

UEE

Unit-1

Electric Drives

Drive: which provides mechanical energy to device or machine. These are of Conventional drive which uses IC-Engine & drives which uses electricity

Types

- ① IC-Engine drive uses diesel
- ② Electric drives

Electric drive: which uses an electrical energy to perform mechanical task. The o/p of this drive is controlled electrically.

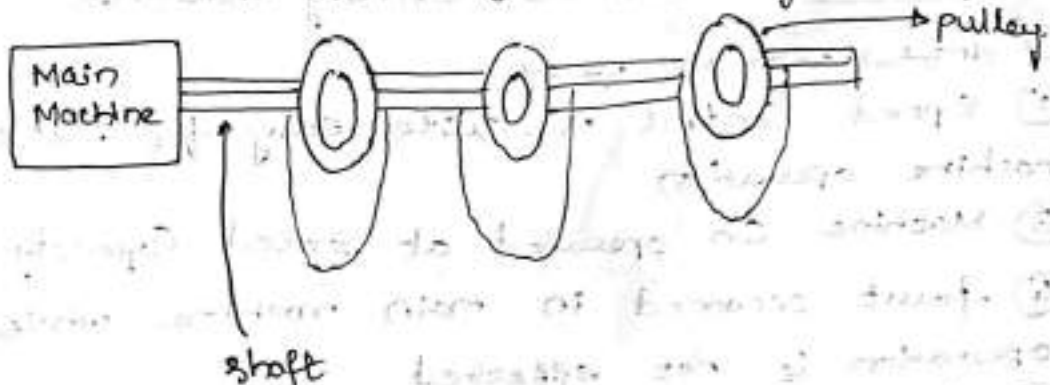
Types of electrical drives

Based on industrial applications it may be divided into 3 stages

- ① Group drive
- ② Individual drive
- ③ Multi-motor drive

① Group drive: It uses single electric motor which drives one or more line shafts supported on bearings.

These drive have very long shaft which drives different machines which are connected by means of pulleys & conveyors.



Advantages

- ① These drives uses single motor to performs different task
- ② These drives uses a single high Capacity machine
- ③ Cost of single drive is less Compared to individual drives.
- ④ By using pulleys different types of speeds can be obtained.

Disadvantages of Group drives

- ① speed Control is complex for individual machine
- ② using pulleys & belts drive train, becomes bulky & less safe to operate
- ③ operation efficiency is low
- ④ Adding an additional machine to existing s/m is limited
- ⑤ fault occurs in main machine then entire unit is stopped.

② Individual drive

Here, single motor can be used to drive each machine.

Example: hand-tool drilling machines

- ① Installation is easy.
- ② Speed Control is quite easy for individual machine operation
- ③ Machine can operated at rated Capacity
- ④ fault occurred in main machine whole operation is not effected
- ⑤ These can be located at convenient

Disadvantages of individual drive

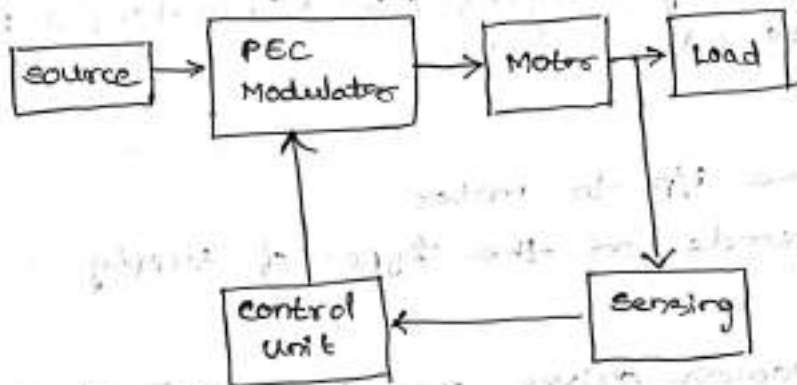
- ① cost of each machine is high
- ② More space is needed to instal
- ③ Multi motor drive s/m

Several individual drives, each serves to operate many machines in production unit.

Examples: Car manufacturing plant

metal cutting machine tools, moulding & pressing machines etc. lifting mechanisms

General electric drive s/m



PEC → power electronic Converter modulator

① Electrical motor

Commonly uses motor are

① DC machines

Separately excited, permanent magnet, shunt, series, Compound type + switched reluctance machines

② AC machines

Induction, Synchronous machines

③ Special machines

BLDC, Stepper motors

② PEC → modulator

Modulates the power flow from source to load.

* Converts electrical energy of source in the form into suitable form to motor.

* performs braking or motoring action.

* PEC modulators are

① Controlled rectifiers (AC to DC Converters)

② Inverters (DC to AC)

③ AC Voltage Controller (AC to AC)

④ DC choppers (DC to DC Converters)

⑤ frequency changers (cycloconverters or PWM Inverters)

③ Sources

* these are i/p to motor

* i/p depends on the type of supply

Capacity

* Low power drives requires single phase AC supply

* Medium power drives uses 3-phase AC supply

* High rating motors which uses 3.3 kV or 6.6 kV or 11 kV

④ Sensing unit

(a) speed sensing

(b) torque sensing

(c) position sensing

(d) Temperature sensing

(e) V & I sensing

⑥ Control unit

which matches the motor i/p with o/p requirement. This modifies the i/ps like V, I, torque, speed, position using sensors

Ratings & choice of electric drives & factors

For successful operation & better efficiency proper selection of driving motor is needed. While selecting a motor the following factors is considered.

① Nature of supply

Electric supply available may be 3 phase or single phase AC or DC. In case 3 phase AC induction motors of squirrel cage is chosen for smaller rating & lower ratings slip ring type induction motor is used.

For better torque & speed controlling DC motors are preferred in place of AC motors.

② Types of Drives

Depending upon the industrial applications these are classified as

- Group drive → one motor drives all machines
- individual drive → each drive motor drives individual machine
- multi-motor drive → these are mainly used in automation process. Here several individual drives, each of which, results to operate many machines in production unit.

③ Nature of load : These are of either active load or passive load which results active & passive torques.

active torques : these are due to gravitational force Ex: hoists, lifts, elevators etc

passive torques : these are due to friction, cutting & deformation of inelastic bodies.

④ sizing of motor

(i) Continuous rating

(ii) Intermittent or variable load rating

(iii) overload capacity (iv) pull out torque

⑤ Mechanical Considerations

(i) Type of enclosures

(ii) Types of bearings

(iii) Types of transmission

(iv) Noise level

(v) Heating & cooling time constant

⑥ Appearance

⑦ Cost Consideration

(a) Capital or initial cost

(b) Running or operating cost

starting & Running characteristics

starting characteristics

It indicates whether the starting torque developed by motor is sufficient to start & accelerate the motor. The torque for accelerating depends on load torque. The following torque requirements are

- ① load requires very small accelerating torque when compared to full load torque
- ② load requiring the torque which may increase with speed & it may be proportional to square of speed in case of fan.

- ③ In case of lifts load torque is constant at all speeds.
- ④ other motors have to start & accelerate full load torque. due to heavy moving parts as in case of rolling mills.

For DC-motors

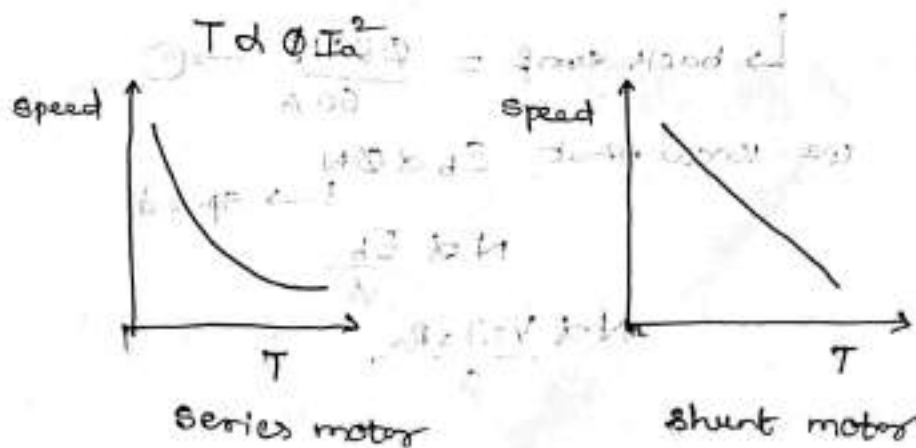
Torque of dc motor $T \propto \Phi I_a$ but torque is independent of speed. For initial a high starting ^{torque} ~~is~~ requires more armature current

In case of dc shunt motor, flux remains constant as field is connected directly across the constant voltage. Armature current is controlled by connecting a starting resistance in series with armature.

In case of dc series motor, field winding is connected in series with armature, as a result current in field winding & armature is same.

flux variation depends on saturation of current.

before saturation point flux is directly proportional to current & after saturation point flux is ~~proportional to~~ proportional to square of current



For AC motors

Torque

An case of 3 phase induction motor

$$T_s = \frac{KV^2 R_L}{(R_1 + R_L)^2 + (X_1 + X_L)^2}$$

R_1, X_1 stator resistance & reactance

R_L, X_L , rotor " & "

→ starting torque becomes maximum if

$$R_L = X_L$$

→ To obtain high starting torque, a resistance is inserted in rotor circuit as start & stop. this also restricts starting current.

Running characteristics

Also called as operating characteristics. these are speed-torque (a)

speed-current (b)

Torque-current (c)

Also losses, efficiency, magnetizing current & power factor at various loads.

Magnetizing current & p.f are considered for AC motor & result of rest of above 3 considered for dc motor.

Running characteristics of dc motor

$$E_b = V - I_a R_a \rightarrow (1)$$

$$\hookrightarrow \text{back emf} = \frac{\phi Z N P}{60 A} \rightarrow (2)$$

we know that $E_b \propto \phi N$

→ speed

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

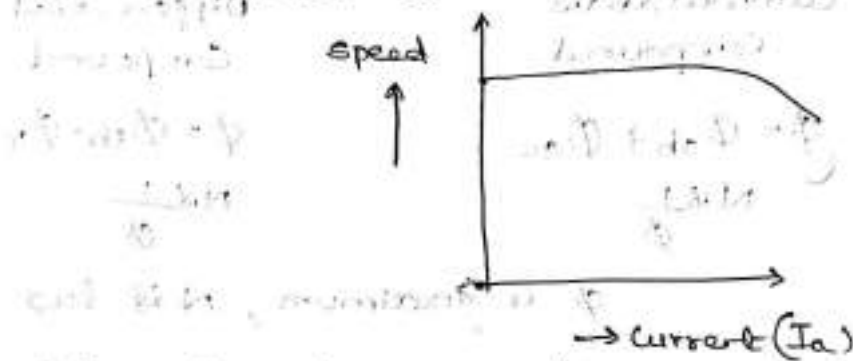
$$N \propto \frac{V - I_a R_a}{\phi}$$

Speed Current characteristics

Case ① DC shunt motor

$$N \propto \frac{V - I_a R_a}{\phi}$$

ϕ is constant, since speed of motor is constant. If V is constant, then speed current characteristics is



so DC motor should be started at light or no load condition only.

Applications

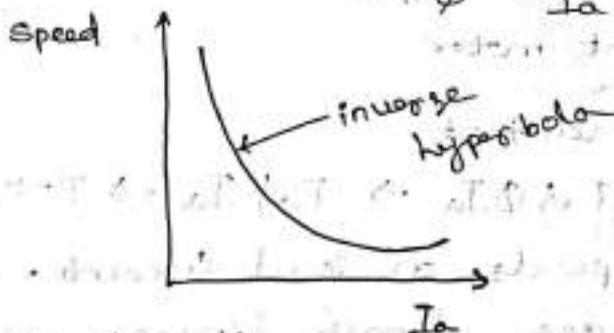
Conveyor belts, Centrifugal pumps, Reciprocating pumps, Grinders, painting processes & cutting machines.

Case ② DC series motor

$$N \propto \frac{E_b}{\phi}, N_a = \frac{V - I_a R_a}{\phi}$$

At constant voltage

$$N \propto \frac{1}{\phi} \propto \frac{1}{I_a} \quad \phi \propto I_a$$



so DC motor of series type started at full load

If started at light ϕ , no load armature current is low & speed is high - this may a break of motor.

Applications

Electric traction

Case 3 DC Compound motor

Cummulative Compound

$$\phi = \phi_{sh} + \phi_{sc}$$

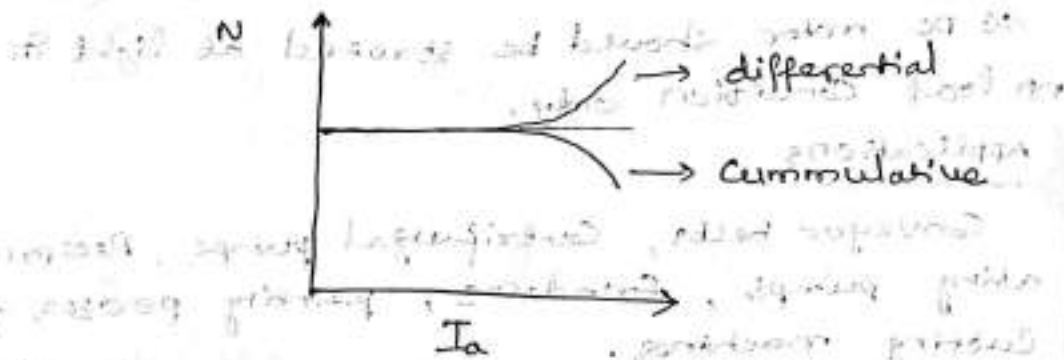
$$N \propto \frac{1}{\phi}$$

Differential Compound

$$\phi = \phi_{sh} - \phi_{sc}$$

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

ϕ is maximum, N is low



Application → Rolling mills

Torque - Current characteristics

Torque in all dc motors is

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

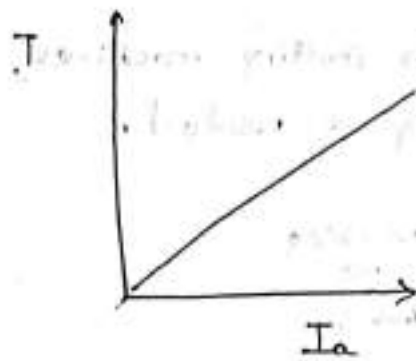
case ① dc shunt motor

ϕ is constant

$$T \propto \phi I_a \Rightarrow T \propto I_a \Rightarrow T = K I_a$$

Torque depends on load current. the characteristics are almost linear

Load

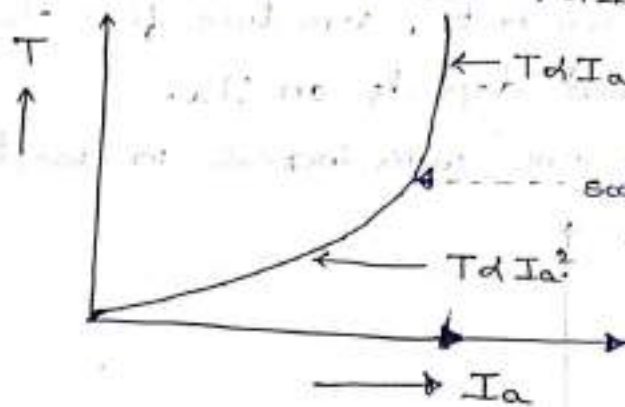


Case ② For DC series motor → initially has high starting torque.

$$T \propto \phi I_a$$

$$\phi \propto I_a$$

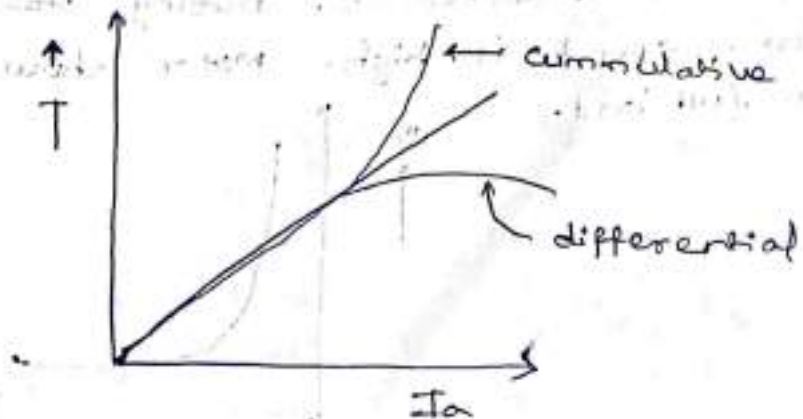
$T \propto I_a^2$ → initial starting torque is high. After the core is saturated then torque $T \propto I_a$



Case iii: for dc compound motor

In Cumulative flux is more, Torque is high $\phi \uparrow, T \uparrow$

In differential Compound $\phi \downarrow$ is low, Torque is less $T \downarrow$



Applications: used in rolling machines, cranes where high starting is needed.

speed-torque characteristics

In dc motors..

$$T \propto \phi I_a$$

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

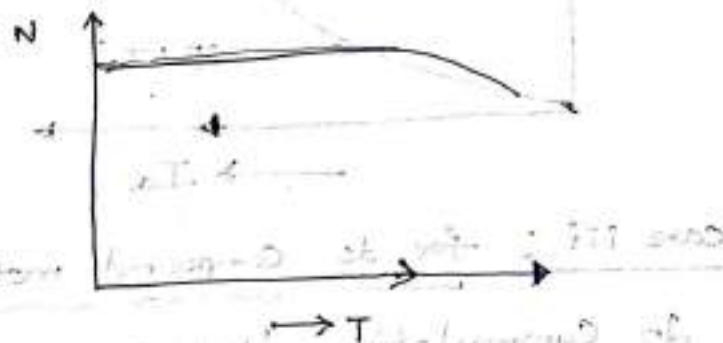
$$N \propto \frac{V - I_a R_a}{\phi}$$

Case 1: For dc shunt motor

if V is constant

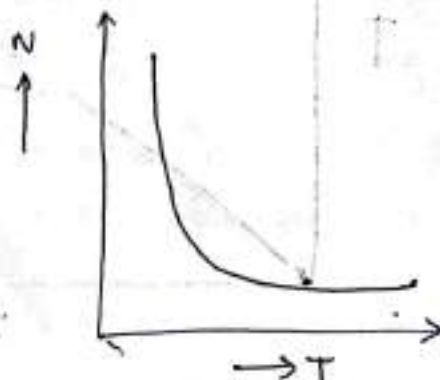
field flux ϕ_f is constant, armature flux also constant and speed depends on I_a .

$N \downarrow$ decreases with increase in armature current



Case 2: For dc series motor

As current increases, Torque also increases, speed will decrease. During starting torque is less, speed is high. Motor should be started on full load.



Case 3: DC- compound motor

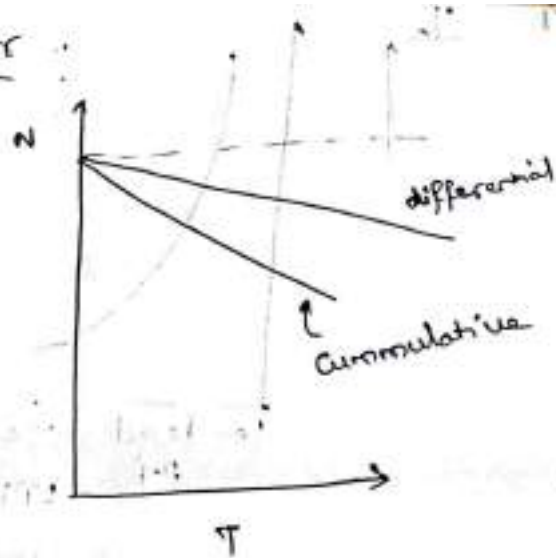
$$T \propto \Phi I_a$$

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

$$E_b = N\Phi$$

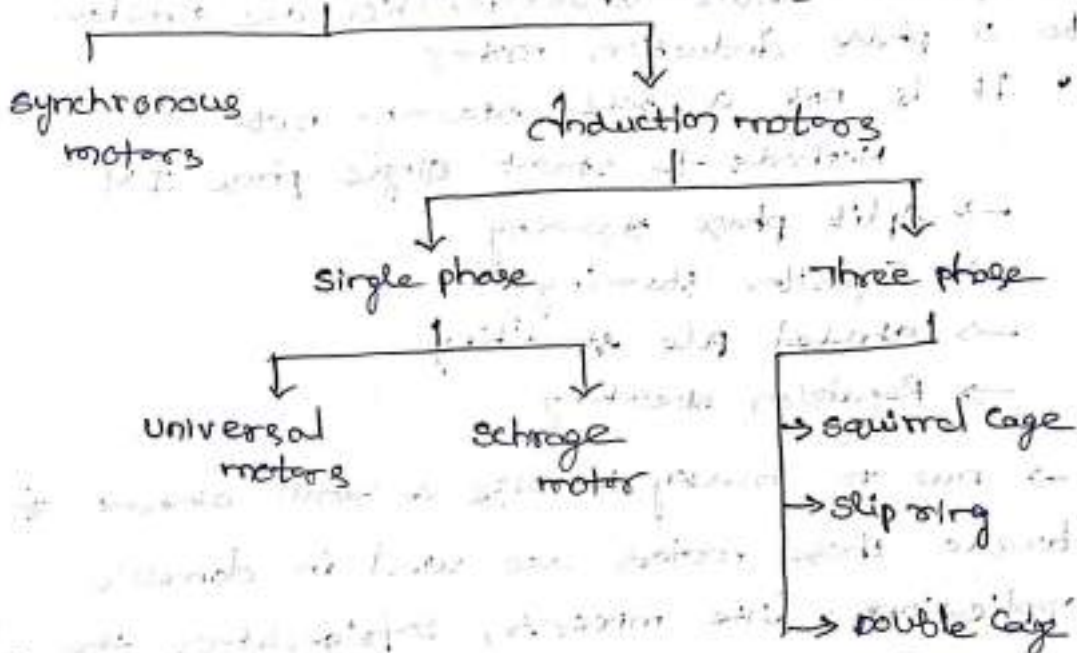
$$N = \frac{E_b}{\Phi}$$

$$E_b = V - I_a R_a$$



Running & operating characteristics of AC motors

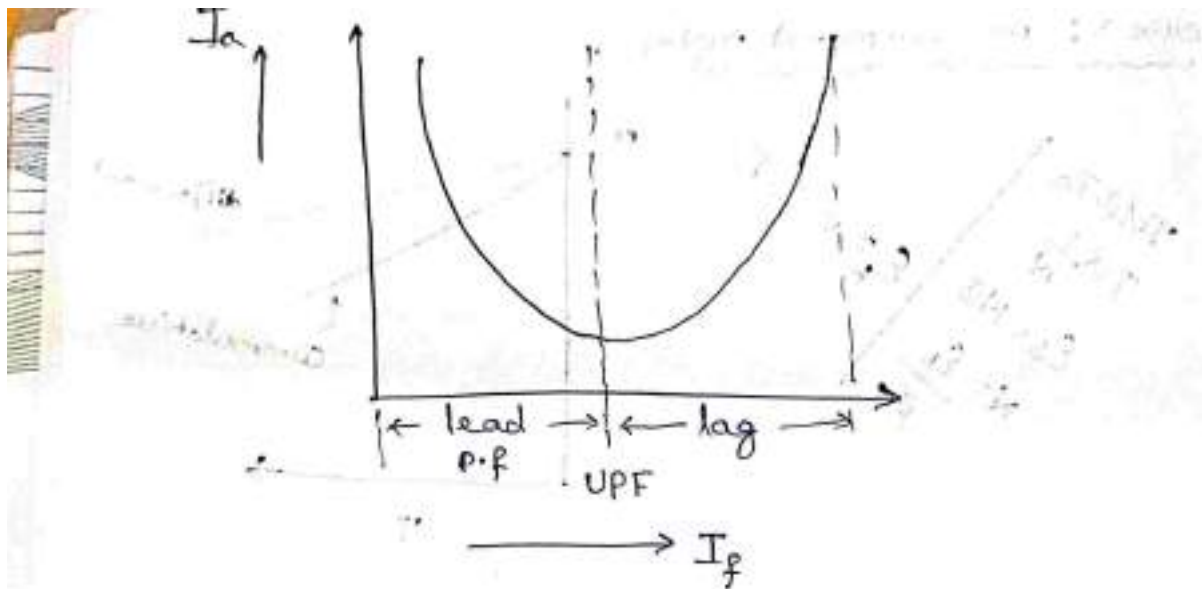
AC motors are classified as:



① Synchronous motor

- * Runs at constant speed called synchronous speed, not self starting
- * Speed does not depend on load
- * power factor can be varied by changing its field current.

Applications is mainly used in rolling mills, motor-generator set, pumps



single phase Induction motor

- * Construction is similar to 3 phase motor
- * Speed-Torque characteristics are similar to 3 phase Induction motor
- * It is not a self starting motor

Methods to start single phase IM

- Split phase starting
 - Capacitor starting
 - Shaded pole starting
 - Repulsion starting
- Due to bulky in size & small amount of torque these motors are used in domestic applications: like mixers, refrigerators etc

3 phase induction motor

① Squirrel Cage Induction motor

$$\text{Starting torque } T_s = \frac{KV^2 R_L}{(R_1 + R_L)^2 + (X_1 + X_L)^2}$$

→ starting torque is low, no chance to add external resistances to improve starting torque.

② Slip ring induction motor

starting torque is improved by adding external resistance.

③ Double Cage induction motor

→ this motor have 2 layers of conductors

(i) inner cage rotor have high inductance which offers high starting torque.

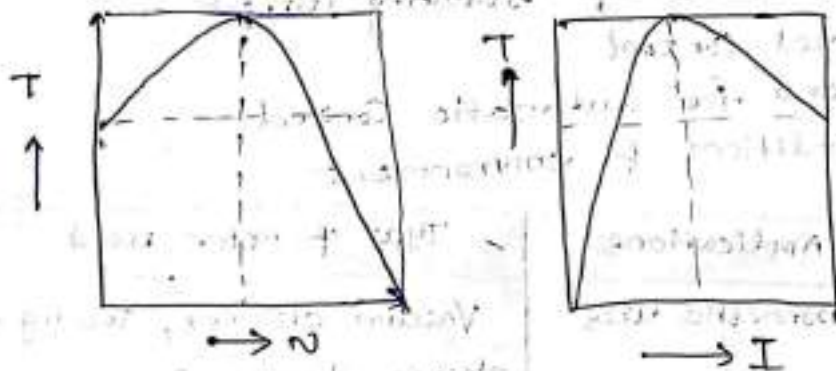
(ii) outer cage rotor have high resistance & low inductance. As motor speeds up stator speed currents will reduce in inner cage rotor. as a result losses in inner cage rotor reduces.

→ P.f is very low at light or no loads

→ P.f improves when motor operates at full load.

Torque-speed characteristics are almost same of 'dc shunt motor'

For slip ring induction motor



Application of Squirrel Cage induction motor
drive pump set, machine tools where constant speed is required.

Repulsion motor

Construction is similar to series motor, here armature itself being short circuited.

characteristics is similar to dc series motor

universal motor

operates on both ac or dc supply

→ It is a series wound motor. Characteristics are similar to dc series motor.

applications

① Sewing machines, table fans, Vacuum cleaners, drill machines.

Particular applications of electric drives

The following are the considerations for a particular application.

- ① starting torque
- ② duty
- ③ limitation of starting current
- ④ speed control
- ⑤ Need for automatic control
- ⑥ Conditions of environment

	Applications	Type of motor used
1	Domestic uses I.e. →	Vacuum cleaners, sewing machines, electric shavers, fans etc. above uses universal motors of series type
2	cranes	DC series or Compound type motors
3	Lifts	AC slip ring induction motors
4	Lathes, grinding machines	DC shunt or squirrel cage IM

Applications	Type of motor used
5 planers	<ul style="list-style-type: none"> → DC shunt & Compound motors for DC supply → for AC supply slip ring induction motor
6 punches, presses, shears	<ul style="list-style-type: none"> → slip ring induction motor & DC cumulative Compound motor
7 Drilling machines	<ul style="list-style-type: none"> → Constant Speed squirrel Cage AC motor & DC shunt motors
8 Blowers & fans	<ul style="list-style-type: none"> → squirrel Cage Induction motor, Synchronous motor
9 Air Compressors	<ul style="list-style-type: none"> → Induction motors squirrel Cage type, synchronous motors for larger unit
10 electric Traction	<ul style="list-style-type: none"> → DC series motors where high acceleration is needed mainly in suburban areas → single phase AC motors
11 pumps	<ul style="list-style-type: none"> → 3 phase slip ring induction motor
12 Refrigeration & air conditioning	<ul style="list-style-type: none"> → 1 phase 230V Capacitor type Induction motor → For turbo compressor synchronous motor is used
13 Belt Conveyors	<ul style="list-style-type: none"> → Double Cage Induction motor
14 Flour mills	<ul style="list-style-type: none"> → enclosed type motors
15 Textile industry	<ul style="list-style-type: none"> → 3 phase AC motor
16 paper industry	<ul style="list-style-type: none"> → squirrel Cage motors

Types of Industrial loads

Industrial loads are classified into 2 types

(I) Active or potential loads

(II) passive loads

(I) Active loads

These loads are due to forces of gravity or tension or any elastic body are called active loads.

Torque associated with these are changes in potential energy. Torque associated in these are either +ve or -ve, whenever

+ve torque when its aiding moment

-ve torque when its opposing moment

* Active torques are hoists, lifts, elevators

(II) passive loads

Torque in passive loads is passive torque

→ these loads are due to friction, cutting & deformation of inelastic bodies

→ They always oppose the direction of drive & change their sign when direction of drive rotation changes.

frictional torque acts opposite to driving torque.

Examples: Rolling mills, Conveyor belts

Beside above loads some other loads are classified based on duty cycle there are

(I) Continuous load (II) Intermittent load

(III)

Types of industrial loads

(i) Continuous load

Load is continuous in nature

Ex: pumps, fans requires constant i/p power. loads operated unlimited time of duration without temperature rise.

(ii) Intermittent load

some times the load is on for short duration & shutt off for longer duration.

→ Example: Mixer grinder in kitchen

→ In this electrical loss is more due to frequent ON/OFF

(iii) Variable loads

→ These loads continuously varying with time.

→ some times the load consumption is high & sometimes the load consumption is low. It is based on time, seasonal

→ Example lighting s/m/s daytime off night off, electrical fans

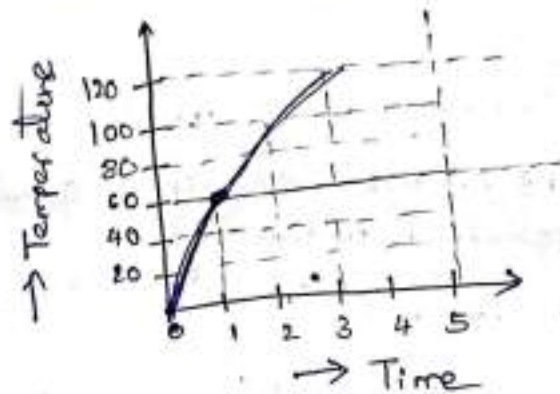
Above all 3 classifications is based on temperature rise which again depends on duty cycle of load.

The relation b/w temperature rise & time is given by when machine is loaded

$$\theta = \theta_m (1 - e^{-t/\tau})$$

↳ θ_m : maxi: temperature rise
↳ temp: rise in centigrade

T = heating time Constant
 t = time in seconds



During cooling period motor speed reduces
 temperature equation will be

$$\theta = \theta_m e^{-t/T}$$

→ According to rating of motor

① Rating of motor for Continuous load

→ If motor has constant load torque T & it is running at velocity ω rad/s, power rating is

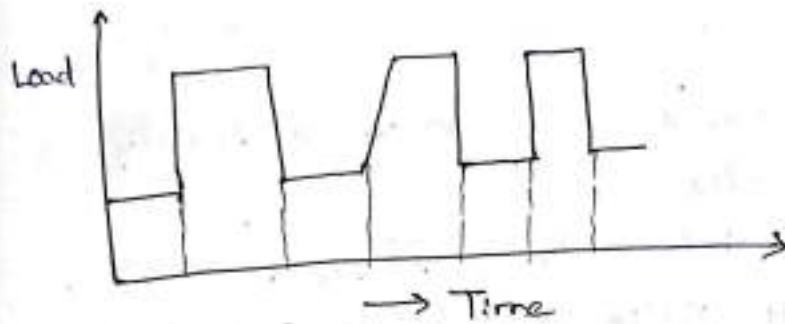
$$P = \frac{T \cdot \omega}{1000} \text{ Kw} \quad \text{or} \quad P = \frac{T \cdot \omega}{746} \text{ hp} \quad 1 \text{ Kw} = 746$$

② Rating of motor for intermittent loads

Motor is loaded for short-time & off for long time.

→ the motor is switched on before ambient temperature such loads are referred as fluctuating loads. Heating is proportional to square of current or load.

