Important suggestions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and communication skills)
4) While assessing figures, examiner may give credit for principle components indicated in a figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case some questions credit may be given by judgment on part of examiner of relevant answer based on candidate understands.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1 A)	**Attempt any THREE :**	**3 x 4 = 12 Marks**
a)	**Define electric drive. List at least four advantages of electric drive.**	
Ans:	**Electric Drive:**	**(2 Marks)**

It is a machine which gives mechanical power. e.g. drives employing electric motors are known as electric drives.

Following advantages of electric drive: **(Any Four point Expected: 1/2 each point: 2 Marks)**

1. It is more economical.
2. It is more clean.
3. No air pollution.
4. It occupies less space.
5. It requires less maintenance.
6. Easy to start and control.
7. It can be remote controlled.
8. It is more flexible.
9. Its operating characteristics can be modified.
10. No standby losses.
11. High efficiency.
12. No fuel storage and transportation cost.

13. Less maintenance cost.
14. It has long life.
15. It is reliable source of drive.

b) State the causes of failure of heating element.

Ans: Following of the different causes of failure of heating element:

(Any Four causes expected: 1 Mark each)

i) **Formation of hot spo**t:

Hot spot on heating element is the point which is at higher temperature than remaining heating element portion. So there is possibility of breaking of heating element at hot spot.

ii) Due to oxidization:

At high temperature material gets oxidized which may cause failure of heating element.

iii) **Due to corrosion**:

If heating element is directly exposed to chemical fumes then there is possibility of rusting of heating element which causes failure of heating element.

iv) **Mechanical Failure**:

Measure heating element alloy contain iron which is brittle. Due to frequent heating & cooling of heating element, it may break (fail) due to small mechanical injury also.

c) Suggest suitable electric drive for following application :(i) Paper mills (ii) Stone crusher (iii) Textile mill and (iv) Electric traction

Ans: **(Each Suitable Any one Drive suggestion: 1 Mark each)**

S.No	Application	Suitable electric drive
i)	**Paper mills**	Slip-Ring Induction Motor, Synchronous Motor
ii)	**Stone crusher**	A.C. Series Motor, Slip-Ring Induction Motor
iii)	**Textile mill**	Squirrel Cage Induction Motor
iv)	**Electric traction**	D.C. Series Motor, 1 Phase Slip-Ring Induction Motor

d)	**Draw the curve and estimate suitable H.P. of motor having following duty cycle :** **(i) Rising load from 200 to 400 HP 4 minutes** **(ii) Uniform load of 300 HP 2 minutes** **(iii) Regenerative braking from 50 to zero H.P. —1 minute** **(iv) Idle for 1 minute**

Ans:

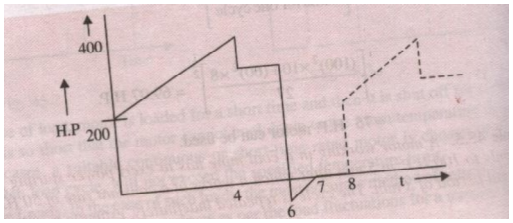
(When Final answer of Numerical is correct Give Full Marks & if final answer is wrong give stepwise marks)

i) Load rising from 200 to 400 HP :- 4 min

ii) Uniform load of 300 HP :- 2 min

iii) Regenerative braking from 50 to zero : 1 min

iv) idle for : 1 min



or Equivalent fig----------(1/2 Mark)

$$HP = \sqrt{\frac{\frac{1}{3}\left(H_1^{\,2} + H_1 H_2 + H_2^{\,2}\right)\times t_1 + H_3^{\,2} t_2 + \frac{1}{3} H_4^{\,2} t_3}{T}}$$ ---------- **(1/2 Mark)**

Where, $T = t_1 + t_2 + t_3 + t_4$

$T = 4 + 2 + 1 + 1$

T = 8 min.---------- **(1 Mark)**

$$HP = \sqrt{\frac{\frac{1}{3}\left(H_1^{\,2} + H_1 H_2 + H_2^{\,2}\right)\times t_1 + H_3^{\,2} t_2 + \frac{1}{3} H_4^{\,2} t_3}{8}}$$ **(1/2Mark)**

$$HP = \sqrt{\frac{\frac{1}{3}\left(200^2 + 200\times 400 + 400^2\right)\times 4 + 300^2 \times 2 + \frac{1}{3} 50^2 \times 1}{8}}$$ ---------- **(1/2 Mark)**

$$HP = \sqrt{\frac{1662500}{24}}$$

$HP = 263\ HP$ ----------Answer---------- **(1 Marks)**

Nearest standard rating of motor is to be selected.

