GOVERMENT POLYTECHNIC,SAMBALPUR

ELECTRICAL ENGINEERING DEPARTMENT

Subject: **UEET (TH4)**

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TH.4 UTILIZATION OF ELECTRICAL ENERGY & TRACTION

Name of the Course: Diploma in Electrical Engineering			
Course code:	Th.4	Semester:	5th
Total Period:	60 Periods	Examination:	3 Hrs.
Theory periods:	4 P / Week	Internal Assessment:	20
Tutorial:	---	End Semester Examination:	80
Maximum marks:	100		

A. Rationale:

There is great demand for utilization of electrical power in various fields in the form of power for electrolysis, illumination, electrical heating, electrical welding, electrical traction and for electrical drives. Hence these aspects are taken care of, in the subject of utilization of electrical energy and traction to give exposure of the student.

B. Objectives:

The subject will facilitate the student :

1. To acquire knowledge of principle of ionic dissociation and electrolysis and loss involving in the process, usage of this process.
2. To acquire knowledge of types of electrical heating as employed in the electrical oven, induction furnaces and arc furnaces and dielectrically ovens.
3. To acquire knowledge of principle of arc welding and resistant welding,
4. To define various terms used in illumination engineering to design lighting schemes with specific attention to laws of illumination to explain the working and construction and use of fluorescent lamp, SV lamp, H.P. MV, Neon lamps and energy saving lamps.
5. To classify various types of industrial drives and their application.
6. To classify various methods of traction and traction motor with their control and types of braking.

C. TOPIC WISE DISTRIBUTION OF PERIODS

Sl. No.	Topics	Periods
1.	Electrolytic Process	08
2.	Electrical Heating.	08
3.	Principles of Arc Welding.	08
4.	Illumination.	12
5.	Industrial Drives.	10
6.	Electric Traction.	14
	TOTAL	**60**

D. COURSE CONTENTS:

1. ELECTROLYTIC PROCESS:

1.1. Definition and Basic principle of Electro Deposition.
1.2. Important terms regarding electrolysis.
1.3. Faradays Laws of Electrolysis.
1.4. Definitions of current efficiency, Energy efficiency.
1.5. Principle of Electro Deposition.
1.6. Factors affecting the amount of Electro Deposition.
1.7. Factors governing the electro deposition.
1.8. State simple example of extraction of metals.
1.9. Application of Electrolysis.

2. ELECTRICAL HEATING:

2.1. Advantages of electrical heating.
2.2. Mode of heat transfer and Stephen's Law.
2.3. Principle of Resistance heating. (Direct resistance and indirect resistance heating.)
2.4. Discuss working principle of direct arc furnace and indirect arc furnace.
2.5. Principle of Induction heating.
    2.5.1. Working principle of direct core type, vertical core type and indirect core type Induction furnace.
    2.5.2. Principle of coreless induction furnace and skin effect.
2.6. Principle of dielectric heating and its application.
2.7. Principle of Microwave heating and its application.

3. PRINCIPLES OF ARC WELDING:

3.1. Explain principle of arc welding.
3.2. Discuss D. C. & A. C. Arc phenomena.
3.3. D.C. & A. C. arc welding plants of single and multi-operation type.
3.4. Types of arc welding.
3.5. Explain principles of resistance welding.
3.6. Descriptive study of different resistance welding methods.

4. ILLUMINATION:

4.1. Nature of Radiation and its spectrum.
4.2. Terms used in Illuminations. [Lumen, Luminous intensity, Intensity of illumination, MHCP, MSCP, MHSCP, Solid angle, Brightness, Luminous efficiency.]
4.3. Explain the inverse square law and the cosine law.
4.4. Explain polar curves.
4.5. Describe light distribution and control. Explain related definitions like maintenance factor and depreciation factors.
4.6. Design simple lighting schemes and depreciation factor.
4.7. Constructional feature and working of Filament lamps, effect of variation of voltage

on working of filament lamps.

4.8. Explain Discharge lamps.
4.9. State Basic idea about excitation in gas discharge lamps.
4.10. State constructional factures and operation of Fluorescent lamp. (PL and PLL Lamps)
4.11. Sodium vapor lamps.
4.12. High pressure mercury vapor lamps.
4.13. Neon sign lamps.
4.14. High lumen output & low consumption fluorescent lamps.

5. INDUSTRIAL DRIVES:

5.1. State group and individual drive.
5.2. Method of choice of electric drives.
5.3. Explain starting and running characteristics of DC and AC motor.
5.4. State Application of:
  5.4.1. DC motor.
  5.4.2. 3-phase induction motor.
  5.4.3. 3 phase synchronous motors.
  5.4.4. Single phase induction, series motor, universal motor and repulsion motor.

6. ELECTRIC TRACTION:

6.1. Explain system of traction.
6.2. System of Track electrification.
6.3. Running Characteristics of DC and AC traction motor.
6.4. Explain control of motor:
  6.4.1. Tapped field control.
  6.4.2. Rheostatic control.
  6.4.3. Series parallel control.
  6.4.4. Multi-unit control.
  6.4.5. Metadyne control.
6.5. Explain Braking of the following types:
  6.5.1. Regenerative Braking.
  6.5.2. Braking with 1-phase series motor.
  6.5.3. Magnetic Braking.

Syllabus coverage up to Internal assessment

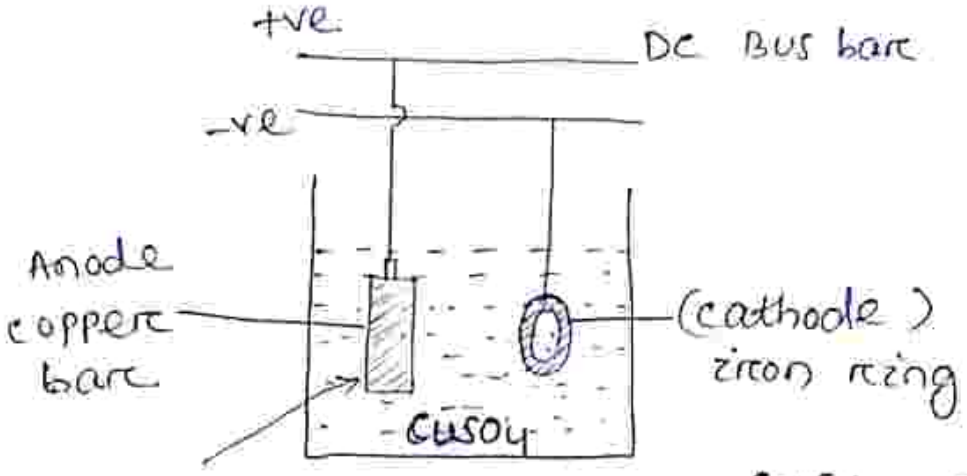
Chapters: 1, 2, 3 and 4.

1st chapter.

Electrolytic process :-

The process of depositing metal on the surface of some other metal by electrolysis is called electroplating.

Basic principle of electro deposition :-



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

(cation) (Anion)

(i) When two electrodes are dipped in an electrolyte, an electrical potential is applied across them, the molecules of the substance dissolved are dissociated into two ions. that is +ve ions and -ve ions.

(ii) Here copper bar is taken as anode and iron ring as cathode. The electrolyte solution is copper sulphat ($CuSO_4$)

(iii) When supply from DC busbar is given

$CuSO_4$ breaks into Cu^{++} (cations) and SO_4^{--} (Anion)

(iv) The cations move towards cathode and the anion towards anode.

(v) Thus at anode $CuSO_4$ molecule is formed and at cathode Cu^{++} receives two electron ($2e^-$) from cathode. and get deposited in metalic form on iron ring.

(vi) In this way the copper is deposited on the iron ring.

<u>Chemical equation</u> :-

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

At anode $\rightarrow$ $SO_4^{--} + Cu^{++} \longrightarrow CuSO_4$

At cathode $\longrightarrow$ $Cu^{++} + 2e^- \longrightarrow Cu$ (metal).

Faraday's laws of electrolysis.

1st law :-

The weight of a substance liberated from an electrolyte in a given time is proportional to the total quantity of electricity passed on it.

$$W \propto Q$$
$$W \propto IT$$
$$W = ZIT \quad (Z = \text{constant})$$

where,

W = The weight of the substance liberated.

I = current in Ampere

T = Time in second.

Q = charge in coulomb.

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

then,

$$\boxed{W = Z}$$

Z = electrochemical equivalent.

2nd law :-

If the same current flows for a given time through several electrolytes, the weight of substance liberated are proportional to the chemical equivalent.

$$\text{chemical equivalent} = \frac{\text{Atomic weight of a substance}}{\text{Valency}}$$

According to this law, if we take the two electrolyte of $CuSO_4$ and Nickel sulphate in which same current flows for the same time.

$$\frac{\text{weight of Cu deposited by given quantity of electricity}}{\text{weight of Nickel deposited by the same quantity of electricity.}}$$

$$= \frac{\text{chemical equivalent of Cu.}}{\text{chemical equivalent of Ni.}}$$

(1) Electrolyte :-

The solution of a salt when used for electrolytic process is called an electrolyte.

(2) Electrodes :-

The plates or rods immersed in an electrolyte and connected to dc 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 direct current is passed through an electrolyte, it gets chemically decomposed into two parts known as +ve and -ve ions.

(6) cations :-

These are the +ve 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.

i.e chemical Equivalent = $\frac{\text{Atomic weight}}{\text{valency}}$.

(9) Electro chemical Equivalent (ECE) :-

ECE of a substance is the amount deposited on passing a steady current of one ampere for one second through its solution.

(10) Atomic weight :-

The atomic weight of an element is a number which is the average of the masses of its various isotopes weight - relative to their abundance on the

atomic weight is the ratio of the weight of an atom of the element to the weight of an atom of hydrogen.

(11) Valency :-

The valency of an atom or a group of atoms is the number of Hydrogen-atoms which it will react chemically. Valency is always an integer (1, 2, 3 etc) but for a given atoms or radical, it can have different value in different chemical reactions.

Current efficiency :-

Due to impurities which cause secondary reaction, the quantity of the substance liberated is less than that calculated from faraday's law.

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

Energy efficiency :-

In actual practice, the actual voltage required for the deposition or liberation of metal highere than the theoritical value. As a result actual energy required is increased.

$$\text{Energy efficiency} = \frac{\text{Theoretical Energy}}{\text{Actual Energy}}.$$

factors affecting the amount of electrodeposition

(i) Time :-

The quantity of electrodeposition is directly proportional to time.

(ii) efficiency :-

With high value of efficiency the amount of electrodeposition is also high.

(iii) current :-

(i) The amount of electrodeposition is directly proportional to current flowing through it.

(ii) But after certain limit colour such blackish will be appeared which is known as burent metal

(4) Strength of solution :-

If the strength of solution is more, then the mass of metal deposited will be more

Factors Governing the better electrodeposition :

(1) current density :-

(i) for low value of current density the ions are released at slow rate and the deposits are crystaline in nature.

(ii) for high value of current density the deposits are of uniform and fine ground.

(iii) If the current density is too high exceeding the limit the deposits are of spongy and porous in nature

(2) Electrolytic concentration :-

(i) Increase in concentration of electrolyte tends to give better deposit and it is generally recommended to use concentrated electrolyte.

(3) Temperature :-

(i) The temperature of the electrolyte is different for different metals. for better deposition.

(4) Addition of agents :-

(i) The quality of deposit can be increased by adding some organic compound like Gums, rubber, Alkali and sugar.

(5) Nature of the electrolyte :-

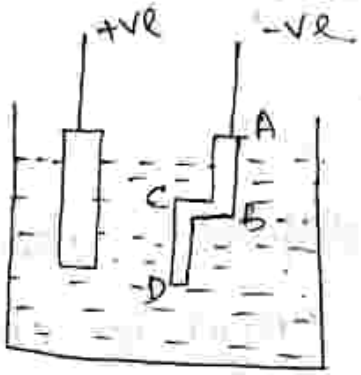
(i) The Nature of the electrolyte greatly affects the smoothness of electro-deposition.

Example :- silver from silver nitrate solution forms rough deposite, but silver from cyanide forms a smooth deposite.

(6) Nature of the metal upon which deposite is to made :-

(7) Throwing power :-

(i) The throwing power of an electrolyte is defined as the quantity which produces a uniform deposite on a cathode having an irregular shape.



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

(ii) The distance between anode and 'AB' is more. so resistance is high and current is less. As a result the deposition is less in 'AB' as compared to 'CD'.

(iii) The throwing power can be improved in two ways.

(a) By increasing the distance between cathode and anode

(b) By using some colloidal particle

which increased the current density.

e.g → cyanide of metals increase the throwing power

Application of electrolysis :-

(1) extraction of metals from their ores.

(i) The ore is first treated with acid to obtained a salt and the solution of the salt is electrolised to liberate the metal.

(ii) when the ore is in molten state, it is electrolised in the furnance.

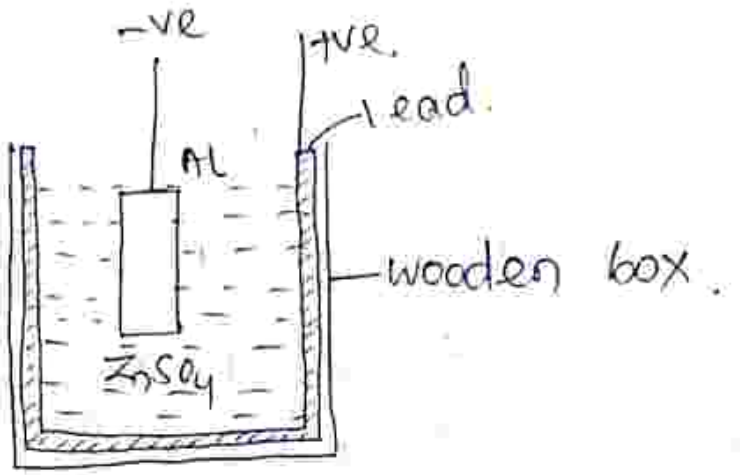
(2) extraction of zinc :-

(i) The zinc oxide (zinc ore) is treated with concentrated sulphuric acid and passed through various chemical process to get rid of impurities like cadmium, copper etc by precipitation.

(ii) Then electrolysis process is carried out in wooden box with inner lining of lead.

(iii) Here anode is lead and cathode is

Aluminium. In this process zinc is deposited on the cathode.



(3) extraction of Aluminium :-

(i) The aluminium ore (cryolite, bauxite) is treated chemically and reduced to aluminium oxide and then electrolytic process is started.

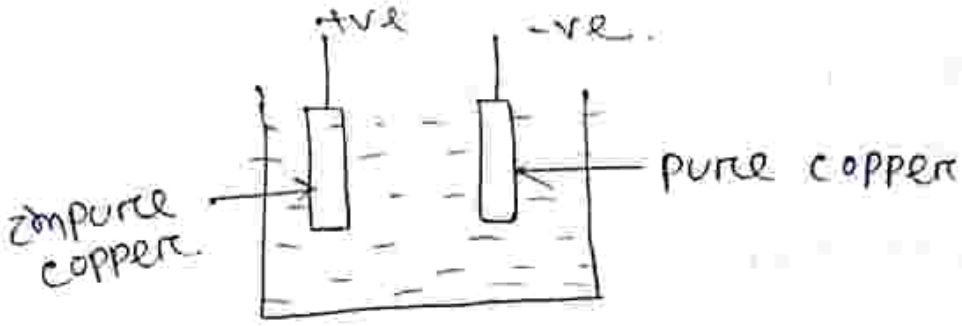
(ii) Then aluminium metals get deposited at the cathode.

(4) Refining of metals :-

(i) The metal extracted are not much pure, so using electrolysis the purity is increased to 99.95 %.

(ii) Copper sulphite is taken as electrolyte and impure copper is as anode.

(iii) Through electrolyte process the pure copper get deposited on the cathode.



(5) Production of chemicals like caustic soda, chlorine gas, Amonium sulphate, hydrogen and oxygen.

(6) Separating metals like aluminium from its compound of aluminium oxide, silica and iron oxide.

(7) Electroforming :-

(i) The production or reproduction of an article by electrodeposition is known as Electroforming.

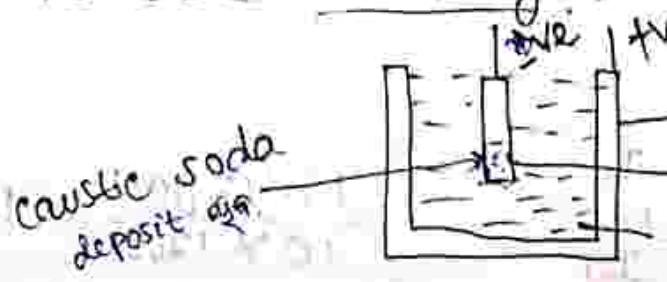
(ii) First of fall an impression of paint is made in wax surface. Then it is coated with graphite powder. in order to make it conducting.

(iii) Then it is dipped in an electroforming cell as a cathode. After the given metal is coated on the mould, the wax is melted out of the metal shell.

(8) Electrodeposition :-

(i) Electro deposition is carried out for deposition of one metal over another.

(9) Electro cleaning :-



caustic soda → oil remove.

Hydrogen (H) → remove grease

(i) Before electroplating process the article is need to be free from grease and oil through electrocleaning process.

(ii) In this process sodium phosphate is taken as electrolyte solution.

(iii) +ve supply is given to the inner lining of tank.

(iv) The workpiece to be cleaned is used as cathode

(v) In this process of electrolysis, caustic soda is deposited on the cathode surface which removes oil from the workpiece.

(vi) In the mean time hydrogen gas is involved which helps to removes grease from the workpiece.

This cleaning process is known as cathodic cleaning.

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2nd chapter

Electrical heating :-

(i) Electrical heating is based on the principle that when the electric current passes through a medium (solid, liquid, gas) heat is produced.

(ii) There are three modes transmission of heat.

- conduction – solid.
- convection – liquid.
- Radiation – gas.