Example for this loads is elevators

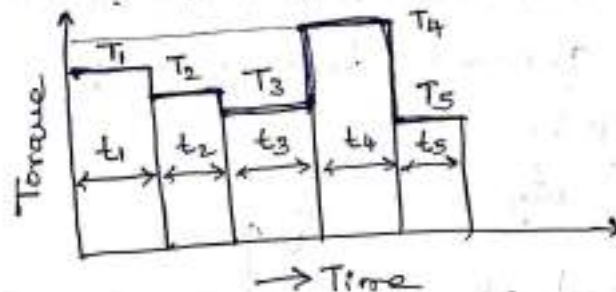


fluctuating loads (elevators)

Rating of motor for variable load

Rating can be determined from load torque vs time. This is called equivalent torque method. In this flux remains constant during load variations.

$$T_{eq} = \sqrt{\frac{\sum_{i=1}^n T_i^2 t_i}{\sum_{i=1}^n t_i}}$$



Advantages & disadvantages of electrical drives

① Advantages of drives

- * provides extensive range of speed, power & torque
- * they do not contaminate the atmosphere
- * synchronous & induction drives provides stable speed where as dc motor provides variable speeds.
- * they have flexible manage characteristics due to utilization of electric braking.

Disadvantages

- drive cannot be used where supply is not available
- power break down stops entire s/m
- primary price of s/m is expensive
- dynamic response of drive is poor
- noise is generated during operation.

Classification of drives based on duty

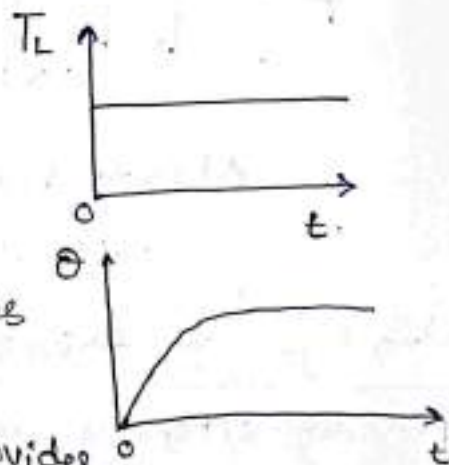
- (1) Continuous duty (2) short time duty
- (3) Intermittent periodic duty (4) intermittent periodic duty with starting (5) intermittent periodic duty with starting & braking
- (6) Continuous duty with intermittent periodic loading (7) Continuous duty with starting & braking (8) Continuous duty with periodic speed changes.

(1) Continuous duty

→ Motor operated at constant load torque

for longer duration as motor temperature reaches steady state value.

→ This characteristic provides constant motor loss.



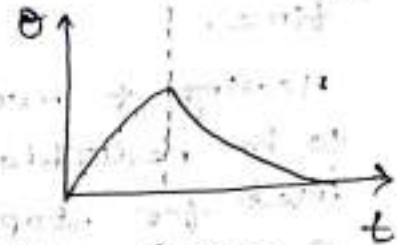
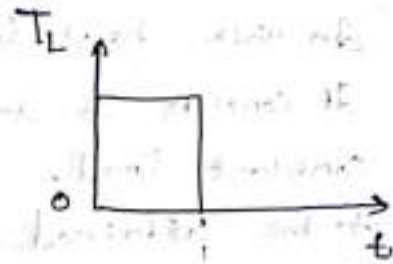
Application: paper mill drives, Compressors, Centrifugal pumps

② short time delay

→ Machine to operate short time & allow the motor to cool off to ambient temperature before to operate next.

Example: crane drives, drives

for house hold appliances, valve drives

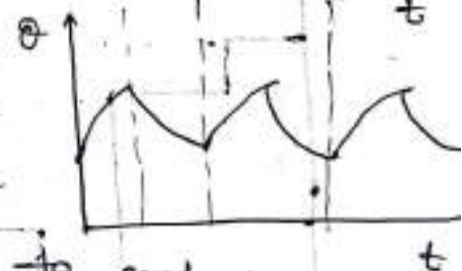
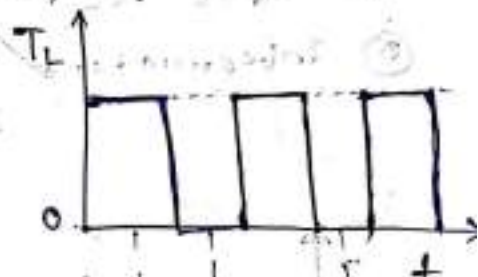


③ Intermittent periodic duty

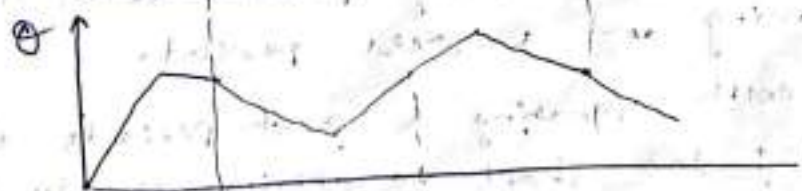
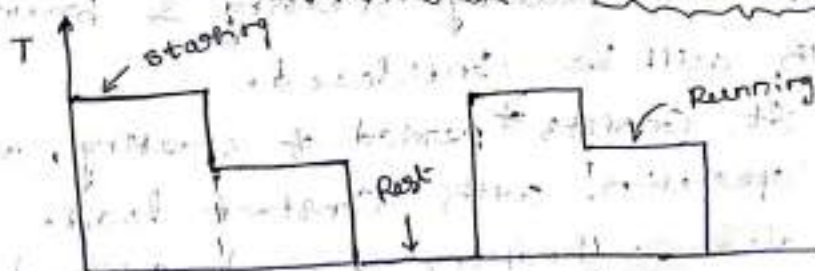
→ It consists of periodic duty cycles, each consisting of a period of running at constant load.

Neither a running period is sufficient to raise the temperature to state state nor rest period is long to cool off

Examples: Pressing, cutting & drilling machines



④ Intermittent period duty with starting

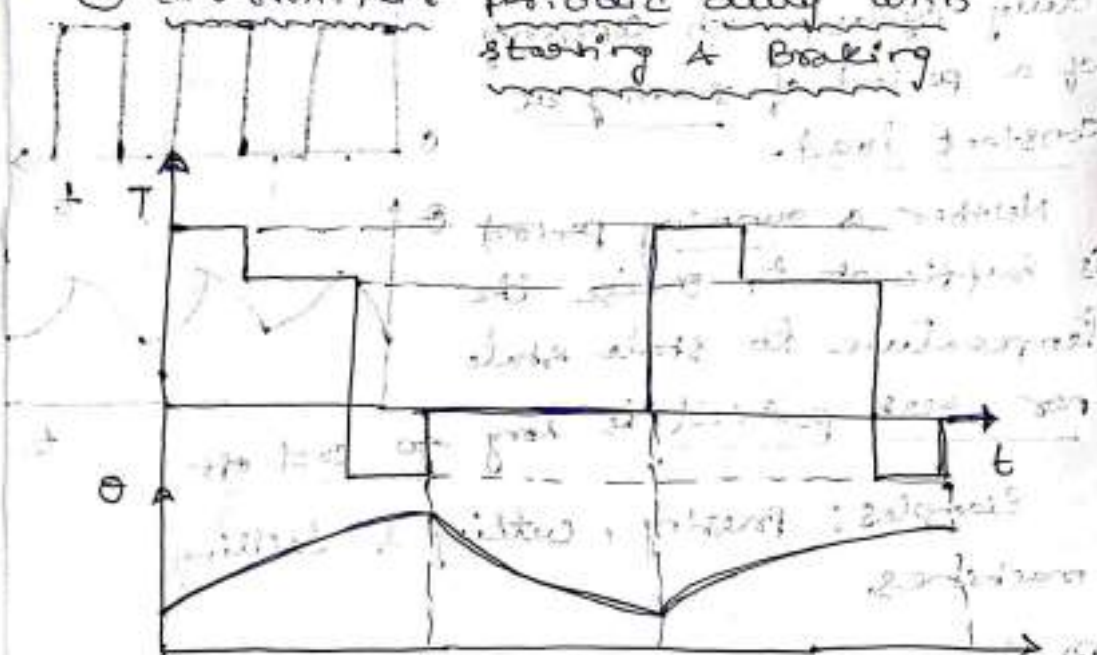


In this, heat losses considered during starting.
 It consists of starting period & operating at a constant load. Here steady state temperatures are to be attained within a short period of time.

Heating of machine during braking is considered to be negligible. since mechanical brakes are used for stopping of motor with its own friction.

Example: metal cutting, drilling tool drives for lifts etc.

⑤ Intermittent periodic duty with starting & braking



- In this during starting & braking both will be considered.
- It consists of period of starting, a period of operation with constant load.
- also a braking period with electrical braking and a rest period.
- with operating & rest periods are being too short to attain steady state temp.

Examples: Billet mill drive,
 trolly buggy drives, manipulator drive,
 mine hoists, drives for electric suburban trains

⑥ Continuous Duty with Intermittent periodic loading

→ It consists of periodic duty cycles, each period consists of constant load at running & a period of running at no load

→ Again the load period & no load period are being too short for respective steady state temperatures.

→ simply says some period running at constant load is followed by a period of running at no load.

Examples: Pressing, cutting, shearing etc.

⑦ Continuous duty with starting & braking

→ It consists of periodic duty cycle, each period having a starting, a period of running at constant load & a period of electrical braking.

→ there is no period of rest.

Example: Blooming mill

⑧ Continuous duty with periodic speed changes

→ It consists of periodic duty cycle, each having a period of running at one load & speed & another period running at different load & speed.

→ Running or operating periods are too short
 → No rest period.

Unit - ②

Heating & WeldingHeating → Introduction

In many domestic as well as residential applications heat can be used for cooking & used as a room heaters. In industrial applications heating is widely used for melting metals, welding metals etc. All these happens & more easily to get heat by the invention of electricity.

Advantages of electric heating

- ① Economical: Electric furnaces are cheaper in initial ^{cost}, as well as maintenance cost.
→ Getting heating from electricity more economical as it is available cheap & produced on large scale.
- ② Cleanliness: Dust & Ashes are completely absent during electric heating.
- ③ Absence of fume gases: No fume gases is produced & more safe to environment.
- ④ Ease of Control: Heat can be controlled by manually or by automatically. Desired temperature can be getting more accurately than other heating s/m's.
- ⑤ Automatic protection: Automatic protection against over currents as well as over heating through suitable switch gears.

⑥ High efficiency of utilization: overall efficiency is high compared to other heating methods. Source can be brought to point where heat is required.
 → 75% to 100% of heat produced by electric heating can be successfully utilised.

⑦ Better working conditions: Radiating losses are less & no noise is produced during heating s/m.

⑧ Safety: Electric heating is quite safe & responds quickly

Modes of heat transfer

Heat transfer its energy from one region to another region will take in 3 modes

① Conduction (ii) Convection (iii) Radiation

In this transfer of heat, one molecule gets heated & transfers the heat to adjacent molecule & so on. Here is transfer from one substance to another substance in contact.

Rate of heat conduction depends on temperature gradient & is expressed in $\text{MJ/hr/m}^2/\text{m}$ or $\text{W/cm}^2/\text{cm}$

let t = plate thickness

x = cross sectional area of 2 parallel plates

T_1 & T_2 are temperature of 2 parallel plates

T = absolute quantity of temperature

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

K = coefficient of thermal conductivity

(II) Convection: Transfer of heat within a fluid by mixing one position of fluid with another. During this liquid or gases to heat up, expand & decrease in density. $H = \alpha (T_1 - T_2)^b \text{ w/m}^2$
 $\xrightarrow{\hspace{2cm}}$ Heat dissipation

(III) Radiation: Transfer of heat through space or matter by means of other than Conduction or Convection.

Heat transfer the heat reaches the substance to be heated from the source of heat without heating the medium.

Heat radiation is given by Stefan's law

$$\text{Heat dissipation } H = 5.72 \times 10^4 \text{ Ke} \left[\left(\frac{T_1}{1000} \right)^4 - \left(\frac{T_2}{1000} \right)^4 \right] \text{ w/m}^2$$

T_1 is temperature of heat source

T_2 is " " substance to be heated.

K = Radiant efficiency $K=1$ for single element

$K = 0.5 \pm 0.8$ more no: of elements placed side by side

e = emissivity $e=1$ for black body, $e=0.9$ for resistive heating element

Design of Heating element

circular cross section wires are used as heating elements. If wattage is known then size & length of wire is obtained.

Assume the heat transfer is through radiation

let P be the wattage of heat element

V be the operating voltage

T_1 be temperature of radiating surface

T_2 be temperature of absorbing surface. Let to find the length & size of heating element.

$$P = \frac{V^2}{R} \quad \text{where } R = \frac{\rho l}{a} \quad r = \frac{d}{2}$$

$$P = \frac{V^2 \times a}{\rho l}$$

Surface area of circular wire $S = \pi d \times l =$

Area of circular wire $a = \pi r^2$ $S = 2\pi r l$

$$P = \frac{V^2 \times \pi \times r^2}{\rho l}$$

Now total heat generated = total heat liberated from Stefan's law heat dissipation

$$H = 5.72 \times 10^{-8} \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right] \text{ W/m}^2$$

$$P = H \times 2\pi r \times l$$

(size) Sizing of Heating element $r = \frac{P}{H \times 2\pi l}$

length of Heating element $l = \frac{P}{H \times 2\pi r}$

Requirements of heating element

- High specific resistance: short length of wire will requires particular resistance
- High melting point: It should have high melting point so that temperatures are obtained
- free from oxidation: Higher temperatures generally increases oxidation Can reduce the

life heating element. so it should not oxidize at high temperature

Lower Temperature Coefficient:

Material should have low temperature coefficient so that its resistance should not change with during operation of temperature changes.

Methods of electric heating

① Power frequency Method:

Direct resistance heating

Indirect " " "

Direct arc heating

Indirect arc heating

② High frequency Heating

Induction Heating

di-electric Heating

Resistance Heating

Direct Resistance Heating

Current is passed through the body to be heated. Due to current flow ohmic losses results in heating the body. This method is used in resistance welding.

Salt bath furnace Consists of 2 electrodes immersed in molten salt having fusing temperature is 1000°C & can be heated upto 1500°C by the passage of current through electrodes.

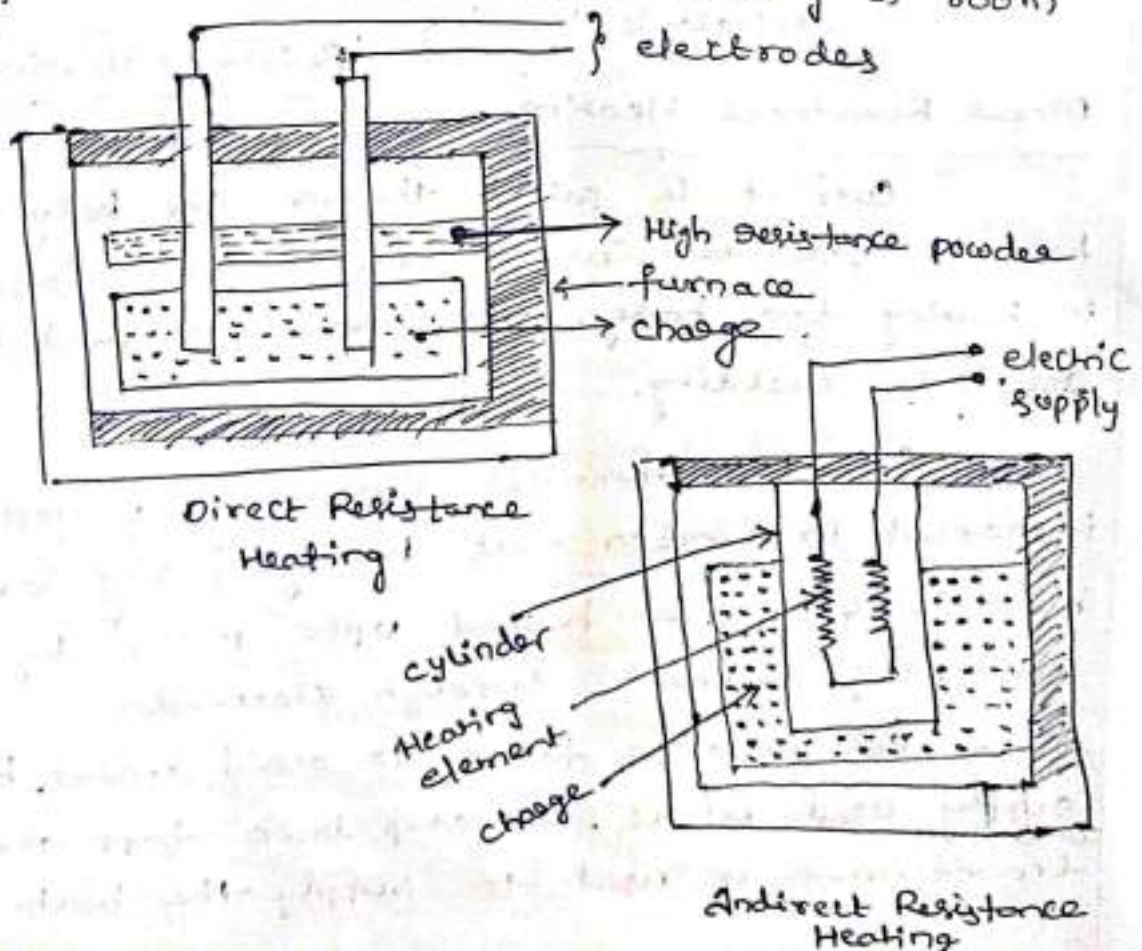
Case must be taken to avoid metal heating. supply used is ac. A step down tapping transformer is used to supply the bath.

The primary voltage is ^{set} off 20V with currents from few amperes to above 3000 amp depending upon charge & furnace to be heated. With increase in temperature of bath its resistance decreases. By adjusting the taps we can adjust the voltage to get constant i/p power.

Salt bath furnaces are mainly used in hardening steel tools & prevents oxidation during hardening process.

Indirect Resistance Heating

Current is passed through a high resistance wire known as heating elements. Heating is produced due to current flow produces ohmic losses. This heat is transmitted through radiation or convection body to be heated. This method mainly in room heaters.



Arc heating: The arc is created between 2 electrodes develops high temperature nearly 3000°C - 3500°C depending on electrode material. The electric arc is used in following different ways.

- By creating arc b/w charge & electrode, heat liberated is directly taken by charge.
- By striking arc b/w electrodes, heat is transferred to charge by radiation.
- By striking an arc b/w an electrode & 2 metal pieces to be joined as in arc welding.

Induction Heating

These are of 2 types

(i) Direct induction Heating: By electromagnetic action a heat is liberated in the body of material. This electromagnetic material action is due to currents. This currents flows in the body to be heated & thus raises the temperature.

In induction furnaces heat is used to melt charge where as eddy current heaters used for heating the metals.

(ii) Indirect Induction Heating

In this method eddy currents are induced in heating element by electro-magnetic action.

Heat transfer to the body heated through radiation & convection: Induction ovens used for heat treatment of metals.

Di-electric heating: Electric heating use of di-electric losses is made to heat non metallic materials. Non metallic material to be heated placed b/w 2 metal electrodes is subjected to very high voltage & frequency develops di-electric losses.

Problems: Power = 20 kW
Voltage = 220V, heating element is circular nichrome. If wire temperature not exceeded 1127°C temperature of charge is 427°C. Calculate size & length of wire. Assume $\epsilon = 0.9$ & radiation efficiency $K = 0.6$. What would be temperature of wire when charge is cad. cold.

from stefan's heat dissipation formula

$$H = 5.72 \times K \times \epsilon \left[\left(\frac{T_1}{1000} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right]$$

$$K = 0.6, \epsilon = 0.9$$

$$\text{temperature of wire } T_1 = T_1 + 273^\circ\text{C} = 1127 + 273$$

$$T_1 = 1400^\circ\text{C}$$

$$\text{temperature of charge } T_2 = T_2 + 273^\circ\text{C} = 427 + 273$$

$$T_2 = 700^\circ\text{C}$$

$$H = 5.72 \times 0.6 \times 0.9 \left[\left(\frac{1400}{100} \right)^4 - \left(\frac{700}{100} \right)^4 \right]$$

$$= 5.72 \times 0.6 \times 0.9 (38416 - 2401) = 111243 \text{ W/m}^2$$

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{220 \times 220}{20 \times 1000} = \frac{48400}{200000} = 2.42 \Omega$$

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

$$\text{area of circle } a = \pi r^2$$

$$2.42 = \frac{\rho l}{\pi r^2}$$

$$\frac{\rho l}{r^2} = 2.42 \times \pi$$

$$1.09 \times 10^{-6} \frac{l}{r^2} = 2.42 \times \pi$$

we know that specific resistance

$$\rho = 1.09 \times 10^{-6} \Omega \cdot m$$

$$\text{Power } P = H \times 2\pi r \times l$$

$$20 \times 1000 = 111243 \times 2\pi r l$$

$$r \times l = \frac{20 \times 1000}{111243 \times 2\pi} = \frac{20,000}{698,960} = 0.02862 \quad \rightarrow \textcircled{1}$$

$$\frac{l}{r^2} = \frac{2.42 \times \pi}{1.09 \times 10^{-6}} = 6.97137 \times 10^{-6} \quad \rightarrow \textcircled{2}$$

Divide $\textcircled{1}$ by $\textcircled{2}$ we get

$$\frac{r \times l}{\frac{l}{r^2}} = \frac{r \times l \times r^2}{l} = \frac{0.02862}{6.97137 \times 10^{-6}} = \frac{0.02862}{6.97137 \times 10^{-6}}$$

$$r^3 = 4105.403583 = 4.1064 \times 10^9$$

$$r = 1.601 \times 10^{-3} \text{ m} = 1.601 \text{ mm}$$

Electric Arc furnace

These are of 2 types (1) Direct arc furnace & (2) Indirect arc furnace

(1) Direct Arc furnace

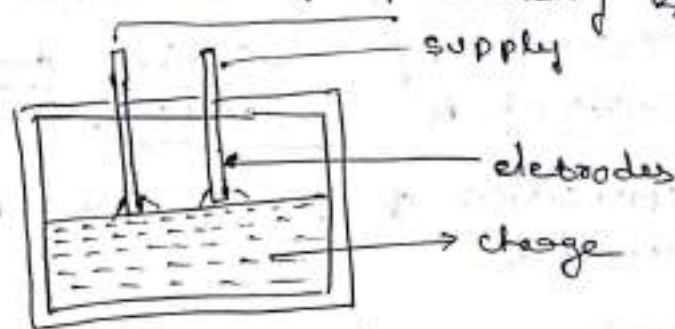
In this case arc is struck b/w the electrodes & charge. Supply voltage for arc furnace is usually 230V 1-phase or 400V 3-phase. Electrodes are generally made of either graphite or Carbon. As the distance b/w the electrodes is very small an arc is created the temperature of arc reaches to 3000-3500°C. The heat produced by the flow of current through the charge offers very low resistance.

In case of large Capacity furnace, 3 phase supply is employed & electrodes are spaced at the corners forms a equilateral triangle.

Arc can be controlled either by controlling the variable voltage or by adjusting the distance b/w the electrodes, as a result resistance changes.

* Current flows in charge, starts stirring action due to electromagnetic force. This results uniform heating of charge.

* These furnaces are costlier & is mainly used in refining process of producing steel.



Direct Arc furnace.

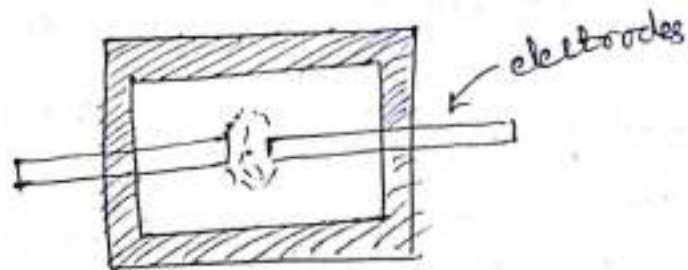
Indirect Arc furnace

In this arc is formed b/w electrodes & ^{later} charge is melted. Simply first arc is made struck b/w the electrodes. Here temperature generated is less than direct arc furnace.

Here current is not flow directly to charge as a result no stirring action in charge. These furnaces are ~~difficult~~ usually in cylindrical shape. The electrodes are projected at the sides of furnace. These furnaces are usually utilizes single phase supply.

Due to absence of stirring action, mixing of charge is done by using electric motor. The phenomenon stirring of charge is called rocking action.

During starting rocking action is carried out at an angle is 15° to 20° & melting of charge starts then angle changes to 200° .



Indirect arc furnace

Heat is transferred by radiation, during rocking action heat transferred is conduction.

→ The main application of this furnace is melting of non ferrous materials.

Induction heating

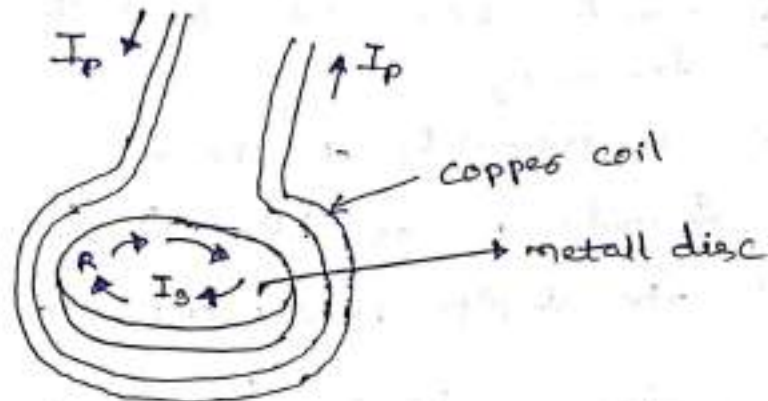
→ its principle is electromagnetic induction similar to transformer.

→ It consists of metallic disc surrounded by the copper coil, in which an a.c current is flowing.

→ We find that a eddy current I_e is used to circulate around the outer surface of the disc. The following are the characteristics of induction heating

- (i) Current in the metal disc surface starts heating.
- (ii) Current flow is axially to the surface of the metal.
- (iii) The heat is generated within the metal without any physical contact b/w coil & metal.
- (iv) The magnetic field can penetrate any non metallic substances placed b/w heat coil & material being heated.
- (v) Extreme temperatures are obtained which can't be obtained from any other methods.

(vi) As current flows continuously in disc, surface of disc attains extreme temperatures.



Principle of induction heating diagram.

Heat in the disc can be increased by

- (i) Increasing the current flow in coil
- (ii) Increasing the no. of turns in coil
- (iii) increasing the supply frequency
- (iv) Reduce the spacing b/w coil & work
- (v) Increase the permeability of magnetic material in the disc.

In case the charge to be heated is a non-magnetic material, heat generated is due to eddy current losses. whereas the charge to be heated is a magnetic material there will be hysteresis loss in addition.

Hysteresis loss is proportional to frequency. & eddy current losses is proportional to square of frequency. At higher frequency, heating due to hysteresis is very small ~~compared to~~ compared to eddy currents.

Depth penetration of induced current into disc

$$d = \frac{1}{2\pi} \sqrt{\frac{\rho \times 10^9}{\mu f}} \text{ cm}$$

ρ = specific resistance of molten charge in Ω

f = frequency

μ = permeability of charge.

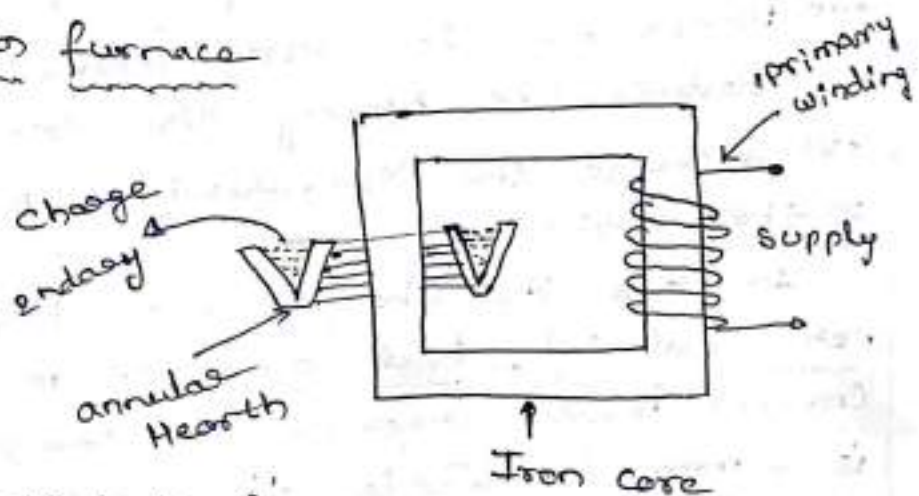
above formula is at high frequency

at low frequency depth penetration $d \propto \frac{1}{\sqrt{f}}$

Types of Induction furnaces

- (i) core type & low frequency furnace
- (ii) coreless type & high frequency furnace

Core type induction furnace



→ In above charge to be forms a endbay circuit & is magnetically coupled with primary winding using iron core.

→ charge in endbay is melted due to high currents
 → To start the furnace some metal or molten metal is poured in Annular hearth.

- This furnace is operating at low frequency
- If operates at high at high frequency magnetic coupling is poor & also operates at low p.f.
- operating frequency of this furnace is about 10Hz only.
- A frequency changer set is required to obtain variable frequency.

② If current density exceeds $5A/mm^2$ formation of bubbles takes place in molten charge & it should be avoided the effect of bubbles in charge is called pinch effect. This pinching effect causes a complete interruption of secondary circuit.

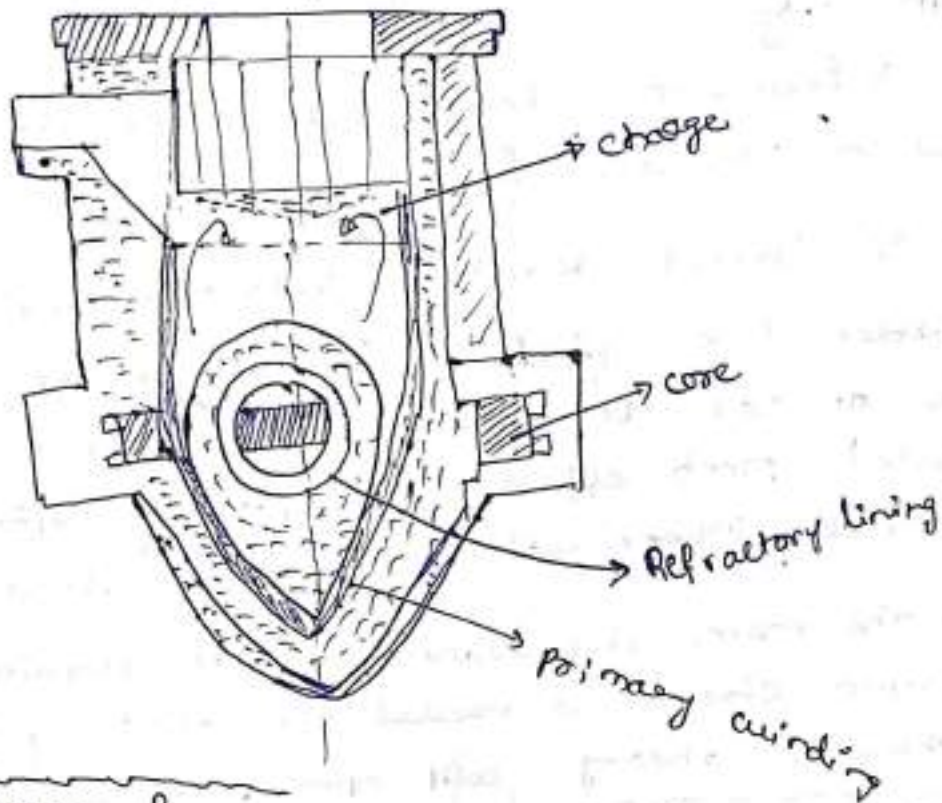
→ The main disadvantage is it requires a necessary molten charge is needed to start up the furnace. otherwise secondary will open & no current will circulate

Ajax Wyatt furnace

- It is an vertically type of core furnace & is an improved version of core type furnace.
- The tendency of currents to interrupt secondary circuit due to pinch effect is avoided due to weight of charge in main body.
- Molten metal is circulated round the Vee portion by convection currents & by electromagnetic forces b/w the currents in 2 halves of Vee.
- As V channels are very small in narrow size, a small quantity of charge is sufficient to close the secondary circuit.

→ Discontinuity of secondary circuit is very less & also improves pf since both primary & secondary are on same central core.

→ It is not suitable to intermittent work.

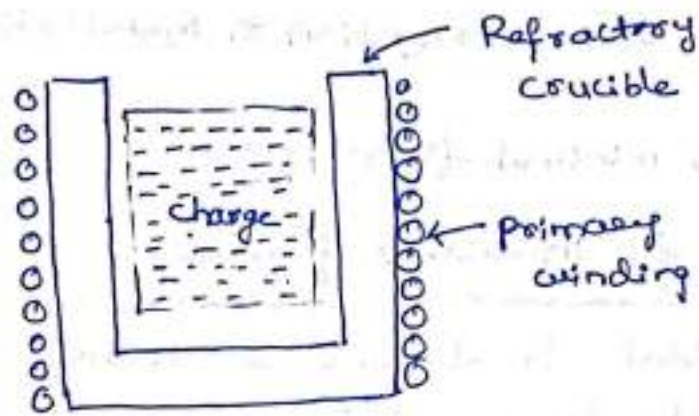


coreless induction furnace

Due to short circuited secondary formed by charge, due to pinch effect, necessity of magnetic yoke core furnace becomes less popular.

The eddy currents developed in any magnetic circuit are given as eddy current $\propto B^2 f^2$
where B = magnetic flux density

In this there is no core & thus flux density is less. Due to absence of core, to compensate flux density primary should be operated at very high frequency. (500 Hz to 1000 Hz)



coreless induction furnace

→ The primary winding is provided around the crucible with a refractory lining containing the charge in it.

