But if we consider (ϕ) is constant, because supply across the field winding is constant (V = const) then eqn (2) becomes $N \propto V - I_a R_a$ -(3)
* From this eqn, if we increase load of the motor, Armature current is also increases, Thus speed is decreases. $[\because I_a \uparrow \Leftrightarrow N \downarrow]$



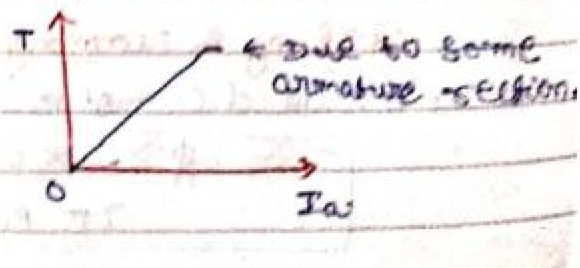
Torque vs Armature current

* For D.C ~~shunt~~ motor

$T \propto \phi I_a$

But ϕ is constant for DC shunt motor.

So $T \propto I_a$

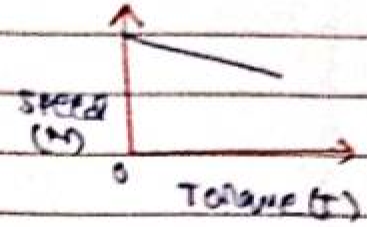


Speed vs torque

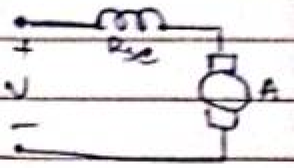
→ From speed eqn of D.C motor $N \propto V - I_a R_a$ & from torque eqn $T \propto \phi I_a$

So $\boxed{N \propto V - TR_a}$

$T \uparrow, N \downarrow$



DC series motor -:



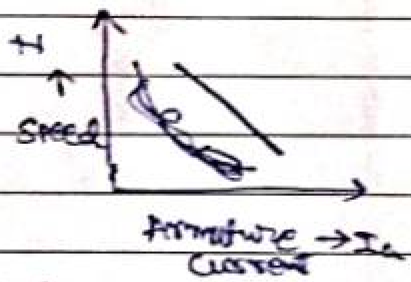
* In dc series motor, the field winding is connected in series with the armature.

Speed vs Armature current (N − I_a)

* $N \propto \dfrac{V - I_a R_a}{\phi}$
* In DC series motor $I_a \propto \phi$.
* for low armature current (I_a), the value of $I_a R_a$ is negleted & if supply vtg is constant, then

$N \propto \dfrac{1}{\phi}$ $(\because I_a \propto \phi)$

So, $N \propto \dfrac{1}{I_a}$

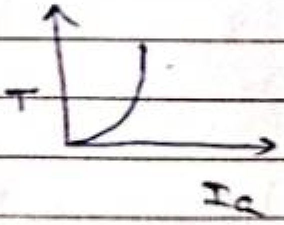


Torque vs Armature current (T − I_a)

* $T \propto \phi I_a$

& $\phi \propto I_a$ (for series motor)

So $T \propto I_a^2$



Speed vs torque (N − T)

→ Speed eqn $N \propto \dfrac{V - I_a R_a}{\phi}$ & $I_a \propto \phi$

& torque eqn $T \propto I_a^2$

$\Rightarrow I_a \propto \sqrt{T}$

So $N \propto \dfrac{V - \sqrt{T} R_a}{\sqrt{T}}$

If v = constant & $\sqrt{T}\,R_a$ is neglected (for small values)
then $N \propto \frac{1}{\sqrt{T}}$