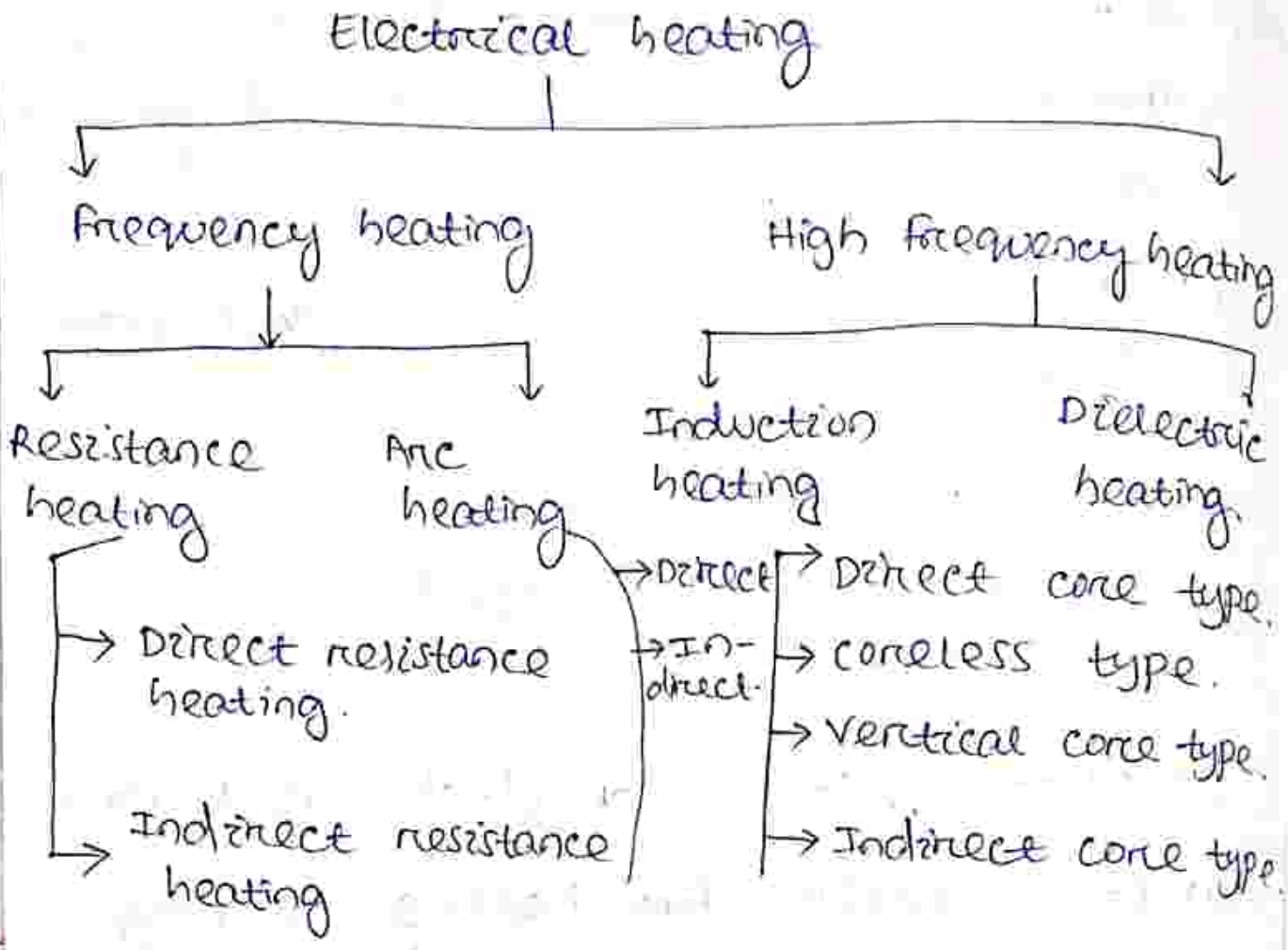
Domestic application of electrical heating :-

(i) Room heater for heating building.
(ii) immersion heater for heating water.
(iii) Geyser
(iv) Electrical iron.
(v) Hot air driers.
(vi) electrical oven.
(vii) electrical toaster.

Industrial application of electrical heating :-

(i) melting of metal.
(ii) electric welding.
(iii) moduling plastic components.

(iv) Enamelling of copper conductors.



Advantages :-

(i) clean and neat atmosphere.
(ii) No pollution.
(iii) Temperature control.
(iv) Automatic switching control is possible.
(v) The heating is uniform through out the proces
(vi) No extra construction is required.
(vii) High efficiency as compare to other heating process.
(viii) Portable in nature.

Methods of heat transfer :-

(1) conduction
(2) convection
(3) radiation.

conduction :-

(i) The flow of heat along a substance or object depends upon the temperature variance.

(ii) Each molecules of the substance get heated and transfer the heat to the adjacent one., thus making heat travel from one point to another

convection :-

(i) most common example of heat transfer by this method is heating of water by an immersion heater, where convection are set up and water gets heated by this.

Radiation :-

(i) heat reaches the object from the source without heating the medium in between them.

Stephan's law (Stephan-Boltzman's law) :-

Heat dissipated $= 5.72 \times 10^{-4} Ke \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4 \right]$ watt/m²

T_1 = Temperature of the source in ° absolute

T_2 = Temperature of the object observing the heat in ° absolute.

K = constant (depending on radiating frequency).

e = emissivity [1 = black body. 0.9 = resistance heating element.]

Stephan's law states that, energy radiated per second per unit area by a perfect body varies directly as the 4th power of its absolute temperature.

mathematically $E \propto T^4$

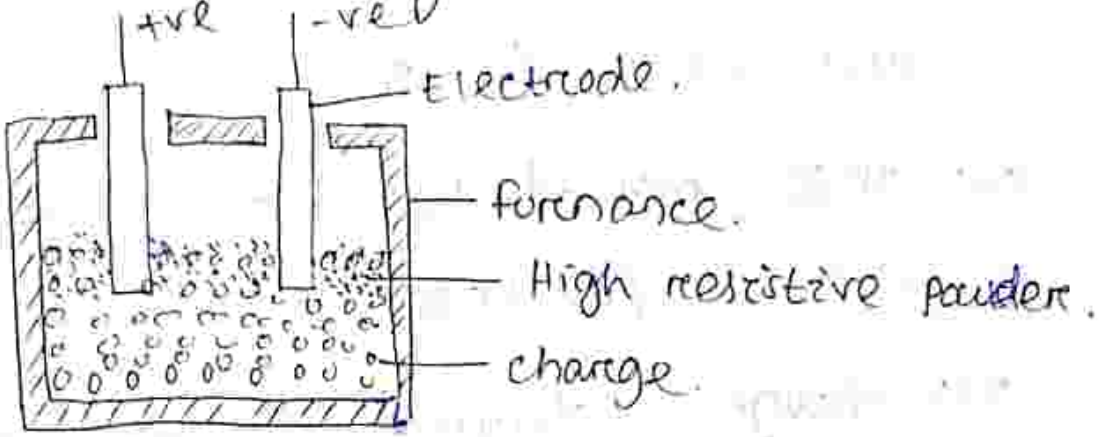
Resistance heating :-

(i) 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. There are two methods of resistance heating.

(i) Direct resistance heating.
(ii) Indirect resistance heating.

Direct resistance heating :-



(i) In this method of heating the material or charge to be heated is taken as a resistance and current is passed through it.

(ii) The charge may be in the form of powder piece or liquid.

(iii) The two electrodes are immersed in the charge and connected to the supply.

(iv) In case of DC or single phase AC, two electrodes are required, but there will be three electrodes in case of three phase supply.

(v) when metal pieces are to be heated a powdere of high resistivity material is sprinkled over the surface of the charge. to avoid direct short circuit

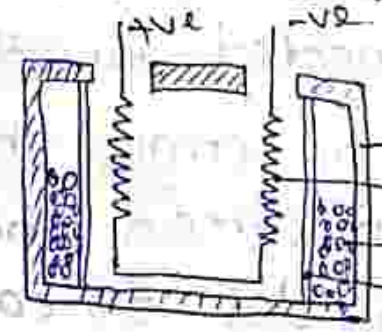
(vi) The current flows through the charge and heat is produced.

(vii) This method has high efficiency, since heat is produced in the charge itself

(viii) Though automatic temperature control is not possible in this method, it gives uniform heat and high temperature.

(ix) one of the major application of this process is ~~fausti~~ salt bath. Its operating temperature ranges between (500°c – 1400°c).

Indirect resistance heating :-



(i) In this method the current passed through a highly resistive element which is either placed above or below the oven depending upon the nature of the job to be performed

(ii) heat proportional to the I^2R losses produced in heating element delivered to the charge either by radiation or by convection.

(iii) In industrial heating the resistance is placed in a cylinder which is surrounded by the charge placed in the jacket as shown in the figure

(iv) The arrangement provides an uniform temperature.

(v) Here automatic temperature control can be provided.

(vi) common example of this type of heating is electrical oven.

Arc furnace :-

(i) The furnace used for melting/extraction of ferus and non ferus metals need a high temperature operation.

(ii) Arc is the flow of current through

an air gap between the two conducting bodies.

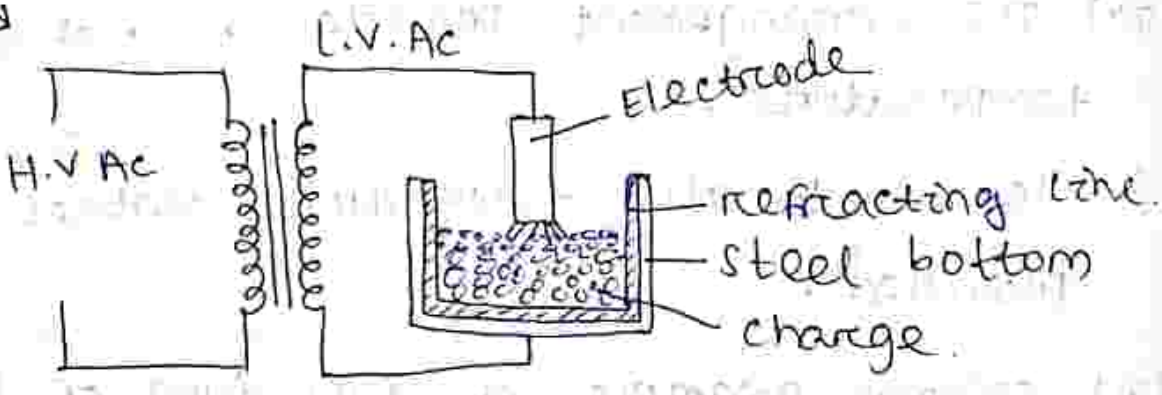
(iii) Two types of arc furnance is there

(1) Direct arc furnance.
(2) Indirect arc furnance.

Direct Arc furnance :-

(i) These furnace can be further subdivide into two categories i.e.

(1) conducting bottom type
(2) Non-conducting bottom type.



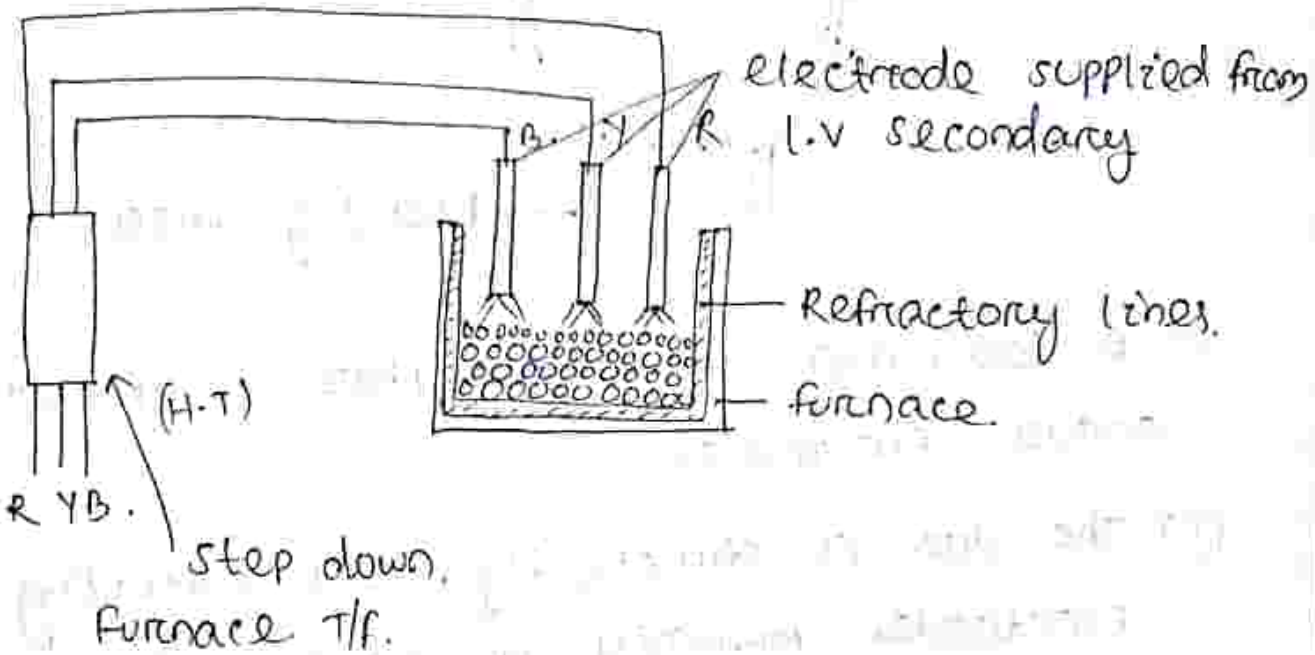
(i) In the conducting ~~to~~ bottom type arce furnace, ~~the conducting~~ steel used as the conducting surface of the furnace to make the electrical ckt complete.

(ii) when the apply a 1-ϕ supply to the electrode through a step down T/f.

high current will flow through the air gap between electrode and charge.

(iii) As a result arc will be produced and the heat is transfered to the charged directly.

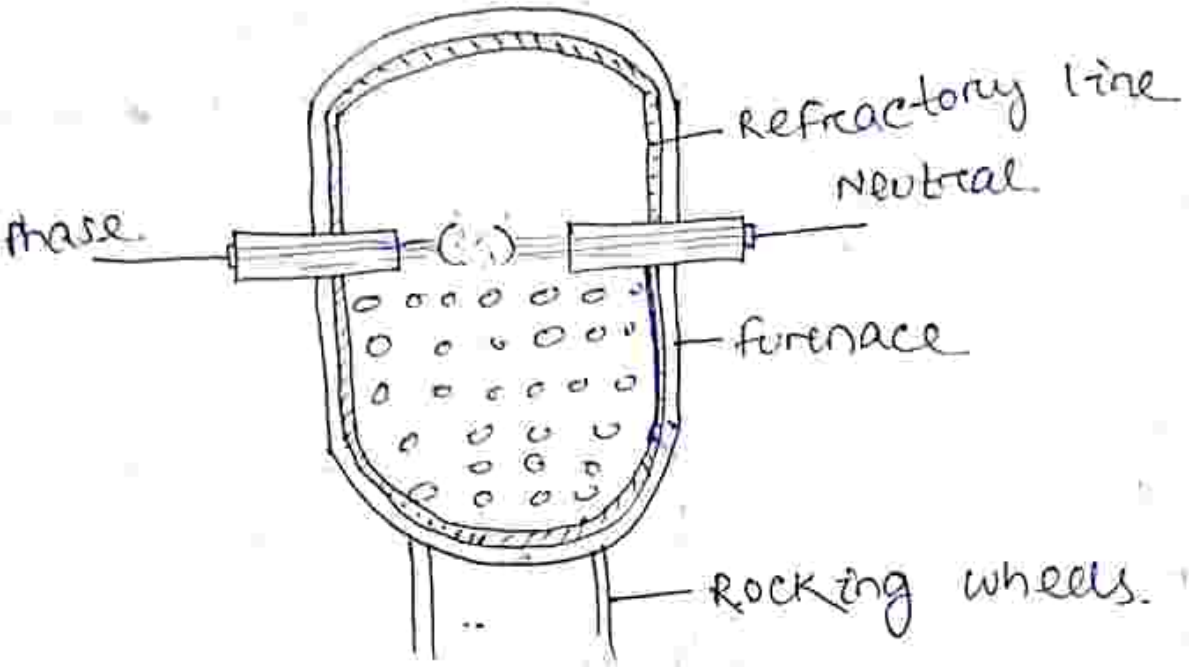
Non-conducting bottom type:-



(i) Here no current flows through the body of the furnace.

(ii) most of the furnace used are non-conducting bottom type due to insulation problem faced in case of conducting bottom.

Indirect arc furnace:-



(i) A low voltage AC single phase is applied across electrodes.

(ii) The arc is struck by short circuiting the electrodes manually or automatically for a moment.

(iii) The heat from the arc is transfered to the charge top layer and refractory line through radiation and from top layer to the bottom through conduction process.

(iv) To distribute the heat properly, the furnace has to be rocked continuously exposing further layer not only from the arc but from the exposed lining.

(v) Since the unit is working on a 1-ϕ a great unbalanced will result, if a furnace transformer without 3-ϕ is not used.

(vi) The furnace are not supposed to handle melting beyond one tonne for the same reason.

(vii) The unit works quite efficiently.

(viii) Special motores with reduction gears with reversing direction are used for rocking.

Principle of induction heating :-

→ Eddy current which provides the basis for induction heating are used for melting of metals.

→ The induced emf is depended upon the rate of change of flux '$\frac{d\phi}{dt}$'. Therefore magnitude of eddy current is proportional to frequency of supply.

→ Heat produced is thus proportional to I^2, the eddy current heating effect is proportional to f^2.

→ The flux density is produced is proportional to relative permeability.

$$B = \mu_0 \mu_r H.$$

where,

$\mu_r \rightarrow$ Relative permeability

$H \rightarrow$ magnetic intensity.

$l \rightarrow$ length of magnetic ckt

$$H = \frac{NI}{l}$$

→ Greater is the no. of turns of the coil greater will be the magnitude of the flux. Thus eddy current heating is a function of 'N'.

$$W_e = K B_m^2 f^2$$

↑
eddycurrent loss.

Hysteresis :-

(i) The losses occurring in any electromagnetic device are name as hysteresis loss.

(ii) The energy lost is converted into heat.

(iii) Greater is the frequency of supply Larger will be the no. of such loops traced /second. , and more will be the heat produced.

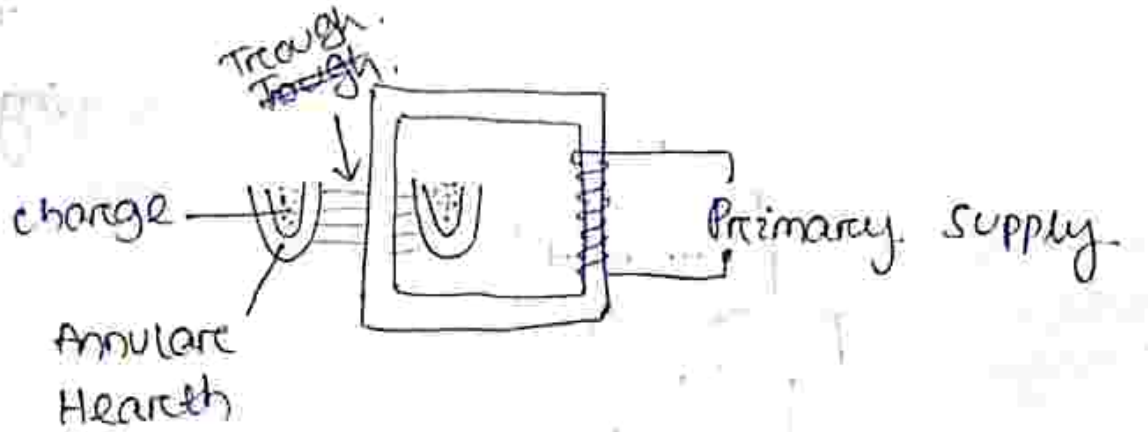
$$W_h = K B_m^{1.6} f$$

Different types of induction furnace :-

(1) Direct core type
(2) Vertical core type
(3) Indirect core type.
(4) core-less type induction furnace

Scanned with CamScanner

Direct core type :-



(i) It is like a T/F, the charge forms the secondary winding and consist of one turn only formed by the metal to be melted.