→ The flux is produced by primary winding set up eddy currents in the charge will make to melting point & also set up electro-magnetic forces which produces a stirring action.

→ P.f of furnace is very low, to improve p.f static capacitors are used in parallel with supply.

→ Due to skin effect & operated at high frequency primary coils becomes heated up, to avoid these hollow type copper coils are used & is circulated with cooling water.

Advantages of coreless induction furnace

- (i) Less time to melt the charge
- (ii) Precise control of power
- (iii) uniform heating of charge
- (iv) furnace can be in any shape (crucible)
- (v) operation is free from dust, smoke & fumes
- (vi) Automatic stirring action

vii) operation cost, erection or installation cost is low

(viii) occupies minimal floor area

Applications of Induction furnaces

- used in heat treatment of metals
- Refining the brass, zinc metals
- Also refines the non ferrous materials
- Also used in steel production
- production of carbon is obtained from ferrous alloys.
- Also used in industrial activities like soldering, brazing, hardening & annealing etc.

Di-electric Heating

When non metallic parts such as wood plastic bones are subjected to an AC supply di-electric losses occur.

- When a material is placed b/w 2 metallic electrodes supplied with high frequency supply of range 20KV.
- For operating point of view these 20KV is reduced to 600V & 3KV.
- Necessary high frequency is obtained from valve oscillator. Overall efficiency is about 50%.
- Current drawn by capacitor, when AC supply voltage is applied across 2 plates, active component of current, heat is produced in di-electric medium.
- The heat in di-electric material is known as di-electric loss. This loss is proportional to frequency of AC supply.

→ In insulators & non conducting materials amount of heat produced is directly proportional to dielectric heating. It is calculated as

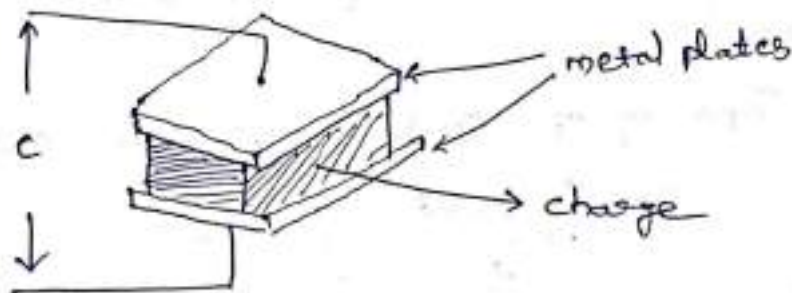
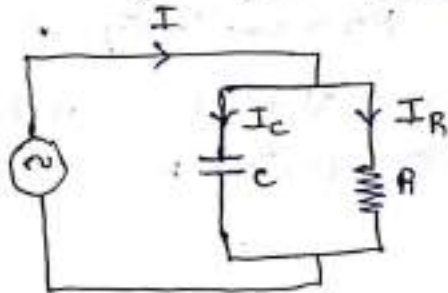
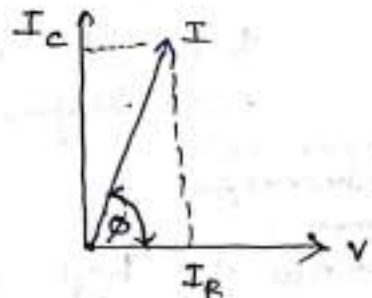


fig:- charge b/w metal parallel plates



Ⓐ Equivalent circuit



Ⓑ phasor diagram

→ The material to be heated may be represented as Capacitance & imperfect dielectric material.

→ from phasor diagram V is supply voltage, f is supply frequency in Hz, C is Capacitance in farads, ϕ is angle b/w I_c & V .

$\cos\phi$ = P.f of load & charge

Current through Capacitor $I_c = \frac{V}{X_c} = \frac{V}{\frac{1}{\omega C}} = \frac{V}{\frac{1}{2\pi f C}}$

$I_c = 2\pi f C \times V = I$

Power produced $P = VI \cos\phi$

$P = V \times 2\pi f C \times V \times \cos\phi$ wat

$P = 2\pi V^2 f C$ watts

→ Di-electric heating depends on value of frequency & voltage. By varying any one of 2 quantities, di-electric heating can be varied.

→ There is a limit on high frequency circuit due to cost factor

Capacity of Condenser can be calculated as

$$C = \frac{\epsilon_r \epsilon_0 \cdot A}{t} \text{ farads}$$

ϵ_r → relative permeability

ϵ_0 → absolute permeability of air = 8.854×10^{-12} F/m

t = thickness of di-electric material in mtrs

A = surface of plates in m^2

Advantages

→ due to high frequency ac supply, heat liberated in charge material is highly uniform

→ Materials heated by this process are non-conducting, as a result other methods of heat cannot be conducted to inside

Applications of di-electric heating

→ preheating of plastic preforms:

Raw materials in the form of tablets or biscuits commonly called plastic preforms. In this before putting moulds or hot moulds, it is to be heated uniformly. A whole mass is converted into fluid. Otherwise surface of fluid is cured & inner part is not cured which results unequal hardening of plastics.

Di-electric heating is only way to preheating of plastic.

→ Gluing of woods:

Main difficulty in using animal glues is taking long time to cure & that parts are joined are to be kept under mechanical pressure upto 24 hours. This is possible by die-electric heating to provide better adhesion.

→ Baking of foundary core:

In foundaries Resin type thermo setting binders are employed as they set, are brought to polymerizing temperature.

polymerizing ^{means} removing of water molecules in core mix of resin materials. This also uses di-electric heating.

→ Diathermy: employed in heating of tissues & bones of body required for treatment of pain relief.

→ sterilization Di-electric heating is also used in sterilization of bandages, absorbent cotton etc

→ Electronic sewing

Now a days raincoats, umbrella, food containers, medicine containers are made from plastic film materials. Thread stitching will no longer water tight. In case of Electronic sewing films are stitched with radio frequency voltage is applied. The heat produced in material is completely seals the filings.

→ food processing: Di-electric heating for food processing widely used in pasteurizing of milk, disinfection of cereals & grains.

Q. Di-electric heating is employed to heat a slab of insulating material of 20mm thickness & 15000 mm² in area. Power requirement is 100W, frequency of 30MHz to be used. Material permittivity is 5 & P.F. is 0.05. determine (a) voltage necessary & current which will flow through material. (b) if voltage is limited to 600V, to what value would the frequency have to be raised.

Sol thickness $t = 20\text{mm} = 20 \times 10^{-3}\text{m}$ $1\text{m} =$

Area of material $\Rightarrow A = 15000\text{mm}^2 = 15000 \times 10^{-6}\text{m}^2$
relative permeability of material $\epsilon_r = 5$

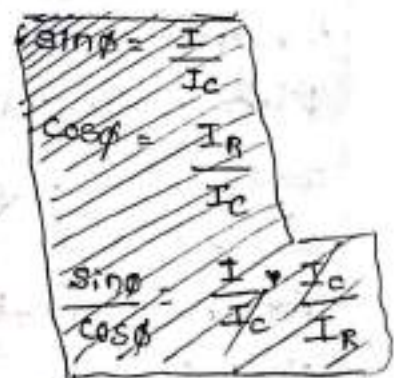
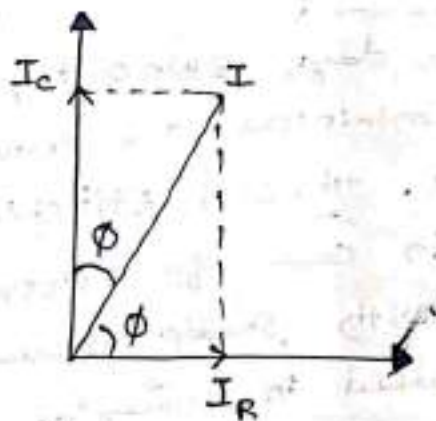
Capacitance of slab is: $C = \frac{\epsilon_0 \epsilon_r A}{t}$

$$\Rightarrow C = \frac{8.854 \times 10^{-12} \times 5 \times 15000 \times 10^{-6}}{20 \times 10^{-3}} = 3.32 \times 10^{-11}\text{F}$$

Given supply frequency $f = 30\text{MHz} = 30 \times 10^6\text{Hz}$

$$\tan \phi = \frac{\text{Reactive}}{\text{Real}}$$

$$\tan \phi = \frac{\text{Reactive}}{\text{Real}} = \frac{I_c}{I_R}$$



$$I_c = \frac{V}{X_c}, \quad I_R = \frac{V}{R} \quad \tan \phi = \frac{\frac{V}{X_c}}{\frac{V}{R}} = \frac{R}{X_c}$$

$$R = X_c \tan \phi$$

$$\cos \phi = 0.05$$

$$\phi = \cos^{-1}(0.05)$$

$$\phi = 87.1^\circ$$

$$\tan \phi = \tan(87.1)$$

$$\tan \phi = 19.74$$

$$R = 0.16 \times 10^3 \times 19.74 = 3.15 \times 10^3 \Omega$$

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi f \times C}$$

$$X_c = \frac{1}{2\pi \times 30 \times 10^6 \times 3.32 \times 10^{-11}}$$

$$X_c = 0.16 \times 10^3 \Omega$$

② Voltage required for the material

$$P = \frac{V^2}{R} \Rightarrow \text{given power } P = 200W$$

$$V^2 = P \times R = 200 \times 3.15 \times 10^3 = 630 \times 10^3$$

$$V = \sqrt{630 \times 10^3} = 793.7V$$

$$\Rightarrow \sin \phi = \frac{I_c}{I} \text{ from phasor diagram}$$

\Rightarrow Current required is

$$I = \frac{I_c}{\sin \phi} = \frac{V}{X_c \sin \phi} = \frac{V \omega C}{\sin \phi} = \frac{V \times 2\pi \times f \times C}{\sin(87.1)}$$

$$I = \frac{793.7 \times 2\pi \times 30 \times 10^6 \times 3.32 \times 10^{-11}}{\sin(87.1)} = 4.97A$$

⑥ If voltage is limited to 600V, assume power required is same $P = 200W$

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{(600)^2}{200} = 1800 \Omega$$

assume p.f is same

$$\tan \phi = 19.74$$

$$\frac{X_c}{R} = 19.74 \Rightarrow X_c = 19.74 \times R$$

$$X_c = 19.74 \times 1800$$

$$2\pi f C = 19.74 \times 1800$$

$$f = \frac{19.74 \times 1800}{2\pi \times 5.32 \times 10^{-11}} = 52.69 \text{ MHz}$$

Electric heating Questions

- ① State the advantages of electric heating → 2M
- ② Discuss the various modes of heat transfer? → 10M
- ③ State the requirements of good heat element & explain the design of heating element? (2+8)
- ④ List out the various types of electric heating (2M)
- ⑤ Discuss about resistance heating with neat diagrams? 10M
- ⑥ Discuss briefly about
 - (a) Direct resistance heating (5M)
 - (b) Indirect resistance heating (5M)
- ⑦ Discuss about arc furnaces with neat sketch? 10M
- ⑧ Explain briefly indirect arc furnace with neat sketch? (10M)
- ⑨ What is induction heating? Explain the core type of induction heating with neat sketch? (2+8)
- ⑩ Discuss about di^e-electric heating? Discuss the advantages of di-electric heating (6+4)
- ⑪ Discuss the various applications of di-electric heating? (10M)

Electric Welding → Unit - ②

Definition of welding: The process of Joining metals together by fusion or by heating them to welding temperatures with or without the application of pressure.

All metals can be joined by welding process. During the welding of metals, a coalescence is formed on welding spot.

Coalescence is growing together or growth into one body of materials being welded.

Importance of welding

- * It is the only way to join metals
- * widely employed in all industrial applications
- * If a joint is welded, then it is a permanent weld.
- * To join 2 metals or materials by bolting or riveting requires holes to accommodate nuts & bolts. This reduces area of cross section. This increases the structure weight
- * Welding avoids the excessive material support to join with nuts & bolts or rivets.

Advantages of welding

- cheapest way of joining metals.
- It affords lighter weight, better utilisation of materials
- used to join all metals

→ It can be flexible to use any where.

Limitations

- welding depends on human factor
- welded position needs internal inspection
- Health problems associating ^{with} welding
- requires more safety to weld metals
- Combustible materials must not allowable near welded areas.

Classification of welding

Modern methods of welding are classified as plastic welding also known as pressure welding & fusion welding called non pressure welding.

→ plastic welding:

Pieces of metal to be joined are heated to plastic state & forced together by external pressure. Ex: forge welding, resistance, thermit & gas welding

fusion → splitting

→ fusion welding: Non pressure welding. Here material at the joint is heated to melting state & allowed to solidify. This gas welding, arc welding, thermit welding without any pressure

Based on electrical Energy heat produced it is classified as

- ① Resistance welding (ii) Arc welding

Resistance welding is again classified as

- (i) Spot welding (ii) Steam welding (iii) Projection welding (iv) Butt welding
 - (a) flash welding
 - (b) upset welding (Spot welding)
 - (c) stud welding

(v) welding process depends on following factors

- Types of metals to be joined
- cost involved
- Nature of products fabricated
- Techniques of production adopted

(a) Resistance welding

In this method current is passed through resistance of the joint to be welded thereby heat is produced upto welding temperature.

This method is used to weld together 2 or more over-lapping pieces.

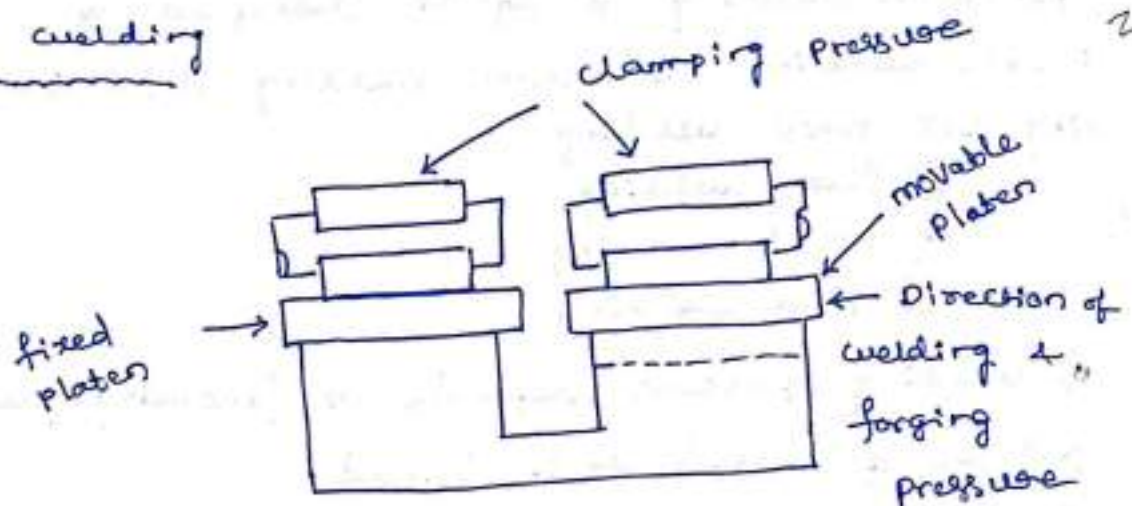
Important resistance type weldings are

- (i) Butt welding (ii) Flash welding (iii) Spot welding (iv) Steam welding (v) Projection welding

Advantages

- (i) Similar & dissimilar metals can be welded
- (ii) quick welding action
- (iii) parent metal is not damaged during welding
- (iv) less skill is required
- (v) difficult & various shapes can be welded.
- (vi) No filled metal is required.

① Butt welding



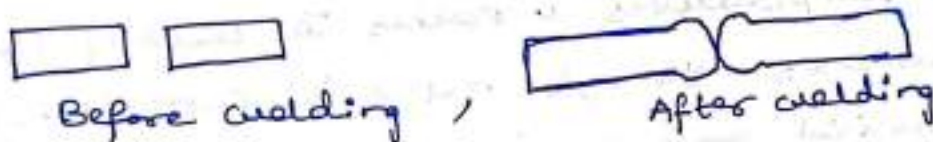
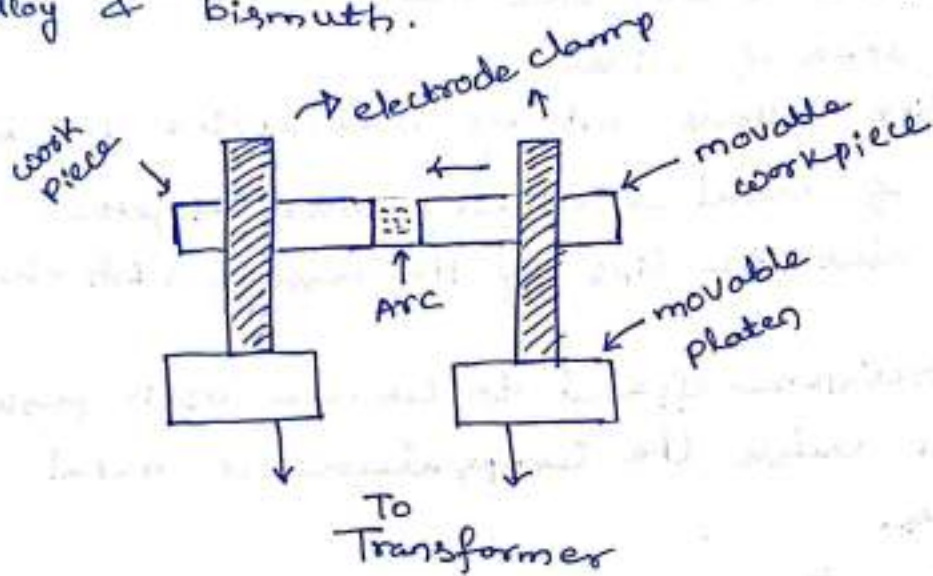
In this welding end to end welding is possible.

- one bar is held in a fixed clamp in butt welding machine & other bar is connected to movable clamp
- The clamps are being electrically insulated & it is connected to source of current
- when 2 ends are brought in contact & current is switched on.
- the resistance at the end joints heats up to welding temperature
- Current is switched off & movable clamp is removed slowly, so that weld is completed.
- voltage across each clamp is only 2-6V.
- used for welding things such as steel rails whose cross section area is as much as 6.25 cm².

② Flash welding

- In this parts to be welded are clamped to electrode fixtures, & 2 metals are butted each
- A current is passed through the joint which heats the ends to red heat.

- The metals are then separated till an arc is developed b/w them & metals begins to melt.
- Impurities are forced out of joint in butting process & a flash is formed.
- This welding is used to join many ferrous & non-ferrous alloy except for cast iron, zinc, antimony alloy & bismuth.



advantages of flash butt claims

- ① Power consumed is less once arc creates
- ② weld is made in clean metal
- ③ faster setting of weld

applications

- used in automobiles for construction of body, axles, axles, other frame parts
- Also used transformer tanks to weld.

② Spot welding (upset welding)

This is an alternative substitute of riveting.

Steel, brass, Copper & light alloys are used to joined.

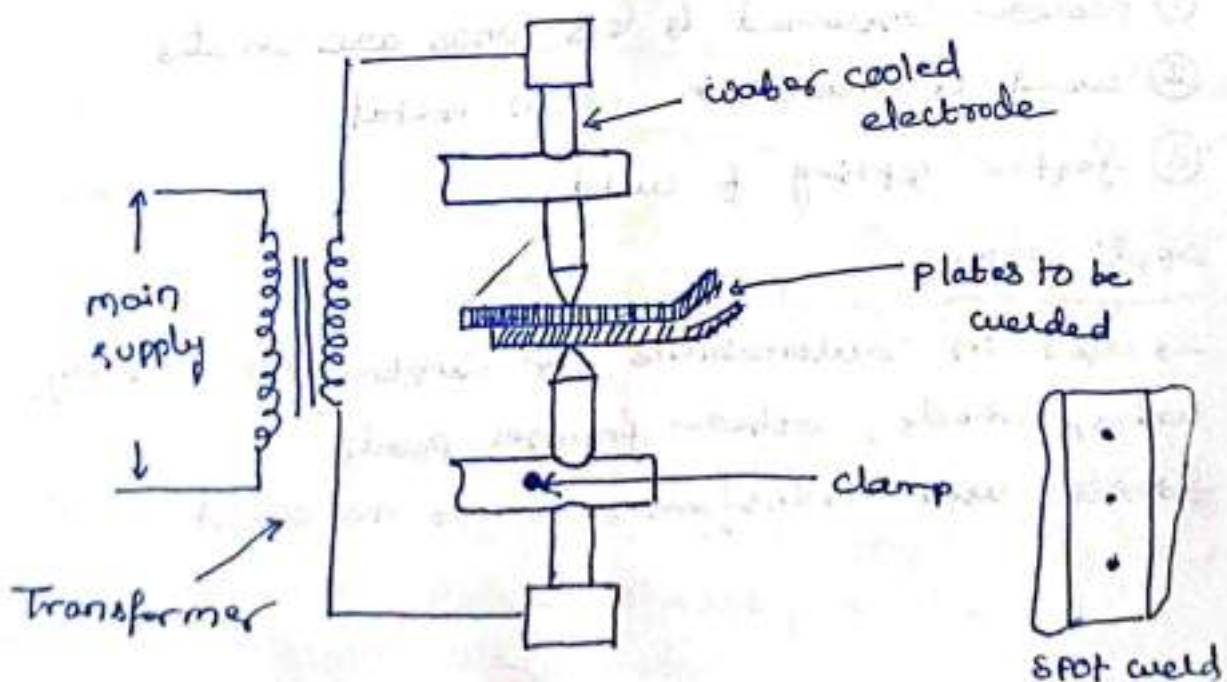
→ Area of fusion at each spot weld is equal to cross section area of rivet.

→ This welding allows out by overlapping the edges of 2 sheets of metal & fusing them together b/w Copper electrode tips by the passage high electric current.

→ Due to resistance offered to current as it passes through metal raises the temperature of metal b/w electrodes.

→ The temperature reaches to welding temperature then current through metal is cut off. & a

→ mechanical pressure is applied to electrodes to forge the weld.



When sheets of unequal thickness are joined, current & pressure setting for thinner sheets is used.

→ Spot welding is used for galvanised, tinned & lead coated sheets, mild steel sheet

→ Also used to join ferrous metals such as brass, aluminium, nickel & bronze.

④ Seam welding

→ This is the special application of spot welding

→ This is used to weld joints in Containers that require air-tight.

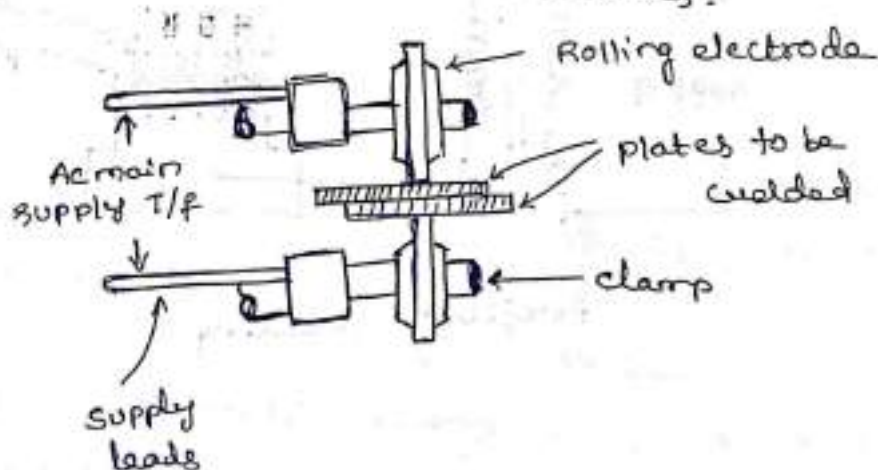
→ It consists of 2 rotating electrodes. One rotating & one bar type electrodes are used for transmitting current.

→ Current is interrupted 300 to 1500 times a minute to give a series of overlapping spot welds.

→ The sheets to be welded are passed between conical type electrodes.

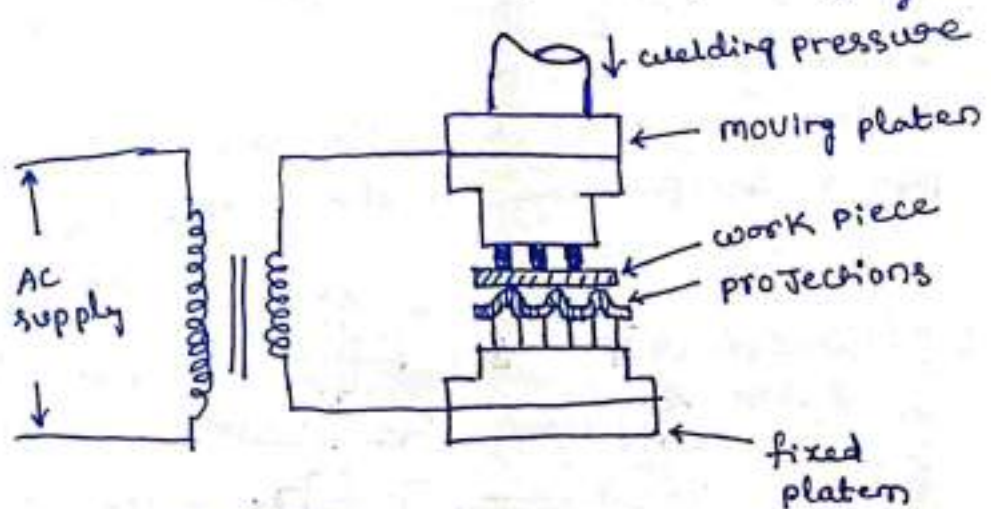
→ This allows the periodic current gives a series of overlapping spot welds. The welding process completely automatic.

→ Here operator sets the current interrupted period & pressure on the electrodes.



⑥ Projection welding

- It is also known as multi spot welding.
- This welding uses resistance to flow of current which creates the heat for welding.
- 2 pieces of base metal are held together b/w the plates.
- one of base metal piece provides projections or bumps on one piece.
- one of the 2 pieces of metal is given through a machine.
- A welding current from a resistance transformer flows through pieces to be welded when clamped b/w flat metal plates.
- Current concentrated at the point which heats up & melts. & then a mechanical pressure is applied b/w the plates to complete the weld.
- Sparking & flashing are present in welding so operator requires goggles & gloves for safety.



Projection welding

Electric Arc welding

It is the process of sm in which metal is melted by heat of an electric arc.

It has done in various methods

- ① Metallic arc welding
- ② Carbon arc welding
- ③ Atomic hydrogen arc welding
- ④ Shielded arc welding.

In above methods fairly short arc length is necessary for getting good welds.

→ The length of arc depends on

- (i) type of electrode with coating & diameter
- (ii) position of welding
- (iii) amount of current used

→ Deflection of arc blow from weld point is arc blow. This is occurred in DC welding sets. During this deflection of arc blow less heat is penetrated in weld spot.

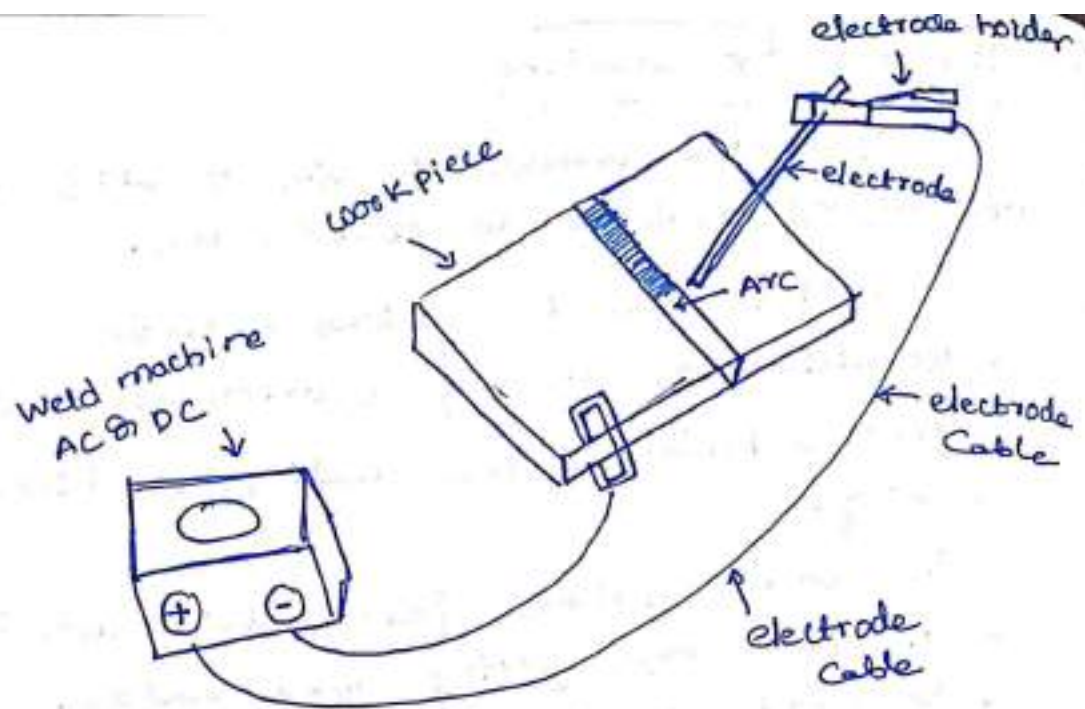
→ To avoid deflection arc use AC welding sets.

① Metallic Arc welding

An arc is established b/w work & filler metal electrode. The heat of arc being welded metal & at the ~~same-time~~ same-time this arc melts the tip of electrode. Electrodes are flux coated one.

→ An arc is maintained molten filler metal from electrode tip is transferred across the arc where fuses the molten base metal.

→ Arc may be formed by AC & DC. Most widely is used a simple transformer AC supply for welding.



Metallic Arc welding diagram

Voltages required for DC is in the range 50-60V & for AC 80-90V. In both case arc length should be kept small & does not allow to drop arc voltage below 13V.

② Carbon Arc welding

It is different from metal arc welding. Here it uses non consumable carbon-graphite electrodes are used instead of flux coated.

Here work part is connected to connected to -ve & carbon rod & graphite electrode are connected to +ve part of electric circuit.

Arc is formed in gap, filling material is provided by fusing wire or filler rod.

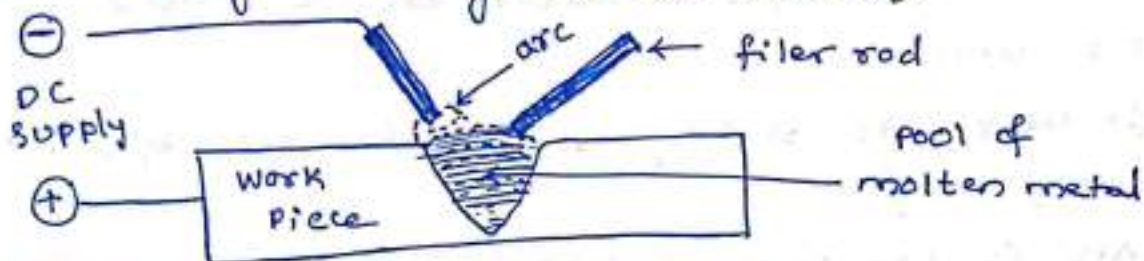
This method of welding provides porous & brittle weld. This welding uses only DC supply

There are 2 modes of arc welding

- ① Carbon electrodes with flux & (II) Carbon electrodes without flux

↳ If Carbon electrode is always connected to -ve side to prevent arc blowing. Suitable to weld ferrous metals
(II) without flux coated electrodes

It is applicable to non ferrous material where strong welding is not needed.



Carbon arc welding Applications

- Suitable to weld galvanised sheets
- Carbon arc welding is easily adaptable to automation
- Copper, silicon, manganese alloys are also used as filler metal
- Useful to weld thin high nickel alloys
- Suitable to weld stainless steel of thinner gauges.

Advantages

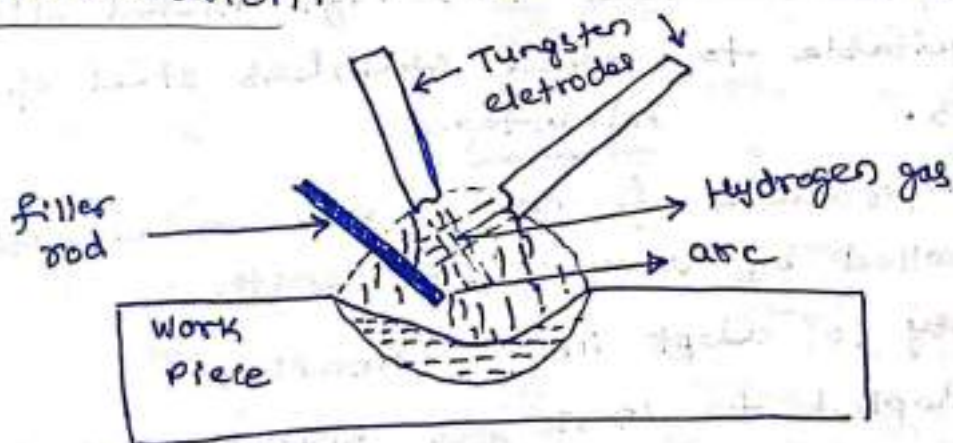
- Temperatures of molten pool can be easily controlled by varying arc length
- Easy to adopt in automation
- Adapted to inert gas shielding of weld
- Acts as excellent heat source for many welding processes such as soldering, brazing etc

Disadvantages

- uses only DC supply
- Carbon electrodes requires twice rated currents to raise the temperature
- separate filler rod has been used
- Blow holes occur due to magnetic arc blow.