Q.1B)	Attempt any ONE of the following : 6 Marks
a)	Describe any six factors governing selection of a motor for a particular application.

Ans:

(Any Six Points From The Following Or Equivalent Points Are Expected 1 Mark To Each Point, Total 6 Marks)

Following Factors governing / or are considered while selecting electric drive (Motor) for particular application:

1. **Nature of supply:**
   Whether supply available is
   - AC,
   - Pure DC
   - Or Rectified DC
2. **Nature of Drive (Motor):**
   Whether motor is used to drive (run)
   - Individual machine
   - OR group of machines.
3. **Nature of load:**
   Whether load required light or heavy starting torque
   - OR load having high inertia, requirehigh starting torque for long duration.
   - OR Whether load torque increases with speed ($T \alpha N$)
   - OR decreases with speed ($T \alpha 1/N$)
   - OR remains constant with speed (T = N)
   - OR increases with square of speed ($T \alpha N^2$)
4. **Electric Characteristics of drive:**
   - Starting,
   - Running,
   - Speed control
   - and braking characteristics

   of electric drive should be studied and it should be matched with load requirements(i.e. machine).
5. **Size and rating of motor:**
   - Whether motor is short time running
   - OR continuously running
   - OR intermittently running
   - OR used for variable load cycle.

	Whether overload capacity, pull out torque is sufficient. 6. **Mechanical Considerations:** ➢ Types of enclosure, ➢ Types of bearing, ➢ Transmission of mechanical power, ➢ Noise ➢ and load equalization **7. Cost:** ➢ Capital, ➢ Running ➢ Maintenance cost should be less.
b)	**State the factors to be considered for selection of shape and size of the car of elevator.**
Ans:	**(Any four points are Expected 1.5 Marks to each Total 6 Marks)** **The size and shape of elevator car depends on following factors:** i) No. of passenger to be carried: While selecting the size of car it is a usual practice to allow. ➢ A Space of 2 Sq.fit/ person. ➢ Average weight of passenger is assumed 68 kg/person. ➢ Thus the maximum load capacity of elevator is considered 34 kg/sq.ft ➢ There should be wide frontage and shallow depth ii) Limitation in the building design: ➢ Shape of elevator depends on space available in building. iii) Type of building iv) Application of elevator
Q.2	**Attempt any FOUR :** **4 x 4 = 16 Marks**
a)	**Define load equalisation for electric motors. Explain how it is obtained for electric motors.**
Ans:	**Define load equalization for electric Motor:** **(Meaning : 2 Mark, Figure: 1 Mark & explanation: 1 Mark)** There are many types of load which are fluctuating in nature e.g. wood cutting m/c, Rolling mill. Etc. For such type of loads, load equalization is necessary to draw the constant power from

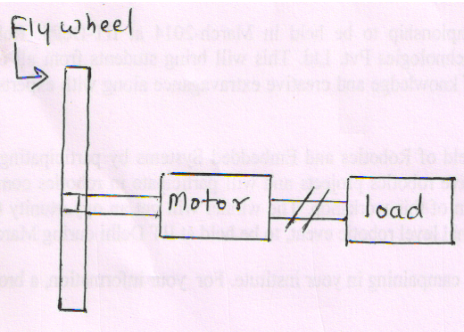
supply. Because,

When there is sudden load on motor, it will draw more current from supply at start to meet additional power demand. Due to this heavy current there is large voltage drop in supply system. This will affect electrical instrument, equipment, m/c, other consumer etc. which are connected across same supply line.

Also to withstand heavy current, size of input cable increases so cost of cable increases, Hence it is necessary to smooth out load fluctuations on motor.

The process of smoothing out load fluctuation is called load equalization.

Diagram of Load Equalization:

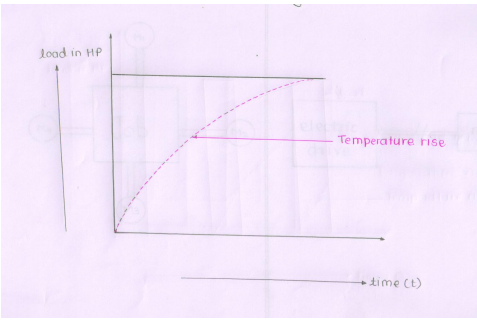


b) Define : (i) Continuous loading, (ii) Short time loading, (iii) Long time (intermittent) loading, (iv) Continuous operation with short time loading.