(ii) The charge is magnetically coupled to the primary winding.

(iii) When there is no molten metal, no current will flow in the secondary

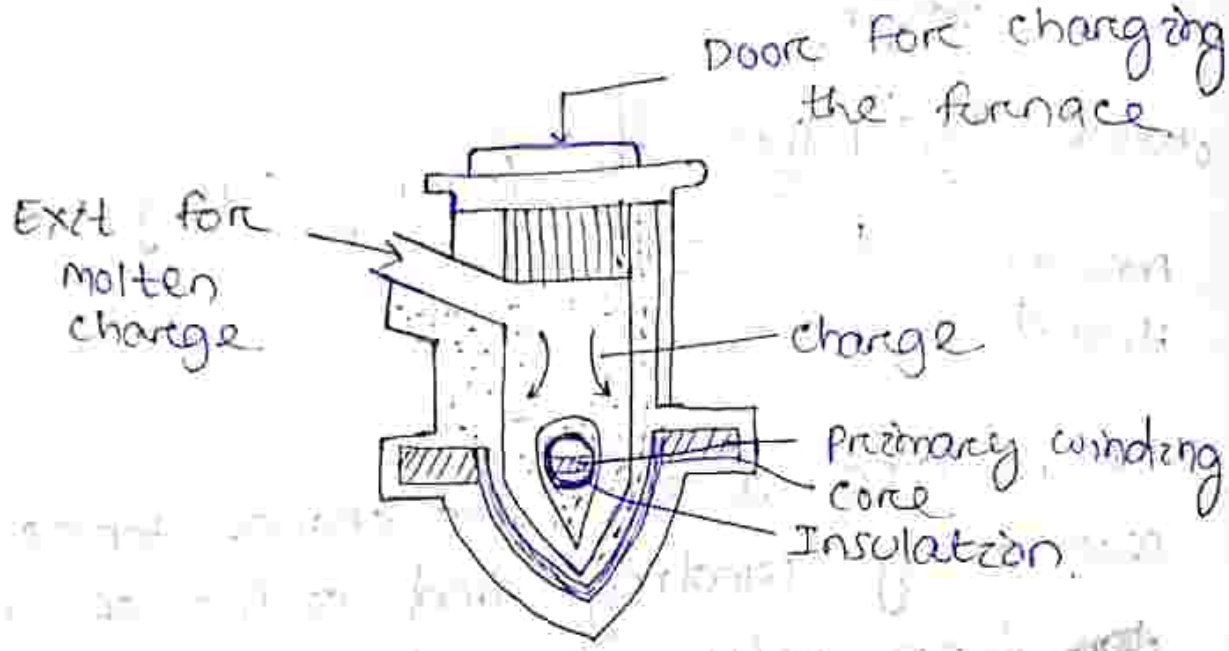
Drawbacks :-

(i) leakage reactance is high.

(ii) P.F is low due to poor magnetic coupling

(iii) Pinch effect causes interruption of secondary.

Vertical core type :-



(Ajax - Wyatt vertical core type)

(i) This furnace is an improved coreless core type furnace.

(ii) It has vertical channel for the charge. It is also known as Ajax-wyatt vertical core type.

(iii) Here the magnetic coupling is better than core type.

(iv) leakage reactance is low, power factor is high.

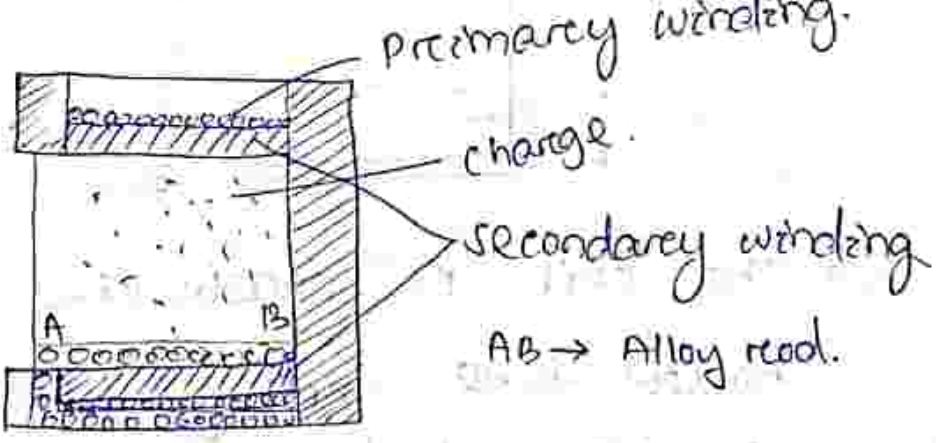
(v) It can be operated from normal frequency supply.

(vi) The circulation of molten metal is kept up round in the V-portion by convection currents as indicated in the figure.

(vii) The furnace is suitable for continuous operation. The ~~trough~~ top is covered with insulated cover which can be removed for charging.

(viii) It is very widely used in industries for melting and refining brass and other non-ferrous metals.

Indirect core type :-



(i) The induction principle can also be used for general heat treatment through radiation process.

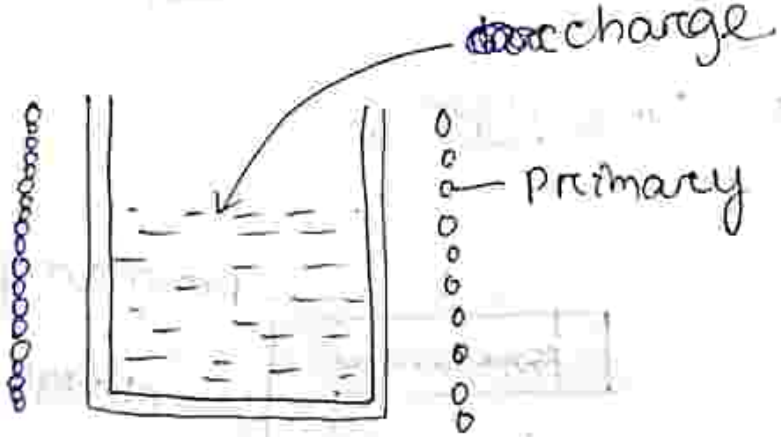
(ii) Here secondary windings forms the wall

of metal container. and the iron core links the primary as well as secondary winding.

(iii) Here the temperature control is possible

(iv) The 'AB' portion indicated in the figure is a special alloy which losses its magnetic property beyond a certain temperature we can easily detached the 'AB' rod for temperature control.

Core less Induction furnace :-



(i) The coil is constructed in the form of hollow tube through which cold water is circulated.

Advantage :-

(i) Time taken to reach the melting temp. is less than other.

(ii) Precize control of heat in to the charged can be employed.

(iii) Charging and pouring is simple.

(iv) There is no dust, smoke, noise etc

(v) cost effective.

Dielectric Heating principle :-

(i) This is called high frequency capacitive heating.

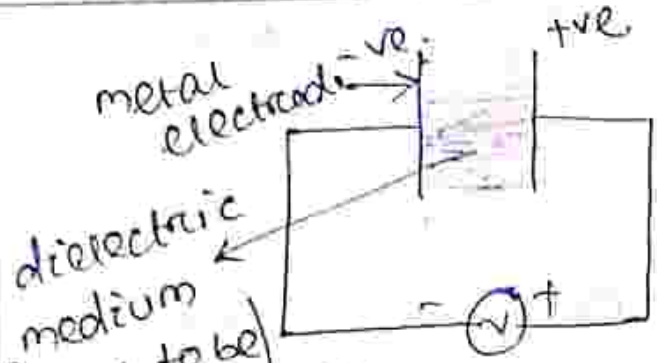
(ii) It is employed for heating of insulating material like wood, Plastic and ceramic, etc.

(iii) Supply frequency of 10-30 m cycle/sec (MHz) with voltage of 20 KV is required for this process.

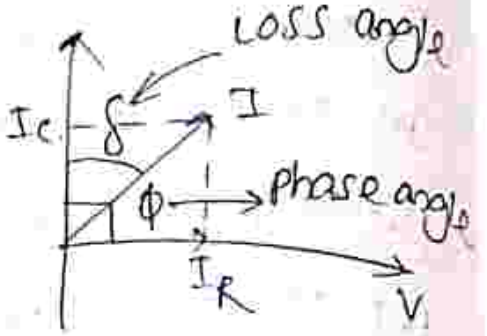
(iv) A principle of operation of dielectric heating is that other a capacitor is subjected to a sinusoidal voltage, the current drawn by, it is never leading the voltage exactly by 90°.

(v) Here the resistance (R) is very high so that current flowing at it is very small. so that

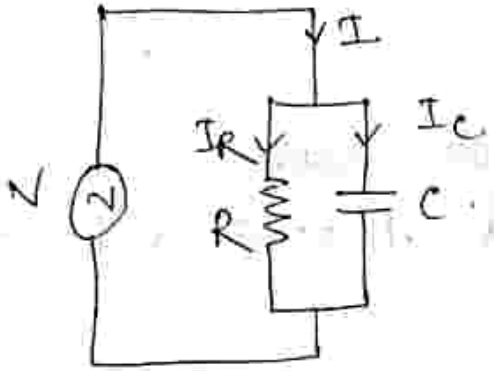
$$I \simeq I_c$$



[Dielectric heating Process]



(Phasor diagram)



(Equipment electrical circuit)

Power consume (P) = $VI\cos\phi$.

$$I_c = \frac{V}{X_c} = \frac{V}{\frac{1}{2\pi f C}} = 2\pi V f C.$$

$$\boxed{I_c = 2\pi V f C.}$$

$\Rightarrow P = V I_c \cos\phi.$

$\Rightarrow P = V 2\pi V f C \cos\phi.$

$\Rightarrow P = V^2 2\pi f C \cos\phi.$

$\phi = 90^\circ - \delta$

$\cos\phi = \cos(90^\circ - \delta)$.

$= \sin\delta$

$P = 2\pi V^2 fc \sin\delta$.

As the loss angle is very very small

$\sin\delta = \tan\delta = \delta$.

$\Rightarrow \boxed{P = 2\pi V^2 fc\delta}$ watt.

$c = K K_0 A/d$. K_0 = permittivity.

where.

$K_0 = 8.854 \times 10^{-12}$ f/m.

A = Surface area of the metal to be heated

d = Thickness of the material to be heated.

Here capacitance c and loss angle δ are constant. so the heat generated is directly proportional V^2 & f.

$P = 2\pi V^2 fc$

so,

$\boxed{P \propto V^2 f.}$

Here.

$\boxed{2\pi c = \text{constant.}}$

Microwave heating :-

(i) In this system the electrical wave is converted in to electromagnetic waves which generates heat energy used cook the food.

(ii) These waves are high frequency radio-waves. also known as microwaves.

(iii) when a microwave energy comes into contact with some substance, it is reflected, transmitted or absorb.

(iv) These waves are reflected by metals transmitted through paper, glass, plastic etc. and absorbed by water or moisture present in the food.

(v) When this energy is absorbed, heat is produced and coocking takes place.

(vi) The microwaves are attracted to water, fat and sugar molecules. They cause these molecules to vibrate at 2450 MHz. leading to friction with in the food. which generates heat.

(vii) The microwave heating is used in the microwave oven for baking purpose.

(viii) The frequency is used is from 900-2400 MHz.

Application :-

(i) Baking and manufacture of bread, toaste, etc.

(ii) drying of paper and textiles.

(iii) food processing and kitchen work.

(iv) Treatment of diseases like cancer.

(v) manufacture of plastic.

(vi) Processing of cement.

Advantage :-

(i) It has neat and clean system.

(ii) It provides uniform heating to the ~~syst~~ substance.

(iii) The system provides quick heating.

(iv) The depth of penetration of heat in to the material is much more.

3rd chapter:-

Arc welding:-

T = 3000°C.

V = 100 V.

I = 75-600 Amp.

Types of arc welding:-

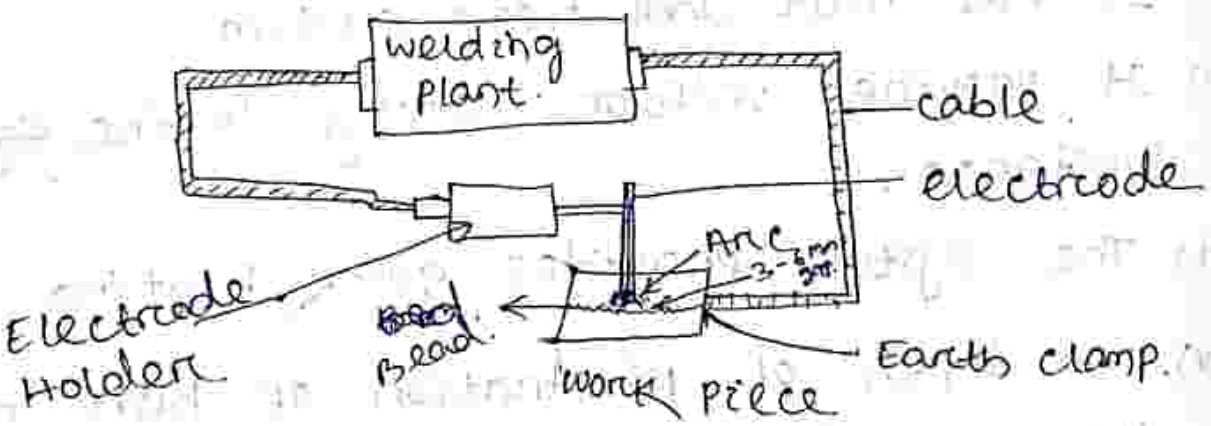
(1) carbon arc welding.

(2) metal Arc welding.

(3) Atomic hydrogen Arc welding.

(4) Helium or Argon Arc welding.

Principle of Arc welding:-



(i) current from an AC or DC source is applied, one terminal is connected to the electrode and the other to the work piece.

(ii) The arc gap of 3mm - 6mm is maintain

to produce the arc. due to the interruption of arc heat is produced with the range of 3700° – 4000°c.

Necessary condition for Arc welding :-

(i) Aluminium and certain alloys can only be welded with DC.

(ii) High striking voltage to maintain the Arc.

(iii) Relatively low supply voltage to enable the earth

(iv) A limited current value to melt the electrode and parent metal without burning

Sparking / striking voltage → 80-100V AC
60 - 80 V DC.

Arc voltage → 20-35 V.

current → 15-600 A.

Types of welding equipment :-

(1) DC welding equipment :-

→ A motor generator set is present in the welding plant. Here 1-ϕ squirrel cage induction motor and differential

compound DC generator are used.

(ii) Due to Drooping characteristics of differential compound generatore, with increase of load current the terminal voltage will be low.

(iii) A ~~balanced~~ ballast resistance is put in series to control current.

(iv) for multioperation separate ballast is used.

AC welding equipment:-

(1) A step down T/F is present in the welding plant a resistance with reactance is used for well operation below saturation point to avoid harmonics and prevents cooling of Arc.

Advantage of DC welding:-

(i) Direct current Electrode positive (DCEP) is used for deeper penetration welds.

(ii) DC electrode negative (DCEN), deposits more metal to the joint.

Disadvantage of DC welding :-

(i) It is more costly as compare to AC welding.

uses of AC welding equipment :-

(i) For moderate operation this type of welding is required.

(ii) More diameter is required to half more AC current.

(iii) The cost is very low.

Resistance welding :-

(i) It may be defined as the method in which a sufficiently strong electric current is sent through the two metals in contact to be welded, bringing the two pieces to the molten state and thus applying mechanical pressure at this time to complete the joint.

The heat generated $H = I^2RT$.

(ii) The amount of current required is 4400 - 5000 A/m^2.

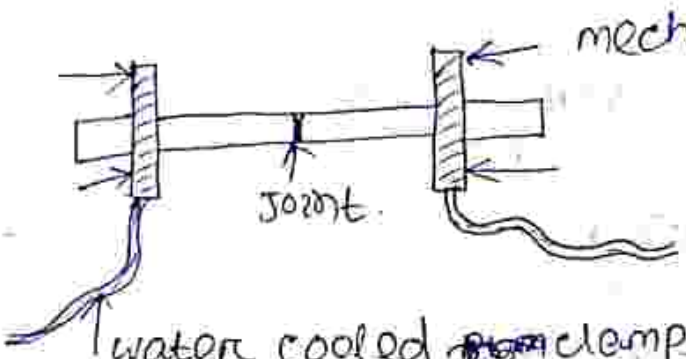
(iii) Pressure varies around 565 kg/m^2.

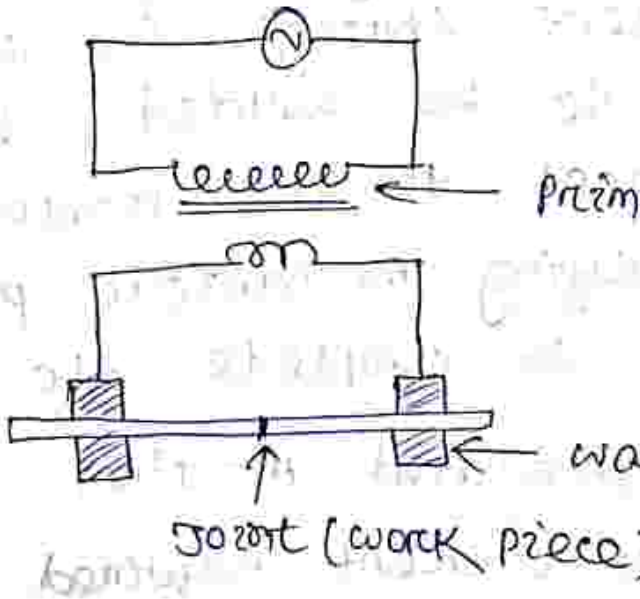
Advantage :-

(i) It is a quick method of joining two pieces.
(ii) There is a very little wastage of metal.
(iii) Process can be accurately controlled.
(iv) The welds are consistantly uniform.

Types of resistance welding :-

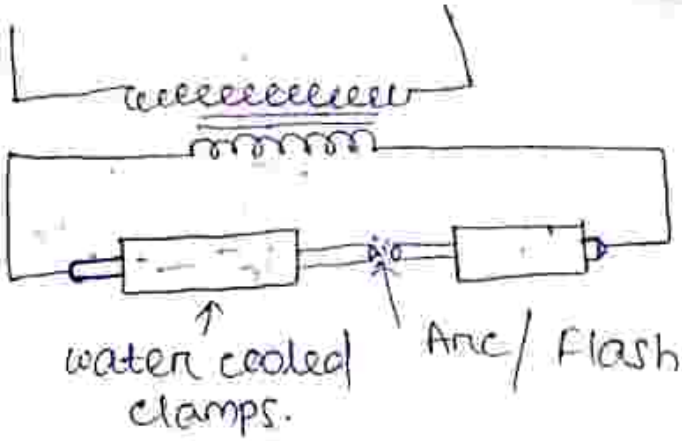
1. Butt welding :-





[Electrical Equivalent]

2. Flash welding :-



(i) This is semilar to butt welding.