③ Atomic Hydrogen welding

- In this 2 tungsten electrodes are used to create arc.
- It uses ac supply to create arc b/w tungsten electrodes
- Arc is created in presence of Hydrogen. Due to arc Hydrogen molecules breaks into atoms & combines with cooler base metal generating intense heat to melt the surfaces to be weld.
- The melted pool is filled with filler rod.
- The Hydrogen gas provides shield the molten metal from oxygen & nitrogen to prevent metal from deterioration.



Applications

Mainly used in high grade work on stainless steel & used in non-ferrous metals

Advantages

- Strong weld
- Allows to weld thick sections
- weld too thin material where gas weld not possible.

Shielded Arc welding

In this molten weld metal is protected from atmosphere by an envelope of reducing chemical effect.

As molten steel has easily react with oxygen & nitrogen to form nitrogen as nitrides & oxides gases that makes metal so weak & brittle. To avoid such, flux coated electrode produces a slag on the top of molten metal & it protects from inert gases. This slag acts as envelope on molten metal.

⑤ Submerged arc welding

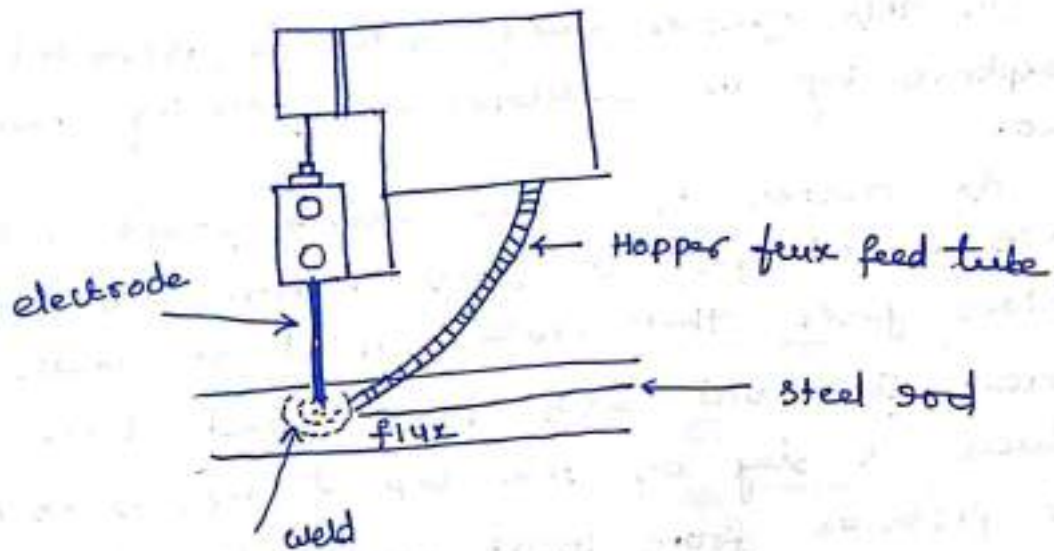
Here in process an arc is created with the base metal electrode & the work piece.

The arc, end of electrode are completely submerged in granular flux powder. During cold flux is non conductor of electricity but in molten state acts good conductor of electricity.

The granular powder or flux powder is fed from a hopper that is carried on welding head. The hopper continuously releasing powder on electrode along the line of weld.

The granular or flux powder acts as shield to protect weld metal from inert gas or from atmosphere.

In order to create arc, steel rod is placed between electrode & work piece. This welds allows a straight line welding.



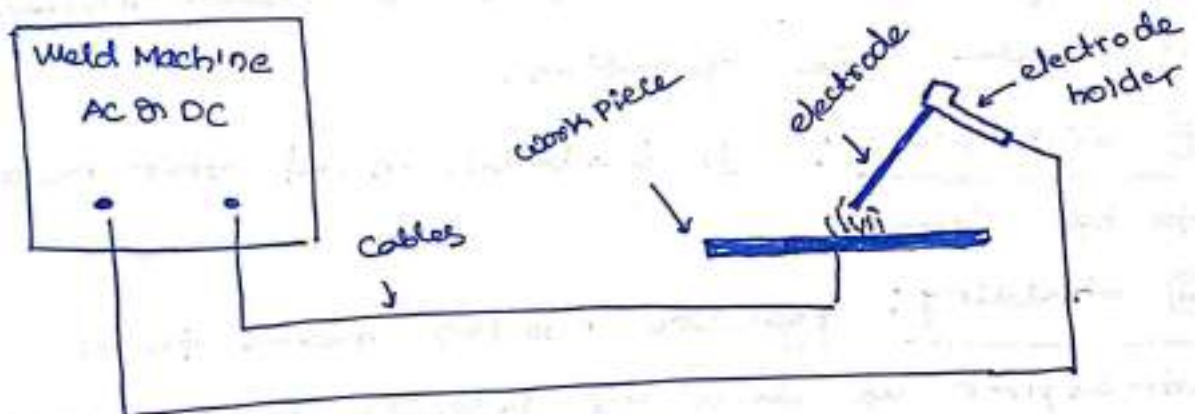
Submerged arc welding

Comparison of AC & DC welding

S.No	Aspect	AC welding	DC - welding
1	power consumption	low	High
2	ARC stability	unstable	ARC is stable
3	cost	Less	more
4	weight	Light	heavy
5	Efficiency	High	less
6	operation	silent	Noisy

S.No	Aspect	AC - welding	DC - welding
7	suitability	Non ferrous metals cannot joined	ferrous & non ferrous is welded
8	Electrode	only flux coated	base or flux coated
9	weld thin sections	Not preferable	Preferred
10	others	Work can acts as cathode while electrode acts as anode or vice versa	Electrode always negative & work is always +ve.

Electric welding Equipment



It is the process of generated heat from an electricity to join the 2 metal pieces is welding.

Here Arc melts the base metal & filler metal which fuses together to form a strong joint after cooling.

① power source: Main source of electric welding is electricity. It may be either AC or DC that depends on metals going to

be ~~used~~ welded. Generally AC or DC supply is preferable.

② Electrode Holder: Holds the electrode which is fusible metal it may be flux coated or base electrode used as a filler metal.

③ Base metal: work piece that needs to be joined.

④ welding Cables: Conduct electricity from power source to electrode holder & work piece. The cables must have required current carrying capacity as well as requires heavy insulation to ensure safe operation.

⑤ work piece: It is a base metal that needs to be joined.

⑥ Shielding: protects molten metal from atmosphere as well as protects from Nitrides & oxides that makes the weld brittle.

Shielding is provided as granular powder or argon, Hydrogen or helium.

QUESTION BANK

- ① Discuss the advantages of electrical heating? 5M
- ② State the properties of heating element? Explain the design of heating element? 5M+5M
- ③ What are the requirements of heating element? Discuss about various modes of heat transfer? 4M+6M
- ④ Explain the various methods of electric heating? 10M
- ⑤ Discuss about the methods of indirect & direct ~~resistance~~ resistance heating with sketches? 8M
- ⑥ Explain the principle ~~of~~ & operation of Ajax ~~type~~ ^{type} furnace with neat sketches? 10M
- ⑦ Discuss about classification of welding? Explain briefly about resistance welding with neat sketches using any 2 methods
- ⑧ Discuss about resistance welding of spot & projection welding with sketches? 10M
- ⑨ Write ^a short notes on
 - (a) Carbon Arc welding
 - (b) Submerged arc welding
- ⑩ (a) Compare AC & DC welding 5M
 - (b) Draw the neat sketch of welding equipment & explain each component in detail 5M

Unit-3

Illumination

Light is a radiant energy which cause a visual sensations. When there is no natural light, use of artificial light is made. Light emitted by bodies depends on temperature of body.

The heat of the body can be classified as red hot or white hot. While body is red hot wave length is very large. When temperature increases the body changes from red hot to white hot state, wave length is smaller.

colour Difference in wavelengths of light radiations.

Relative sensitivity: sensitivity of eye to the lights of different wave length vary person to person and according to age.

Yellow-green color can be seen under poor illumination conditions

Blue-red can not be seen under dim illumination.

Violet color disappear 1st, yellow disappear lost as illumination becomes dim. Finally black will be visible

wave motion is expressed as

$$v = f \cdot \lambda = 3 \times 10^8 \text{ m/sec}$$

λ → wave length
 f → frequency
 v → velocity of propagation

units wavelength

wave length of electromagnetic radiations are very small. Its unit is micron & Angstrom.

$$1 \text{ Angstrom } \text{A}^\circ = 10^{-10} \text{ mtr}$$

$$1 \text{ micron } (\mu) = 10^{-6} \text{ mtr}$$

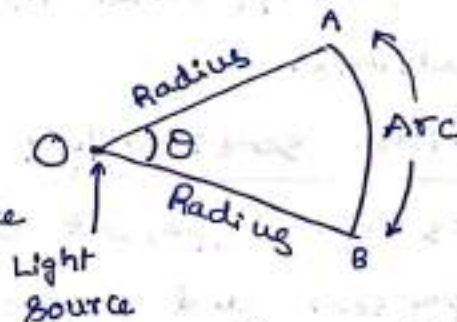
terms used in illumination

plane angle

Angle subtended at a point by converging 2 lines. Its units is radians & degrees & is denoted by (θ)

$$\text{plane angle } \theta = \frac{\text{Arc}}{\text{radius}} \text{ radians}$$

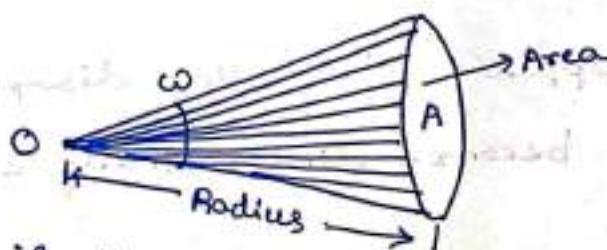
$$1 \text{ radian} = \frac{180}{\pi} \text{ degree}$$



→ plane angle

② solid angle

Consider an area 'A', which is a part of sphere having radius 'r'.



if all points of area are joined to point 'O', a cone shape is formed at 'O' & angle subtended by the area 'A' at point 'O' is known as solid angle. solid angle is denoted as (ω) or steradian

$$\pi \text{ radians} = 180 \text{ degree}$$

$$1 \text{ radian} = \frac{180}{\pi} \text{ "}$$

$$\omega = \frac{A_{\text{area}}}{(\text{radius})^2} = \frac{A}{R^2} \text{ steradians}$$

Incase of sphere, solid angle subtended at a point in all directions is

$$\omega = \frac{4\pi R^2}{R^2} = 4\pi$$

Relation b/w plane angle (θ) + solid angle (ω)

$$\omega = 2\pi \left(1 - \cos \frac{\theta}{2}\right)$$

Light: It is defined as radiant energy emitted from the hot body which causes a visual sensation. It is denoted as (θ) & is expressed as lumen/hour

Luminous flux:

Total quantity of light emitted per second from luminous body. It is denoted as F or ϕ , measured in lumens

$$F = \phi = \frac{\theta}{t} = \frac{\text{lumen hour}}{\text{hour}} = \text{lumens}$$

Luminous intensity:

Luminous flux emitted per unit of solid angle. It is denoted by I & is measured in Candela or lumen/steradian

$$I = \frac{F \text{ or } \phi}{\omega} = \frac{\text{lumen}}{\text{steradian}}$$

Candle power: Light emitting Capacity of source & is defined as no: of lumens emitted in a unit solid angle from given source of light

$$C.P. = \frac{\text{Number of lumens}}{\text{Solid angle}} = \frac{\text{lumens}}{\omega}$$

Lumen: It is defined as amount of luminous flux emitted in a solid angle by a source of one Candle power

$$\begin{aligned} \text{lumen} &= C \cdot P \times \text{solid angle} \\ &= C \cdot P \times \omega \end{aligned}$$

illumination: Amount of ~~illumination~~ light distribution on a surface.

It is denoted as '(E)' & is measured in lux. It is denoted as 'E' & is measured in lux. It is denoted as 'E' & is measured in lux. It is denoted as 'E' & is measured in lux.

$$E = \frac{F}{A} = \text{lumens/m}^2 \text{ or lux.}$$

Brightness or luminance: luminous intensity per unit projected area of either surface of light source or reflecting surface, it is denoted as '(L)'. It is denoted as '(L)'. It is denoted as '(L)'. It is denoted as '(L)'.

If a surface of area (A) has an effective luminous intensity of I Candles in a direction θ to normal then luminance is

$$L = \frac{I}{A \cos \theta} \text{ Candela/m}^2 \text{ or nits}$$

θ is angle between normal surface to the direction of view

Polar Curves

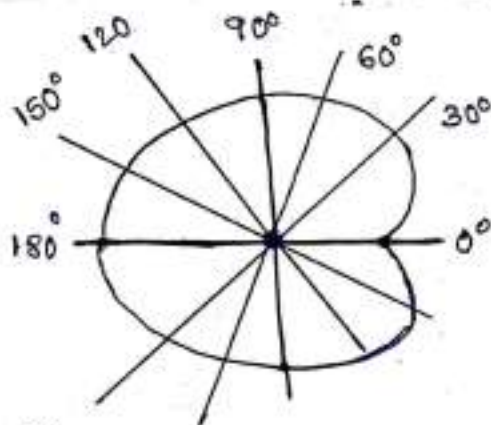
In most of lamps luminous intensity is not same in all directions due to unsymmetrical shape. To find out Candle power or intensity of light in various directions polar curves is needed.

Distance of any point on Curve from origin represent luminous intensity of source.

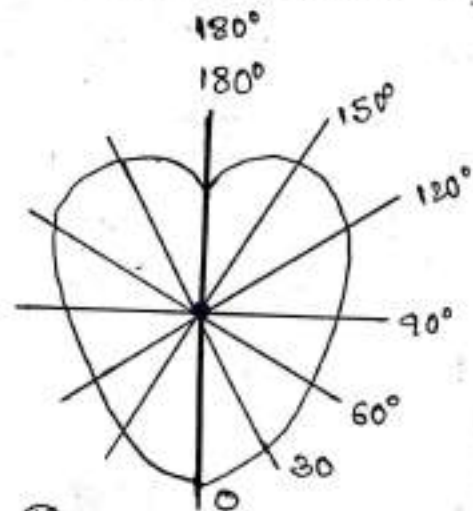
→ If luminous intensity of candle power is measured in a horizontal plane about a vertical axis, a curve is plotted b/w candle power & angular position is

→ If luminous intensity of candle power is measured in a vertical plane about a ~~horizontal~~ horizontal axis a curve is plotted b/w candle power & angular position is known as vertical polar curve

Candle power is measured at angular position in a vertical plane then the curve is known as vertical polar curve.



(a) Horizontal Polar Curve



(b) Vertical Polar Curve

→ polar curves are used to determine

(i) Mean Horizontal Candle Power (MHCP) & Mean Spherical Candle Power (MSCP)

(ii) Actual illumination of a surface by the use of candle power in ~~particular~~ particular direction can read from vertical ~~polar~~ polar curve.

(iii) MHCP of lamp can be determined from horizontal polar curve by taking mean or average of candle power in horizontal direction.

- * Draw a circular circle with convenient radius with 'O' as center
- * Draw PA line parallel to YY' line & equal to vertical diameter of circle.
- * Draw a line from point 'O' meet at polar curve point as E & at a circle as A.
- * Let 'G' be the projection on line PA.
- * with distance OE, draw a horizontal line from point 'G'. Let the straight line GT (ordinate)

$$OE = GT$$

* By similar construction draw other ordinates. The curve PSQUTVP obtained by joining these ordinates is known as Rousseau's curve.

* The mean ordinates of this curve gives mean spherical candle power (MSCP)

$$\text{Mean ordinate of this curve} = \frac{\text{Area of PSQUTVP}}{\text{Length of PA}}$$

Mean Horizontal Candle Power (MHCP)

if luminous intensity I_n , Candle power in all directions in horizontal plane containing source of light

Mean Spherical Candle Power (MSCP)

It is defined as luminous intensity I_n Candle power in all directions ~~in all directions~~ & in all planes from the source of light

$$\text{MSCP} = \frac{\text{Total flux}}{4\pi}$$

Lamp efficiency: It is defined as ratio of luminous flux to the i/p power. It is expressed as lumens/watt

$$\text{Lamp efficiency} = \frac{\text{Lumens emitted by source}}{\text{Wattage of light source}}$$

Mean Spherical Candle Power (MSCP)

It is defined as Mean of luminous flux or mean of Candle power in all directions above or below the horizontal plane passing through source of light

Reduction factor ratio of mean spherical Candle power to mean horizontal Candle power

$$\text{Reduction factor} = \frac{\text{MSCP}}{\text{MHCP}}$$

Glare: Opening or closing of human eye is controlled by iris. If eye is exposed to very bright light, iris automatically contracts in order to reduce amount of light admitted & prevents the damage to retina. During this case objects within the field of vision can be imperfectly seen. This effect is called as Glare. This is major problem with car head lamps.

Glare is defined as "brightness within the field of vision, such a brightness causes an annoyance, discomfort or eye fatigue & strain"

utilization factor or co-efficient of utilization

It is defined as total lumens received by working plane to the total lumens produced by lamp.

$$UF =$$

$$\frac{\text{Total lumens received by working plane}}{\text{Total lumens produced by lamp}}$$

Maintenance factor: (MF)

$$MF = \frac{\text{illumination under normal working conditions}}{\text{illumination when every thing is clean}}$$

Depreciation factor: Inverse of maintenance factor.

$$DF = \frac{\text{Initial meter Candles}}{\text{ultimate meter candles}}$$

DF value greater than unity

Absorption factor: It is related to the atmospheric conditions like full of smoke, fumes, fog etc there is certain amount of light is absorbed.

It is defined as ratio of total lumens available after absorption to total lumens produced by light source

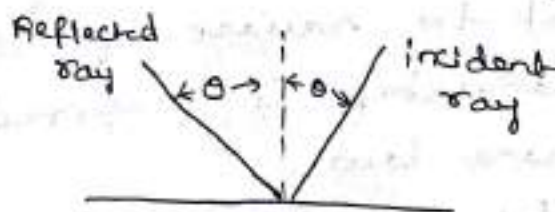
AF is unit for clean atmosphere

AF is 0.5 for foundations.

Beam factor: Ratio of lumens in the beam of a projector to the lumens given by lamp.

Its value varies from 0.3 to 0.6

Reflection factor: when a light falls on a surface, it is reflected from the surface at an angle of incidence.



Ratio of reflected light to incident light is reflection factor.

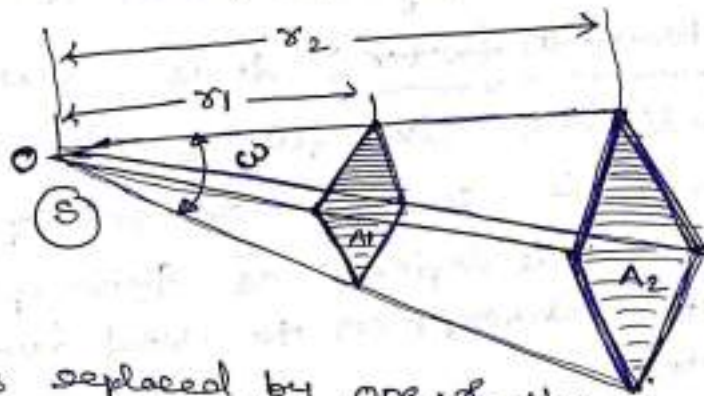
Laws of illumination

illumination laws are of 2 types

- ① Law of inverse squares ② Lambert's cosine law

If a light source is placed at the center position of sphere i.e. hollow sphere, the light will fall uniformly on inner surface of sphere, so surface will be same amount of light

$$E \propto \frac{1}{r^2}$$



If the sphere is replaced by one of the larger radius, total amount of light spread over a larger area is proportional to square of radius

Consider 2 parallel plates which is in form of pyramid shape placed at different distances from source of light.

Areas of these surfaces are proportional to square of these distances. Amount of light which falls on one unit area is (^{inversely} proportional to) inversely proportional to square of distance from source. This relationship is referred as law of inverse ~~area~~ square law.

Let A_1, A_2 surface areas of 2 parallel plates.

r_1, r_2 are distances from point source 'S' to A_1, A_2 .

Let I be the luminous intensity of point source
 Let ω be solid angle

Total Luminous flux radiated = $I \cdot \omega = F$

→ illumination of surface Area A_1

$$E_1 = \frac{F}{A_1} = \frac{I\omega}{A_1} \quad \text{lumens/m}^2 \text{ or lumens per unit Area}$$

$$E_1 = \frac{I\omega}{A_1} \quad \text{Area } A_1 = \omega r_1^2$$

$$E_1 = \frac{I\omega}{\omega r_1^2} = \frac{I}{r_1^2}$$

→ illumination of surface Area A_2

$$E_2 = \frac{I\omega}{A_2} = \frac{I\omega}{\omega r_2^2} = \frac{I}{r_2^2} \quad \text{lumens per unit area}$$

Hence illumination is proportional to luminous flux & same is inversely proportional to square of distance b/w surface & light source provided that distance b/w surface & source is sufficiently large.

Let I be the luminous intensity of point source
 Let ω be solid angle

Total Luminous flux radiated = $I \cdot \omega = F$

→ illumination of surface Area A_1

$$E_1 = \frac{F}{A_1} = \frac{I\omega}{A_1} \quad \text{lumens/m}^2 \quad \text{or lumens per unit Area}$$

$$E_1 = \frac{I\omega}{A_1} \quad \text{Area } A_1 = \omega r_1^2$$

$$E_1 = \frac{I\omega}{\omega r_1^2} = \frac{I}{r_1^2}$$

→ illumination of surface Area A_2

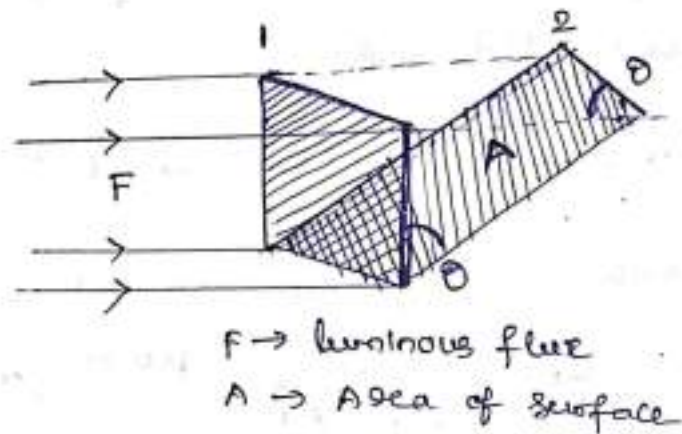
$$E_2 = \frac{I\omega}{A_2} = \frac{I\omega}{\omega r_2^2} = \frac{I}{r_2^2} \quad \text{lumens per unit area}$$

Hence illumination is proportional to luminous flux & same is inversely proportional to square of distance b/w surface & light source provided that distance b/w surface & source is sufficiently large.

② Lambert's cosine law

According to this law if illuminated surface is not normal to the direction of light but it is inclined to normal illuminated source.

Here illumination E is directly proportional to cosine of angle made by normal to the illuminated surface with the direction of incident flux.



Let (F) be flux incident on surface of Area (A) , when in position 1. When this surface is turned back through an angle θ , then flux incident on it is $F \cos \theta$

Hence illumination of surface when in position ① is

$$E_1 = \frac{F}{A} \text{ but in position ② } E_2 = \frac{F \cos \theta}{A}$$

$$\frac{E_2}{E_1} = \frac{F \cos \theta}{A} \times \frac{A}{F} = \cos \theta$$

$$E_2 = E_1 \cos \theta$$

from law of inverse square law

$$E = \frac{I}{d^2} \cos \theta \quad \text{lumens per unit Area}$$

② flux emitted by a lamp in all directions is 1000 lumens. Calculate its MSCP.

sol Total flux from lamp = 1000

$$\text{MSCP} = \frac{\text{Flux}}{4\pi} = \frac{1000}{4\pi} = 80$$

③ Voltage of lamp is 250V, total flux from lamp is 3000 lumens, current consumed by lamp is 0.5A. Calculate ① lumens/watt (ii) MSCP per watt

Voltage of lamp $V = 250$, $I = 0.8A$

$$\textcircled{1} \text{ lumens per watt} = \frac{\text{o/p of lumens}}{\text{Wattage of lamp}}$$

$$\text{Wattage of lamp} = V \times I = 250 \times 0.8 = 2000 \text{ W}$$

$$\text{lumens/watt} = \frac{3000}{200} = 15 \text{ W}$$

(ii) MSCP per watt = ?

$$\text{MSCP of lamp} = \frac{F}{4\pi} = \frac{3000}{4\pi} = 240$$

$$\text{MSCP per watt} = \frac{\text{MSCP of lamp}}{\text{Watt of lamp}} = \frac{240}{200} = 1.2$$

$\textcircled{3}$ Deduce the relation to find illumination at any point on the surface due to light source suspended at a height 'h' from plane surface.

Sol Let us consider a point

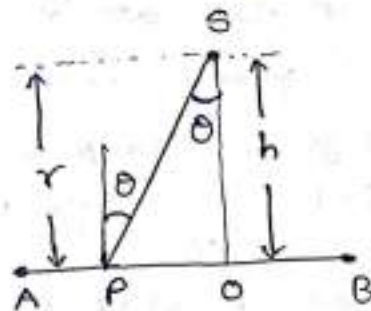
(P) on plane surface AB.

(S) be the light source of candle power (CP).

Let (h) be height of

source from point (S) to normal plane surface AB.

Let (r) be the distance b/w source light (S) to point (P).



By illumination law

$$E = \frac{I}{r^2} \cos \theta \quad \text{or} \quad E = \frac{CP}{r^2} \cos \theta$$

from Δ SOP

$$\cos \theta = \frac{\text{OPP}}{\text{HYP}} = \frac{\text{adjacent}}{\text{HYP}} = \frac{OS}{SP}$$

$$\cos \theta = \frac{h}{r} \Rightarrow r = \frac{h}{\cos \theta}$$

$$\textcircled{1} \text{ lamp efficiency} = \frac{\text{o/p of lamp}}{\text{i/p of lamp}} = \frac{\text{luminous flux}}{\text{Wattage of lamp}}$$

$$\text{given } \boxed{\text{MSCP} = \frac{F}{4\pi}} = F = 1000 * 4\pi$$

$$= \frac{F}{\text{Wattage of lamp}} = \frac{1000 * 4\pi}{500} = 25.13 \frac{\text{lumens}}{\text{wat}}$$

(iii) illumination at the working plane 1.2 mtrs away from vertical axis of lamp.

$$E \text{ at point (P)} = \frac{CP \cos^3 \theta}{h^2}$$

$$\cos \theta = \frac{\text{adj}}{\text{HYP}} = \frac{OB}{PB} = \frac{h}{r} = \frac{2.7}{3.6} = 0.99$$

$$\cos \theta = 0.99$$

$$\left. \begin{array}{l} CP = I = F = \\ 1000 \\ r = \sqrt{(2.5)^2 + (2.7)^2} \\ r = 3.6 \end{array} \right\}$$

$$E \text{ at point (P)} = \frac{1000 * (0.99)^3}{(2.7)^2} = \frac{1000 * 0.997}{(2.7)^2}$$

$$E \text{ at point (P)} = 137.17 * 0.997 = 136.76$$

⊗ problem

Illumination at a point on working plane directly below the lamp is 100 lumens/m². Lamp gives 256 CP uniformly below the horizontal plane. Determine the height at which the lamp is suspended. Also

find illumination at a point on working plane 1.2 mtrs away from the vertical axis of lamp.

luminous intensity of lamp $I = 256 \text{ CP}$

Illumination $E = 100 \text{ lumens/m}^2$

Let (h) be height of the lamp suspended from working plane above

$$E = \frac{I}{h^2} \Rightarrow 100 = \frac{256}{h^2} \Rightarrow h^2 = \frac{256}{100}$$

$$h = 1.6 \text{ m}$$

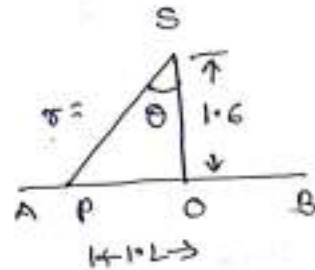
illumination of working plane 1.2 mtrs away from the working plane vertical axis of the lamp.

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

$$r = \sqrt{(1.6)^2 + (1.2)^2} = 2$$

$$\cos \theta = \frac{OS}{PS} = \frac{1.6}{2} = 0.8$$

$$E = \frac{256 \times (0.8)^2}{(1.6)^2} = 51.2 \text{ lux}$$



urp urp

Q. A lamp has uniform CP of 200 in all directions is provided with a reflector which directs 60% of total light uniformly on circular area of 10m diameter. The lamp is provided at a height 6m above the working area. Calculate illumination

(i) at the center (ii) illumination at the edge of surface with & without reflector. (iii) determine average illumination

Sol Candle power $CP = I = 200$

$$d = 10\text{m}$$

$$h = 6\text{m}$$

with reflector lumens on surface = 60% = 0.6

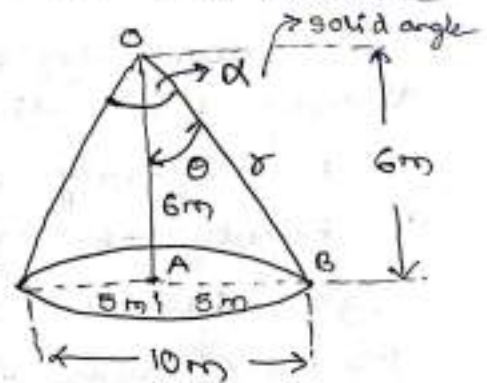
(i) illumination at the center of sphere & working plane.

$$E_A = \frac{CP \times I}{h^2} = \frac{200}{(6)^2} = 5.56 \text{ lux}$$

(ii) illumination at the edge with & without reflector

(a) illumination on surface without reflector

$$E_1 = \frac{I}{h^2} \cos^3 \theta$$



from ΔOAE

$$\cos \theta = \frac{\text{adj}}{\text{hyp}} = \frac{AO}{OE} = \frac{6}{\pi} = \frac{6}{\sqrt{(AB)^2 + (OA)^2}}$$

$$\cos \theta = \frac{6}{\sqrt{(5)^2 + (6)^2}} = 0.768$$

$$E_1 = \frac{CP}{h^2} \cos^2 \theta = \frac{200}{(6)^2} \times (0.768)^2 = 2.52 \text{ lux}$$

(b) illumination at the edge with reflector

$$E_2 = ?$$

with ~~with~~ reflector illumination at the edge as well as center is same on uniform surface.

we know that $CP = \frac{F \Phi I}{4\pi}$

$$1m = 100cm$$

$$1cm = \frac{1}{100}$$

lumens given by lamp is o/p of total lumens

$$F \Phi I = CP \times 4\pi$$

$$F \Phi I = 200 \times 4\pi = 800\pi$$

Total lumens reaching the surface

$$= \frac{60}{100} \times 800\pi = 60\% \text{ of total lumens of lamp with reflector}$$

Total lumens reaching surface

$$= 60\% \times F = \frac{60}{100} \times 800\pi = 0.6 \times 800\pi$$

$$\text{Average illumination} = \frac{\text{Total lumens received by surface}}{\text{Area of surface}}$$

$$\text{Area of surface}$$

$$\text{Area of surface } A = \pi r^2 = \pi (5)^2 = 25\pi$$

$$\text{Average illumination} = \frac{0.6 \times 800\pi}{25\pi} = 19.2 \text{ lux}$$

(iii) Average illumination without reflector
solid angle subtended by area of the lamp

$$\omega = 2\pi \left[1 - \cos \frac{\alpha}{2} \right] \quad \alpha = \frac{\theta}{r} + \frac{\theta}{r} = 2\theta$$

$$\omega = 2\pi \left[1 - \cos \theta \right] = 2\pi \left[1 - \cos(0.768) \right]$$

$$\omega = 0.464\pi \text{ steradians}$$

$$\begin{aligned} \text{Total flux reaching the surface} &= I \times \omega = CP \times \omega \\ &= 200 \times 0.464\pi \end{aligned}$$

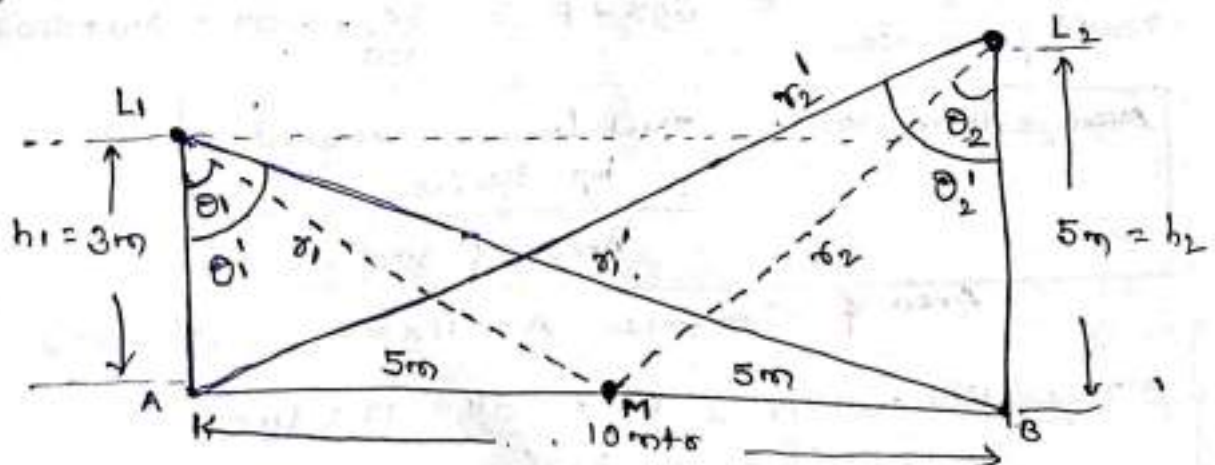
$$\begin{aligned} \text{Average illumination} &= \frac{\text{Total flux received by surface}}{\text{Area of surface}} \\ &= \frac{200 \times 0.464\pi}{\pi (5)^2} = 3.7 \text{ lux} \end{aligned}$$

20) 2 lamps 500w each with an efficiency 25 lumens/w are mounted on 2 lamp posts 10mtr apart. The posts are 3m & 5m height. Find illumination

(i) below the lamps

(ii) at a point mid away b/w the lamps.