Ans:

(Each Definition 1 Mark , Total 4 Marks, Graphical Figure Not expected)

(i) Continuous loading:-

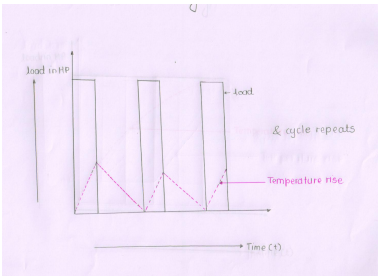


or eqivalent figure

This is an output which a motor can deliver continuously without exceeding the permissible temperature limit.

It can deliver 25% over load for two hours without rise in temperature.

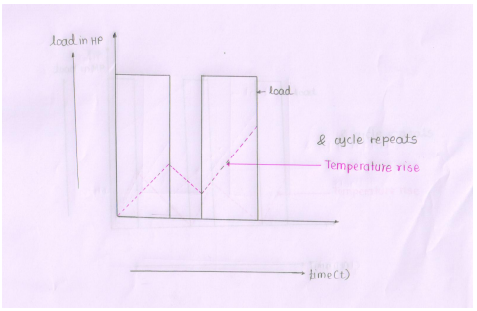
(ii) Short time loading:-



or eqivalent figure

In short time loading motor is operated for short time continuously without exceeding the permissible temperature limit.e.g. 15min., 20min., 30min. etc than it is made OFF This OFF load interval is sufficient to cool the motor temperature to its normal value.

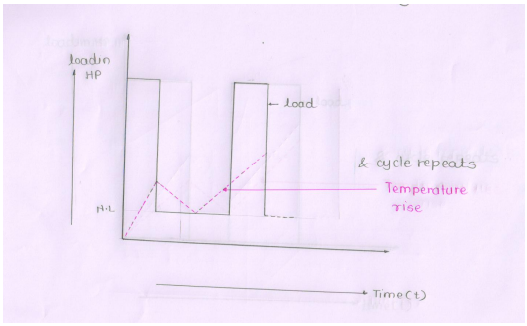
(iii) Long time (intermittent) loading:-



or eqivalent figure

Explanation :-In this case motor is operated continuously for long time and interval between two load is not OFF- load but motor runs at no load for short time. So temperature of drive continuously increases.

(iv) Continuous operation with short time loading:-



or eqivalent figure

Explanation :-In this case motor is operated continuously for short time and interval between two load is not OFF- load but motor runs at no load for long time. So temperature of drive continuously increases. So temperature rise is more than short-time loading.

c) State the principle of induction heating. Write four applications of induction heating.

Ans:

Principle of Induction heating: **(2 Mark)**

The basic principle of induction heating is that, supply is given to primary winding of furnace transformer & heat is produced in the secondary (charge) due to electromagnetic action.

OR

Principle of Induction heating:

It is based on principle of transformer. In this type primary winding is as usual which is wound around one limb of magnetic core but secondary winding is actually charge which is to be melted is kept in crucible.

When AC Supply is given to primary winding current flows through primary winding which creates alternating flux in magnetic core this flux links to the secondary winding i.e. charge through magnetic core. Hence according to faraday's law of electromagnetic induction emf will be induced in secondary winding, that is in the charge. As charge forms a close circuit (secondary) heavy current flows through charge this current is responsible to produce heat in charge due to I2R losses. This heat is utilized to melt the charge.

Where, R = Resistance of charge & I secondary current

Following are applications of induction heating:

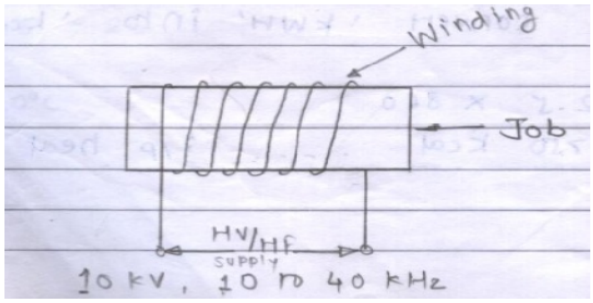
(Any Four point expected: 1/2 each, Total 2 Marks)