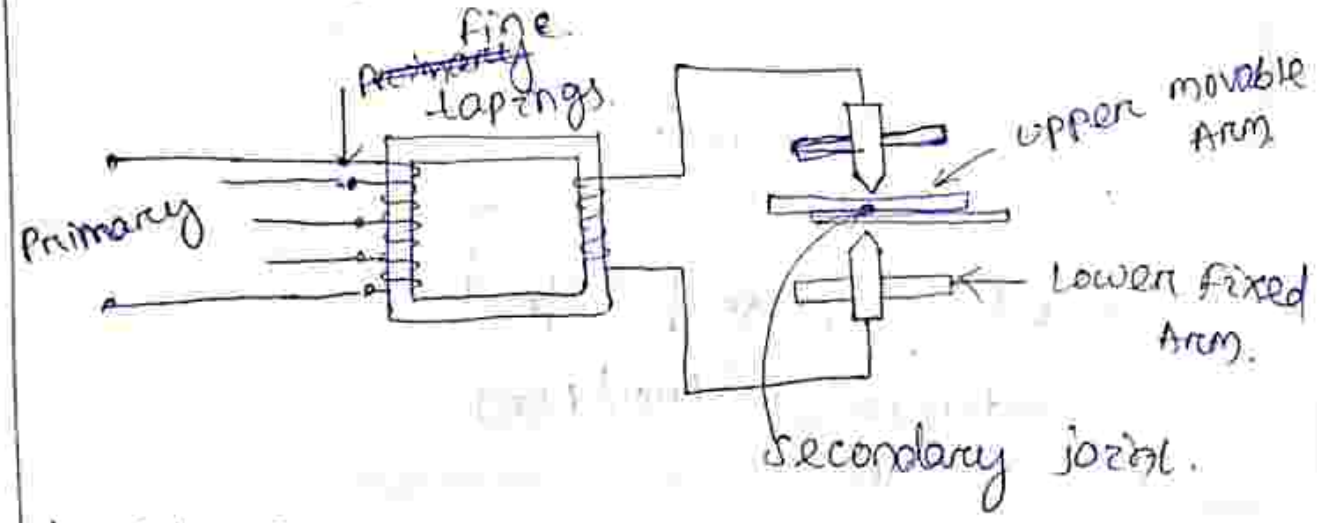
(ii) Before welding separation between two metal is kept. by the application of secondary supply voltage, a high current pass through the gap and formation of Arc/Flash takes place.

(iii) In this process the two surface of the metal get heated and through the mechanical spring action the two metal faces are brought together.

Application :-

(i) Pipes and rods.

- Spot welding :-



(i) This is the simplest and most universally adopted method of making lap welds in thin sheets up to a maximum thickness of 12.7 mm.

(ii) In it's simplest form the spot welding machine consist of a transformer to produce high current at low voltage electrodes are connected to the ends ~~to the work~~ of the secondary winding for leading the current to the work and to apply the necessary mechanical pressure

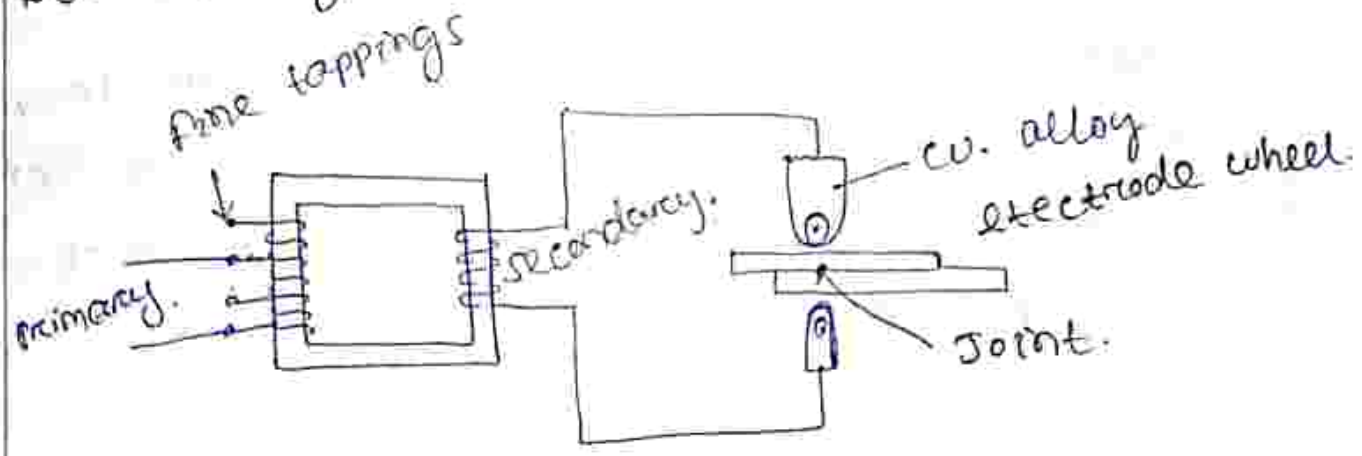
Application :-

(i) It is applied to welding of sheets.

(ii) It may be applied to all types of boxes, cores and enclosing cases etc.

(iii) It is used for fabricating all types of sheet metal structure.

4 Seam welding :-



(i) This similar to spot welding, but series of spot are produced due to rollers mechanism.

(ii) As the roller passes over the overlapped metals under pressure, current passing between them produced it.

(iii) The main objective is to produce gas and liquid leak proof lap joints.

(a) when current turns off regularly a overlapped spot produced.

(b) An uninterrupted flow of current to the electrodes will ~~flow~~ form a continuous seam.

Application :-

(i) used for making lap joints. and butt joints

(ii) It is quicker than spot welding.

(iii) used for pressure tight and leak proof joints. for example. circular or rectangular containers, car body section, T/F radiator unit.

Automatic hydrogen Arc welding :-

The essentials of automatic hydrogen welding process are.

(i) Electrode energy is supplied to an Arc between two tungsten electrode where it is transferred into heat.

(ii) molecular hydrogen is blown through this arc and transferred into automatic form due to high temperature of 6000°c.

(iii) The heat recombination process arround the vicinity of arc produced.

(iv) To strike and maintain the arc an open ckt voltage of 300V. is necessary and for hand welding 50A current is required. In this type of welding the arc is struck between two tungsten electrodes and hydrogen is passed through the arc.

(v) Due to high temperature hydrogen changes to its automatic form when the automatic hydrogen travels to coolere reasen in the vicinity of the arc. It regains its molecular form by given of heat energy

(vi) Thus a very intense heat is produced which is used it additional metal is needed for making a joint.

(vii) This method is successfully used for welding stainless steel and moist non- ferous metal.

4th chapter

Illumination :-

Nature of radiation :-

Corpuscles Theorem :-

Light consist of a stream of extreemely minuee particale called corpuscles which were shoot from a hot body, when impinged on human eye produced some sensation.

Wave Theory :-

The wave theory states that There is a need of medium to transmit the light.

Later a Principle theory known as quantum theory was introduced. Energy is emitted and absorb only indescreate quanta of magnitude 'hf'.

[h = Plank's constant
= 6.547×10^{-27} erg sec.

The descreate bundles ~~card~~ or quanta of energy is known as photon.

→ The electron from lower orbit transmitted to the higher orbit by absorbing photons after 10 nsec, they come to the normal state by emitting energy.

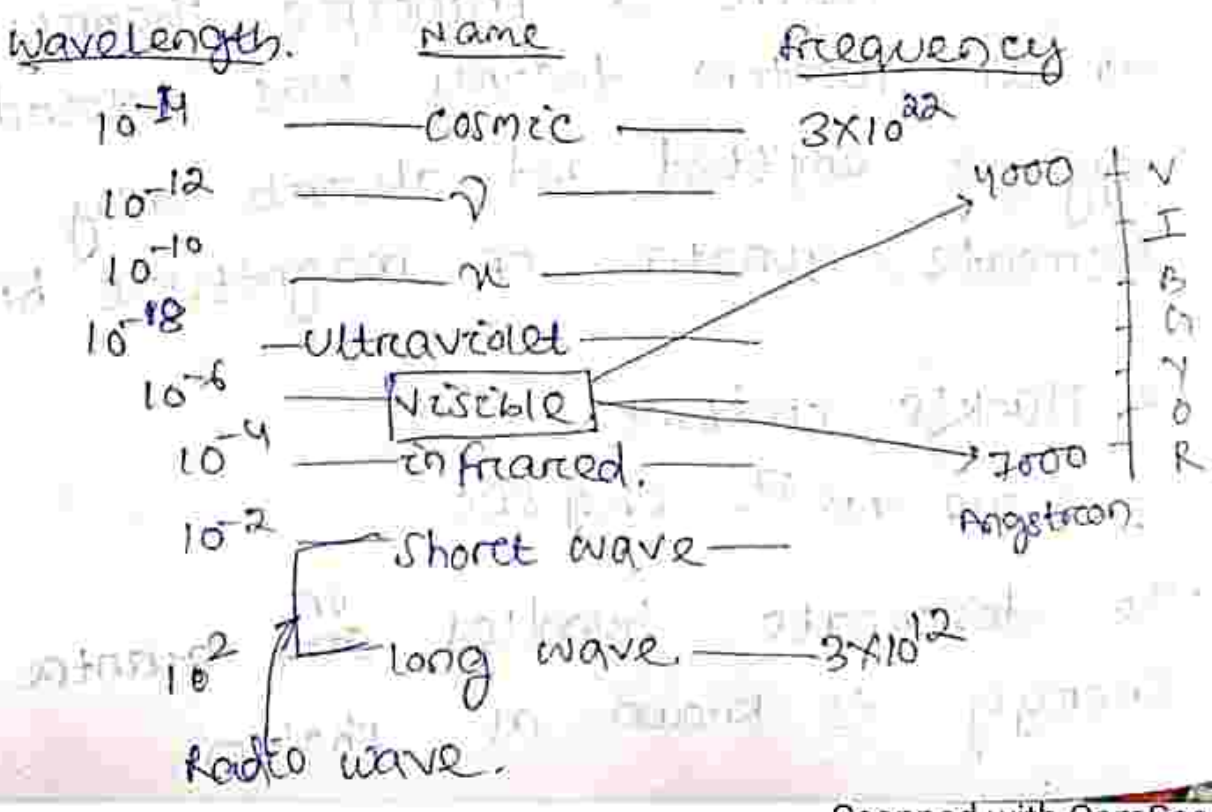
→ Each photons may be considered as a wave. so it is associated with frequency, wavelength and velocity.

$$v = \lambda f.$$

→ The light spectrum consist of 7 colour ~~consist of~~ 'VIBGYOR'.

→ unit of wavelength → Angstrom. $= 10^{-10}$ m.

1 micron $= 10^{-6}$ m.



Terms used in illumination :-

Luminous Intensity :-

(i) Luminous intensity in any particular direction is the luminous flux emitted by per unit solid angle by a point source and is denoted by 'I'.

$$I = \frac{F}{\omega} = \frac{\phi}{\omega} \text{ lumens / steradian or candla.}$$

(ii) It is the ratio of brightness of a source of light to that of standard candle. one candle gives out luminous flux of 4π lumen in space. Thus lumens emitted by one candle source of light is one lumen / steradian.

(iii) In scientific terms candla is defined as the luminous intensity in the perpendicular direction of a surface of 1/600,000 sq. metre of a full radiator at the temperature of freezing Plantinum under a pressure of 101,325 N/sq. metre.

Illumination :-

(i) When the light falls upon any surface, the phenomenon is called illumination. It is defined as the number of lumens falling on the surface per unit area.

(ii) It is denoted by symbol E and is measured in Lumens per square metre or Lux or metre candle.

(iii) If a flux of ϕ Lumens falls on a surface of area A, then the illumination of that surface is $E = \phi/A$ Lumens/m^2 or Lux or metre-candle.

Bigger unit of illumination is phot.
one phot = 10^4 Lux.

MHCP (mean Horizontal candle power) :-

(i) It is average of all the candle powers in all directions in the horizontal plane containing the source of light.

MSCP (mean Spherical candle power) :-

It is defined as the average of candle powers in all directions ~~above or~~ and in all plans ~~through~~ from the source of light

MHSCP (mean hemi-Spherical candle Power) :-

It is defined as the average of candle powers in all directions above or below the horizontal plane passing

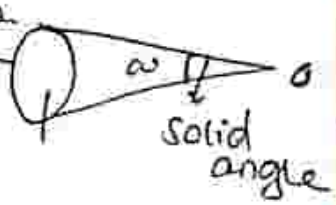
through the source of light.

Solid angle :-

(i) solid angle is the angle generated by the line passing through the point in space and the periphery of the area or A solid angle enclose a volume by an infinite number of lines lying on a surface and meeting at a point.

(ii) It is measured in steradians and is denoted by ω and

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



(iii) where one steradian is the angle subtended at the centre of a sphere by an area on the surface of the sphere which is numerically to the square of the radious.

(iv) The total plane angle subtended by circumference of a circle at the centre of circle is 2π radians.

(v) similarly total solid angle subended at a point in space is obtained by considering point at the centre of sphere and the surface area of the sphere.

Luminous efficiency :-

It is defined as the output in lumens per watt of the powere consumed by the source of light. It is measured in lumens per wattage.

If,

E = Energy radiated at wave length λ.

h = The relative sensitivity of eye at wave length λ.

K = maximum possible efficiency if whole of the electrical input were transform into radiating energy at 5550 A.U

= 620 lumens / watt.

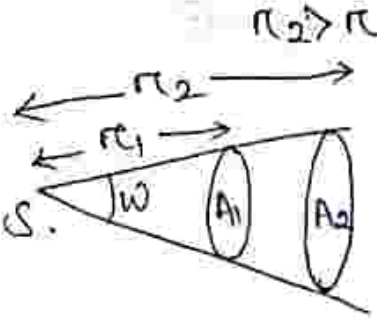
Efficiency at wave length λ, $= hK$

Laws of illumination :-

1. Inverse square law :-

This law states that the illumination of a surface is inversely proportional to the square of the distance between the source and surface, provided that the distance between the surface and the source is sufficiently large. So that the source

can be regarded as a point source.



→ consider a point source 'S' having an intensity I lumens/steradian.

→ let two surface having area A_1, A_2 be placed at distance r_1 and r_2 respectively from the source.

→ The two surface are enclosed in the same solid angle 'w'.

for surface A_1

Total luminous flux (ϕ) = Iw. $\left[I = \frac{\phi}{w} \right]$.

Solid angle (w) = $\frac{\text{Area}}{(\text{distance})^2} = \frac{A_1}{(r_1)^2}$

Total flux (ϕ) = Iw.

$= I \times \frac{A_1}{(r_1)^2}$ ①

illumination (E_1) = $\frac{\phi}{A_1} = \frac{I A_1}{r_1^2} \times \frac{1}{A_1} = \frac{I}{(r_1)^2}$

Similarly we can find

$$E_2 = \frac{I}{(r_2)^2} \quad \text{---} (2)$$

$$\frac{E_1}{E_2} = \frac{(r_2)^2}{(r_1)^2}$$

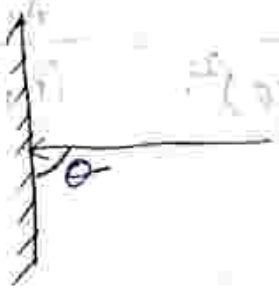
2. Lambert's cosine Law :-

This law states that illumination of a surface varies directly as the cosine of the angle between the normal to the surface and direction of incident light.

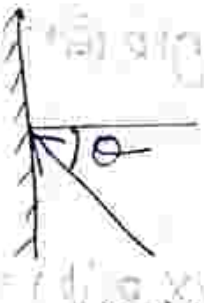
$$E \propto \cos\phi$$

(i) For normal surface, $E = \frac{\phi}{\text{Area}}$.

(ii) For inclined surface, $E = \frac{\phi}{\text{Area}} \cos\phi$



(for normal surface)



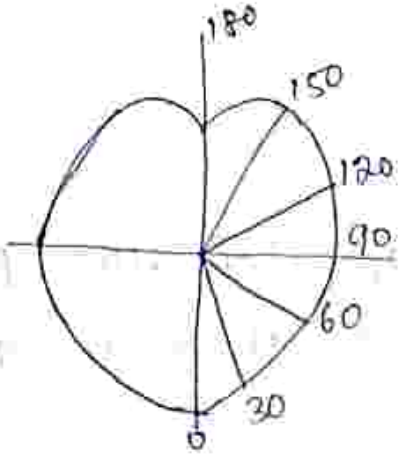
(for inclined surface)

Polar curves :-

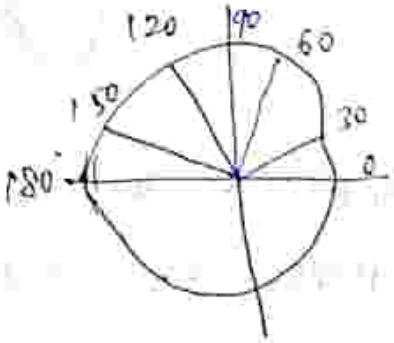
- The curve representing the unequal distribution of luminous intensity or candle power in any direction due to its unsymmetrical shape is known as polar curve.

→ A radial ordinate in any particular direction on a polar curves represents the luminous intensity of this source when viewed from that direction.

- Horizontal ~~Power~~ polar curves is obtained between candle power and angular position in a horizontal plane



(Vertical polar curve)



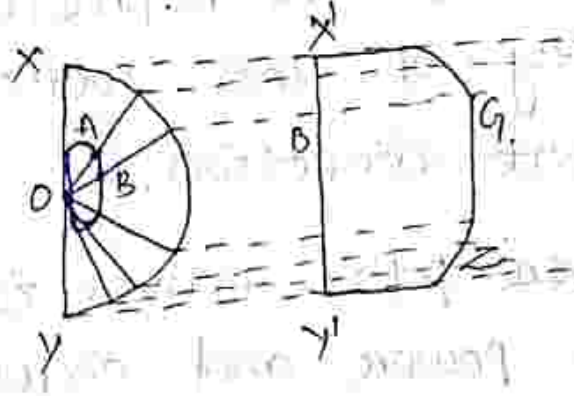
(Horizontal polar curve)

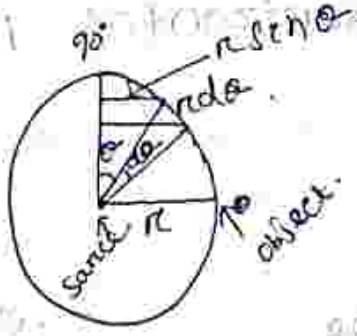
- Similarly the luminous intensity measured in vertical plane about a horizontal axis gives vertical polar curves

→ The polare curves are used to find the mean horizontal candle power (MHCP) and mean spherical candle power (MSCP)

→ The polare curves are also used to find the actual illumination of a surface by employing the candle power in that specific direction.