20)



Wattage of 2 lamps = 500W

We know that lamp efficiency = $\frac{\text{lumens o/p}}{\text{Wattage of lamp}}$

efficiency of lamp = 25

lumens o/p or flux produced by lamp = 25×500
= 12500

→ Candle power or Intensity of lamp each one

$$CP = \frac{F}{4\pi} = \frac{12500}{4\pi} = 994.7 \text{ CP}$$

$$\text{from } r_1 = \sqrt{h_1^2 + (5)^2} = \sqrt{3^2 + 5^2} = 5.83 \text{ mtr}$$

$$r_2 = \sqrt{h_2^2 + (5)^2} = \sqrt{5^2 + 5^2} = 7.07 \text{ mtr}$$

$$r_1' = \sqrt{h_1^2 + (AB)^2} = \sqrt{3^2 + 10^2} = 10.44 \text{ mtr}$$

$$r_2' = \sqrt{h_2^2 + (AB)^2} = \sqrt{5^2 + 10^2} = 11.2 \text{ mtr}$$

$$\rightarrow \cos \theta_1 = \frac{\text{Adj}}{\text{HYP}} = \frac{h_1}{r_1} = \frac{3}{5.83} = 0.5145$$

$$\cos \theta_2 = \frac{\text{Adj}}{\text{HYP}} = \frac{h_2}{r_2} = \frac{5}{7.07} = 0.707$$

$$\cos \theta_1' = \frac{\text{Adj}}{\text{HYP}} = \frac{h_1}{r_1'} = \frac{3}{10.44} = 0.287$$

$$\cos \theta_2' = \frac{\text{Adj}}{\text{HYP}} = \frac{h_2}{r_2'} = \frac{5}{11.2} = 0.446$$

→ Illumination below or under the lamp L1

E_A = illumination directly below lamp E_1 + illumination due to L_2

$$= \frac{CP}{h_1^2} + \frac{CP}{h_2^2} \cos^3 \theta_2' = 114 \text{ lux}$$

illumination under the lamp L_2

$E_B =$ illumination directly below due to L_2 + illumination due to L_1

$$= \frac{CP}{h_2^2} + \frac{CP}{h_1^2} \cos^3 \theta_1 = 42.4 \text{ lux}$$

case ii illumination at the mid point 'M' b/w 2 lamps

$$E_M = \text{Diagram showing two lamps A and B with a point M between them. Lines connect A to M and B to M. The diagram is shaded with diagonal lines.$$

$=$ illumination due to L_1 + illumination due to L_2

$$= \frac{CP}{h_1^2} \cos^3 \theta_1 + \frac{CP}{h_2^2} \cos^3 \theta_2$$

$$= \frac{994.7}{3^2} \cos^3 (0.514) + \frac{994.7}{5^2} \cos^3 (0.707)$$

$$= 29.11 \text{ lux}$$

illumination under the lamp L_2 .

$$E_B = \text{illumination directly below due to } L_2 + \text{illumination due to } L_1$$

$$= \frac{CP}{h_2^2} + \frac{CP}{h_1^2} \cos^3 \theta_1 = 42.4 \text{ lux}$$

case ii illumination at the mid point 'M' b/w 2 lamps

$$E_m =$$

= illumination due to L_1 + illumination due to L_2

$$= \frac{CP}{h_1^2} \cos^3 \theta_1 + \frac{CP}{h_2^2} \cos^3 \theta_2$$

$$= \frac{994.7}{3^2} \times (0.514)^3 + \frac{994.7}{5^2} \times (0.707)^3$$

$$= 29.11 \text{ lux}$$

Sources of light

→ these are classified as 3 types

(i) Incandescence → current is passed through thin wire

(ii) Arc lamps → creating arc b/w 2 electrodes

Examples: Carbon arc lamps, flame arc lamp, magnetic arc lamp.

(iii) Discharge lamps:

In this lamps gas or vapour is used to produce light by electric discharge. The color & intensity depends on nature of gas or vapour.

Examples: Mercury vapour lamp, sodium vapour lamp, neon gas lamp, fluorescent lamp.

Discharge lamps:

Here by the use of gas or vapour an electric current is passed through, emits light. Most commonly used elements are neon, mercury & sodium vapours.

Neon discharge → orange-red light

Mercury discharge → bluish

Sodium Vapour discharge orange-yellow

Type: 1

color of light depends on gas or vapour
Ex: sodium, mercury, neon gas lamps

Type: 2 uses fluorescence phenomenon. These lamps uses vapours produces ultra violet rays is absorbed by phosphor material which emits light.

Ex: fluorescent lamps

Demerits

- (i) High initial cost
- (ii) P.f is very poor
- (iii) starting requires starters or transformers
- (iv) takes time to produce full light
- (v) These are having -ve resistance characteristics again needs electronic ballasts

Mercury Vapour lamp

It consists 2 bulbs, first bulb have arc tube containing electric discharge & outer bulb which provides protection against external temperature changes.

→ Inner tube or arc bulb is made from quartz

→ outer bulb is made from hard glass

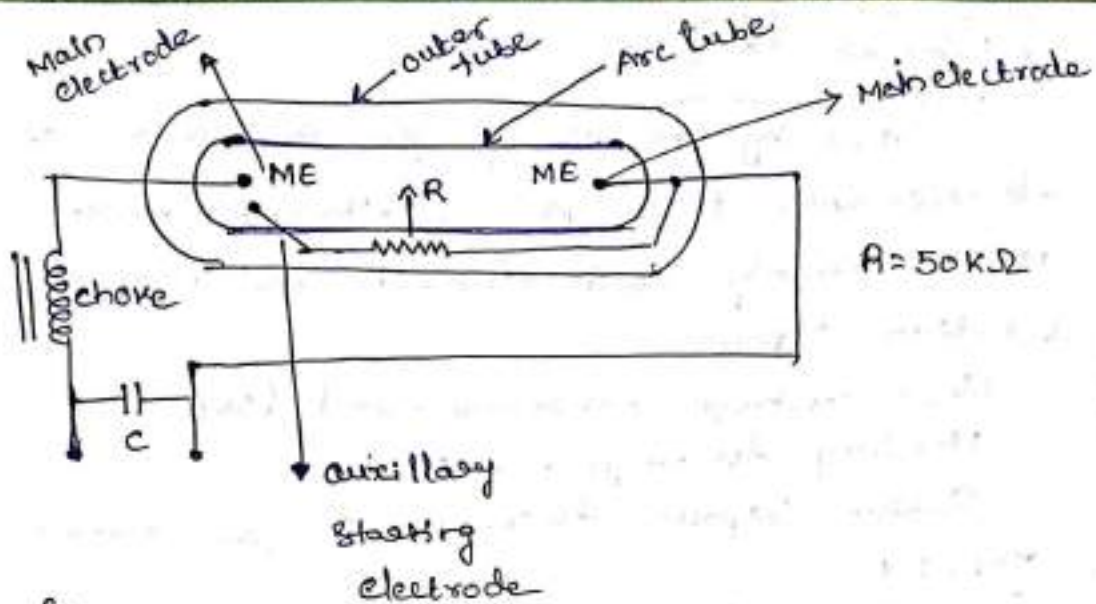


fig: Mercury Vapour lamp

- Arc tube which consists of mercury & argon gas.
- Also it consists of 3 electrodes, 2 are Main electrodes & other one is auxillary electrode are connected high resistance.
- Main electrodes consists of tungsten coils coated with electron emitting.
- Working
 When supply is switched on, electric discharge takes place b/w auxillary electrode & main electrode in the presence of argon gas. After few seconds electric discharge takes b/w the 2 main electrodes in the presence of argon gas.
- During electric discharge produces heat which vaporises the mercury. During this potential difference b/w main electrodes reaches from 20V to 150V. It takes 5 to 7 minutes to produce greenish-blue light.

→ choke limits the currents to safe value during this ~~period~~ p.f becomes lower, to avoid that a capacitor is connected across the circuit to improve p.f.

→ efficiency of this lamp is 30-40 lumens/watt which uses 220-250V ac supply.

→ Applications

- * used in industrial lighting
 - * used in railway yards & ports
 - * used in working areas & shopping malls
- above applications where greenish-blue color light is objectionable.

Another advanced mercury lamps are mercury iodide lamps, additionally along with mercury an iodide elements are added in presence of argon gas. Efficiency is about 70-90 lumens/watt.

Sodium-Vapour lamps

→ due to large in length, e/p of light intensity is very low.

→ It consists of U-shaped tube provided with oxide coated electrodes provided at ends.

→ U shaped tube consists of little amount sodium & neon gas.

→ Again U shaped tube is surrounded with double walled tube to keep temperature within range.

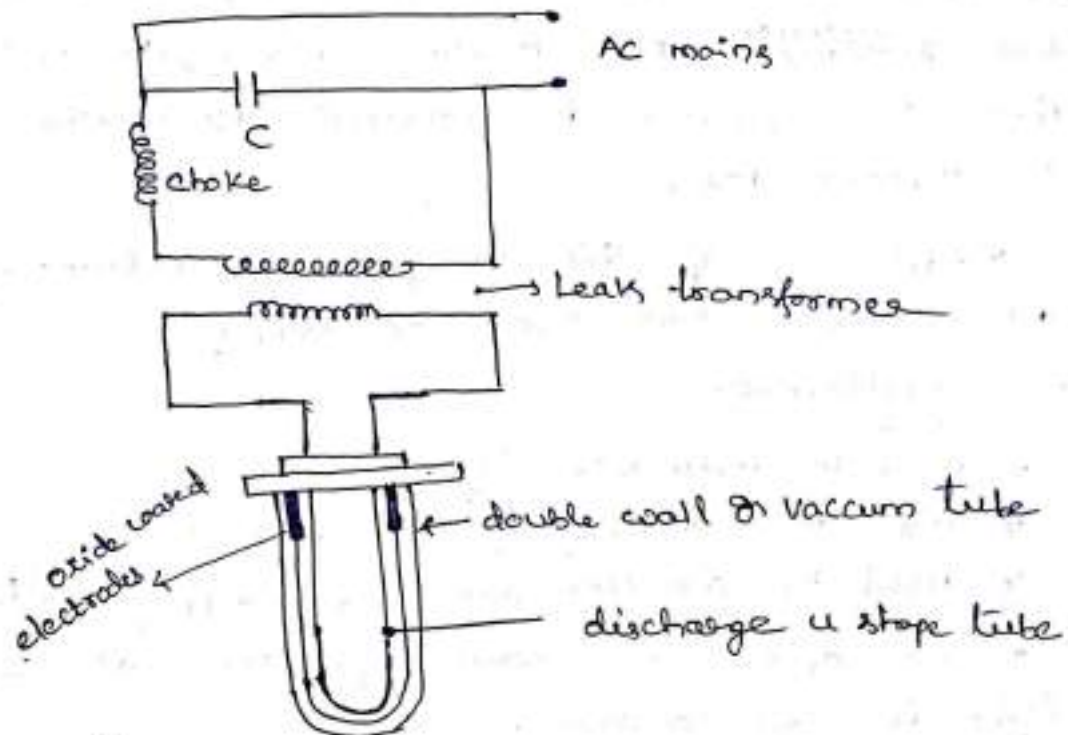


fig: Sodium Vapour lamp

Working

Before the lamp is on, sodium is in the form of solid particles which deposits on sides of a stoped walls

→ At beginning when switch on operates at low pressure produces pink color.

→ As temperature increases, sodium starts vapourised produces yellow light

→ After 10-15 minutes it produces full yellow light.

→ In order to start the lamp a striking voltage of 380V for 40W & 450V for 100W is required. This high reactance transformer or auto-transformer.

→ Due to poor regulation of transformer, at no load this lamp gives low light at starting.

→ lamp must be operate horizontally to maintain uniform distribution of sodium

→ The P lamp fails to operate

- ① if electrodes are completely burn out
- ② electrons emitting stops
- ③ sodium particles concentrated at one side
- ④ sodium vapours forms a black ash around the inner tube which reduces light out

→ under practical conditions, efficiency of lamp is about 40-50 lumens/watt, due to ageing its o/p reduces to 15%.

→ Mainly used in street lights, highway lighting also outdoor light where color discrimination is not required. Its life span is about 3000hrs burning time if not any voltage variations.

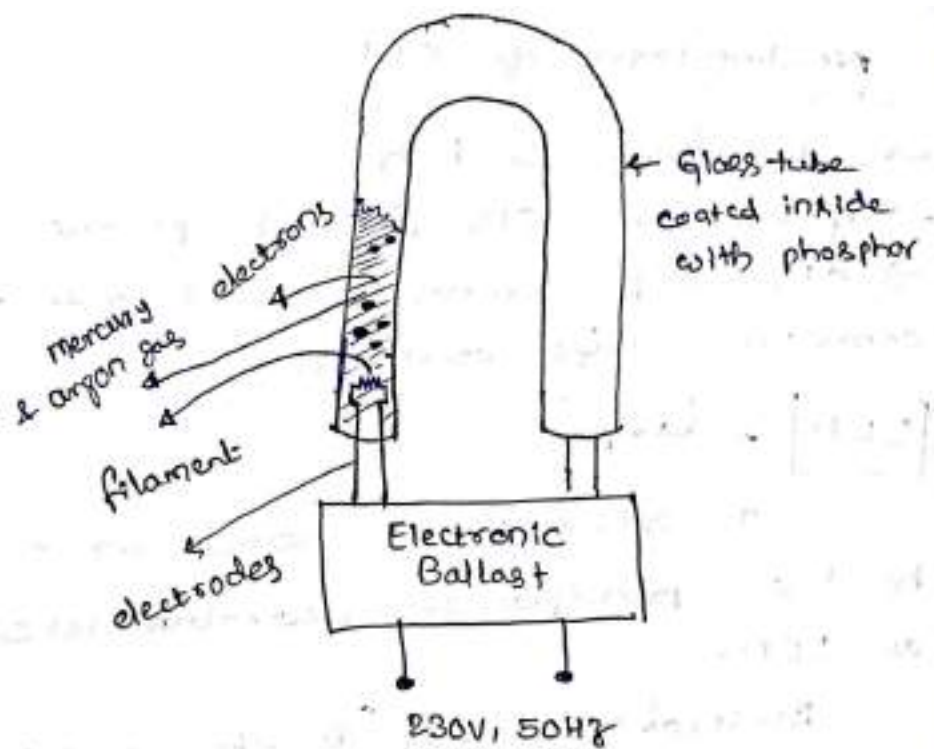
Comparison b/w tungsten filament lamp & fluorescent lamp

Factor or Aspect	Tungsten filament lamp	Fluorescent lamp
① Voltage fluctuation	More effect on light o/p	Less effect on light o/p
② efficiency	luminous efficiency increases with increase in voltage	luminous efficiency increases with increase in wattage
③ Natural light	close to natural light, objects seen properly	Not close to natural color, color rendering is defective
④ <u>luminous efficiency for colored lamps</u>	luminous efficiency for colored lamps is very poor due to colored glasses	luminous efficiency is high & better colors are obtained due to fluorescent powder

Aspect	Tungsten filament lamp	Fluorescent lamp
Radiation effect	Due to high working temperature heat radiation effect High	Due to low working temperature heat radiation is low.
Brightness	More brightness	Less brightness
Stroboscopic effect	No stroboscopic effect	objectionable stroboscopic effect
Working hours	1000 working hours	7500 working hours
Initial cost	quite low	cost is High per tube
lumens o/p	for same lumens output more number of lamps are needed. Extra wires. Extra holders is needed. Maintenance is High	for same o/p less no: of tubes are required. Maintenance is low

Compact fluorescent lamp (CFL)

- * These are energy saving light bulbs which last longer & use less energy than incandescent light.
- It works on the principle of gas discharge by ionization of gas by electric current.
- CFL's are widely used in residential as well as commercial lighting.
- A CFL consists of U shaped glass tube filled with mercury vapour & argon gas.
- one side of tube consists of 2 electrodes.



- when electric supply is switched on, an electric arc is created b/w the 2 electrodes.
- This electric arc releases electrons which bombards with mercury vapours releases a UV light.
- This UV light is absorbed by phosphor gives light.
- o/p of CFL changes with temperature. At very low temperatures light o/p from CFL can decline to $\frac{1}{3}$ rd of rated value, at low temperatures mercury vapor will condense at cold spot.

Advantages of CFL

- energy efficient
- operating cost is low
- produces less heat compared to incandescent bulbs
- Lamp efficiency is high 50-75 lumens/watt
- does not require any starters
- Life span is high.
- operates both AC as well as DC also.

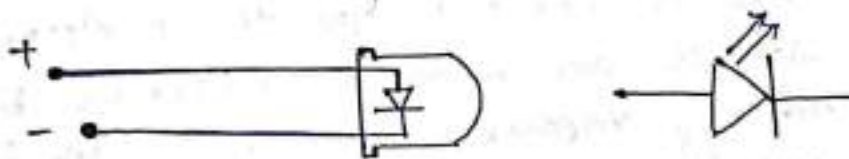
Disadvantages of CFL

- cost of lamps is high
- if overheat CFL fails to produce light
- CFL lamps cannot be used with timer switches otherwise life reduces.

LED - lamps

An optoelectronic device which emits light based on principle of electroluminescence is known as LED.

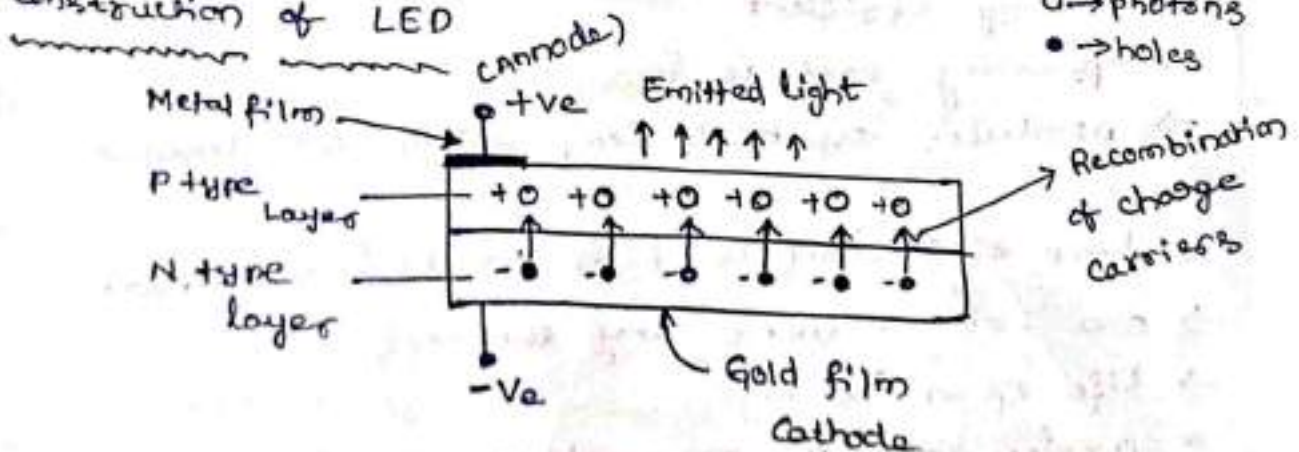
Electroluminescence is the emission of light due to interaction of an electric field.



Gallium junction was found to be an efficient emitter of radiation when it is in forward biased. Here Gallium is used as semiconductor material.

- Gallium + phosphide → Green/Red
- Gallium Arsenide → Yellow/Red
- Gallium Nitride → white.

Construction of LED



→ In order to construct led, a p-type semiconductor material is placed above the n-type semiconductor layer.

→ A metal ^{film} on p-type layer forms anode connection, whereas gold film on n-type layer forms a cathode connection.

→ The gold film acts as a reflector of light from bottom surface of device.

Working of LED:

If dc supply is given to led lamp which is in forward biased, majority charge carriers starts drifting

i.e. electrons towards +ve terminal & holes towards -ve terminal

At p-n junction, recombination of holes & electrons takes place which releases energy in the form of heat & light.

Semiconductor materials such as gallium phosphide, gallium nitride, Gallium arsenide emit light on during recombination of charge carriers.

Advantages of LED lamps

- * operating cost is low
- * Compact in size
- * Remote switching is possible using timer switches
- * Longer life span 1,00,000 hours
- * High energy efficient
- * color rendering is excellent
- * Environment friendly.

Disadvantages of LED lamps

- * Cost of LED is high compared to fluorescent
- * Cannot withstand with high temperatures
- * Works on DC, so it requires separate rectifier unit
- * Its brightness highly impact on insects.

Principles of Light Control

Light is in form of radiation which causes a visual sensation to humans. It is emitted from luminous object.

- It travels through the vacuum
- It travels through transparent object but not pass through opaque object

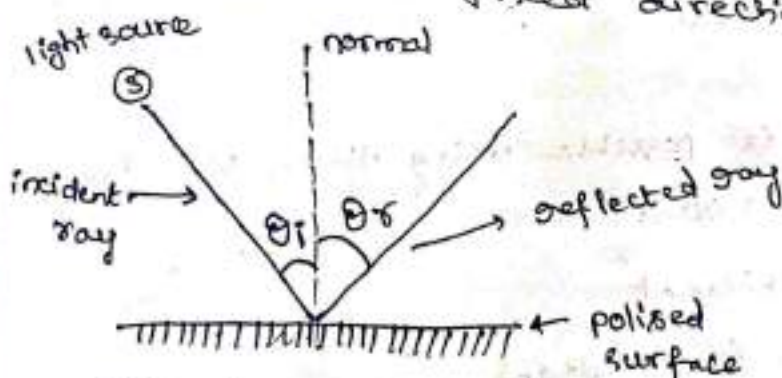
Basic principles of light

- * Reflection, Refraction, Diffusion, Absorption

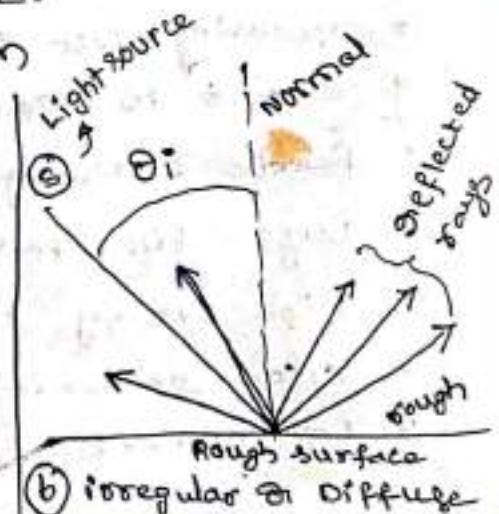
↳ these are again classified as 2 types

- (a) Regular Reflection (b) irregular or Diffuse Reflection

- In regular reflection, light is not scattered.
- It takes on polished surface when a beam of light incident on polished surface.
- It has some fixed direction



(a) Regular Reflection



(b) irregular or Diffuse

(b) Irregular or Diffuse Reflection

→ In this, light is scattered in all directions & viewer can see only illuminated surface not the source of light. It is shown in fig (b)

→ It takes on rough surface when light falls
ex: wood, wall

(c) Refraction

When a ray of light passed through 2 transparent mediums having different densities, its velocity & directions can be changed.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$n_1, n_2 \rightarrow$ refractive indices of medium 1 & 2

$\theta_1, \theta_2 \rightarrow$ angle of light in medium 1 & 2

(d) Diffusion

→ it is related to rough surface

→ when a light ray fall on rough surface, light is scattered in all directions

→ To prevent the glare from light source, a diffusion glass screen is introduced b/w viewer & light source.

(e) Absorption

→ the phenomenon of taking up & storing of light energy without reflected or diffused falling on surface is absorption.

Here surface absorbs light to prevent reflection & diffusion.

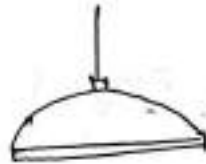
Types of lighting schemes

These are classified as

① Direct lighting

Most commonly used lighting scheme is direct lighting. In this 90% of total light falls directly on working plane.

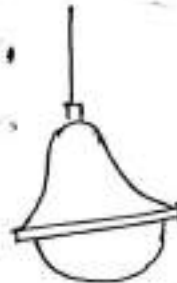
- Glare & shadows is occurred
- used in outdoor lighting



② Semi-direct lighting

60-90% of light falls ^{directly} on working plane with the help of semi-direct reflectors.

- Remaining % of light is used to illuminate ceiling & walls.
- used to rooms with high ceilings where uniform illumination is needed. Glare is minimized



③ Semi-indirect lighting

In this lighting scheme 60-90% of total light flux is thrown upwards to ceiling for diffuse & best reaches the working plane.

- this lighting scheme is with soft shadows & glare free



④ Indirect lighting

More than 90% of total flux light is thrown upwards to ceiling for diffuse reflection by using inverted bowls.



- In such s/m, Ceiling acts as a light source & glare is reduced minimum.
- It is used in decoration purposes in cinemas halls, hotels, drawing rooms, workshops where direct lighting is objectionable.

(5) General Lighting

In this lighting s/m lamps made of diffusing glass are used which give nearly equal illumination in all directions.



General diffusing lighting

Requirements of good lighting

- Good lighting provides visual comfort
- Good lighting provides better illumination levels
- illumination provides minimum glare
- Good lighting should have minimum brightness & contrast
- Light source should provide shielded by luminaries
- Reflected glare should be avoided
- using diffusing, absorbing fixtures reduces glare

Design of lighting schemes

It may provide

- (i) Adequate illumination
- (ii) uniform distribution of light all over the working plane
- (iii) Provides adequate color
- (iv) should avoid glare & hard shadows
- (v) Provides better visual comfort

illumination level A sufficient illumination provides better visual to see our surroundings. It depends on degree of illumination. Degree of illumination depends on (i) size of object seen (ii) distance b/w observer & object (iii) Contrast b/w object & background. (iv) objects which are seen longer duration requires more illumination.

(ii) uniform distribution of illumination

Human eye adjust automatically with brightness if it is in within field of vision. if there is lack of uniformity, eye adjust frequently which causes a fatigue of eye. Range of brightness should not exceed 3:1, this is achieved by using localized brightness which uses general lighting.

(iii) color of light Appearance of body color depends on color of incident light. Day out fluorescent tubes now a days make it possible to illuminate economically with good color rendering.

For street lights color rendering is not important.

(iv) Shadows

Formation of long & hard shadows causes fatigue to eyes. Certain amount of lights have some shadows. Shadows are desirable in artificial lighting as it helps to give shape to solid object & make them to recognized. By increasing height of light source shadows somewhat eliminated.

⑤ Glass: It may be direct or reflected.

It may come directly from light source or reflected brightness. Most commonly glass is direct glass, which can be obtained from light source & reflected glass is obtained from polished surface.

⑥ Mounting Height

It indicates type of building & type of lighting scheme is employed.

In direct lighting rooms of large floor area, luminaries should be mounted as close to ceiling.

⑦ Colour of surrounding walls

Illumination in any room depends on light reflected from walls & ceilings. White walls & ceilings reflect more light.

Methods of Lighting Calculations

Lighting arrangement should provide:

- (i) Sufficient illumination
- (ii) uniform of distribution of light
- (iii) Minimum presence of glare
- (iv) absence of shadows

They are 3 of them methods are commonly used to design lighting schemes.

① Point-by-point method

(ii) Lumen or flux method

(iii) Watt per sq meter method

↳ This is employed where illumination at a point uses one or more nos of lamps. Illumination at a particular point can be calculated using inverse square law. This is employed in outdoor lighting installation.

$$\text{Total lumens required} = \frac{E_{av} \times A}{u_f \times MF}$$

$$MF = (1 - 20\%) = 1 - 0.2 = 0.8$$

$$= \frac{60 \times 15 \times 100}{0.4 \times 0.8} = \frac{141400}{0.32} = 281,250.$$

$$\begin{aligned} \text{Total wattage required} &= \frac{\text{Total lumens required}}{\text{luminous efficiency}} \\ &= \frac{281250}{16} = 17,578 \text{ W} \end{aligned}$$

$$\begin{aligned} \text{No: of lamps} &= \frac{\text{Total lumens required}}{\text{Total wattage}} = \frac{281250}{17578} \\ &= 16.00 \text{ lamps} \end{aligned}$$

② A hall 30m long, 12m wide, $UF = 0.5$, illumination required is 50 mtr Candles. Five types of lamps having lumens o/p as given below

Watts 100 200 300 500 1000

lumens 1615 3650 4700 9950 21500

Take O.F is 1.3 . Calculate no: of lamps needed & assume a suitable mounting height & calculate space-height ratio of lamps.

Sol

$$\text{Area 'A'} = 30\text{m} \times 12\text{m} = 360$$

$$\text{illumination } E = 50, \text{ } UF = 0.5, \text{ } DF = 1.3$$

$$\text{Gross lumens required } \phi \text{ or } F = \frac{A \times E \times DF}{UF}$$

$$F = \frac{360 \times 50 \times 1.3}{0.5} = 46,800$$

if lamps of 100W are used, no: of lamps

$$= \frac{\text{Total lumens required}}{\text{lumens o/p of 100W lamp}}$$

$$= \frac{46800}{1615} = 29$$

→ if 200W lamps are used, no: of lamps required

$$= \frac{\text{Total lumens required}}{\text{lumens o/p of 200W lamp}} = \frac{46800}{3650} = 13$$

→ if 300W lamps are used, no: of lamps required

$$= \frac{46800}{4700} = 10$$

→ if 500W lamps are used, no: of lamps required

$$= \frac{46800}{9195} = 5$$

→ if 1000W lamps are used, no: of lamps required

$$= \frac{46800}{21300} = 2$$

Let mounting height be 5mtrs ✓

Most suitable type of lamp is 300W required

10 lamps arranged in rows, each row having

5 lamps

$$\text{length wise spacing} = \frac{30}{5} = 6\text{mtr}$$

$$\text{width wise} = \frac{6}{5} = 1.2\text{mtr.}$$

3 x 5

5 x 2

R C

L H

flood lighting

- used to illuminate huge open area.
- to illuminate either high rated filament & discharge lamps are used.
- Mainly used in stadium, advertisement boardings, railway & mine yards etc.
- This is done using a projector. This also called as projector lamps. These are classified based on beam or spreading.

* Narrow beam projectors, beam spread b/w 12-25° are used to cover 70mtrs distance

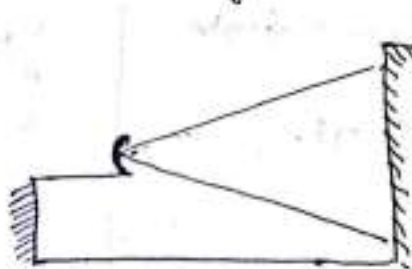
* Medium angle projectors, beam spread b/w 25-40° are used to cover a short range distance b/w 30-70 meters.

* wide angle projectors, beam spread b/w 40-90° are used to cover a distance range 3-30mtrs.

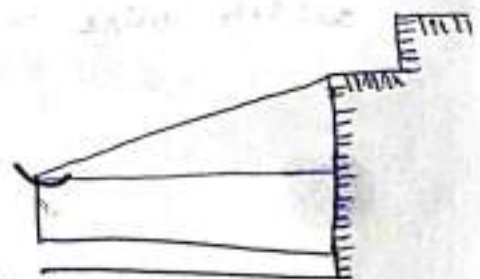
Possible location of projector lamps

2 possible locations of projectors in practice.

(a) Symmetric projector kept 20-35 mtrs away from surface, having beam spread is 25°-30°.



(a) Symmetric projector



(b) Asymmetric projector

(b) asymmetric reflector mounted in basement area which directs more intense light towards top of building

flood lighting calculations

step ① illumination level required: lumens/m²

It depends on type of building, purpose of flood lighting.

step ②: Type of projector :- which indicates size of beam & light o/p.

step ③: No. of projectors :- which indicates intensity over a particular surface, no. of projectors is obtained from

$$N = \frac{A * E * D.F * \text{Waste light factor}}{UF * \text{Wattage of lamp} * \text{luminous efficiency of lamp}}$$

A → area of surface to be illuminated

E → illumination level required in lumens/m²

UF → utilisation of factor, DF → depreciation factor

Waste light factor:

When surface is illuminated some amount of light is wasted on overlapping & falling of light beyond the edges.

Multiply the theoretical value of lumens required by 1.2 for rectangular area where as for irregular areas is 1.5.

Depreciation factor: Due to dirt & smoke depositing on reflector's surface light o/p reduces to 50% or more.

D.F is defined as ratio of illumination under ideal conditions to be illumination under normal conditions.

Co-efficient of utilization: Also known as beam factor.