Rousseau's construction:-



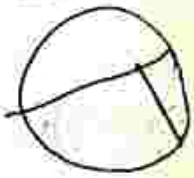


→ With 'O' as the centre of the polare curve and OX is the radius of semi-circle.

→ X'Y' is drawn parallel with XY. the ordinates are set equal to the corresponding radius on the polare curve

mean ordinate of the curve

$$= \frac{\text{Area of } x'GZY'}{\text{Length } x'Y'}$$



Luminous intensity $I = \lim_{\delta\omega \to 0} \frac{\delta f}{\delta \omega}$.

$$I_\theta = \frac{df}{d\omega}$$

$$d\omega = \frac{r d\theta \cdot 2\pi r \sin\theta}{r^2}$$

$$= 2\pi \sin\theta \, d\theta$$

$$\Rightarrow df = I_\theta d\omega$$

$$F_{\theta_1,\theta_2} = \int_{\theta_1}^{\theta_2} I_\theta d\omega$$

$F \rightarrow$ Total flux.

$\omega \rightarrow$ solid angle

$$= \int_0^{90^\circ} I_\theta 2\pi \sin\theta \, d\theta.$$

$$= I_\theta 2\pi \int_0^{90^\circ} \sin\theta \, d\theta.$$

$$= I_\theta 2\pi.$$

$$\boxed{F = I_\theta 2\pi}$$

$$I_\theta = \frac{F_{0,90^\circ}}{2\pi} = \frac{\text{Total flux in upper horizontal}}{2\pi}.$$

I_θ → upper mean Hemispherical candle power.

Design of lighting schemes :-

(1) Space height ratio :-

$$\frac{\text{Horizontal distance between the lamps}}{\text{mounting height of lamp.}}$$

→ The mounting distance of a lamp should be in between 2.2 – 2.45 metre. and the value of this ratio lies between 1 to 2.

(2) utilization factor :-

$$\frac{\text{Total utilised on working plane.}}{\text{Total lumens radiated by lamp.}}$$

→ This value depends upon

(i) The area to be illuminated

(ii) height at which the lamps are fitted.

(iii) The colour of surrounding walls ceiling or fittings.

(iv) The type of lights (direct or indirect)

The range of direct light → 0.25 to 0.5.

" " " In " " → 0.1 to 0.3

(3) Depreciation factore :-

illumination under normal working condition illumination when everything is clean.

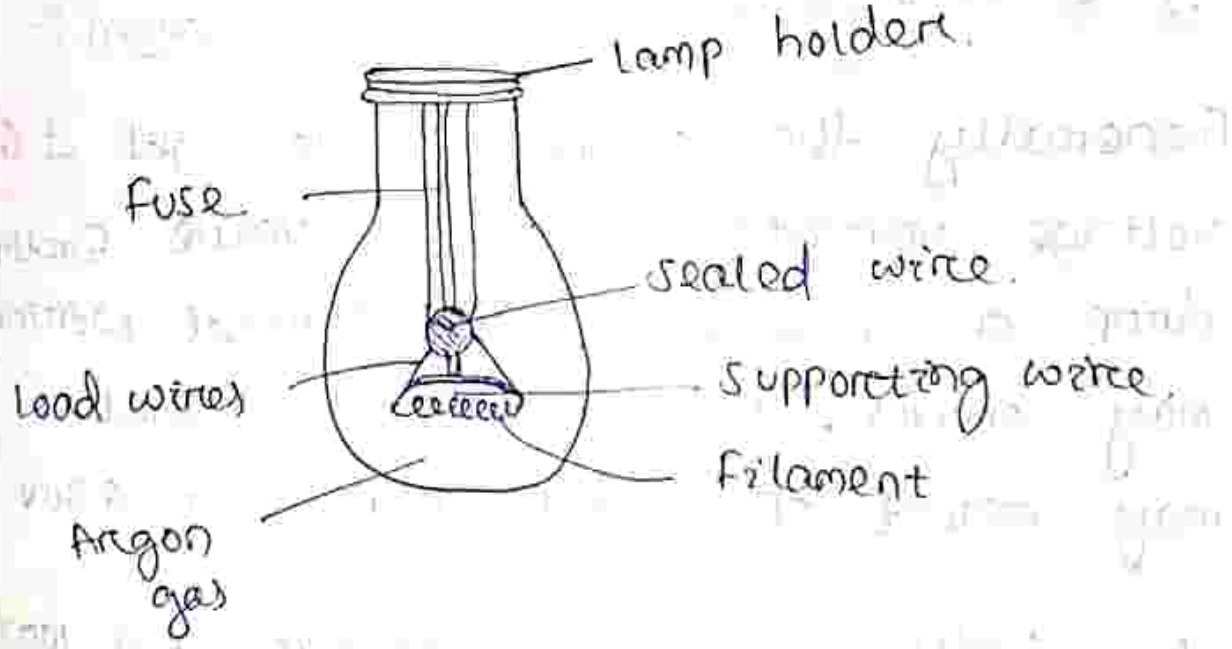
≃ 0.8.

(4) Maintenance factor :-

(1) The ratio of illumination on a area given after a period of time to the initial illumination on the same area.

Electrical source of Light :-

(1) Incandescent lamp :-



(i) The space within the lamp is replaced with inert gas like argon which can reach

a temperature of 2400 K with out evaporation.

(ii) To prevent heat loss coiled coil / spiral filaments are used.

(iii) However gradual evaporation makes a ~~large~~ dark deposit on the wall of the bulb.

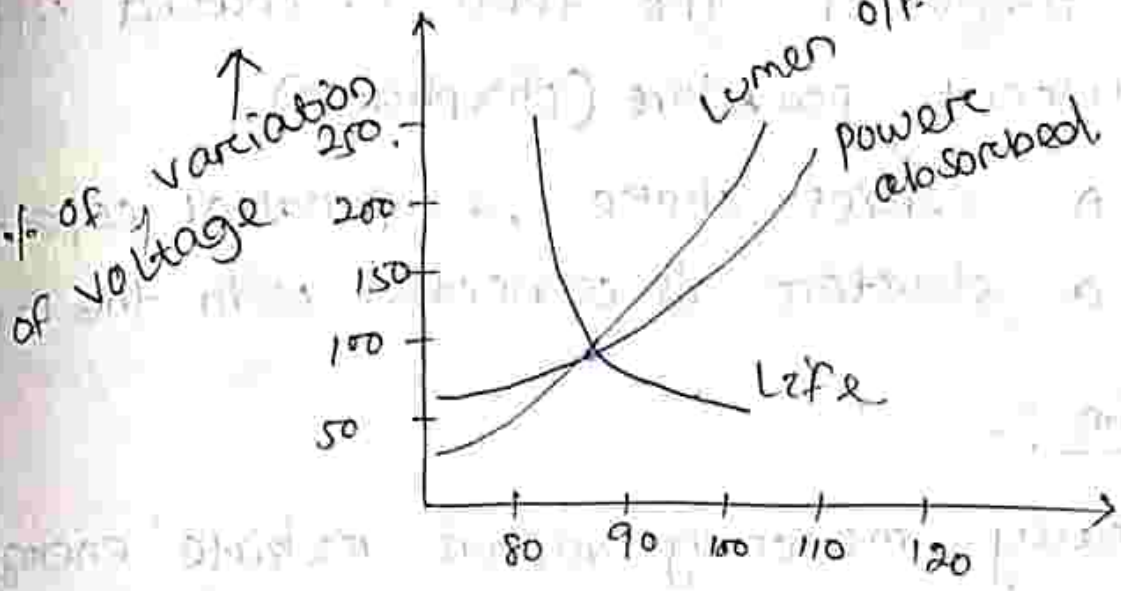
(iv) With flowing of current in the filament initially, a red colour appearance occurs in the filament tube. With the increase of heat a white spot appears across the filament.

Effect of voltage variation on the filament:-

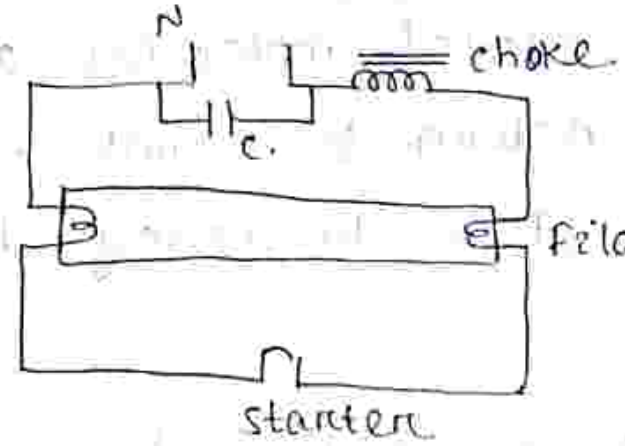
(i) Generally the consumer side get ±6% voltage variation of rated value. Further drop of voltage in the electrical wiring may occurs. Thus a voltage variation may result of 212 to 224V on a 230V

(ii) A study of the behaviour of a 100 watt filament gives the characteristics curve for its life Lumen o/p.

and power absorbed.



Constructional features of fluorescent lamp:-



(i) The fluorescent lamp is in the form of a tube, 3 to 5 cm in diameter and 0.5 m to 1.5 m long.

(ii) with an electrode at each end which are in the form of coil filaments coated with an electron emitting material.

(oxide of barium or strontium).

(iii) The inside of the tube is coated with fluorescent powdere (phosphorus).

(iv) A series choke, a parallel capacitor and a starter is connected with the lamp

Operation :-

(i) Generally mercury vapour radiate energy which comes under ultraviolet region. so they are of no use as a source of light. However these radiation are used in exciting certain materials.

(ii) When the excited molecules of these materials return to normal, they emit a radiation at a frequency different from original.

(iii) Now the emitted radiation comes under visible region. materials which poses this property is known as fluorescent and the process is known as fluorescence

(iv) When the supply is switched on, the current flows through the choke, starter

and electrodes, the starter raises the temperature of the bimetal contacts and they get closed. After flow of the steady current they cooled down and get separated suddenly. There by the current through the choke is interrupted and approximately 1000 volt causes the tube to strike.

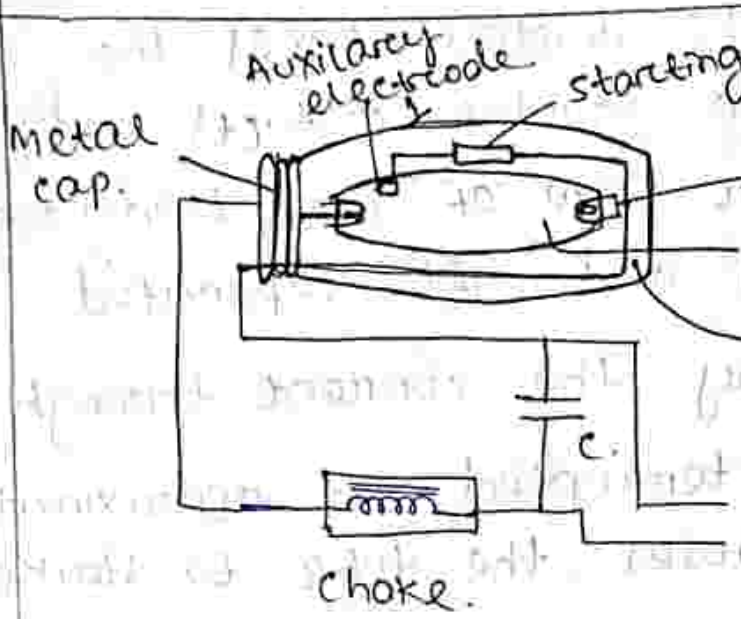
(v) once the tube strike, the tube current flows throw the ionised molecules inside the tube and the bimetal contacts remain open.

(vi) The gas inside the starter is Argon or Neon, and the filament coating contains oxide of barium or strontium.

Mercury vapour lamp :-

(i) In case of mercury vapour atoms, the excitation to different level is possible some of the important wave length radiated are 2537 AU, 5561 AU, 4358 AU, 4047 AU. (Austronomical unit - AU).

(ii) The first one i.e 2537 AU fall in the ultraviolet range and the last three are in the visible range.



Construction :-

(i) The tube containing mercury vapour is made up hard glass.

(ii) the outer glass cover protects the inner tube from coming into direct contact with atmospheric temperature variation. It also absorbs the ultraviolet radiation emitted from the lamp during the work.

(iii) There are two main electrodes made up tungsten wire and a starting electrode which is spaced ~~wide~~ while closed to main electrode (1) through a high series resistance along with the main electrode (2).

(iv) The phase comes to the main electrode through a series choke and a capacitor in parallel.

Working Principle :-

(i) When ckt is energised the supply voltage appears between the main electrode (1) and the starting or auxiliary electrode

(ii) The argon or neon coming between these two electron is immediately ionised because distance between these two electrode is very small and a glow appears betn the said electrodes.

(iii) A small current starts flowing through the starting resistore in series with the auxiliary electrode.

(iv) This results to building of pressure due to heating of mercury which is originally in the condensed form.

(v) Ultimately medium between the main electrodes is ionised and the current starts flowing between the two electrodes due to the negative

temperature coefficient.

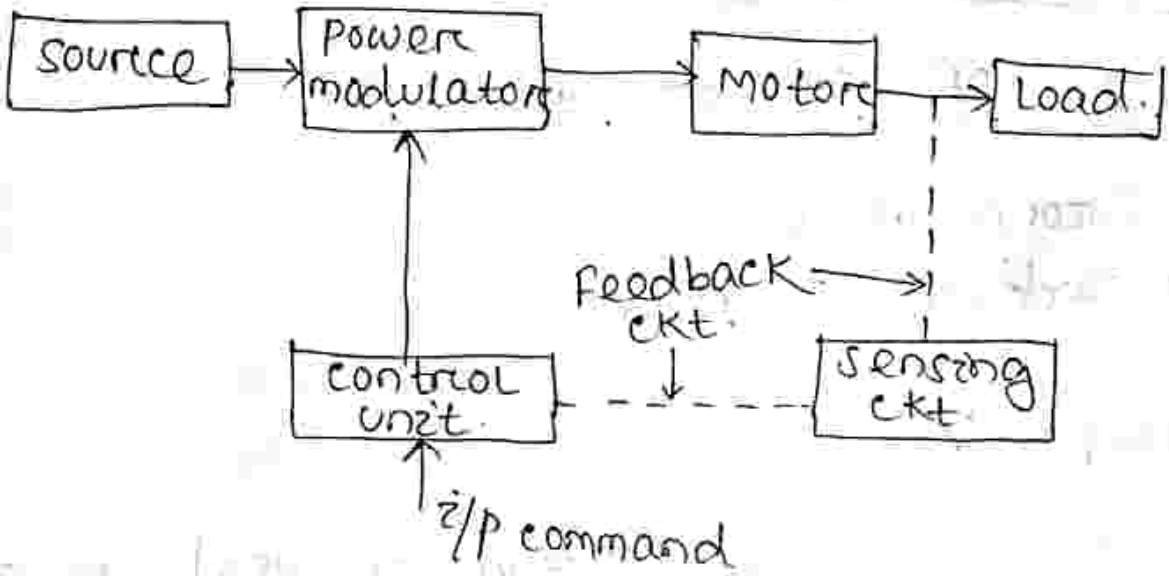
(vi) Now it is controlled by the choke to limit the current so as to counter at the low resistance of the path between the two electrodes.

Chapter-5

Industrial drive

Electric drive :-

(i) An electric drive is defined as a form of machine equipment design to convert electrical energy to mechanical energy and provide electrical control of these process.



Source :-

It is may be of AC or DC.

Power modulator → It converts AC to DC or DC to AC. It limits the current during starting, breaking and reversing motion.

→ It also selects the modes i-e motoring and breaking.

Load :→

for example fans, machine tools.

motor

sensing unit

control unit

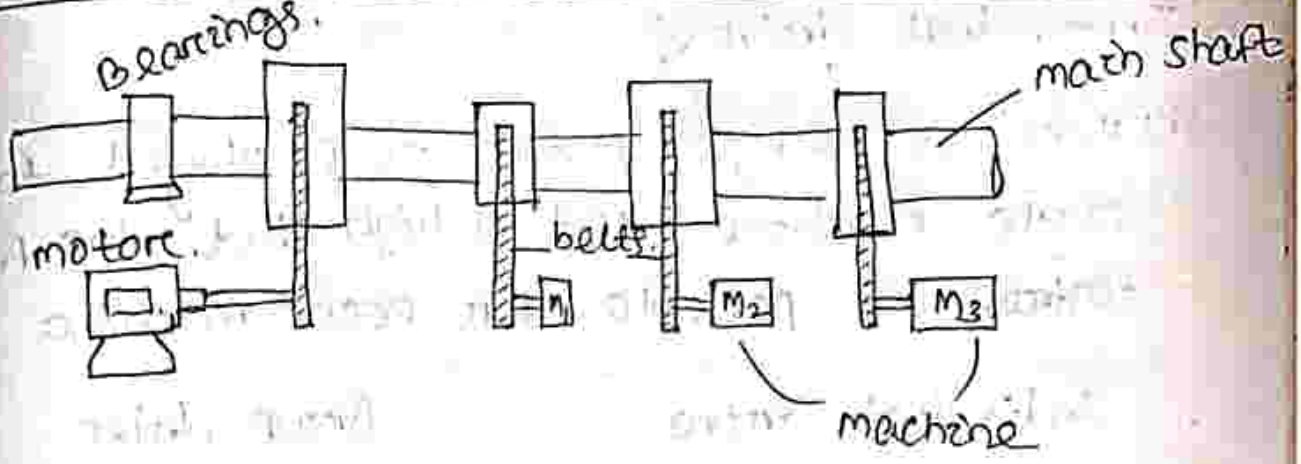
Types of electric drive :—

(1) Group drive

(2) Individual drive.

Group drive :-

(i) In this one motor is used as a drive for two or more than two machines. The motor is connected to a long shaft on which other machines are mounted through belts.



Advantage :-

(i) The effective cost is less as compare to individual drive.

(ii) Disadvantage :-

(i) In case of fault all the machines mounted are fail to operate.

(ii) Efficiency will be low when all machine are not working.

(iii) It is not possible to install a new machine at a far away distance.

(iv) This drive is heavy and difficult to control.

Individual drive :-

(i) Here a single motor is employed for a single machine. cost is high but the personal control is possible for each machine.

Individual drive	Group drive
(i) Initial cost is more	(i) Initial cost is less.
(ii) It works at good power factor.	(ii) It works at low power factor.
(iii) It has high efficiency	(iii) It has low efficiency (light load)
(iv) It has high reliability.	(iv) It has less reliability
(v) It can be fitted anywhere	(v) such arrangement is not possible.
(vi) use less, where sequence of operation is required.	(vi) useful, because all the operation stopped simultaneously.
(vii) space can be fully utilized.	(vii) more space is required.
(viii) This must for driving heavy machines e.g cranes, lifts, etc	(viii) This system not employed such cases.

Explain the factors which you will consider while selecting a motor for a particular industrial drive.

The factors which should be consider while selecting a motor for a particular industrial drives are :-

(i) nature of electricity :-
whether AC or DC supply is to be used for the drive.

(ii) nature of drive :-
whether the particular motors is going to drive individual machines or a group of machine

(iii) capital cost and running cost of the drive.

(iv) maintenance required for the drive.

(v) Types of insulation.

(vi) space and weight restriction ~~of motor~~.

(vii) Ambient temperature

(viii) efficiency of the machine.

(ix) surrounding environment and location.

(x) nature of load, whether the load requires light ~~and~~ or heavy starting

torque, or the load torque increases with speed and remains constant.

(x) Electrical characteristics such as starting characteristics, running characteristics, speed control and breaking characteristics.

(xi) Mechanical characteristics such as, types of enclosure, bearings, noise level, heating and cooling arrangement.

As the above all condition are not achievable at all time the main important points, we need to consider are

mark

(i) nature of mechanical load drive
(ii) suitable speed - torque characteristics
(iii) starting and running condition.

Application of DC motor (shunt motor):-

The characteristics of a shunt motor reveals that it is a constant speed motor. It is therefore used

(i) where the speed is required to remain almost constant from

no load to full load.

(ii) where the load has to be driven a no. of speed at any one of which is required to be remain constant.

Application :-

(i) Lathe machine.
(ii) Drills.
(iii) Boring mills.
(iv) Spinning & weaving machine.

Series motor :-

→ It is a variable speed motor i.e speed is low at high torque. However at light loads the motor tends to attend dangerously high speed.

→ Therefore it is used to a high starting torque is used.

Application :-

(i) Electric Traction.
(ii) Trains.
(iii) Elevators.
(iv) air compressor. Vacuum cleaner, hair dryer etc

(3) compound motor :-

Differential compound motors are rarely used because of their poor torque characteristics however cummulative compound motors are used where a fairely constant speed is required with irregular loads or suddenly applied heavy loads.

Application :-

Electric traction, crane, elivators, air compressor, vacuum cleaner, hair drier, sewing machine, etc.

Presses, shears, machine, respirocating machine etc.

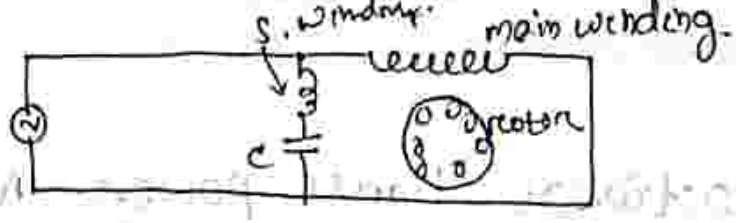
Application of 1ϕ IM :-

01. split phase induction motor (IM) :-

These motors have suitable when a moderate starting torque is required.

e.g → fans, washing machine, oil burner small machine tools (low to 250w.

02. capacitore start motore :-



Those are used where with stationary torque is required and where the starting may be long

uses :- compressor, large fan, pump, high inertia loss, Here the equipments are of high rating i.e 120 watt to 7.5 KW.

03. capacitore start capacitore run motore :-

(i) Because of constant torque the motore is vibration free and can be used in hospital, studios and other places where silence is important

Shaded pole induction motor :-

(i) The salient features of this motors are extremely simple construction and absense of centrifugal switch

(ii) since starting torque, efficiency and power factore are very low. These motors are only suitable for low power application.

e.g → small Fans, Toys, hair driers, desk fans

Application of series motor and universal motor :-

(i) The fractional horse power AC series motor have high speed and large starting torque. They can be therefore used to drive high speed vacuum cleaners, sewing machine, electric shavers, drills

Repulsion motor (application) :-

(i) Due to their high starting torque repulsion motor's are used to operate device such refrigerators, Pump compressors etc

Application of synchronous motor :-

(i) over excited synchronous motors can be used to improve power factor of a plant while carrying their rated speed.

(ii) They are used to improve the voltage regulation of transmission line

(iii) High power electronic converters generating very low frequencies

enable us to run synchronous motors at ultra low speed. (Thus huge motors 10 MW range drive crushers, rotatory kilns, variable speed ball machine).

Application of 3 phase induction motors :-

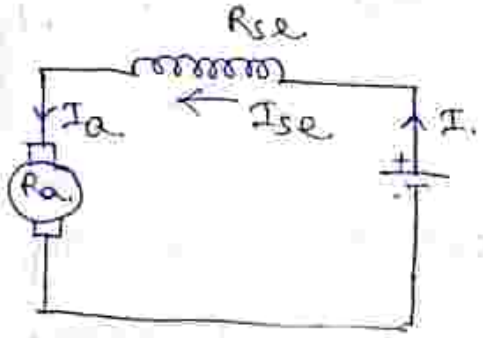
(i) This motor is nearly constant speed motor with a poor starting torque. It has high overload capacity and operates always at lagging p.f from 0.7 to 0.9.

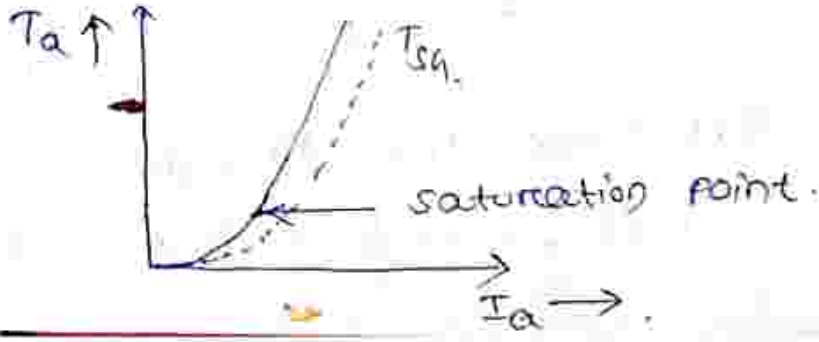
(ii) The squirrel cage IM can be used for driving low and medium power drives, where speed control is not required.

(iii) Tubewells, lathe machine, drilling machine, saws machine, grinders etc.

characteristics of DC series motor.

(1) T_a Vs. I_a :-





$T \propto \phi I_a$

$\phi \propto I_{se}$.

$\phi \propto I_a$.

$\Rightarrow$ $\boxed{T \propto I_a^2}$ ← before saturation.

$\boxed{T \propto I_a}$ ← After saturation.

(i) Before saturation torque $\propto I_a^2$. At light load I_a is small, hence flux is small. As I_a increases, armature torque T_a also increases as square of the armature current.

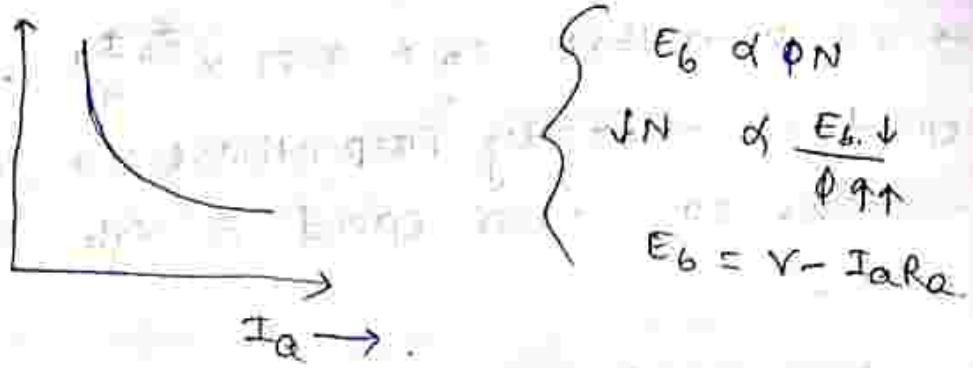
(ii) Hence, initially the torque is parabolic but after saturation the flux is almost independent of I_a, hence torque (T_a) $\propto I_a$. So, the characteristics become linear after saturation.

(iii) The shaft torque (T_{sh}) is shown by the doted line. It is less than armature torque due to stray loss.

(iv) From the characteristics we can conclude that, series motor use where huge starting torque

is required for accelerating heavy masses like electric train.

(2) N Vs. I_a :-



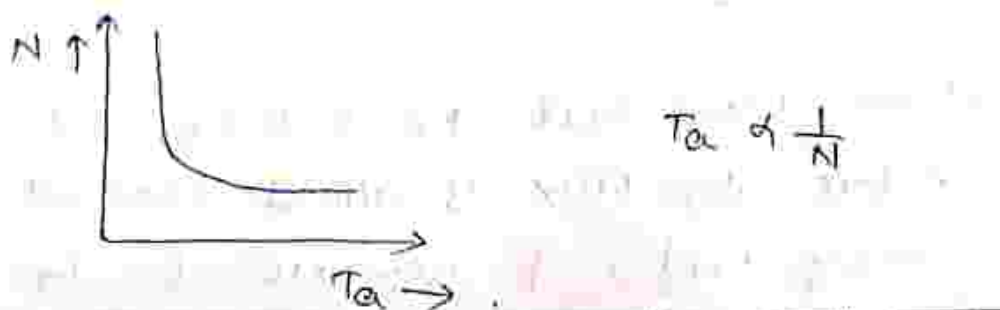
(i) Variation of speed can obtain from the formula $N \propto \frac{E_b}{\phi}$.

(ii) As load increase I_a increase, with increases the flux. Here change in E_b for various load current is very small.

(iii) Hence the speed varies inversely as the armature current. when load is heavy, I_a is large and speed will be low.

(iv) when load is small I_a falls to a very small value. As a result speed become very high.

(3) N Vs. T_a characteristics :-



$$T_a = 9.55 \times \frac{E_b I_a}{N}$$

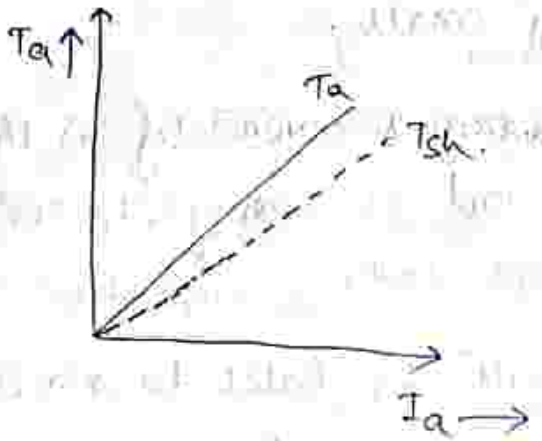
$N \propto \frac{E_b}{T_a}$ because. $\phi \propto I_a$.

→ we know that $T_a = 9.55 \times \frac{E_b I_a}{N}$. Here speed is inversely proportional to armature torque. so. when speed is high, torque is low.

→ when speed is low, torque is high.

Shunt Motors.

T_a Vs I_a characteristics:-



$T_a \propto \phi I_a$

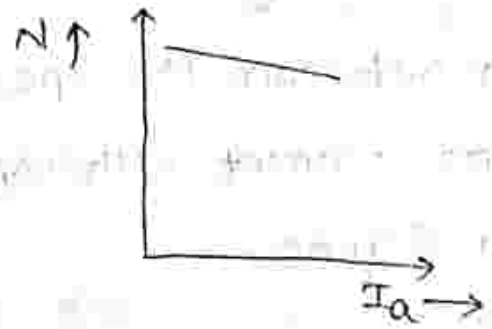
$\boxed{T_a \propto I_a}$ {because ϕ is constant}

(i) we know that $T_a \propto \phi I_a$ but in shunt motors the flux is almost constant only of heavy load. ϕ decrease due to increase

in armature reaction.

(ii) Therefore, In a shunt motor $T_a \propto I_a$. So the characteristics is a straight line passing through the origin (linear).

N Vs I_a characteristics :-



$N \propto \frac{E_b}{\phi}$ ← constant.

$N \propto V - I_a R_a$

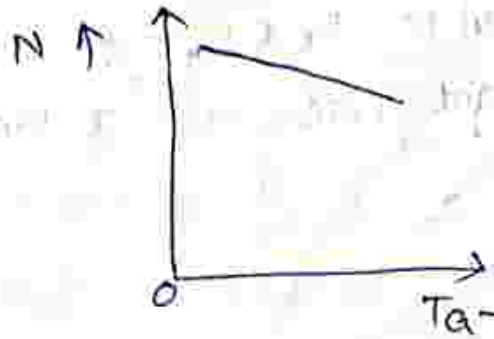
(i) In a shunt motor, Flux is almost constant, therefore $N \propto E_b$. But practically both E_b and Flux decreases with increase in load

(ii) However, decrease in E_b is more than the flux, as a result there is some decrease in speed.

(iii) From the characteristics we can notice that there is no appreciable change in the speed of DC shunt motor from no load to full load.

(iv) Therefore these motor are used where sudden change in the load takes place like wood cutting Latho machine, etc.

N Vs Ta characteristics. :-



(i) This curve is drawn between the speed of the motor and armature current with various amps. as shown in the figure.

(ii) From the curve it is understood that the speed reduces when the load torque increases.

(iii) With the above three characteristics, it is clearly understood that when the shunt motor runs from no load to FULL load there is slight change in speed. Thus, it is essentially a constant speed motor.

Since the armature torque is directly proportional to the armature current, the starting torque is not high.

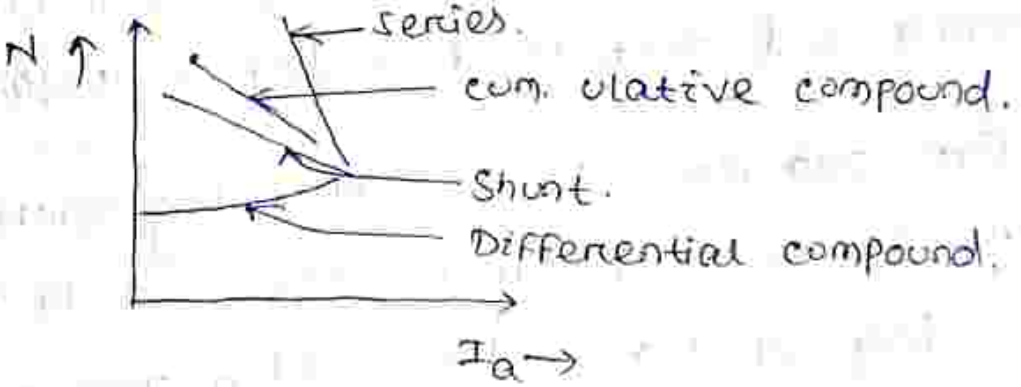
compound Motors :-

(i) These motors have both series and shunt winding

(ii) If series field flux is in the same direction with shunt field flux, then motor is said to be cumulative compound motor.

(iii) If the series field opposes the shunt field, then the motore is said to be differential compound motor.

N vs Ia characteristics :-



cumulative compound.

$\phi_t = \phi_{sh} + \phi_{se}$.

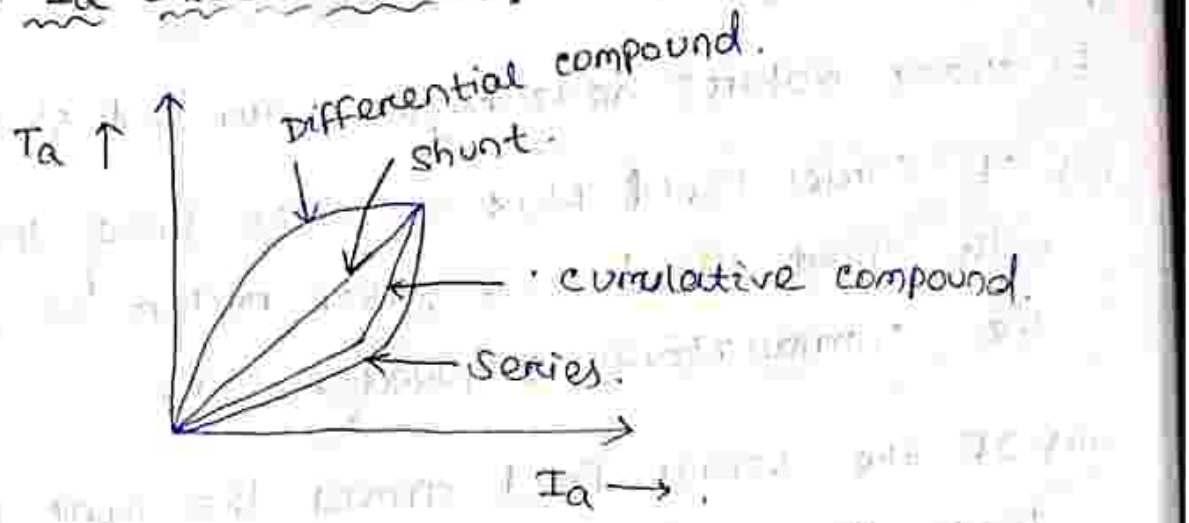
Load ↑ I_a ↑ ϕ_{se} ↑ ϕ_t ↑ N ↓.

Differential compound.

$\phi_t = \phi_{sh} - \phi_{se}$

Load ↑ I_a ↑ ϕ_{se} ↑ ϕ_t ↓ N ↑

Ta Vs Ia characteristics :-



cumulative compound Motor :-

(i) These motors are used where properties of both series and shunt field winding is required.

(ii) For example. In a coal cutting machine sudden change in load takes place. Due to shunt winding it can handle sudden change in load and due to series field it will be able to take heavy load.

(iii) cumulative compound motors are used where high starting torque is required with pulsating loads.

Differential compound Motors :-

(i) As series field opposes the shunt field, if load is increased, total flux will decrease.

(ii) Therefore speed of differential compound motors is constant when load is less, but speed increases with increase in load.

(iii) Therefore, these motors are not commonly used.

Explain DC and AC Traction Motor. :-

(i) DC traction motors are generally used for dc traction purposes, dc locomotives and drives.

(ii) The speed can be changed by the variation of the field winding taps.

(iii) By using the rheostat taps the resistance is varied and accordingly the speed will be varied. Also for the control in a dc drive, dc traction motor (series type) can be changed.

(iv) These traction motors may be opted in series or parallel. for the higher speed requirement, the motors are operated in parallel and for lesser speeds series connected motors are essential.

(v) In case of parallel operation of two traction motors the dc supply voltage available will be constant (high) and as speed $\propto$ 'V' $\Rightarrow$ speed increases.

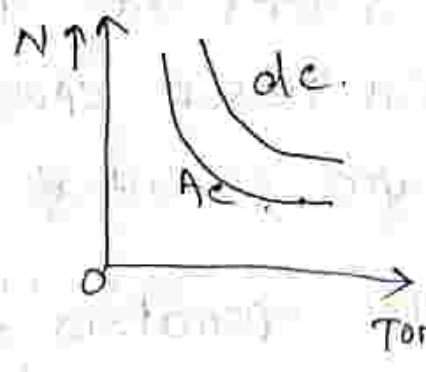
(vi) ALSO Ac series traction motors may be operated in Ac drive system i.e.,

in Railways AC traction motors are preferred.

(vii) The single phase compensated series motors have been built for traction work upto sizes of several hundred HP.

(viii) They have low PF at starting and therefore starting torque is low. The AC series motor is not well suited to sub-urban services and stops are frequent.