It is the ratio of beam lumens to lamp lumens. Its value lies b/w 0.3 & 0.5. This factor is due to fact that all light emitted by projector is not along the direction of the beam but some of it is absorbed by reflector & by front glass.

—XXX—XXX—XXXX—XXX—

UNIT - 4

Electric Traction

Traction: It is a process which is used to move any type of vehicle.

Electrical Traction: S/m which uses electrical energy to produce necessary traction power.

In electrical Traction required driving force is obtained from electric motors.

Non-electric traction: which uses other than electrical drives to produce necessary power
ex: steam engines, diesel & petrol IC Engines.

Electric Traction

Traction power for locomotive is secured by using electrical energy. It is divided into 2 groups

- ① Self power generating S/m ② Vehicles receives power from electrical network

↳ these are again classified as 2 types

- ③ Diesel - electric S/m ④ Battery electric S/m

↳ which uses diesel as a fuel source that drives the generator to produce necessary power to drive the vehicle

ICE → Coupled with generator

ICE → runs at lower rpm

Generator → provides high starting torque

① Battery electric s/m

Electric s/m which uses batteries as a source to drive the locomotive. Mainly used in minings.

② Vehicles that secures power from electrical n/w's

Here locomotive secures power from distribution cables that converts the electrical drive output into mechanical energy.

Locomotives generally secures power from overhead lines.

DC - 600V used for tramways

DC > 1500 - 3000V used in main railways

History of railways in India

- In India first railway appeared in April 1853 from Bombay to Thane (53 km)
- In 1920 Government of India set up a Committee to nationalise the whole railway s/m.
- In the year 1890, first electric traction was introduced by British railways at 600V DC using 3rd rail. Due to low voltage & heavy currents, losses as well as risk to life. To avoid the voltage levels is raised to 1500V using rotary converters.
- During the period 1925 - 1932 1st electrification take place in India.
- In 1957 after making sure that single traction is adopted which uses 25kV, 50 cycle.

Requirements of electric traction

- (1) High adhesion coefficient: To provide high starting torque & quick acceleration of train can be obtained.
- (2) possibility of overloads for short periods
- (3) Minimum wear of brake shoes, wheels & track
- (4) Possible to use regenerative braking on descents
- (5) Locomotive or train unit should be self contained so that it runs on any route
- (6) It should be free from pollution.

Advantages of electric traction

Electric traction is most efficient than any other forms & all over the world looking to adopt in transportation sector.

(1) Electric motors: Necessary traction power is provided by electric motors. Electric motors have high starting torque & provides quick acceleration. Also speed control is quite easy. Energy recovery is possible by the use of regenerative braking.

- (ii) More suitable for urban & suburban areas where frequent starting & stopping.
- (iii) Coefficient of adhesion is high, which provides higher speeds are possible during gradients
- (iv) Allowing the motors to run for overload during a short period of time
- (v) Center of gravity is lower than other type

of locomotives results run faster even at curved routes.

Disadvantages of electric traction

- High Capital cost for laying overhead lines
- power failures can cause traffic jams
- Communication lines which run parallelly along the overhead lines creates disturbances
- not suitable for all areas where electrification is not possible.

Systems of electrification or supply systems for electric traction

four types of track electrification is possible

(1) DC - s/m → 600V, 750V, 1500V, 3000V

(2) single phase AC s/m → 15 - 25 KV, 50KV,
25Hz & 50Hz

(3) 3 phase AC s/m → 3.3 - 3.6 KV at $16\frac{2}{3}$ Hz

(4) Composite s/m → Conversion of single phase into 3 phase AC or DC

① DC system

s/m which uses DC series motors, to provide necessary traction power. DC compound motors are also used in tramsways & trolley cars.

→ DC Current at 600V - 750V is universally employed for tramways in urban area & 1500V - 3000V DC is employed in suburban railroads.

→ Now a days ~~is~~ in order to get smaller currents a 3rd rail or 3rd Conductor upto 750V DC is employed.

→ Substation are spaced 3 to 5 km for heavy suburban traffic &

→ for main lines operating at higher voltages say (1500-3000 KV) substation are spaced 40-50 km.

→ These substations receive power from 110KV/132KV 3 phase grid. These high voltage 3 phase is converted into single phase AC supply.

→ Low voltage single phase is converted into required DC using suitable rectifiers like rotary converter, mercury arc, metal & semi conductor rectifiers.

(2) Single phase AC system

s/m which uses AC series motors for getting necessary traction power

Required voltages are 15KV - 25KV at a frequency $16\frac{2}{3}$ Hz or 25 Hz is stepped down in locomotive upto 300V or 400V. Again a small step down transformer step down high voltage to necessary voltage to run 1- single phase AC series motors.

→ spacing of substation is 50km - 80km

→ change of supply frequency is necessary to achieve improved commutation & better performance

of AC series motor operated at low frequency

→ Low frequency AC supply has following advantages

- * Improving Commutation, increases efficiency
- * At low frequency line reactance is less so that line voltage drop reduces
- * Telephonic interference is reduced

③ 3 phase AC s/m

operating voltage is 3.3 KV to 3.6 KV at 16 2/3 Hz supply. Substations receives power at very high voltage from 3 phase transmission lines. this high voltage is step down to 3.3KV where as frequency is reduced from 50Hz to 16 2/3 Hz using frequency converters.

Induction motors employed in these section are quite simple, robust & give trouble free operation. At speeds above synchronous speed it acts a generator. They possess also a regenerative braking during descent on gradient.

Disadvantages

- speed-torque characteristics are not suitable for parallel operation
- At crossings & junctions overhead lines becomes complicated
- due to constant speed characteristics its not suitable for traction work.

④ Composite system

Two Composite s/m's employed are

- (a) single to 3 phase ac (Kando s/m)
- (b) single phase to DC

(a) Single phase to 3 phase AC on trolley s/m

→ operating voltage is single phase 16KV, 50Hz is converted into 3 phase supply by means of phase Converter carried in locomotive

→ the main advantage is 3 phase s/m is replaced by single phase s/m. By using SCR as inverter it is possible to get variable frequency 3 phase supply at $\frac{1}{2}$ to 9Hz frequency. 3 phase motor develops very high starting torque.

(b) Single phase AC to DC:

single phase 25KV 50Hz is step down by transformer provided in the locomotive.

→ this step down single phase AC is converted to DC which drives DC series motor.

advantages.

- High starting torque
- High adhesion coefficient
- requires less no. of substations
- design of substation is simple
- Installation cost is less

Disadvantages

- single phase supply is not a balanced supply
- produces interference in tele communications

Review of existing traction s/m in india

- First electric traction is introduced in year 1925.
- It uses 1.5KV or 1500V DC & 1st electric train ran b/w Bombay's Victoria terminal & Kurla line of total distance 9.5 miles.
- In the year 1957 Govt decided to adopt 25KV 50Hz AC traction. The 1st actual train using 25KV AC was on Dec 15 1959 from Kendposi to Rajkhari Swan section.
- In the year 1925 first electric traction uses 1500V DC supply can be obtained from substations equipped with rotary converters.
- Due to advancement rotary converters is replaced by mercury arc rectifiers. Again most recent advancements these are completely replaced by solid state semi-conductors which can increase the levels from 1.5KV - 3KV DC.
- upto Mar 31 2016, nearly 42.42% of railway network is completely electrified.
- In present scenario 51.2% of passenger & 65.02% freight traffic are operated by electric traction.
- Nearly 27,999 km of traction is converted by electrified.

Special features of traction motors

Main features considering for traction motors are

- (1) Mechanical features
- (2) Electrical features

- It must have high mechanical strength & should withstand with mechanical vibrations.
- traction motor used is completely enclosed type to protect from personal safety & also protect from moisture & dust
- It must have compact in size, to arrange easily beneath the locomotive coach.
- A traction motor have minimum weight to reduce fuel consumption with increased load capacity.
- It must be mechanically strength & robust in construction.
- It must have high coefficient of adhesive
- It must have low center of gravity.

(2) Electrical features

(1) High starting torque: It must have high starting torque during the loading condition should able to provide quick acceleration at starting.

→ speed control: Control of traction motor is completely electrically controlled. This is necessary for frequent starting & stopping in urban & suburban areas.

Dynamic & regenerative braking:

Traction motors are dynamically withstand voltage fluctuations during regenerative braking.

Temperature: Traction motor while operating generates high temperatures. Traction motor should have the capability to ~~handle~~ handling transient conditions.

overload Capacity: Traction motors should have the capability of handling excessive loads.

parallel running: More number of motors need to run in parallel to carry more load. Therefore traction motor speed-torque & Current-torque characteristics must be same to share total load equally.

Commutation: Traction motors must have better commutation to avoid sparking at brushes & commutator segments.

Speed time Curves for different services

A Curve plotted with time in seconds or minutes in abscissa (x-axis) & speed in kmph as ordinate (y-axis) at different instants from start to stop is known as speed-time Curve.

Speed time Curves gives information about motion of train.

Importance of speed-time Curve

- ① Speed at various time instants after the start of run.

- (2) Gives the energy consumption
- (3) upward slope gives acceleration & downward slope gives retardation
- (4) area under curve represent distance covered in corresponding time.

Speed-time Curves for various services

Main line service

→ acceleration & retardation is not important due distance of run is large

→ Requirements of main line service

(i) High maximum speed

(ii) Minimum cost of overhead structure

Cost of main line service is reduced by using single phase overhead structure

→ single phase means single conductor, cost & no: of conductors is reduced.

→ If high voltage is used for distribution, smaller diameter conductors is used which reduces the current flow.

→ If high voltage is used, distance b/w substation increases, this reduces the no: of substations

→ Initial maintenance & operating cost of AC substations are less

→ Single phase to 3 phase or single phase to DC or Composite s/m is easily gained.

→ Speed time Curve has following components

(i) Acceleration

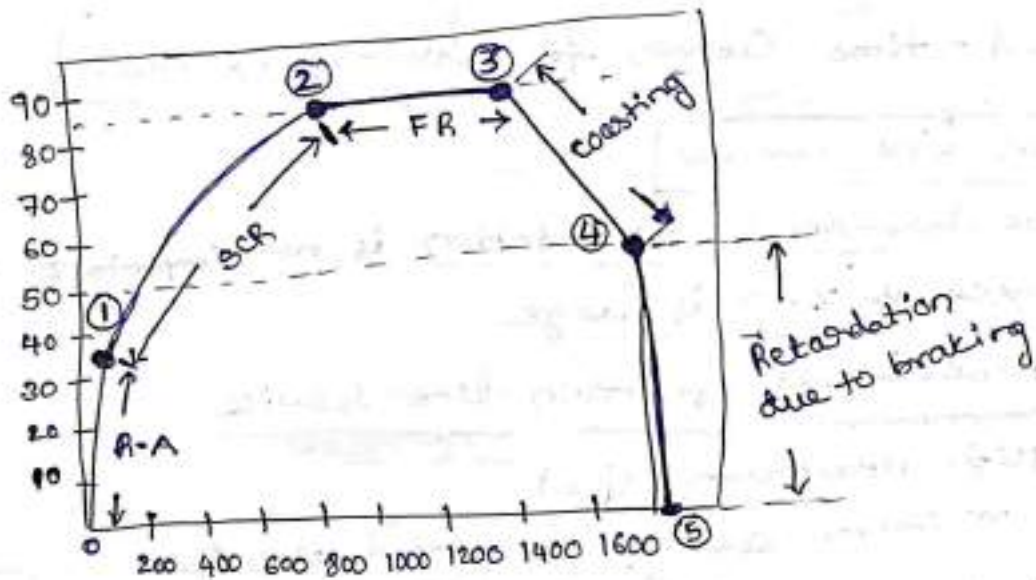
(a) Rheostatic acceleration

(b) Speed curve running

(ii) Free running

(III) Coasting

(IV) Retardation due to braking



RA → Rheostatic Acceleration

SCR → Speed Curve Running

FR → free running

$$T d\phi I d \frac{1}{N} \propto R$$

$$R \propto \frac{V}{I}$$

① Acceleration It has 2 components

② Rheostatic & Constant acceleration during notching up

Acceleration of train is maintained during this period indicated as 0-1.

* This is obtained by increasing the starting resistance slowly until the constant voltage appears across the motor

$I \rightarrow \text{constant}$
 $V \rightarrow \uparrow$
 $R \rightarrow \uparrow$

* From section 0-1 acceleration remain constant & tractive effort also constant.

* So in this mode current is kept constant & voltage applied to the increases by gradually increasing the starting resistance.

(ii) Speed Curve Running & Acceleration on Speed Curve

during speed curve running region from 1 to 2 voltage across motor is kept constant & current starts decreasing with increase in speed.

V kept constant

$I \downarrow N \uparrow$

→ this current decreases until the rated current achieves.

→ during this period, acceleration decreases with increase in speed & finally it becomes zero.

→ At this speed tractive effort developed by motor exactly equals to resistance to motion of train.

(iii) free Running & Constant speed Running

during this period i.e. region from 2 to 3, train attains the maximum speed, during this period train speed is constant & draws constant power.

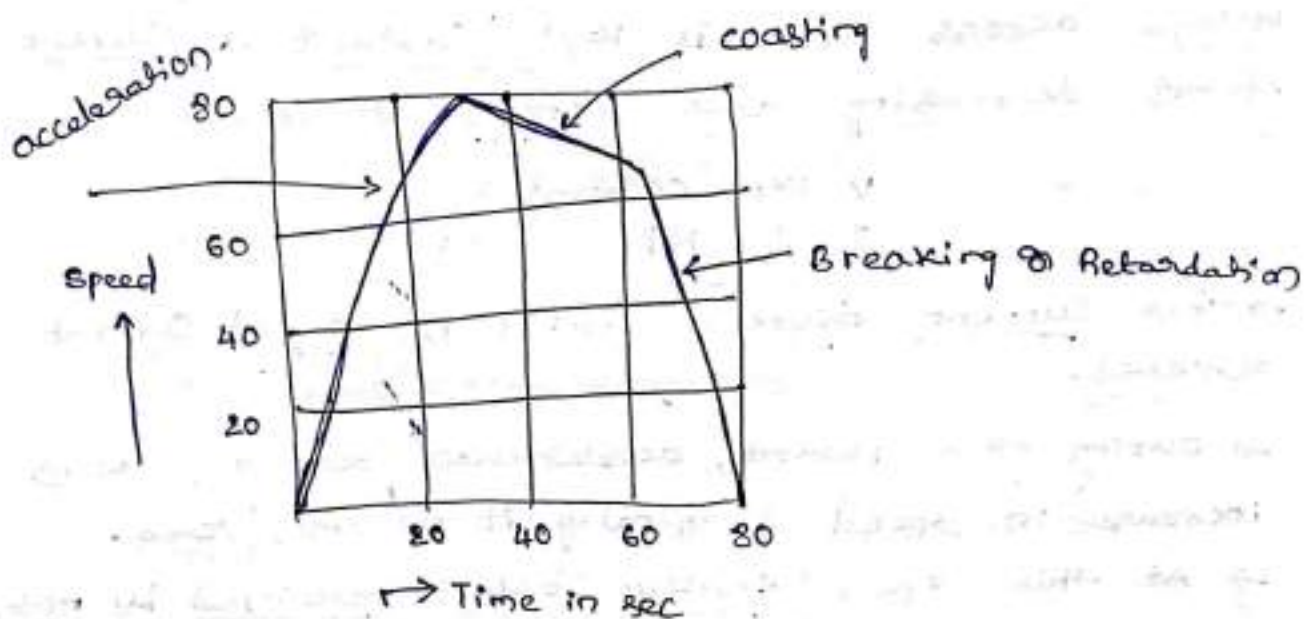
(iii) Coasting: At the end of free running period, power supply is cut off & train is allowed to run under its own momentum. The region of coasting is indicated as 3-4.

The speed of train decreases due to resistance to the motion of train. The speed at rate at which speed decreases during coasting period is coasting retardation.

(iv) Retardation & Braking period

At end of coasting period i.e. from region 4-5, the brakes are applied to bring the train to rest. During this period speed decreases rapidly finally reaches to zero.

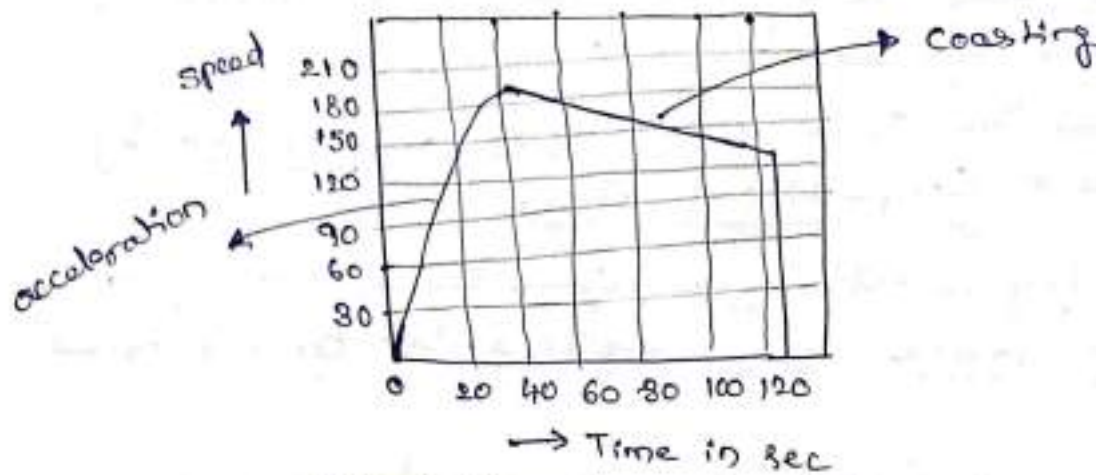
Typical Speed time Curves for urban & city service



- In this service distance between stations is very small i.e. 0.75 km to 1 km. Therefore time required for this run is very small.
- Acceleration & retardation must be very high to meet the speed
 - In this there is no free running period due to small distance b/w stations.
 - The values of acceleration is b/w 1.5 & 4 km/hr/s & value of retardation 3 & 4 km/hr/s

Speed time Curves for suburban service

- ① Requires quick acceleration & retardation due to frequent starting & stopping
- ② Distance b/w 2 stops is little larger than the urban service i.e. 1 to 3 km.
- ③ Here also no free running is possible
- ④ Coasting period is comparatively longer
- ⑤ Mainly these services uses DC supply.



Speed time Curves for ^{sub}urban service
Important terms in traction

crest speed: Maximum speed of a train during
the run

Average speed: Mean of the speeds from start to
 stop

$$\text{Average speed} = \frac{\text{Distance b/w the stops}}{\text{Actual time of run (T)}}$$

Scheduled speed: - Ratio of distance b/w the stops &
total time of run including the stop time

$$\text{schedule speed} = \frac{\text{Distance b/w stops}}{\text{Actual time run + stop time}}$$

Scheduled speed is always smaller than
 average speed.

Simplified Speed (train) time Curves

→ performance of service at different schedule
 speeds, speed time Curves are replaced by simple
 geometric shaped Curves. These Curves are
 quadrilateral & trapezoidal Curves.

- speed time Curve ^{of} urban service is replaced by equivalent quadrilateral Curve
- Speed time Curve of mainline is replaced by equivalent trapezoidal Curve
- In trapezoidal Curve speed Curve during Coasting periods are replaced by constant speed period
- In quadrilateral Curve, initial acceleration & Coasting periods are extended.

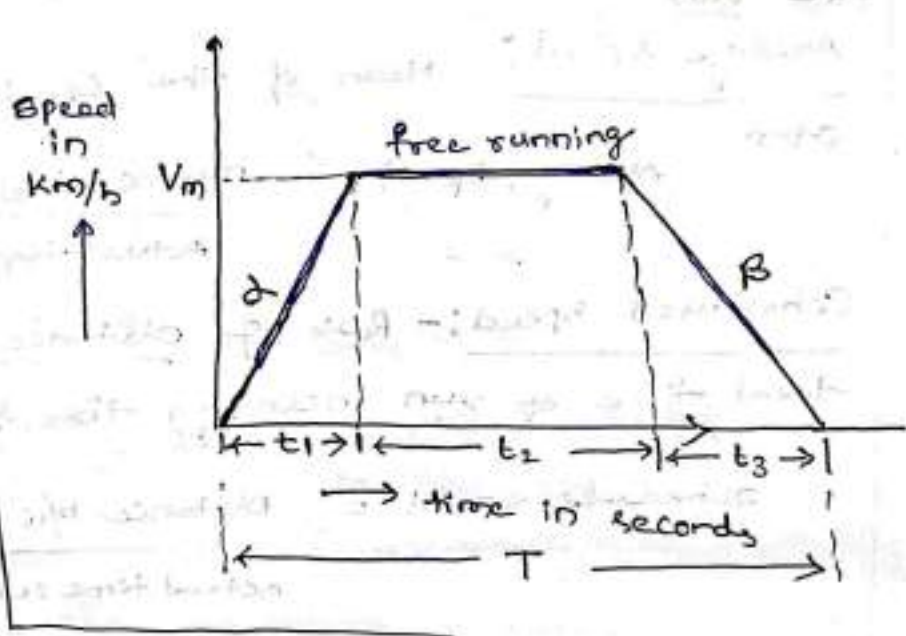
⇒ Calculations of Trapezoidal Speed-time Curve:

Let α = acceleration in km/h/s

β = Retardation in km/h/s

V_m = crest speed in kmph

T = total time of run in sec



Time for acceleration in sec, $t_1 = \frac{V_m}{\alpha}$

" " Retardation in sec, $t_3 = \frac{V_m}{\beta}$

free running be $t_2 = T - (t_1 + t_3)$

$$t_2 = T - \left[\frac{V_m}{\alpha} + \frac{V_m}{\beta} \right] = T - V_m \left[\frac{1}{\alpha} + \frac{1}{\beta} \right]$$

$$T = t_1 + t_2 + t_3$$

$$t_2 = T - (t_1 + t_3)$$

Let 's' be total distance travelled on sun in km

s = Distance travelled during [acceleration + free running + braking or Retardation]

$$s = \frac{1}{2} V_m \cdot \frac{t_1}{3600} + V_m \cdot \frac{t_2}{3600} + \frac{1}{2} V_m \cdot \frac{t_3}{3600} \rightarrow \textcircled{1}$$

substitute $t_1 = \frac{V_m}{\alpha}$, $t_2 = T - \left[\frac{V_m}{\alpha} + \frac{V_m}{\beta} \right]$

$t_3 = \frac{V_m}{\beta}$ in above eqn $\textcircled{1}$ we get

$$s = \frac{V_m^2}{7200\alpha} + \frac{V_m}{3600} \left[T - \left\{ \frac{V_m}{\alpha} + \frac{V_m}{\beta} \right\} \right] + \frac{V_m^2}{7200\beta}$$

$$s = \frac{V_m^2}{7200\alpha} + \frac{V_m \cdot T}{3600} - \frac{V_m^2}{3600\alpha} - \frac{V_m^2}{3600\beta} + \frac{V_m^2}{7200\beta} \rightarrow \textcircled{1}$$

$$= V_m^2 \left[\frac{1}{7200\alpha} + \frac{T}{3600} - \frac{1}{3600\alpha} - \frac{1}{3600\beta} + \frac{1}{7200\beta} \right]$$

$$s = V_m^2 \left[\frac{1}{3600\alpha} + \frac{1}{3600\beta} + \frac{T}{3600} \right] = \frac{V_m^2}{3600} \left[\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{T} \right]$$

$$s \cdot 3600 = \left[\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{T} \right] V_m^2 \Rightarrow \frac{1}{\alpha} + \frac{1}{\beta} = k$$

$$s \cdot 3600 = k V_m^2 + \frac{V_m^2}{T} \Rightarrow s \cdot 3600 = \frac{k V_m^2 T + V_m^2}{T}$$

Rough work.

$$\Rightarrow s T 3600 = k V_m^2 T + V_m^2$$

$$k V_m^2 T + V_m^2 - s T 3600 = 0$$

$$T [k V_m^2 - s \cdot 3600] + V_m^2 = 0$$

Rough work

$$s = V_m^2 \left[\frac{1}{2 \cdot 3600\alpha} + \frac{T}{3600} - \frac{1}{3600\alpha} - \frac{1}{3600\beta} + \frac{1}{2 \cdot 3600\beta} \right]$$

$$s = \frac{V_m^2}{3600} \left[\frac{1}{2\alpha} - \frac{1}{\alpha} - \frac{1}{\beta} + \frac{1}{2\beta} \right] + \frac{V_m T}{3600}$$

$$S = \frac{V_m^2}{3600} * \left[\frac{1}{2\alpha} \right] + \frac{V_m^2}{3600} * \left[\frac{1}{2\beta} \right] - \frac{V_m^2}{3600\alpha} - \frac{V_m^2}{3600\beta} + \frac{V_m T}{3600}$$

$$S = \frac{V_m^2}{3600} \left[\frac{1}{2\alpha} - \frac{1}{\alpha} \right] + \frac{V_m^2}{3600} \left[\frac{1}{2\beta} - \frac{1}{\beta} \right] + \frac{V_m T}{3600}$$

$$S = \frac{V_m^2}{3600} \left[\frac{1}{\alpha} \left\{ \frac{1}{2} - 1 \right\} \right] + \frac{V_m^2}{3600} \left[\frac{1}{\beta} \left\{ \frac{1}{2} - 1 \right\} \right] + \frac{V_m T}{3600}$$

$$S = \frac{V_m^2}{3600} \left[\frac{-1}{2\alpha} \right] + \frac{V_m^2}{3600} \left[\frac{-1}{2\beta} \right] + \frac{V_m T}{3600}$$

$$S = -\frac{V_m^2}{3600} * \frac{1}{2\alpha} - \frac{V_m^2}{3600} * \frac{1}{2\beta} + \frac{V_m T}{3600}$$

$$S = -\frac{V_m^2}{3600} \left[\frac{1}{2\alpha} + \frac{1}{2\beta} \right] + \frac{V_m T}{3600} \Rightarrow -\frac{V_m^2}{3600} [K] + \frac{V_m T}{3600}$$

Since $\frac{1}{2\alpha} + \frac{1}{2\beta} = K$

$$S = -\frac{V_m^2}{3600} [K] + \frac{V_m T}{3600} \Rightarrow \boxed{3600S = -V_m^2 * K + V_m T}$$

↳ ①

$$V_m^2 * K + 3600S - V_m T = 0 \Rightarrow V_m^2 * K - V_m T + 3600S = 0$$

by quadratic equation $ax^2 + bx + c$, its

Complex roots are $\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = 0$

$$a = K, b = -T$$

$$c = 3600S$$

$$\frac{-(-T) \pm \sqrt{T^2 - (4K * 3600)S}}{2K} = \frac{T \pm \sqrt{T^2 - 4K * 3600S}}{\sqrt{4K^2}} = 0$$

$$\frac{T}{2K} \pm \sqrt{\frac{T^2}{4K^2} - \frac{4K * 3600S}{4K^2}} = \boxed{\frac{T}{2K} \pm \sqrt{\frac{T^2}{4K^2} - \frac{3600S}{K}}}$$

+ve sign will be higher than that is possible in practice. So -ve sign will be used

$$V_m = \frac{T}{2K} - \sqrt{\frac{T^2}{4K^2} - \frac{3600S}{K}}$$

Consider equation ①

$$3600S = V_m T - V_m^2 K$$

$$V_m^2 K = V_m T - 3600S$$

$$K = \frac{V_m T - 3600S}{V_m^2} = \frac{T}{V_m} - \frac{S \times 3600}{V_m^2}$$

$$K = \frac{3600}{V_m^2} \left[\frac{V_m T}{3600} - S \right], \text{ Take 'S' as common}$$

$$K = \frac{3600}{V_m^2} \left[\frac{1}{S} \left\{ \frac{V_m T}{3600} \right\} - 1 \right] = \frac{3600 \times S}{V_m^2} \left[\frac{V_m T}{S \times 3600} - 1 \right]$$

$$V_a = \frac{S}{\frac{T}{3600}} = \frac{S \times 3600}{T}$$

average speed = V_a

$$V_a = \frac{\text{distance of stops}}{\text{Time run}}$$

$$= \frac{S}{T \text{ in hrs}}$$

T in hrs

$$1 \text{ hr} = 60 \text{ min}$$

$$1 \text{ hr} = 60 \times 60 \text{ sec}$$

$$1 \text{ hr} = 3600 \text{ sec}$$

$$1 \text{ sec} = \frac{1 \text{ hr}}{3600}$$

$$T_{\text{sec}} = \frac{T}{3600} \text{ hr}$$

$$V_a = \frac{S}{\frac{T}{3600}} = \frac{S \times 3600}{T}$$

$$K = \frac{3600 \times S}{V_m^2} \left[\frac{V_m}{V_a} - 1 \right]$$

we know that

$$K = \frac{1}{2a} + \frac{1}{2b} = \frac{1}{2} \left[\frac{1}{a} + \frac{1}{b} \right]$$

$$K = \frac{1}{2} \left[\frac{1}{a} + \frac{1}{b} \right] = \frac{3600 \times S}{V_m^2} \left[\frac{V_m}{V_a} - 1 \right]$$

$$\left[\frac{1}{a} + \frac{1}{b} \right] = \frac{7200 \times S}{V_m^2} \left[\frac{V_m}{V_a} - 1 \right]$$

Problem suburban train runs with average speed
 $V_a = 45 \text{ kmph}$, distance b/w stations is 1.8 km apart.
 Values of acceleration & retardation are 2 kmph/s &
 3 kmph/s . Find maximum speed of train assume
 trapezoidal speed time curves.

average speed $V_a = 45 \text{ kmph}$

distance b/w stations is $s = 1.8 \text{ km}$

Acceleration $\alpha = 2 \text{ kmph/s}$

Retardation $\beta = 3 \text{ kmph/s}$

we know that average speed

$$V_a = \frac{\text{distance}}{\text{Time in hr}} = \frac{s}{\frac{T}{3600}} = \boxed{\frac{s \times 3600}{T}}$$

where $T = \text{Total time of run}$

$$T = \frac{s \times 3600}{V_a} = \frac{1.8 \times 3600}{45} = 144 \text{ sec}$$

from Trapezoidal Curve maximum speed..

$$V_m = \frac{T}{2K} - \sqrt{\frac{T^2}{4K^2} - \frac{3600S}{K}}$$

$$\text{where } K = \frac{1}{2} \left[\frac{1}{\alpha} + \frac{1}{\beta} \right] = \frac{1}{2} \left[\frac{1}{2} + \frac{1}{3} \right] = 0.4165 \text{ m/s}$$

$$V_m = \frac{144}{2 \times 0.4165} - \sqrt{\left(\frac{144}{4 \times 0.4165} \right)^2 - \frac{3600 \times 1.8}{0.4165}} = 53.19 \text{ kmph}$$

Problem Assume a simplified speed time Curve for a
 train which has got schedule speed $V_0 = \text{Scheduled}$
 speed = 50 kmph , distance b/w stops $s = 2 \text{ km}$ apart.
 Find the crest speed of train over the run, if
 the stop is of 30 sec duration & values acceleration
 are 2.5 kmph/s & 3.4 kmph/s .

sol V_s : Scheduled speed = 50 kmph

Distance b/w stops $S = 2 \text{ km} =$

Crest speed or maximum speed = ?