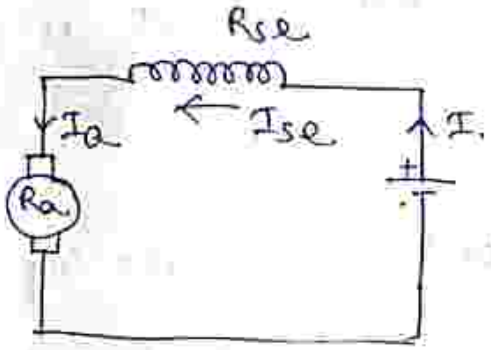
(ix) The speed-torque characteristics is similar to that of a dc series traction motor and is drawn below.

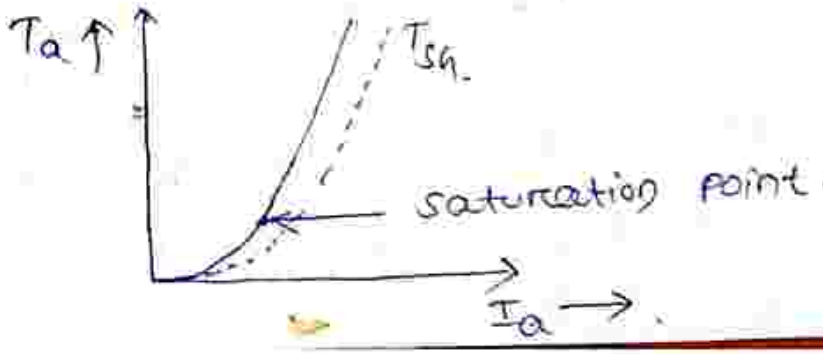


(x) ALSO 3ϕ induction motor can be used for the traction purpose but with lesser extent. It has been used in the Kando system.

characteristics of DC series motor

(1) T_a Vs. I_a :-





$T \propto \phi I_a$

$\phi \propto I_{se}$.

$\phi \propto I_a$.

$\Rightarrow$ $\boxed{T \propto I_a^2}$ ← before saturation.

$\boxed{T \propto I_a}$ ← After saturation.

(i) Before saturation torque $\propto I_a^2$. At light load I_a is small, hence flux is small. As I_a increases, armature torque T_a also increases as square of the armature current.

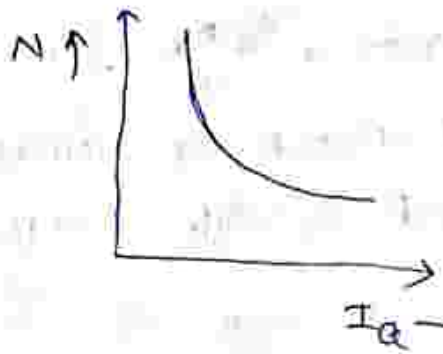
(ii) Hence, initially the torque is Parabolic but after saturation the flux is almost independent of I_a, hence torque $(T_a) \propto I_a$. So, the characteristics become Linear after saturation.

(iii) The shaft torque (T_{sh}) is shown by the doted line. It is less than armature torque due to stray loss.

(iv) From the characteristics we can conclude that, Series motor use where huge starting torque

is required for accelerating heavy masses like electric train.

(2) N Vs. I_a :-



$E_b \propto \phi N$

$\downarrow N \propto \frac{E_b \downarrow}{\phi \uparrow}$

$E_b = V - I_a R_a$

(i) Variation of speed can obtain from the formula

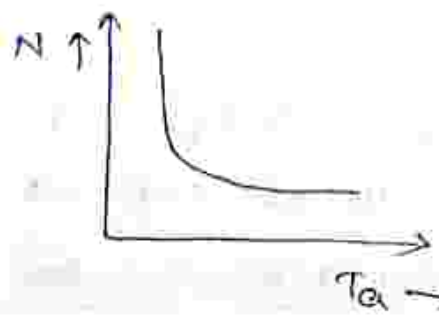
$N \propto \frac{E_b}{\phi}$.

(ii) As load increase I_a increase, with increases the flux. Here change in E_b for various load current is very small.

(iii) Hence the speed varies inversely as the armature current. when load is heavy, I_a is large and speed will be low.

(iv) when load is small I_a falls to a very small value. As a result speed become very high.

(3) N Vs. T_a characteristics :-



$T_a \propto \frac{1}{N}$

$$T_a = 9.55 \times \frac{E_b I_a}{N}$$

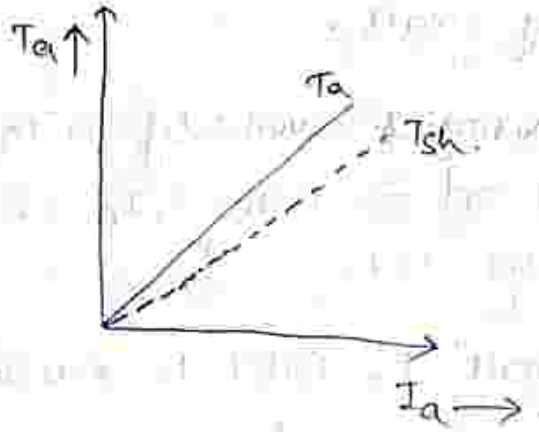
$N \propto \frac{E_b}{T_a}$ because. $\phi \propto I_a$.

→ we know that $T_a = 9.55 \times \frac{E_b I_a}{N}$. Here speed is inversely proportional to armature torque. so, when speed is high, torque is low.

→ when speed is low, torque is high.

Shunt Motor.

T_a Vs I_a characteristics :-



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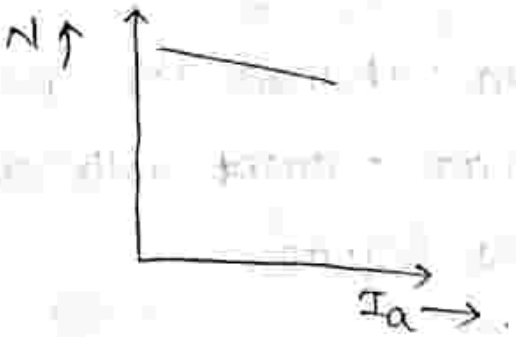

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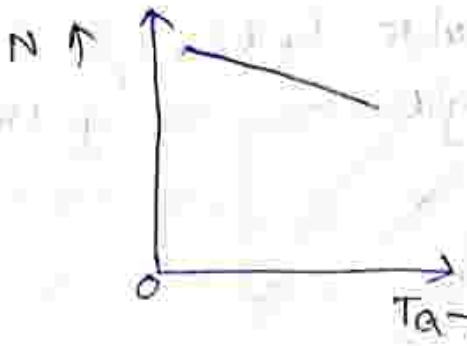
(ii) However, decrease in E_b is more than the flux, as a result there is some decrease in speed.

(iii) From the characteristics we can notice that there is no appreciable change in the speed of DC shunt motor from no load to full load.

(iv) Therefore these motor are used where sudden change in the load takes place like wood cutting, Lathe machine, etc.

N Vs Ta characteristics. :-



(i) This curve is drawn between the speed of the motor and armature current with various amps. as shown in the figure.

(ii) From the curve it is understood that the speed reduces when the load torque increases.

(iii) With the above three characteristics, it is clearly understood that when the shunt motor runs from no load to full load there is slight change in speed. Thus, it is essentially a constant speed motor.

Since the armature torque is directly proportional to the armature current, the starting torque is not high.

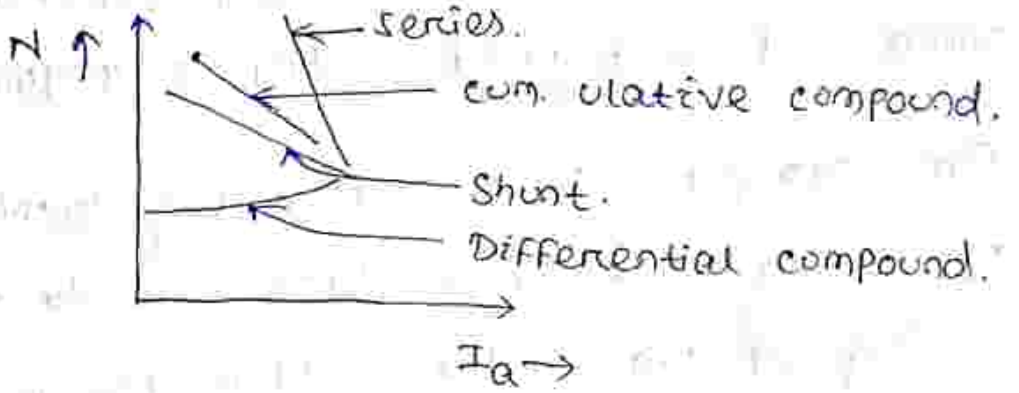
compound Motors :-

(i) These motors have both series and shunt winding

(ii) If series field flux is in the same direction with shunt field flux, then motor is said to be cumulative compound motor.

(iii) If the series field opposes the shunt field, then the motore is said to be differential compound motor.

N vs Ia characteristics :-



cumulative compound

$\phi_t = \phi_{sh} + \phi_{se}$.

Load ↑ I_a ↑ ϕ_{se} ↑ ϕ_t ↑ N ↓.

Differential compound

$\phi_t = \phi_{sh} - \phi_{se}$

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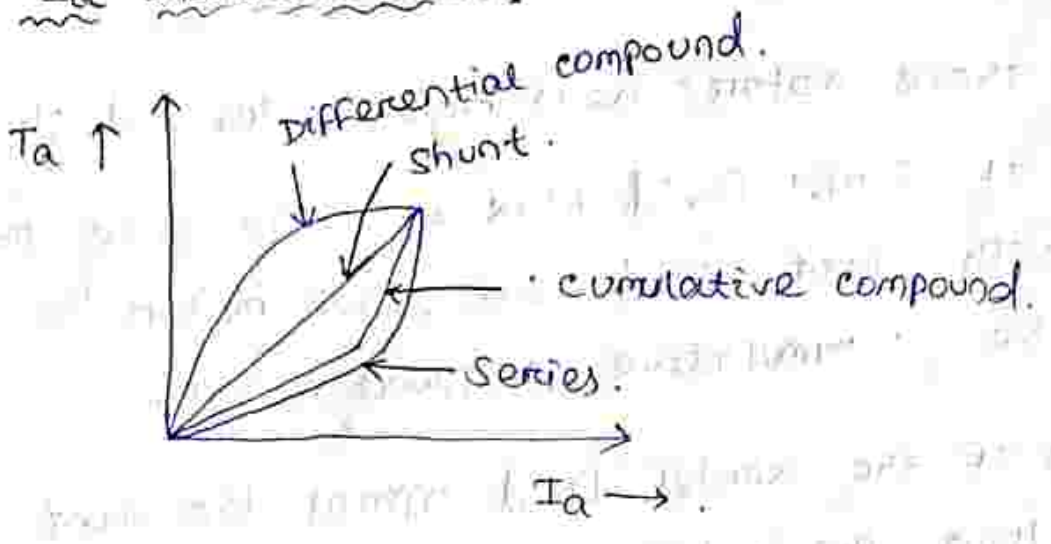
Ta Vs Ia characteristics :-



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(i) These motor are used where properties of both series and shunt field winding is required.

(ii) For example. In a coal cutting machine sudden change in load takes place. Due to shunt winding it can handle sudden change in load and due to series field it will be able to take heavy load.

(iii) cumulative compound motor are used where high starting torque is required with pulsating loads.

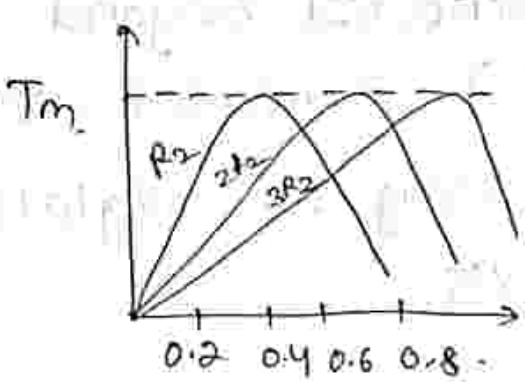
Differential compound Motor :-

(i) As series field opposes the shunt field. if load is increased, total flux will decrease.

(ii) Therefore speed of differential compound motors is constant when load is less, but speed increases with increase in load.

(iii) Therefore, these motors are not commonly used.

Torque-slip characteristics of induction motor



→ As we know $T = \frac{K_2 S R_2}{R_2^2 + (S X_2)^2}$

(i) as $S = 0$, $T = 0$ so the curve starts from origin.

(ii) At normal speed the slip is more, so that SX_2 is negligible as compared to R_2. Hence $T \propto \frac{S}{R_2}$ as R_2 is constant

$\boxed{T \propto S}$. Hence torque-slip curve is a straight line from zero slip to a slip

that corresponds to full load

→ as slip increases beyond full load slip the torque increases and becomes maximum at $s = \frac{R_2}{X_2}$. The maximum torque in a induction motor is called pulled out torque or break down torque.

→ when slip increases beyond that, the term $(s^2 \cdot X_2^2)$ increases very rapidly so that R_2^2 may be neglated as compare to $(sX_2)^2$.

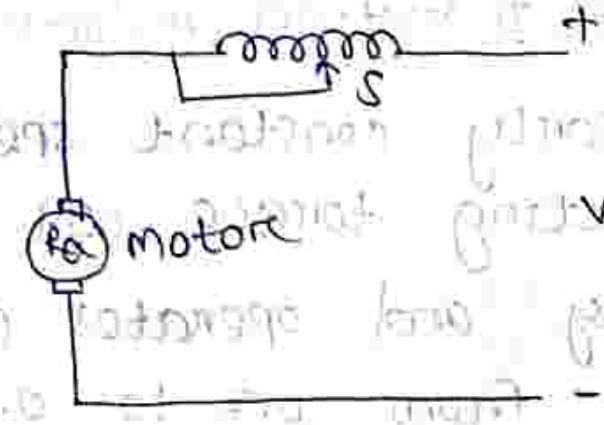
$$T \propto \frac{s}{s^2 X_2^2}$$

$$T \propto \frac{1}{s}$$

Thus the torque is inversely proportional to slip

control of motors

(i) Tapped field control of motors :-



(i) Here traction motors have run up to a speed and increase the speed limit by 15% to 30% by weakening the field strength.

(ii) Since, speed is inversely proportional to flux by reducing the field strength the speed is increased. for this purpose a tapping arrangement is provided at the series field of DC motors.

(iii) The advantage of field control is that it makes the equipment very flexible. As for instances in frequently stopped station the speed is low,

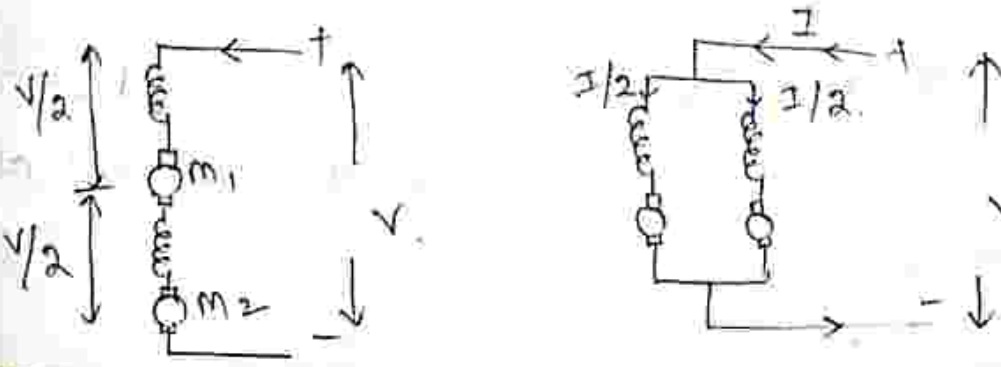
but between intercurban station the speed require is high. At that time tapped field control arrangement comes fruitfull.

(iv) In this method flux is reduced by decreasing the number of turns of the series field winding. The switch 'S' can short ckt any part of the field winding thus decreasing the flux and raising the speeds.

(v) with full turns of the field winding the motor runs at normal speed and as the field turns are cut out speeds higher than the normal speed are achieved.

Series-parallel control :-

(i) In this system two or more than two similar DC series motor are mechanically coupled to the same load.



$N \propto \frac{E_b}{\phi} = \frac{V/2}{I} = \frac{V}{2I}$ (series).

$\frac{1}{2}\left(\frac{V}{I}\right)$.

$\frac{V}{I/2} = \frac{2V}{I}$ (parallel).

$2\left(\frac{V}{I}\right)$ ∫ 4 times greater than series

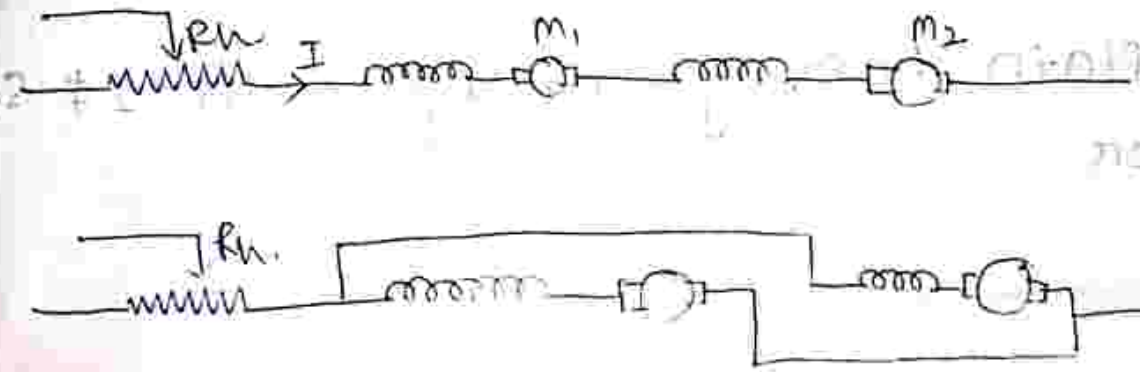
(i) when the motors are connected in series each motor armature will receives $\frac{1}{2}$ of the normal voltage. Therefore the speed will be low

(iii) when the motors are connected in parallel each motor armature receive the normal voltage and half of the supply current Thus the speed is high.

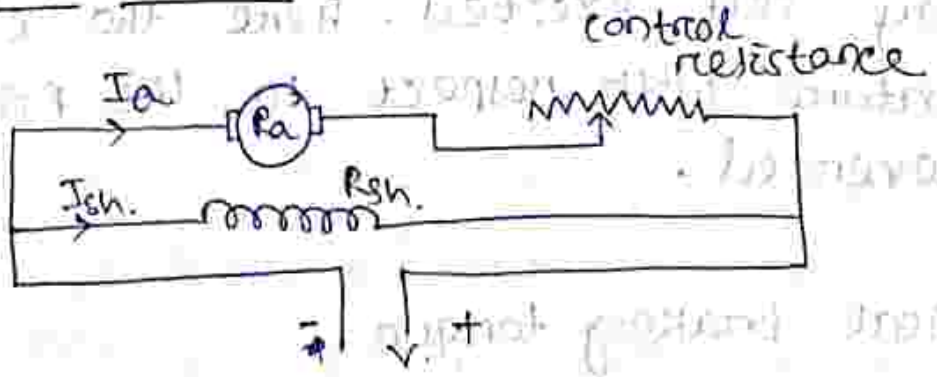
(iv) thus we can obtained two speed in the above figure. the speed obtained in parallel connection is four times that of in series connection.

(v) for better speed control a resistance control mechanism is added to the above arrangement.

(vi) At standstill the motors are connected in series via a ~~static~~ starting rheostat and in the process the resistance are cut out to attain the increase speed.



Rheostatic control :-



This method consist of obtaining reduce speed by the insertion of external series resistance in the armature circuit it can be used with series, shunt and compound motors.

Advantage :-

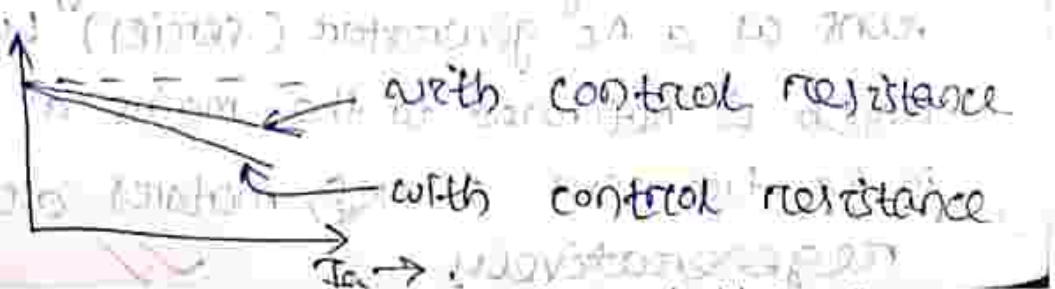
(i) The ability to achive speeds below the normal rated speed.

(ii) Simplycity and easy of connection.

Disadvantage :-

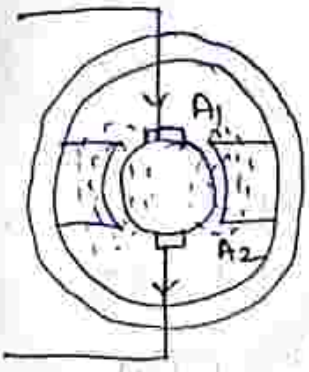
(i) Relatively high cost of large continuously rated variable resistore capable of dissipating large amount of power.

(ii) Poore speed regulation.

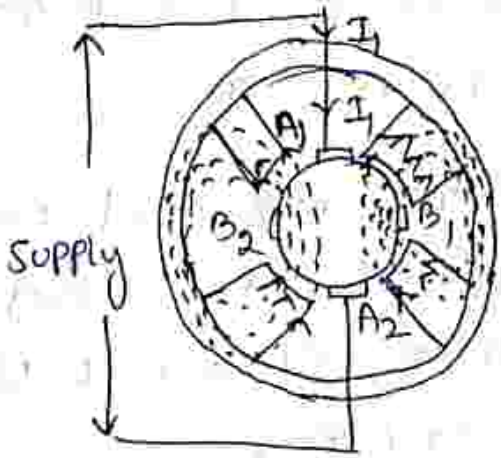


- In armature or rheostatic control method of speed the voltage across the armature is varied by inserting variable rheostat fault control resistance in series with armature
- As the controller resistance is increased the P.D across the armature is decreased, ~~there~~ there by decreasing the armature speed.
- For a load of constant torque speed is proportional to the P.D across the armature
- From the speed armature point characteristics it is seen that greater the resistance in armature greater in the fall in speed.

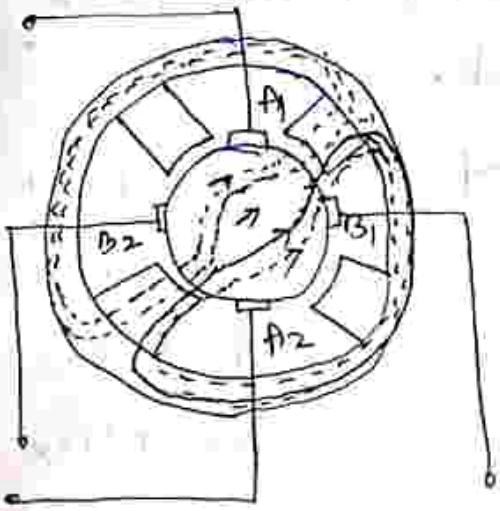
Metadyne control of Motors :-



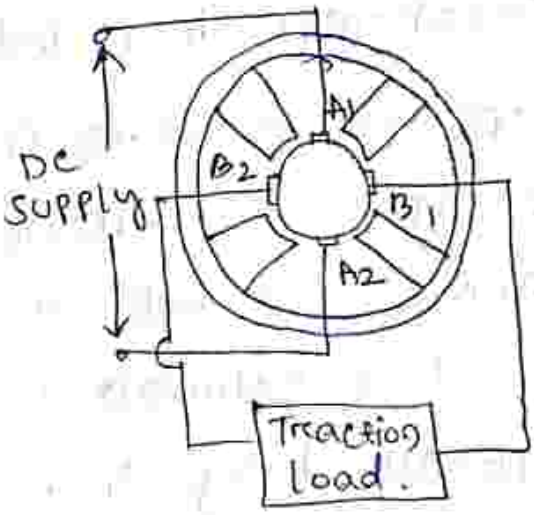
(fig - 1a)



(Fig 1-b.)



(Fig 1-c.)



(Fig 1-d.)

(i) The metadyne system of speed control estimates the energy loss and achieves a very smooth control during the acceleration period.

(ii) Consider a dc armature with two brushes and two poles. If current is supplied

to the brushes A_1, A_2. the armature flux will be as shown and mainly confined the poles as in Frg.

(iii) If there are load four brushes, current is supplied to brushes A_1, A_2 and the armature flux will take up the path as shown in fig.

(iv) If now the current supply to brushes B_1, B_2 as in Fig, the armature cross flux takes up path as indicated.

(v) If the armature is rotated at constant speed and current 'I_1' is fed into brushes A_1 A_2, an emf an emf is induced in the winding between B_1 B_2 due to the flux produced by I_1.

(vi) No emf is induced between A_1 A_2 and the voltage between A_1 A_2 is on account of the voltage drop due to I_1.

(vii) Since an emf is induced across B_1, B_2 a current I_2 will flow in a load connected between them.

(viii) The rotation of the armature in ϕ_2 induces emf E_1 between A_1 and A_2 which opposes the supply voltage. since the current is to kept at its original value of the supply voltage must be induced to over come E_2. under steady state condition.

$$E_1 \propto \phi_2 = KI_2, \quad E_2 \propto \phi_1 = KI_1$$

$$E_1 I_1 = E_2 I_2 = KI_1 I_2$$

(ix) This shows that the m/c behave like a dc Transformer only the rotational losses of m/c need be supplied by the driving motor.

Regenerating braking :-

(1) Reduce

(2) Field excitation ↑ Φ ↑ E_b ↑ $E_b = \frac{P\Phi ZN}{60A}$.

(3) Speed suddenly increased.

Regenerating braking apply to DC shunt motors :-

(i) Regenerative braking can be applied easily to DC shunt motors with out any change of connection.

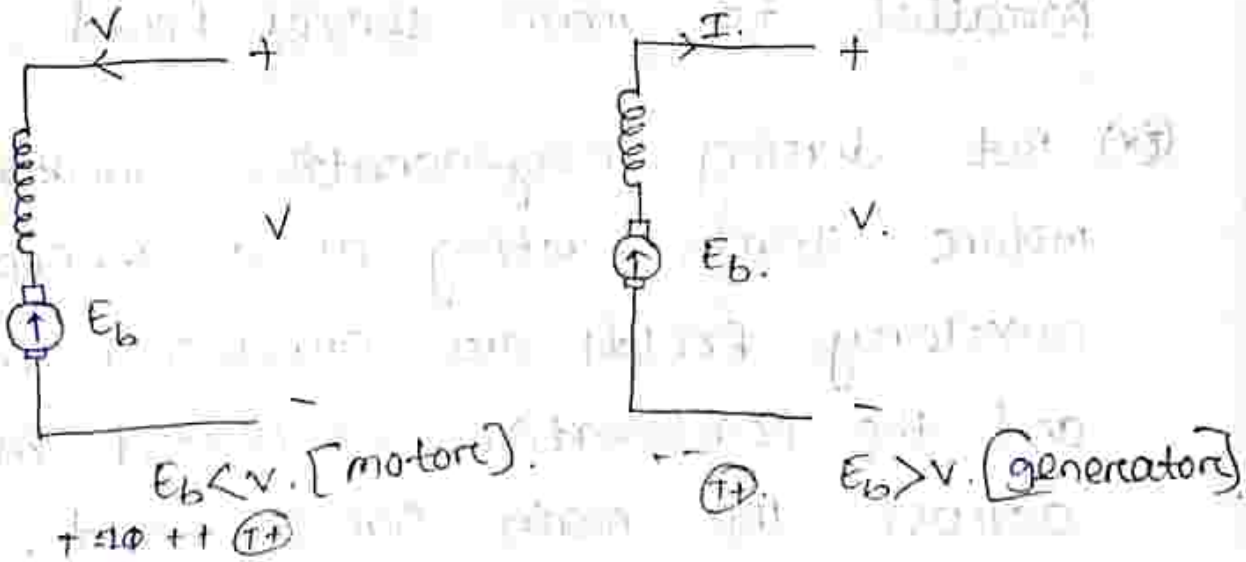
(ii) In normal working of DC shunt motor supply voltage V is greater than the induced EMF E_b. and motor is drawing current from the supply.

(iii) If due to the overhauling loads

the speed of the motor becomes greater than 'V' and as a result direction of armature current get reversed. This feeds back the power to supply and produces opposing torque due to which the speed of the motore comes down.

(iv) Regenerative braking can be easily apply to DC shunt motors, particularly in case where it is required to hold a load at a certain speed fore instantse lowering the hoists.

Regenerative braking applied to DC series motor



$E_b < V$. [motore]. — (T+). $E_b > V$. [generator]

(i) ~~Fore DC Series motore~~ regenerating braking can be applied to DC Series motore as such because as the direction of current is reversed in the armature, fore

regenerative purpose, the direction of field current also get reversed. Thus series field connection must be reversed. If the series field connection are not reversed the torque applying on the motor will same as previous.

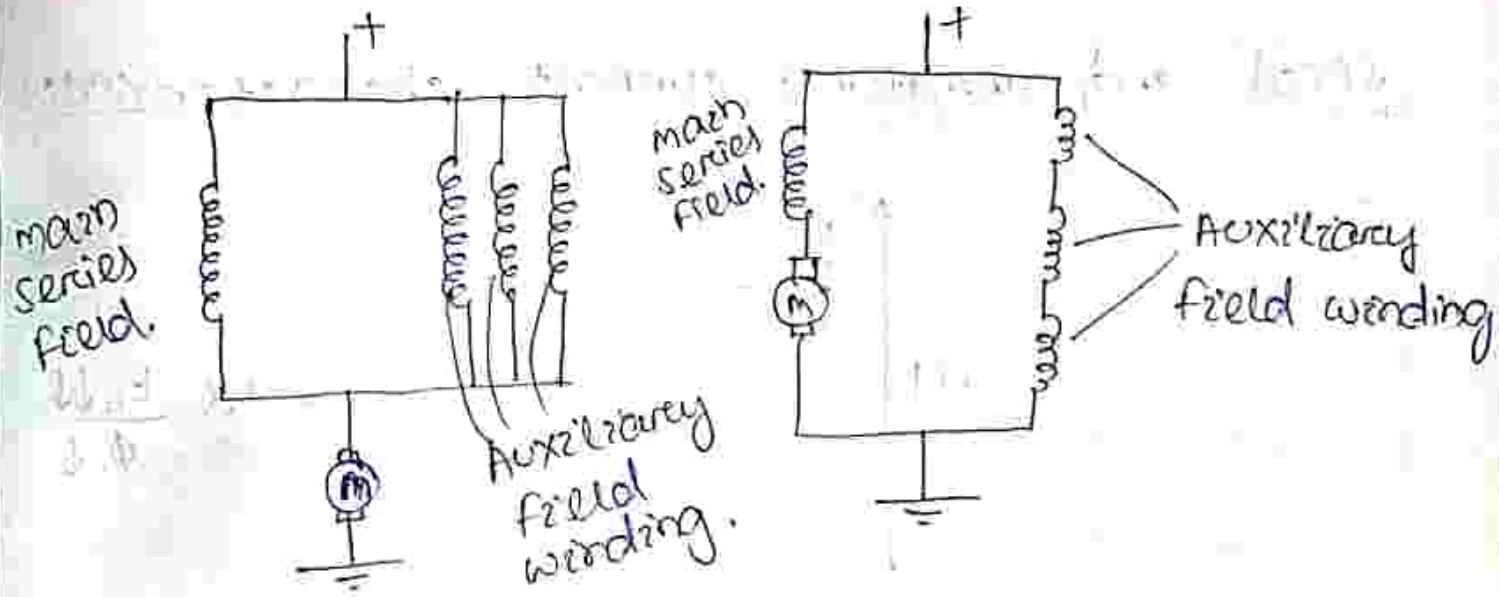
(iii) So we need to have some special arrangement in field connection of DC series motor.

(iii) During motoring the auxiliary field winding are bunched together in parallel and the whole bunch is connected in parallel to main series field.

(iv) But during regenerative breaking, the motor starts acting as a generator. The auxiliary fields are arranged in series and the combination is placed in parallel across the main series field. Thus making the machine to behave as a differentially compound generator

(v) If there is slight change in line voltage the shunt field will immediately

cause increase in the generated emf. Thus the arrangement will be self compensating. This method is known as french method.

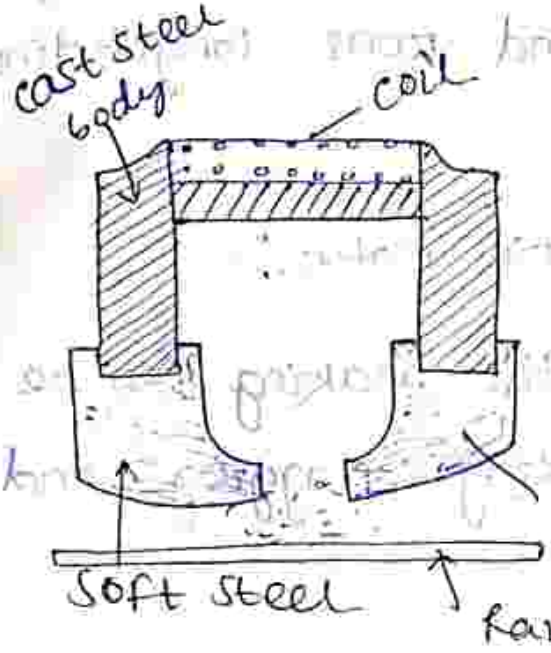


[motoring action] [Generating action].

Magnetic braking :-

(i) The magnetic brake consist of bipolar electromagnet with employed pole faces a short distance apart and along with rails.

(ii) It's body is made up cast steel and pole faces of soft steel. pole faces are parallel to the rail.



(iii) Passage of current to exciting coil produces magnetism which passes perpendicular to the rail face. as shown by doted lines. This produces force of attraction between magnetic pole faces and rail which is given by the equation

$$F = \frac{B^2 a}{2\mu_0} \text{ Newton.}$$

$$= \frac{B^2 a}{8\pi \times 10^{-7}} \cdot N$$

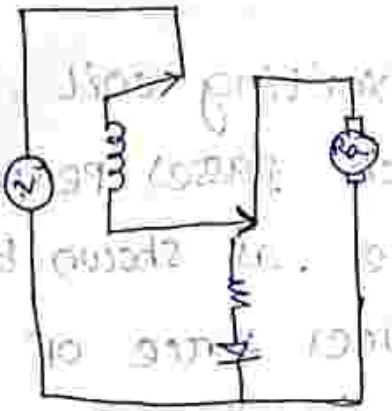
This magnetic force increases the weight on braking wheel with the result that

the braking force of magnitude 'F' is produced.

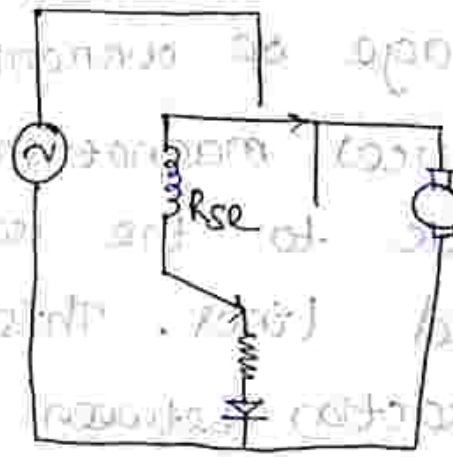
(iv) magnetic break is fitted in between wheels of the boggies. and runs longitudinal along the track.

Braking with 1-ϕ series motor:-

(i) In this motor, the braking can be done by rheostatic braking, plugging and regenerative braking.



(normal working cond^n).



(braking action).

(i) In the rheostatic braking the armature is disconnected from the supply and work as an Ac series generatore. for this it is necessary that the total resistance in the motore ckt should be less than

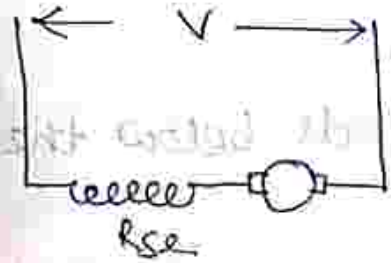
the critical resistance, so that the generator may self excited. Here the connection of armature with respect to the field is also reversed.

Electrical braking torque :=

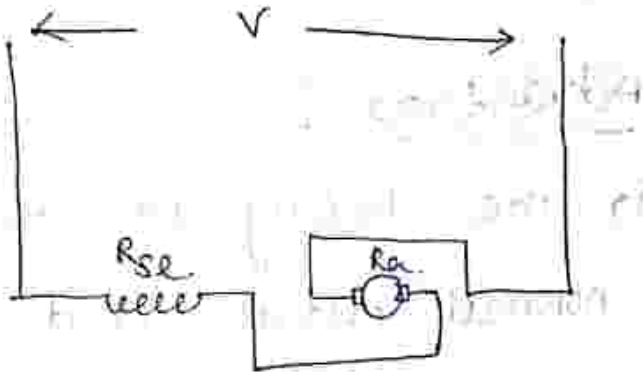
$$= K\phi I_a$$

$$= K\phi \frac{E_b}{(R + R_a + R_{se})}$$

Plugging :-



(normal working)



(braking condition).

(i) In plugging the armature connection is reversed so that a reverse ~~protecting~~ rotating torque is applied which provides necessary breaking torque.

→ In a regenerative braking the AC series motor runs as a AC generator (series) by the K.E of the load. which is returned to the mains as electric energy. mainly in AC traction works, motors are to be braked regeneratively.