$V_m = ?$

stop time duration is $t_s = 30 \text{ sec}$

Acceleration $\alpha = 2.5 \text{ kmphps}$

deceleration $\beta = 3.4 \text{ kmphps}$

→ we know that Scheduled speed

$$V_s = \frac{\text{Distance b/w stops}}{\text{Actual run time } (t_r) + \text{stop time } (t_s)}$$

$$\text{Total time of run } T = t_r + t_s = \frac{\text{Distance}}{V_s} = \frac{S \times 3600}{V_s}$$

$$T = \frac{2 \times 3600}{50} = 144 \text{ sec}$$

$$\text{Actual run time } (t_r) = T - t_s = 144 - 30 = 114 \text{ sec}$$

$$\text{Maximum speed } V_m = \frac{T}{2K} - \sqrt{\left(\frac{T}{4K}\right)^2 - \frac{3600S}{K}}$$

$$K = \frac{1}{-2} \left[\frac{1}{2.5} + \frac{1}{3.4} \right] = 0.3471$$

$$V_m = 85.1 \text{ kmph}$$

⊕ Acceleration of train $\alpha = 1.5 \text{ kmphps}$, braked at 3 kmphps . train has average speed $V_a = 45 \text{ kmph}$, a level track of 1500 mtrs b/w stations. Determine actual time of run (ii) maximum speed (iii) distance travelled before brakes are applied (iv) scheduled speed. Assume time for stop as 15 sec & run according to trapezoidal speed time Curve.

$$\alpha = 1.5 \text{ kmphps}$$

$$\beta = 3 \text{ kmphps}$$

$$V_a = 45 \text{ kmph, distance b/w stops } S = 1500 \text{ mtrs} = 1.5 \text{ km}$$

$$\text{stop time } t_s = 15 \text{ sec}$$

$$1500 \text{ m} = 1.5 \text{ km}$$

$$\frac{1500}{1000} = \frac{1.5 \text{ km}}{1000}$$

$$\textcircled{1} \text{ Average speed } V_a = \frac{\text{Distance b/w stops}}{\text{Time of run}} = \frac{S \times 3600}{T}$$

$$\text{time of run } T = \frac{S \times 3600}{V_a} = \frac{1500 \times 3600}{45}$$

$$\text{Actual time of run } T = \frac{1.5 \times 3600}{45} = 120 \text{ sec}$$

$$\textcircled{2} \text{ Maximum speed } V_m = \frac{T}{2K} - \sqrt{\left(\frac{T}{2K}\right)^2 - \frac{S \times 3600}{K}}$$

$$K = \frac{1}{2} \left[\frac{1}{\alpha} + \frac{1}{\beta} \right] = \frac{1}{2} \left[\frac{1}{1.5} + \frac{1}{3} \right] = 0.5$$

$$V_m = \frac{120}{2 \times 0.5} - \sqrt{\left(\frac{120}{2 \times 0.5}\right)^2 - \left(\frac{1.5 \times 3600}{0.5}\right)} = 60 \text{ kmph}$$

(iii) Brake time or Braking time or retardation time

$$t_3 = \frac{V_m}{\beta} = \frac{60}{3} = 20 \text{ secs}$$

Distance travelled during braking (S_3)

$$S_3 = \frac{V_m \times t_3}{2} = \frac{60 \times 20}{2 \times 3600} = \frac{1}{6} = 0.166 \text{ km}$$

Distance travelled before brakes are applied

$$S_{BB} = S - S_{AB}$$

$$S_{AB} = S_3$$

→ distance b/w stops - distance travelled after braking

$$S_{BB} = 1.5 - 0.166 = 1.33 \text{ km}$$

(iv) Schedule speed

$$V_s = \frac{\text{Distance b/w stops}}{\text{Schedule time}} = \frac{S \times 3600}{T_s + T}$$

$$V_s = \frac{1.5 \times 3600}{120 + 15} = 40 \text{ Kmph}$$

② A train run b/w 2 stations 1.6 km apart at an average speed (V_a) = 40 Kmph

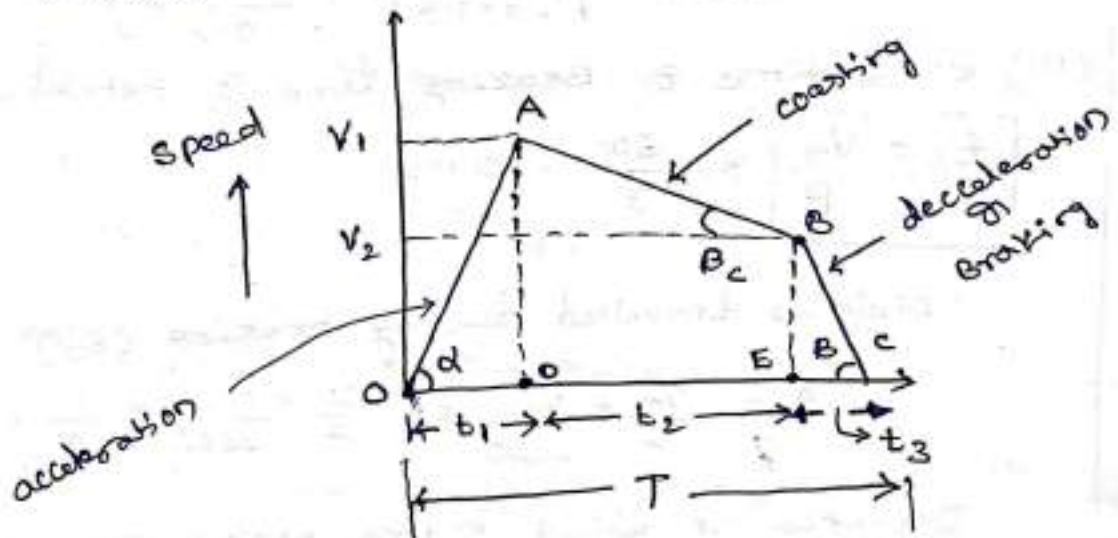
Quadrilateral speed time Curve

→ This Curve is preferred if distance b/w stops is less.

→ It is used to evaluate the speed in urban & suburban services.

The following are the assumptions.

- No free running period
- Acceleration & deceleration also included.
- Initial acceleration period is high compared to coasting period.



Let V_1 → speed at end of acceleration

V_2 → " " " " " coasting

α → acceleration kmph

β → deceleration or braking or retardation in kmph

t_1 → acceleration period, t_2 → coasting time

t_3 → braking or retardation or deceleration time

$$t_1 = \frac{V_1}{\alpha} \quad t_2 = \frac{V_1 - V_2}{\beta_c} \quad t_3 = \frac{V_2}{\beta}$$

Total distance travelled in km = Area of acceleration + area of coasting + area of deceleration

$$S = S_a + S_c + S_d$$

$\begin{cases} \rightarrow \text{distance travelled during deceleration} \\ \rightarrow \text{distance " " during coasting} \\ \rightarrow \text{distance travelled during acceleration} \end{cases}$

$$S = \frac{V_1 \times t_1}{2} + \left(\frac{V_1 + V_2}{2}\right) \times \frac{t_2}{3600} + \frac{V_2 \times t_3}{2} \times \frac{1}{3600}$$

$$S = \frac{V_1 \times t_1}{7200} + \frac{V_1 \times t_2}{7200} + \frac{V_2 \times t_2}{7200} + \frac{V_2 \times t_3}{7200}$$

$$S = \frac{V_1}{7200} (t_1 + t_2) + \frac{V_2}{7200} (t_2 + t_3) \rightarrow \textcircled{1}$$

Total time $T = t_1 + t_2 + t_3 \Rightarrow \boxed{t_2 = T - t_1 - t_3}$

have $t_1 + t_2 = T - t_3$ & $t_2 + t_3 = T - t_1$

so we $t_1 + t_2$ & $t_2 + t_3$ are to be substituted in equation $\textcircled{1}$

$$S = \frac{V_1}{7200} [T - t_3] + \frac{V_2}{7200} [T - t_1]$$

$$= \frac{T}{7200} [V_1 + V_2] - \frac{V_1 t_3}{7200} - \frac{V_2 t_1}{7200}$$

$$t_3 = \frac{V_2}{\beta}$$

$$t_1 = \frac{V_1}{\alpha}$$

$$S = \frac{T}{7200} [V_1 + V_2] - \frac{V_1 \times V_2}{7200 \beta} - \frac{V_2 \times V_1}{7200 \alpha}$$

$$S \times 7200 = T [V_1 + V_2] - \frac{V_1 V_2}{\beta} - \frac{V_1 \times V_2}{\alpha}$$

$$S \times 7200 = T [V_1 + V_2] - V_1 V_2 \left[\frac{1}{\alpha} + \frac{1}{\beta} \right]$$

$$S = \frac{1}{7200} \left[T(V_1 + V_2) - V_1 V_2 \left\{ \frac{1}{\alpha} + \frac{1}{\beta} \right\} \right]$$

we know that $t_2 = \frac{V_1 - V_2}{\beta_c} \Rightarrow V_1 - V_2 = t_2 \beta_c$

$$V_2 = V_1 - t_2 \times \beta_c = V_1 - \beta_c (T - t_1 - t_3)$$

$$V_2 = V_1 - \beta_c \left[T - \frac{V_1}{\alpha} - \frac{V_2}{\beta} \right]$$

$$V_2 = V_1 - \beta_c \left(T - \frac{V_1}{\alpha} \right) + \beta_c \frac{V_2}{\beta}$$

$$V_2 - \frac{V_2 \beta_c}{\beta} = V_1 - \beta_c \left(T - \frac{V_1}{\alpha} \right)$$

$$V_2 \left[1 - \frac{\beta_c}{\beta} \right] = V_1 - \beta_c \left[T - \frac{V_1}{\alpha} \right]$$

$$V_2 = \frac{V_1 - \beta_c \left(T - \frac{V_1}{\alpha} \right)}{1 - \frac{\beta_c}{\beta}}$$

$$\textcircled{1} \frac{\partial V_2}{\partial T} = \frac{\partial}{\partial T} \left(\frac{V_1 - \beta_c \left(T - \frac{V_1}{\alpha} \right)}{1 - \frac{\beta_c}{\beta}} \right)$$

$$\left[\frac{\partial}{\partial T} \left(T - \frac{V_1}{\alpha} \right) \right] \frac{1}{1 - \frac{\beta_c}{\beta}} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

$$\frac{\partial V_2}{\partial T} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

of benefit/cost and the zero profit condition and the

① interest

$$\frac{\partial V_2}{\partial T} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

$$\left[\frac{\partial}{\partial T} \left(T - \frac{V_1}{\alpha} \right) \right] \frac{1}{1 - \frac{\beta_c}{\beta}} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

$$\frac{\partial V_2}{\partial T} = \frac{1}{1 - \frac{\beta_c}{\beta}} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

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$$\left[\frac{\partial}{\partial T} \left(T - \frac{V_1}{\alpha} \right) \right] \frac{1}{1 - \frac{\beta_c}{\beta}} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

$$\left[\frac{\partial}{\partial T} \left(T - \frac{V_1}{\alpha} \right) \right] \frac{1}{1 - \frac{\beta_c}{\beta}} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

of benefit/cost and the zero profit condition and the

$$\left(\frac{\partial}{\partial T} \left(T - \frac{V_1}{\alpha} \right) \right) \frac{1}{1 - \frac{\beta_c}{\beta}} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

$$\left[\frac{\partial}{\partial T} \left(T - \frac{V_1}{\alpha} \right) \right] \frac{1}{1 - \frac{\beta_c}{\beta}} = \frac{1}{1 - \frac{\beta_c}{\beta}}$$

$$V_2 = \frac{V_1 - \beta_c \left(T - \frac{V_1}{a} \right)}{1 - \frac{\beta_c}{\beta}}$$

Problem

A train is required to run b/w 2 stations 2 km apart at an average speed $V_a = 40 \text{ kmph}$. If maximum speed V_m is 60 kmph , acceleration is 2 kmph/s , coasting retardation $(\beta_c) = 0.15 \text{ kmph/s}$ and braking retardation 3 kmph/s .

Determine duration of acceleration, coasting and braking period. The run is made according to quadrilateral speed time curve

Sol

Distance b/w stations $S = 2 \text{ km}$

average speed $V_a = 40 \text{ kmph}$

Maximum speed $V_m = 60 \text{ kmph}$

$a = 2 \text{ kmph/s}$, Coasting retardation $\beta_c = 0.15 \text{ kmph/s}$

braking retardation, $\beta = 3 \text{ kmph/s}$.

$$V_1 = V_m = 60 \text{ kmph}$$

for
Time of acceleration $t_1 = \frac{V_1}{a} = \frac{V_m}{a} = \frac{60}{2} = 30 \text{ kmph}$

Time of run $T = \frac{3600 \times S}{V_a} = \frac{180 \text{ sec}}{40}$

Duration of coasting $t_2 = \frac{V_m - V_2}{\beta_c} = \frac{60 - V_2}{0.15}$

Duration of braking $t_3 = \frac{V_2}{\beta} = \frac{V_2}{3} \text{ sec}$

Time of run $T = t_1 + t_2 + t_3$

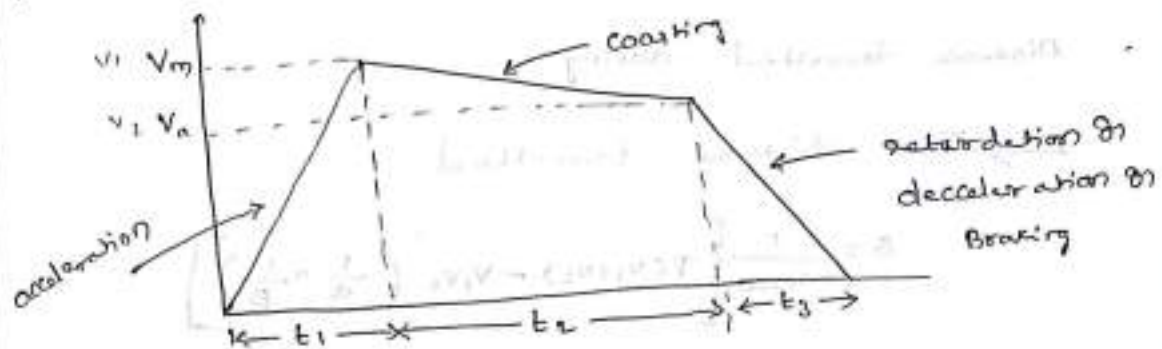
$$180 = 30 + \frac{60 - V_2}{0.15} + \frac{V_2}{3}$$

$$V_2 = \frac{250}{6.334} = 39.47 \text{ kmph}$$

$$\text{duration of coasting } t_2 = \frac{V_m - V_2}{\beta_c} = 136.87 \text{ sec}$$

$$\text{duration of braking } t_3 = \frac{V_2}{\beta} = 13.16 \text{ sec}$$

- ⑥ Distance b/w 2 stations 5 km, $V_a = 50 \text{ kmph}$, $\alpha = 3 \text{ kmph/s}$, $\beta_c = 0.2 \text{ kmph/s}$, $\beta = 4 \text{ kmph/s}$. Taking quadrilateral speed-time curve. Determine duration of acceleration, coasting & braking periods and distance covered during each period.



sol

Distance b/w stops $S = 5 \text{ km}$

$V_a = 50 \text{ kmph}$

Acceleration $\alpha = 3 \text{ kmph/s}$

Braking retardation $\beta = 4 \text{ kmph/s}$

Coasting retardation $\beta_c = 0.2 \text{ kmph/s}$

time for acceleration $t_1 = ?$

time for coasting $t_2 = ?$

time for braking $t_3 = ?$

Distance travelled during acceleration $S_1 = ?$

Distance travelled during coasting $S_2 = ?$

Distance travelled during braking $S_3 = ?$

$$\text{we know that } V_a = \frac{\text{Distance b/w stop}}{\text{Actual run time}} = \frac{S + 3600}{T}$$

$$\text{actual run time } T = \frac{S + 3600}{V_a} = \frac{5 + 3600}{50} = 360 \text{ sec}$$

Speed at the end of coasting period

$$V_2 = \frac{V_1 - \beta_c \left(T - \frac{V_1}{\alpha} \right)}{1 - \frac{\beta_c}{\beta}}$$

$$= \frac{V_1 - 0.2 \left(360 - \frac{V_1}{3} \right)}{1 - \frac{0.2}{0.4}}$$

$$V_2 = 1.1288V_1 - 75.79$$

Distance travelled during

→ Total distance travelled

$$S = \frac{1}{7200} \left[T(V_1 + V_2) - V_1 V_2 \left(\frac{1}{a} + \frac{1}{b} \right) \right]$$

$$S = \frac{1}{7200} \left[360 \left(V_1 + 1.1288V_1 - 75.79 \right) - V_1 \left(1.1288V_1 - 75.79 \right) \left(\frac{1}{3} + \frac{1}{4} \right) \right]$$

$$S \times 7200 = 360 \times V_1 + 404.208 V_1 - 27284.4 - \left(1.1288V_1^2 - 75.79V_1 \right) 0.58$$

$$= 360 \times V_1 + 404.208 V_1 - 27284.4 + 0.6512 V_1^2 + 44.208 V_1$$

$$36000 = 0.655V_1^2 + 808.416V_1 + 27284.4$$

$$0.655V_1^2 - 808.416V_1 + 63284.4 = 0 \quad \left\{ \begin{array}{l} V_1^2 - \frac{808.416V_1}{0.655} + \frac{63284.4}{0.655} = 0 \end{array} \right.$$

$a = 0.655, b = -808.416, \Delta = 63284.4$

$$V_1 = \frac{808.416 \pm \sqrt{(808.416)^2 - 4 \times 0.655 \times 63284.4}}{2 \times 0.655}$$

$$V_1 = \frac{808.416 \pm \sqrt{487731.30}}{1.31}$$

$$V_1^2 - 1234.22 V_1 + 96617.40 = 0$$

$$V_1 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{(1234.22) \pm \sqrt{(1234.22)^2 - 4 \times 96617.41}}{2}$$

$$V_1 = \frac{1234.22 - 1066.22}{2} = 84$$

Consider the -ve sign

$$V_2 = 1.1228 V_1 - 75.79 = 1.1228 \times 84 - (75.79) = 27.361 \text{ kmph}$$

→ Duration of acceleration or time for acceleration

$$t_1 = \frac{V_1}{\alpha} = \frac{84}{3} = 28 \text{ seconds}$$

→ Duration of coasting retardation

$$t_2 = \frac{84 - 27.361}{0.2} = 283.19 \text{ sec}$$

$$t_2 = \frac{V_1 - V_2}{\beta_c}$$

→ Duration of braking or retardation or deceleration

$$t_3 = \frac{V_2}{\beta} = \frac{27.361}{4} = 6.841 \text{ sec}$$

* → Distance travelled during acceleration

$$S_1 = \frac{V_1 \times t_1}{2 \times 3600} = \frac{(27.361) \times 28}{2 \times 3600} = 0.3267 \text{ km}$$

* Distance travelled during coasting retardation

$$S_2 = \left(\frac{V_1 + V_2}{2} \right) \times \frac{t_2}{3600} = \left(\frac{84 + 27.361}{2} \right) \times \frac{283.19}{3600} = 4.38 \text{ km}$$

* Distance travelled during deceleration or retardation or braking

$$S_3 = \frac{V_2 \times t_3}{2 \times 3600} = \frac{27.361 \times 6.841}{2 \times 3600} = 93.59 \text{ km}$$

⑧ A train is required to run b/w stations 2 kms apart at an average speed $V_a = 40$ kmph. If the maximum speed is 60 kmph, acceleration is 2 kmph/s, coasting retardation is 0.15 kmph/s and braking retardation 3 kmph/s. Determine duration of acceleration, coasting retardation and braking periods.

sol average speed $V_a = 40$ kmph

maximum speed $V_m = 60$ kmph

acceleration $\alpha = 2$ kmph/s

coasting retardation $\beta_c = 0.15$ kmph/s

braking retardation $\beta = 3$ kmph/s

distance b/w stations $S = 2$ kms



Given average speed $V_a = \frac{S \times 3600}{T}$

actual running time $(t_r) = T = \frac{2 \times 3600}{40} = 180 \text{ sec}$

we know that speed at the end of coasting period

$$V_2 = V_1 - \beta_c \left(T - \frac{V_1}{\alpha} \right)$$

where $V_1 =$ maximum speed of train $= V_m$

$$V_2 = \frac{60 - 0.15 \left(180 - \frac{60}{2} \right)}{1 - \frac{0.15}{2}} = 39.47 \text{ kmph}$$

duration time during acceleration

$$t_1 = \frac{V_1}{a} = \frac{V_m}{a} = \frac{60}{2} = 30 \text{ sec}$$

* duration time during coasting retardation

$$t_2 = \frac{V_1 - V_2}{\beta_c} = \frac{60 - 39.47}{0.15} = 136.842 \text{ sec}$$

* Duration time during braking

$$t_3 = \frac{V_2}{\beta} = \frac{39.47}{3} = 13.16 \text{ sec}$$

* Distance travelled duration acceleration

$$S_1 = \frac{V_1 * t_1}{2 * 3600} = \frac{60 * 30}{2 * 3600} = 0.25 \text{ Kmp}$$

* Distance travelled duration Coasting period

$$S_2 = \left(\frac{V_1 + V_2}{2} \right) * \frac{t_2}{3600} = \left(\frac{60 + 39.47}{2} \right) * \frac{136.842}{3600}$$

$$S_2 = 1.89 \text{ Km}$$

* Distance travelled duration braking

$$S_3 = \frac{V_2 * t_3}{2 * 3600} = \frac{39.47 * 13.16}{2 * 3600} = 0.072 \text{ Km}$$

Power o/p from driving axels

power \rightarrow rate of doing work

$$P = \frac{\text{work}}{\text{Time}}$$

$$\text{work} = \text{Force} * \text{distance}$$

$$P = \frac{\text{Force} * \text{distance}}{\text{Time}}$$

we know that Speed = $\frac{\text{distance}}{\text{time}}$

$$P = \text{Force} * \text{speed}$$

$$P = \text{Tractive effort} * \text{speed}$$

$$P = F_t * V$$

AC - equipment → starting & speed control

Single phase motors: Maximum voltage for 1- ϕ series motor is about 300V, so transformer is an essential equipment in locomotive coach.

for starting & speed control variable voltage is applied to series motor. This is achieved by providing tapings on transformer.

The tapings are generally provided on low voltage side.

But locomotives which uses 11000V, transformer tapings are provided on high voltage side.

Induction motors

for controlling the speed of Induction motor mainly employs either cascaded connection or pole changing method.

If railways speeds 24 & 50 km/h cascaded connection is preferred.

If railways speeds 37, 51, 74 & 102 km/h both cascaded & pole changing method is employed.

Electric braking

In this process, kinetic energy of rotating parts of motor is converted as electrical energy & is returned to the motor. Here no energy is dissipated in brake shoes.

Advantages of electric braking

- smooth, fast & reliable
- Higher speeds control be easily maintained.
- It is more economical than mechanical braking since wearing & tearing of brakes & replacement is negligible
- Heat produced in electric braking is less

→ possibility of generating energy is fed back electric supply during braking period.

Disadvantages of electric braking

during braking period, motor acts a generator & electric brakes almost stop the motor but it cannot holds stationary so it requires mechanical braking

→ initial cost of electric braking is costlier.

Types of electric braking

(1) plugging (2) Rheostatic braking (3) Regenerative braking

(1) plugging

In this braking, electric motor which is already in running condition, reconnect to the supply, thus motor develops a torque in opposite to the direction motor movement. Now motor starts decelerates until motor speed reaches to zero, A disconnect motor from supply.

Here kinetic energy of motor is wasted & in addition energy is required to develop torque in reverse direction.

(2) Rheostatic or dynamic braking

In this method of braking, motor is disconnected from supply during braking & is reconnected across some resistance.

But field winding of motor is continuously excited in same direction. It starts working as a generator. all kinetic energy of motor is

plugging of DC motor

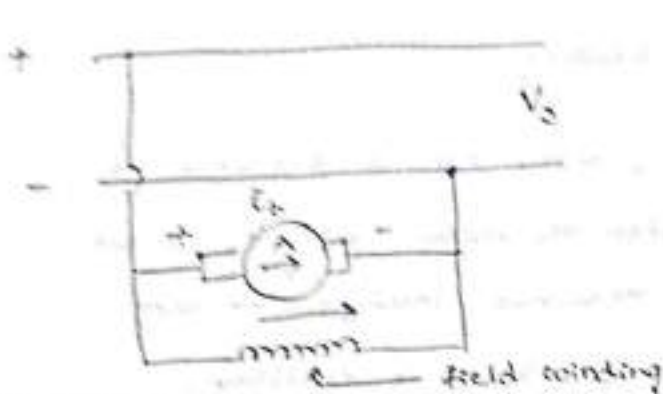


fig DC motor during non period

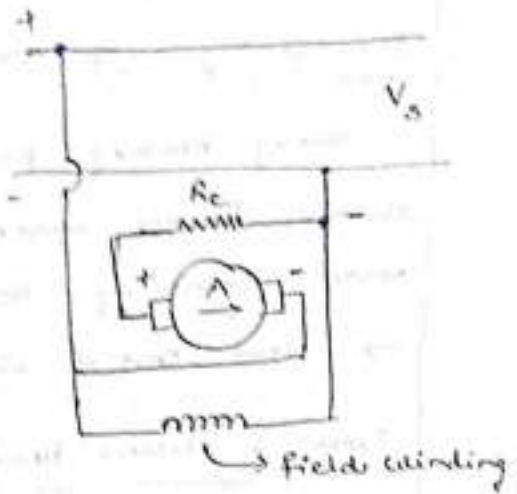


fig DC motor during braking period

Resistive & dynamic braking

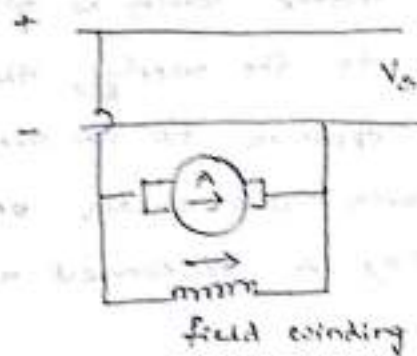
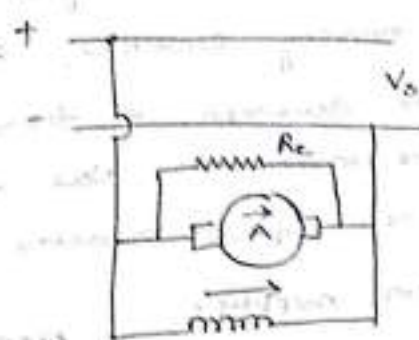
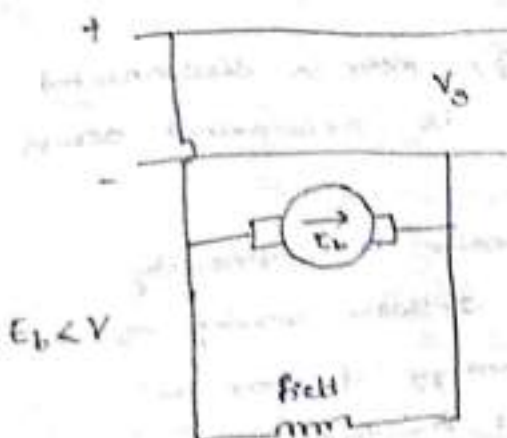


fig DC motor during running period



Regenerative braking



DC motor during normal running period

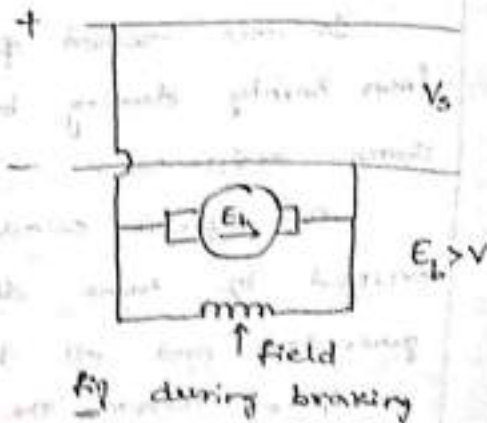


fig during braking

In case of plugging, some energy is drawn from the supply during braking.

In case of rheostatic braking, generated electrical energy is wasted in external resistance.

The above disadvantages can be overcome by using regenerative braking.

Here generating electrical energy is fed back to the supply system without wasting.

In case of dc shunt motor, electrical energy is fed to the supply. If rotational emf (E_b) is greater than supply voltage ($E_b > V$).

During braking period, excitation & speed of motor is adjusted until rotational & back emf is greater than supply voltage.

Here $E_b > V$

if $E_b > V$, motor acts as a generator, current through armature is reversed, torque developed by motor also reversed.

$$I_a = \frac{V - E_b}{R_a}$$

Regenerative braking for 3- ϕ AC induction motors

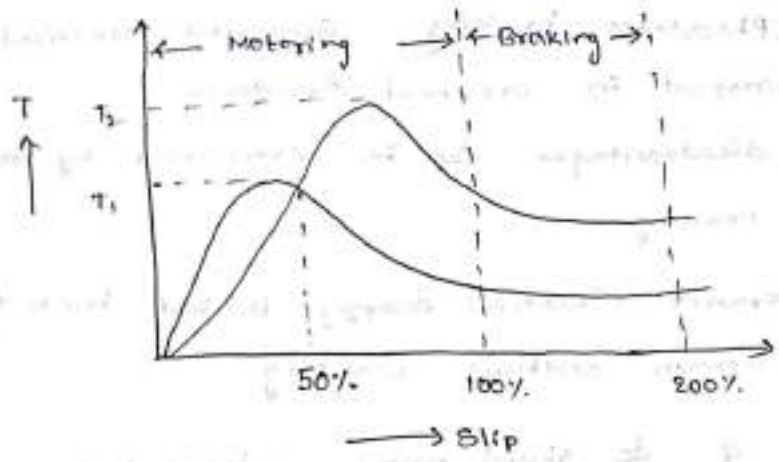
Here Regenerative braking is applied

if speed of induction motor is more than synchronous speed.

NTNs then induction motor acts as a induction generator

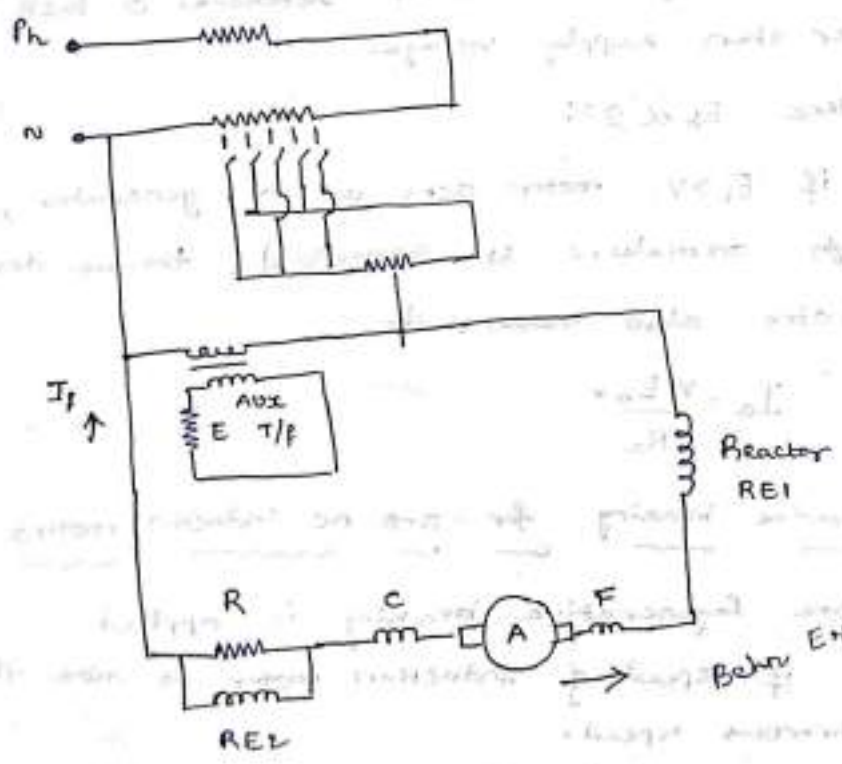
The main advantage of induction motor is during braking period placing an external resistance in rotor circuit.

this braking method for induction motor can save 20% of total energy by reducing operating cost.



Torque Vs Slip characteristics.

Regenerative braking for AC series motor



Braking in this method is complex. Since armature of motor connected to Tap charging transformer, commutating pole & iron core sectors.

Also it requires an auxiliary t/transformer to provide excitation to the field windings of motor.

Due to the presence of reactor, If current of motor lags behind the supply voltage by 90° . Braking torque developed by motor is proportional $I_a \cos \phi$. power returned to supply also proportional to $I_a \cos \phi$.

→ If the series motor operated at high P.f field of motor must separately excited by other auxiliary devices.

→ Also it requires proper phase shifting device to ensure correct phase angle.

To overcome above 2 cases, a special arrangement known as ^{Ban} Escherburg method of braking is used ^{fig 1}.

Control equipment

In case of railway networks, control equipments deals with heavy currents. Here industrial used down controllers are ^{not} suitable. So railways uses master controllers. Any number of locomotives & motor coaches can be controlled from master controller ~~situated~~ situated at any one of locomotive coach.

Here all locomotives are connected with controllers must carried coach to coach by means jumpers plugged into sockets at the end of coaches.

3 types of master controllers uses

- (i) All electric equipment
- (ii) Electro-pneumatic equipment
- (iii) Camshaft equipment (either electric & pneumatic drive)

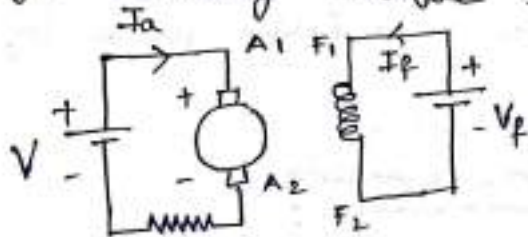
All above controllers are manually & semi automatic & fully automatically controlled.

Electric Braking

(i) plugging (ii) Rheostatic or dynamic (iii) regenerative braking

Plugging: It is a rapid braking method that running motor is disconnected & reconnected to supply with reverse polarity to create a reverse torque & quickly bring the train to stop.

During plugging supply voltage V_s & motor emf E_b will act in same direction. Voltage across armature will be $V + E_b$ which is twice the supply produces a reverse current & high braking torque is produced.

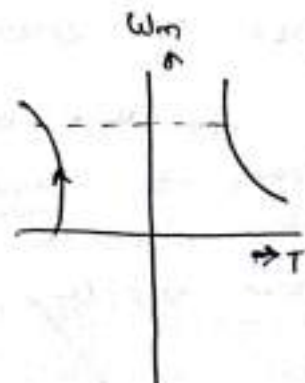
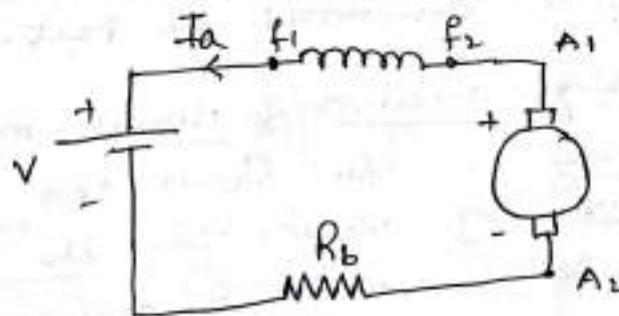


R_b fig shows plugging in shunt motor

- $V \rightarrow$ supply voltage
- $V_f \rightarrow$ field "
- $R_b \rightarrow$ external resistance
- $I_a \rightarrow$ Armature Current
- $I_f \rightarrow$ field Current

An external (~~resistor~~) current limiting resistor is connected in series with armature to limit armature current to a safe value.

Plugging in dc series motor



For braking a series motor either field or armature terminals must be severed.

→ Both are not allowed to sever, in that any one is allowed for reverse.

→ At zero speed, braking torque is not zero. The motor must be disconnected from supply. It can be done using Centrifugal switches.

demerits

- Most inefficient for moving masses
- additional power supply is needed for the development of counter torque.
- additional power losses will take place by the use of resistor.

(2) Rheostatic & Dynamic braking.

In this all kinetic energy of moving masses is converted into electrical energy which is dissipated in resistance as load.

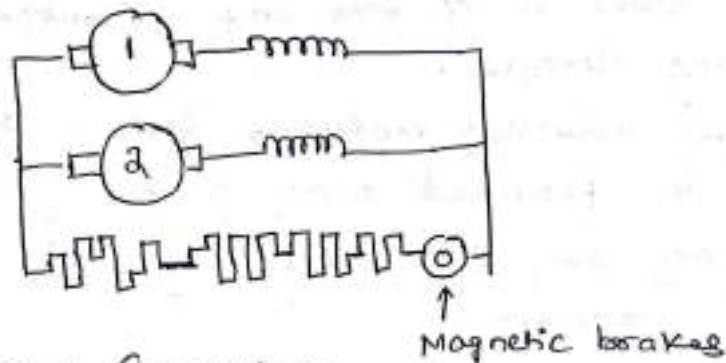
Here motor is made to work as generator.

In traction 2 or more are connected in parallel across a resistance. Now kinetic energy of vehicle motor acts as generator which dissipates its energy in resistance as heat.

In this braking, direction of torque making them to sever to slow down the motor. This can be done by disconnecting the motor from supply. It is connected to resistor.

Equalizer Connection

Two series motor are operated in parallel are connected across the resistance. These motors are self excite. This connection prevents the motor from short circuit due to large currents.

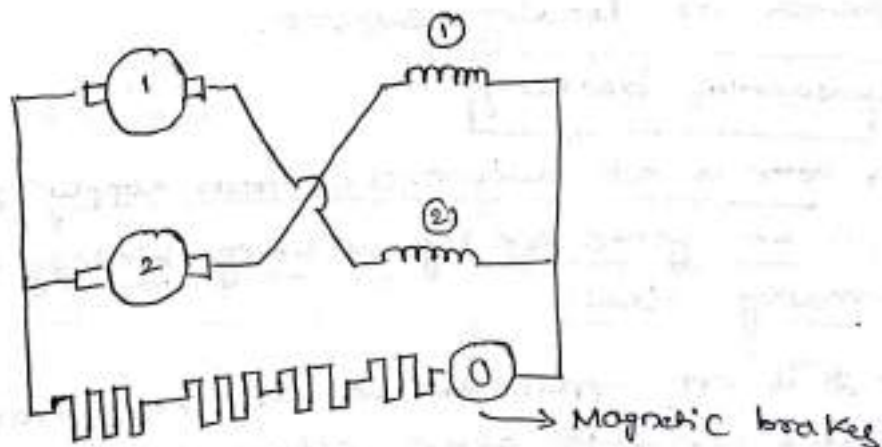


Equalizer Connection

Cross Connection:

field windings of motor are another field winding of motor.

field winding of 1st motor is connected to the armature of 2nd motor or vice versa such a connection is called as cross section connection.



suppose Machine ① voltage > Machine ② voltage, Machine ① send a larger current to field winding of machine ② causing it to excite at higher voltage. will reduce an amp of machine ②.

2nd method is more advantageous than 1st method. since field is build up in series & they are short circuited themselves, they provide emergency braking.

Rheostatic braking in induction motors

* If induction motor is disconnected from supply, there is no ~~emf~~ emf generated in rotor, no braking torque.

After induction motor is disconnected supply a sotor is provided with a steady dc supply, induces an emf in sotor generating required braking torque.

→ In case of AC series motor, stretchic braking is obtained by operating machine as generator excited from supply - which dissipates energy to resistive load. In this field of motor are excited from one of motor acting as series generator, as a result DC will be generated in sotors of motor & kinetic energy of motor will be dissipated as DC power in loading resistor.

Regenerative braking

→ Motor is not disconnected from supply but allow to run as generator by utilizing kinetic energy of moving train.

→ It is not applicable to dc series motor

→ Here generator action offers braking torque

Advantages

- * Reduced energy consumption.
- * Less maintenance
- * Less wear & tear of train track.

- avoids of ~~Waste~~ hard braking, as a result life span brakes more
- Easy & Safety with heavy loads can be ~~pull~~ hauled over steep ~~gradients~~ gradients.
- Higher value of braking retardation.
- High speeds are possible.

Disadvantages

- Increased Capital cost
- Need to increase the size of motors
- Additional cost on Controlling equipment where methods of operations are complicated.
- Mechanical braking is required at a speed 6.5 km/h to bring the locomotive to rest.
- Due to recovering of braking energy, operation of substation becomes complicated.

Regenerative braking in DC series motor

To do this terminal voltage of DC series motor must exceed the supply voltage

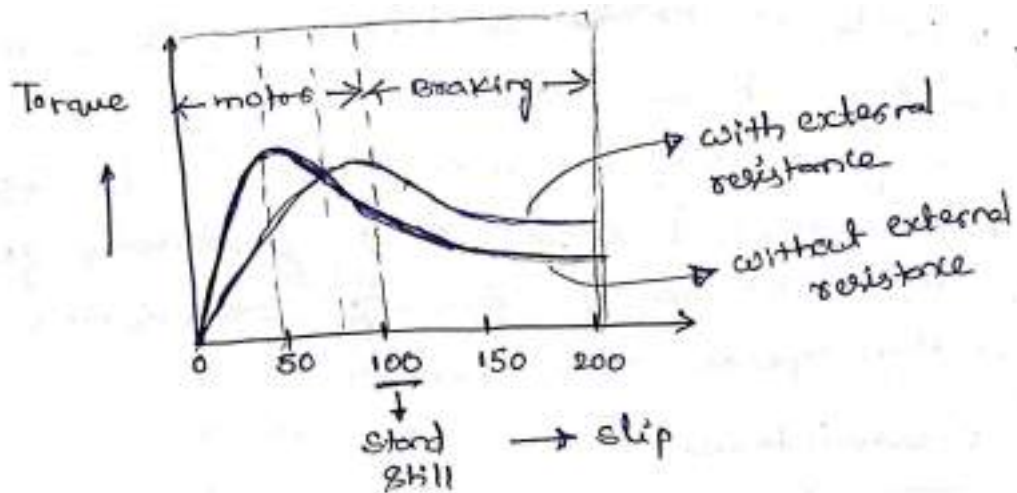
$$V_t > V_s \quad \text{or} \quad E_b > V_s$$

- this will allow us to varying speed as well as braking torque.
- without the reversal of field connections motor emf, supply voltage & back emf would aided each other leads to short circuit condition.

Regenerative braking in 3 phase Induction motor

It is achieved if motor speed runs above the synchronous speed. ($N > N_s$).

$N > N_s$ means it act as induction generator

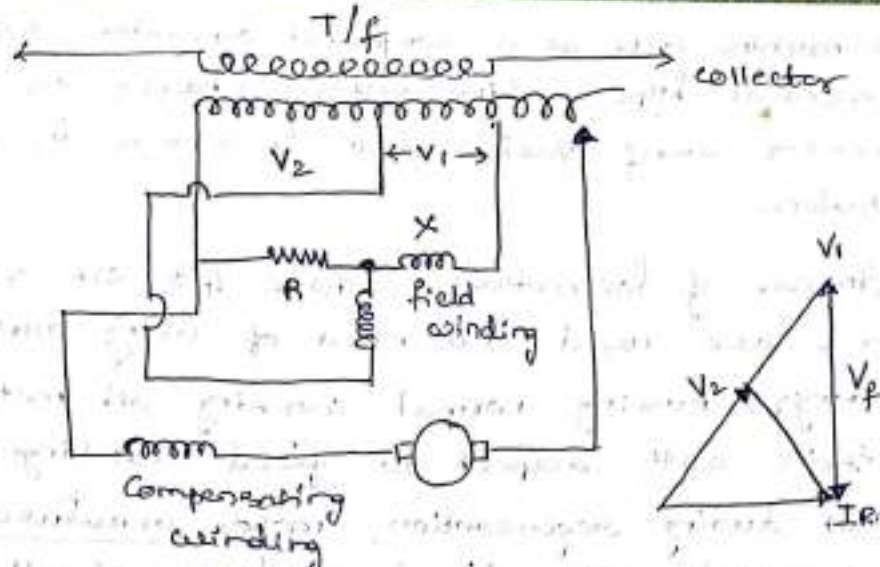


- Torque Curve of an induction motor shown above. With no extra resistance in rotor circuit, there is a slight variation in speed with torque.
- By adding extra resistance speed slightly increases for a particular braking torque.
- While braking ~~if~~ any extra resistance in rotor circuit, speed will be kept constant.
- At light loads, increased speeds are obtained by inserting external resistance in rotor, it is more advantageous to maintain railways. This saves 20% of brake shoe wear.

Regenerative braking in AC series motor

In case of regenerative braking, generated power should be at frequency of main supply. This necessitates energizing of field winding from main supply.

- 2ndly, generated current should be in phase opposition to applied voltage, also flux
- Voltage supplied to ~~field~~ field winding must be 90° out of phase with respect to supply voltage.



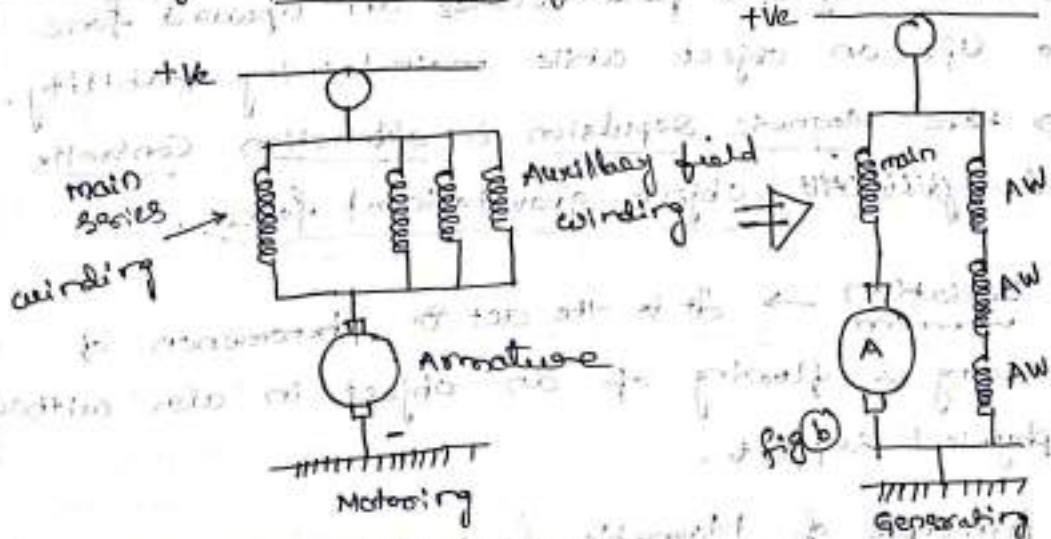
Regenerative braking in AC series motor

Regenerative braking in DC series motor

To do this terminal voltage of DC series motor gets reversed so that terminal voltage of motor is slightly greater than supply voltage

$$V_t > V_s$$

If there is single series motor consists of main series field winding placed in parallel with auxiliary field windings during motoring mode



→ during regenerative braking, auxiliary field windings are placed in series with each other & switched over in parallel across the armature & main field, shown fig (b).

The machine acts as a Compound generator with differential type. Line voltage changes as generator armf varies due to change in shunt excitation.

→ In case of locomotives where 4 or six series motors are used, no need of using auxiliary windings. During normal working all motors are in series with respect to field windings.

But during regeneration, motor armatures are in parallel with field windings of all motors except one.

Magnetic Levitation - Vehicles

Magnetic Levitation:

- This is the technology of suspended an object in air without any physical support.
- Suspended object in air uses magnetic field to counter ^{act} the gravitational forces.
- The magnetic field creates an upward force to lift an object while maintaining stability.
- Here Magnetic repulsion or attraction controls the object gravitational forces.

Levitation → It is the act or phenomenon of suspending or floating of an object in air without physical support.

Principle of Magnetic Levitation

Magnetic levitation uses a magnetic properties of principle.

Here like poles of ~~attract~~ magnets repel & opposite poles trying to attract. These are 2 main approaches

(I) EMS → electromagnetic suspension

(II) EDS → electrodynamic suspension

EMS → approach

Magnetic field of magnets which uses electromagnets to create strong attraction b/w vehicle & track, pulling the vehicle up from below. (Attraction forces creates a lift force)

EDS → approach

uses Super Conducting magnets to create a repulsive force b/w vehicle & the track.

Here repulsive forces creates levitation in vehicle. Magnetic field interacts with coil induces the repulsive forces.

Applications of Magnetic levitation

→ used in Maglev trains

where trains are levitated, are propelled & are guided along a track without physical contact to achieve higher speeded speeds & reduced friction.

→ Magnetic bearings

rotating parts in machine is suspended in magnetic field to reduce friction

→ Product displays:

uses Magnetic levitation to keep items floating in mid-air.

UEE - UNIT 5

Electrolytic Process

Electrolytic process

The process of creating a change in chemistry or chemical properties using electrical energy is electrolytic process.

It is used to extract pure metals from their ores such as Aluminium, Zinc, Copper, Magnesium sodium etc. Also used to produce various chemicals such as Caustic soda, potassium, Hydrogen, oxygen, chlorine etc.

Principle of electrolysis

The process of studying chemical properties is electrolysis.

It is defined as the process of decomposing ionic compounds into elements by passing a dc current in fluid or liquid is electrolysis.

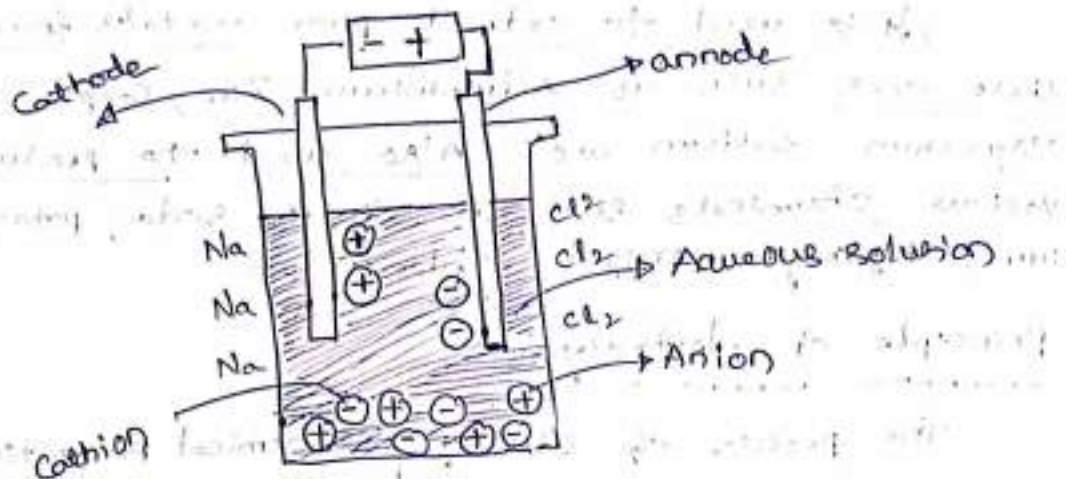
Cations are reduced at Cathode & anions are oxidized at anode.

Main components to conduct electrolysis are electrolyte, electrodes & an external power source. Sometimes an ion exchange membrane partition is needed.

An acidified or salt containing water can be decomposed by passing an dc current to its original elements, hydrogen & oxygen, Molten sodium chloride can be decomposed into sodium & chlorine. Oxidation & reduction reactions are called as redox reactions.

The cell which converts electrical energy into chemical energy is called an electrolytic cell.

During electrolysis redox reactions occurs at electrodes. specially oxidation at anode is a +ve plate while reduction occurs at cathode is a -ve plate.



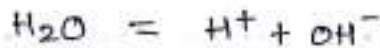
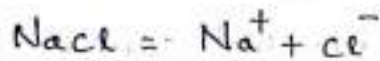
The entire chemical reaction is carried out in a special vessel is called as electrolytic cell. Electrolytic cell consists of 2 electrodes cathode & anode. When ever an electric dc current is passed through the solution an ions exchange takes place through the solution. Here we force cations to get attracted to cathode & anions to get attached to anode of electrolytic cell.

Electrolysis of NaCl solution

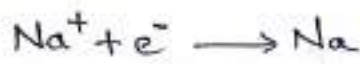
Aqueous solution of NaCl has Na^+ , Cl^- , H^+ & OH^- ions are present in it.

Now electrodes are introduced in solution by passing electricity it allows Na^+ & H^+ ions moves towards negatively charged electrode (cathode)

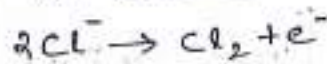
$Cl^- + OH^-$ are move towards +vely charged electrode (anode)



At Cathode



At anode



as a result sodium formed at cathode as a metal & chlorine is released at anode.

Movement of ions in electrolytic solution depends on cell potential. Example ions mobility is very low then cell potential of electrolytic cell must be high & ions mobility is high then electrolytic cell must be ~~low~~ low.

Cell potential = standard oxidation + standard reduction of cell potential.

Faraday's laws of electrolysis

→ this laws provides information about masses of a substance & charge in electrolysis process. There are of 2 faradays laws.

① Faraday's first law

Masses of substance that undergoes electric is directly proportional to charge supplied.

We know that

$$i = \frac{q}{t}$$

from 1st law Mass of substance is proportional to charge
m ∝ Q

$$m = Z \times Q$$

Q → charge associated with cell
 Z → electrochemical equivalent
 m → mass of substance undergoes electrolysis

$$m = Z \times i \times t$$

from current $i = \frac{Q}{t}$
 $Q = i \times t$
 t → time in sec.
 i → current through substance

Faraday's second law

This law states that amount of electrolyte deposited at electrodes is directly proportional to equivalent weight of material. If amount of electricity passing through solution is constant

$$W_1/E_1 = W_2/E_2 = W_3/E_3$$

W_1, W_2 ----- mass of 1st, 2nd substance

E_1, E_2 ----- equivalent weight of 1st, 2nd substance.

Energy Efficiency

Due to side reactions, amount of metal deposition & liberated requires more voltage than theoretical value which increases the energy requirement

It is defined as ratio of theoretical energy required to the actual energy required for depositing a given quantity of metal

$$\text{Energy efficiency} = \frac{\text{theoretical energy required}}{\text{actual energy required}}$$

Applications of electrolysis

- ① Electro deposition
 - Electro plating
 - electro deposition of subbe
 - electro metallization
 - Electro facing
 - Electro forming
 - Electro typing
- ② Manufacturing of chemicals
- ③ Anodizing
- ④ Electro polishing
- ⑤ Electro cleaning
- ⑥ Electro plating & stripping
- ⑦ Electro metallurgy
 - * Electro extraction
 - * Electro refining

Electro deposition

The process of depositing a metal over another metal or non metal electrically is called electro-deposition.

The process of depositing a metallic coating is formed on the surface of objects like wires

→ Compounds into solution dissociate into +ve & -ve ions when subjected to electric field toward electrode, then one of following event takes place

* Incase of ion, After electric charge is applied to electrode, then there is no chemical reaction with electrode material, It will be deposited on electrode. This principle is employed in electro deposition & electro extraction.

* Incase of ion, After electric charge is applied to electrode undergoes chemical reaction, the product is soluble in electrolyte states absorb a water by electrode. This is electro refining.

* Incase of ion, After electric charge is applied to electrode, does not react with electrode material, will react with water solution liberating oxygen & hydrogen.

Factors which effect the quality of electro-deposition

- (i) Nature of electrolyte: Complex ions obtained from electrolyte provides a smooth deposit
- (ii) Current density: deposit of metal should be uniform & fine grained, if higher current density is used. The deposit should be spongy & porous if rate of nuclei formation is very high.
- (iii) Temperature: At low temperatures forms small crystals of metal & at high temperatures large crystals of metal is formed.
- (iv) Conductivity: Good conductivity provides less power consumption

(V) Electrolytic Concentration:

By increasing the concentration of electrolyte, current density increases to form uniform & fine grain deposit.

(VI) Additional agents:

Addition of acids or other substances to electrolyte reduces its resistance. This will influence the nature of electrolyte. The crystal nuclei absorb the addition agent added in electrolyte produces fine grained deposit.

(VII) Throwing power

Ability of electrolyte to produce uniform deposit on irregular shape.

→ Due to irregular shape distance between Cathode & anode is different

→ Due to unequal distance, resistance of Current path through electrolyte of various positions of cathode will be different.

But potential b/w anode & any point on Cathode will be same.

(XI) Polarization:

With increase in electroplating Current density, rate of metal deposition also increases upto certain limit, After that electrolyte surrounding base metal becomes depleted of metal ions.

factors affecting the quantity or amount of electro-deposition

Time: Quantity of electro deposition depends on time. More mass will be deposited needs more time is needed. other conditions remain constant i.e. temperature, current density remain constant

Efficiency: efficiency is directly proportional to quantity of metal deposited. High efficiency means greater quantity of metal is deposited.

Strength of solution: If strength of the solution is more, then mass of metal deposited will be more as compared to dilute solution of electrolyte.

Current: Current is directly proportional to mass of metal deposited. Higher the current means mass of metal deposited also high.

Simply quantity of metal deposited depends on & is proportional to time, efficiency, strength of solution & current.

Extraction of metals

Extraction of Zinc: Ore consisting of Zinc is treated with concentrated sulphuric acid, roasted & passed through other process to get rid of impurities by precipitation. Then zinc sulphate solution is then electrolysed. It is carried out in large lead lined wooden boxes having aluminium cathodes & lead anodes, zinc deposited at cathode removed periodically once or twice a day

Extraction of Aluminium:

Ores of aluminium are produced from bauxite, silica & iron oxide

→ 1st ore (bauxite) is separated to aluminium oxide by chemical treatment & it is dissolved in fluxed cryolite (solution of aluminium fluoride & fluoride of either sodium, potassium or calcium). This mixture then undergoes electrolysis

→ fusion & electrolysis are carried out in specially designed rectangular ^{steel} bath coated & lined with carbon.

→ Carbon anodes are projected downwards into the bath & bottom of bath forms as cathode.

→ When a dc current is passed through electrodes an arc struck creates high temperature starts melting the charge.

→ The liquid metal deposited at cathode & settles at bottom of bath.

→ Aluminium obtained from these are 99.5% pure.

(III) Extraction of magnesium

It is obtained from magnesium chloride undergoes electrolysis. Current density $160-350 \text{ A/m}^2$
Energy Consumption $17-20 \text{ kWh/kg}$, operating temp: is 360° to 670°C

(IV) Extraction of sodium

Sodium is obtained by electrolysis of sodium hydroxide, sodium nitrate, & sodium chloride requires $10-20 \text{ kWh/kg}$

Fuel Cell

A fuel cell is a device that converts chemical energy into electrical energy. fuel directly converts an energy source into electricity through a chemical reaction.

Difference b/w battery & fuel cell

→ battery stores energy, fuel cell generates energy by converting available fuel.

I/P → H_2, O_2
O/P → electricity
cathode

Types of fuel cells

→ these are classified based on electrolyte

→ H₂O₂ electrolyte permit the ions to pass b/w anode & cathode. If electrons could travel through electrolyte it disrupts the chemical reaction.

As long as fuel supplied with hydrogen & oxygen it will generate electricity.

- polymer electrolyte membrane fuel cell
- Direct methanol fuel cells
- Alkaline fuel cells
- phosphoric acid fuel cells
- Molten carbonate fuel cells
- Solid oxide fuel cells
- Reversible fuel cells.

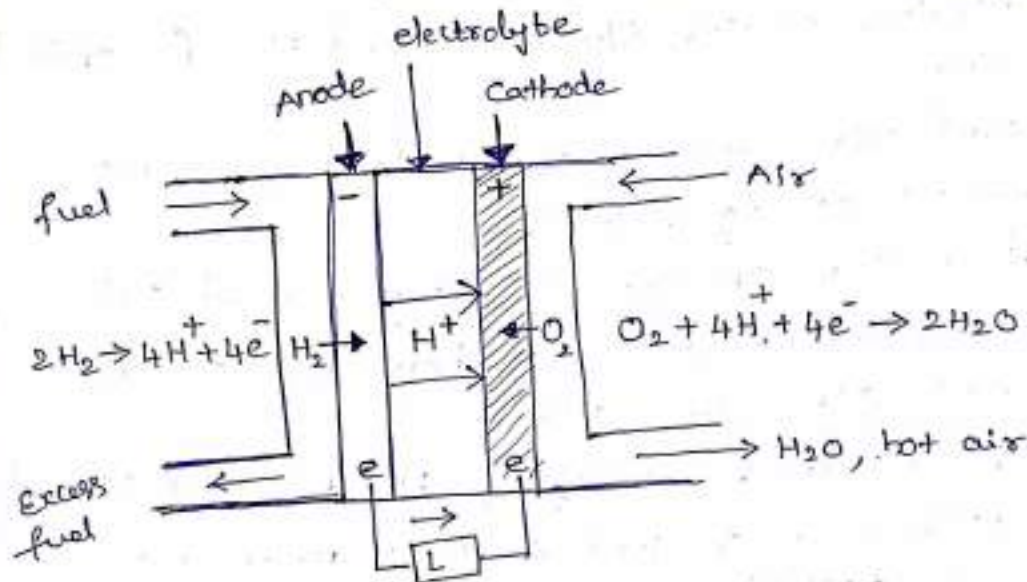
Fuel cell working

A fuel consists of cathode, an anode, an electrolyte, a separator b/w the electrode chambers.

Cathodes are +ve & anodes are -ve terminals of cell.

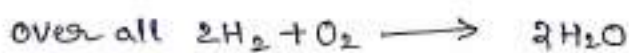
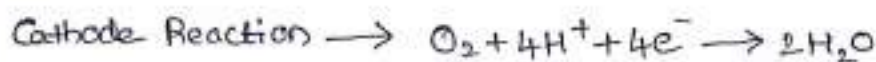
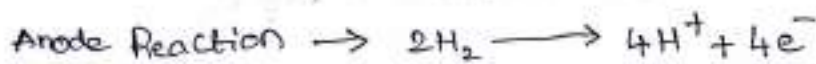
→ these 2 terminals are placed inside the electrolyte for ions transfer.

→ Anode is continuously fed with fuel (H_2) while Cathode is fed with oxidant (O_2 from air).



Schematic diagram of H_2 fuel cell

Above fuel cell structure uses fuels & oxidants



→ At anode protons (H^+) & electrons (e^-) are generated move towards to cathode side

→ Here protons (H^+) moves directly to cathode via electrolyte & electrons moves to cathode flows through an external circuit.

→ All protons (H^+) & electrons (e^-) at cathode again combines with oxygen at cathode releases water.

→ Here Tailgate emission is only water no greenhouse gases.

Important points to remember fuel cell

- It is a static device
- No moving or mechanical rotating parts
- less maintenance
- Requires cooling s/m & Control s/m for optimal working
- fuel cells acts as a catalyst & are not consumed during reaction
- fuel cell operates as long as fuel cell needs fuel & does not have recharged.
- fuel cells are costly
- production & storing of H_2 is very critical
- Main part of fuel stack is membrane electrode (MEA). consists of cathodes & anodes as well as their catalyst layers, ion conducting electrolyte & a gas diffusion layer.

Utilization of Electrical Energy-III-I HM23

UNIT I Electric Drives:

1. Discuss the advantages and disadvantages of electric drive over other drives. 5M
2. What are the factors governing the selection of motor 5M
3. Discuss the terms 'continuous', 'intermittent' and 'variable' loads with examples. 5M
4. What is an electric drive? Explain the different types of electric drives 10M
5. What are the factors influencing the choice of electrical drives 10M
6. List out the different types of Industrial motor loads? Explain. 5M
7. Discuss about the starting characteristics of electric drives? 5M
8. Explain about the running characteristics of electric drives? 10M
9. Define Electric drive? Discuss various components in electrical drive with neat block diagram. 10M

UNIT II Electric Heating

1. Discuss the various methods of electrical heating? 10M
2. What are the requirements of heating element? How to design a heating element? 4M+6M
3. a) Discuss the advantages of electric heating? 4M
b) Discuss about the electric Arc Heating? 6M
4. Explain about direct & indirect resistance heating with suitable diagrams? Write the applications of resistance heating? 8M+2M
5. What is dielectric heating? Explain the principle & operation of di-electric heating? 2M+8M
6. Explain the principle & operation of Ajax Wyatt furnace with necessary sketch? 10M
7. Compare & differentiate cored induction furnace & coreless induction furnace? 10M
8. a) What is welding? Mention the classifications of welding? 2M+4M
b) Discuss the advantages of welding? 4M
9. Discuss about carbon arc welding & projection welding? 10M
10. Compare & differentiate the AC welding & DC welding? 10M
11. What is welding? Explain the various components of welding equipment with suitable diagram? 10M
12. Write any two advantages of electric heating? 2M
13. Explain the principle & operation of induction heating in detail? 10M
14. With neat sketch describe the process of metal arc welding? 6M
15. With neat sketch describe the process of submerged arc welding? 6M

16. Dielectric heating is employed to heat a slab of insulating material of thickness 20mm & $15000 \times 10^{-6} \text{ m}^2$ in area. Power requirement is 200w , frequency 30Mhz is used Material permittivity is 5. Power factor is 0.05. Determine a) voltage required & current flow in material b) If voltage is limited to 600V then what would be the value of frequency raised. 10M

UNIT III ILLUMINATION

1. State & explain the laws of illumination? 10M

2. a) write a short note on polar curves? 5M

b) Discuss the construction of Rouseau's diagram? 5M

3. Discuss the following terms

a) Illumination b) Brightness c) Solid angle d) Luminous intensity e) Candle Power 2+2+2+2+2M

4. Discuss the construction & working of sodium discharge lamp with neat sketch? 10M

5. a) Compare & differentiate tungsten filament lamps & fluorescent lamps 6M

b) Explain the working principle of LED lighting? 4M

6. Explain the construction & working of Mercury vapour lamp with neat sketch? 10M

7. What are the principles of light control? Explain about the various types of lighting schemes employed? 4M+6M

8. a) Briefly explain the requirements of good lighting scheme? 5M

b) Explain the methods of calculations of lighting schemes employed? 5M

9. A room measuring 30m×15m is to be illuminated by 10 lamps and the average illumination is to be 85 lux. Determine the MSCP of each lamp if the utilization and depreciation factors are 0.5 and 0.8 respectively. 10M

10. Deduce the relation to find illumination at any point on surface due to light source suspended at a height 'h' meter from the working plane. 10M

11. A lamp has uniform CP of 200 in all directions is provided with reflector which directs 60% of total light on uniformly on circular area of 10mtr diameter. The lamp is provided at a height 6mtr above the working area. Calculate i) illumination at the centre ii) illumination at the edge of surface with & without reflector. Iii) Determine the average illumination.

UNIT IV ELECTRIC TRACTION

1. Compare A.C traction with D.C traction with necessary examples. 10M
2. Discuss the special features of traction motors? 5M
3. How the electric traction system is classified? Briefly discuss. 10M
4. A train has schedule speed of 30 km/hr over a level track distance between stations being 1 km. Duration of stop is 20 sec. Assuming braking retardation of 3 km/hr/sec and maximum speed 25% greater than average speed, calculate acceleration required to run the service. 5M
5. Discuss the speed-time curves for main line services? 10M
6. Explain about the different methods of electric braking systems in the case of traction? 10M
7. Discuss the speed-time curves for urban & suburban service. 5M
8. Discuss the importance of simplified speed time curves? 3M
9. Derive the calculation of crest speed for simplified speed time trapezoidal curve? 10M
10. A train has schedule speed of 60 km/hr between the stops which are 6 km apart. Determine the crest speed over the run assuming trapezoidal speed time curve. The train accelerates at 2 km/hr/sec and retards at 3 km/hr/sec. Duration of stops is 60s. 10M
11. Suburban train runs with average speed $V_a = 45$ kmph, distance between the stops is 1.8 kmph. Values of acceleration & retardation is 2 km/hr/sec & 3 km/hr/sec. Find the maximum speed of train assume the speed time curve is trapezoidal. 10M
12. Acceleration of train is 1.5 kmphps & is braked at 3 kmphps a train has average speed 45 kmphps, distance between the stations 1500mtrs apart. Determine 1) actual time of run ii) maximum speed iii) distance travelled before brakes are applied iv) scheduled speed. Assume time for stop as 15sec & the train is running according to trapezoidal speed time curve.
13. Explain about the different methods of electric braking systems in the traction. 10M
14. Derive the calculation for simplified speed time Quadrilateral curve? 10M
15. Discuss about plugging & regenerative braking in electric traction? 10M

UNIT V ELECTROLYTIC PROCESS

1. Discuss about the faraday's laws of electrolysis? 5M
2. Explain the factors affecting the better electro deposition? 5M
3. Write short note on electro deposition with neat sketch? 10M
4. Briefly describe about the application of electrolysis? 10M