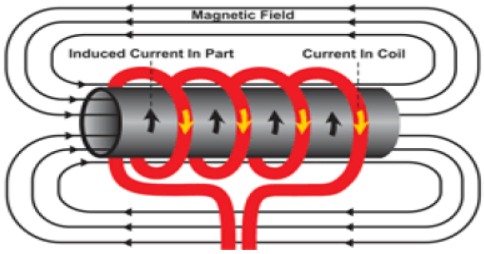
1. Melting of steel and non ferrous metals at temperatures up to 1500 °C.
2. Heating for forging to temperatures up to 1250 °C.
3. Annealing and normalizing of metals after cold forming using temperatures in the range of 750 – 950 °C.
4. Surface hardening of steel and cast iron work pieces at temperatures from 850 – 930 °C (tempering 200-300 °C)
5. Soft and hard soldering at temperatures up to 1100 °C,
6. Moreover, special applications such as heating for sticking, sintering

d)	**State the principle and nature of supply used for eddy current heating. State the advantages and disadvantages of eddy current heating.**

Ans:

Figure of Eddy Current Heating:- **(1 Mark)**





or Equivalent fig.

Principle:- **(1 Mark)**

Heat produced α **eddy current loss** $\alpha\ B^2 f^2$

Depth of penetration of heat $\alpha \frac{1}{\sqrt{F}}$

The job which is to be heated is wound by coil as shown in figure.

Supply of high voltage (10KV) & high frequency (10-40 KHz) is given to coil which induces eddy current in job according to Faraday's law of Electromagnetic induction & these eddy currents are responsible to produce heat in job itself due to eddy current loss.

In high frequency eddy current heating the phenomenon of skin effect plays an important role.

Skin effect at high frequency is more pronounced (effective). Due to this surface of job is more heated as compared to its depth.

Nature of supply used for eddy current heating: **(1 Mark)**

- High voltage (10KV)
- High frequency (10-40 KHz)

Advantages eddy current heating:- **(Any one point expected)** **(1/2 Mark)**

1) No heat transfer loss as heat is produced in job itself. So it has high efficiency.
2) As heat is produced in job itself so time required for heating is less. For e.g. in some cases operating time taken for heating is of only one second.

3) By simply controlling frequency, we can control temperature accurately.

4) By simply controlling frequency, depth of penetration of heat can be controlled easily.

5) Very thin material surface can be heated easily.

6) Operation is simple & automatic.

7) For heating low attention is required.

8) Heating can be taken place in vacuum or other special atmospheric condition where other methods are not possible.

9) It is clean and convenient method.

Disadvantages of eddy current heating:- **(1/2 Mark)**

1) High initial cost because of high voltage high frequency supply equipment is required.

e) Compare Single phase 25 kV AC and 1500 V DC track electrification.

Ans: **(Any Four point expected: 1 Mark each, Total 4 Marks)**

S.No	Points	Single phase 25 kV AC track Electrification	1500 V DC track electrification
1.	Supply given to O/H condition	1-ph, 25KV, AC 50 Hz	600/750V-Tromways 1500/3000V urban/suburban
2.	Type of drive used	1-ph, AC series motor	DC series motor for tramways. DC compound motor
3.	Weight of traction motor	1.5 times more than d.c. series motor.	1.5 times less than a.c series motor
4.	Starting torque	Less starting torque than d.c series motor	High starting torque
5.	Accl^{n} and retardation	Less than d.c series motor	High
6.	Overload capacity	Less than d.c series motor	High
7.	Method of speed control	Simple and smooth	Limited, except chopper method
8.	Maintenance cost of traction motor	More	Less
9.	Starting Efficiency	More	Less
10.	Ridding quality	Less, better than d.c.	Smooth (Better)
11.	Insulation cost	High	Low
12.	Cross section of conductor	Less	More
13.	Design of supporting structure	light	Heavy

14.	Distance between two substation	More	Less
15.	No. of substation required for same track distance.	Less	More
16.	Size (capacity) of traction substation	More	Less
17.	Capital & maintenance cost of substation	Less	More
18.	Cost track electrification for same track distance	Less	More
19.	Applications	Main line services	Urban and suburban area

f) State the various types of welding.

Ans: **(Total 4 Marks)**

i) Resistance Welding:-

1) Spot welding

2) Seam welding

3) Projection Welding

4) Butt Welding- i) Simple butt welding

ii) Flash butt welding

ii) Arc welding:-

1) Carbon Arc Welding: a) shielded welding b) unshielded welding

2) Metal Arc Welding: a) shielded welding b) unshielded welding

Q.3 Attempt any TWO : 2 x 8 = 16 Marks

a) i) (i) State advantages and disadvantages of electric braking over mechanical braking.

(Any Four Points From The Following Or Equivalent Points Are Expected For Advantages 1/2 Mark To Each Point, Total 2 Marks & For Disadvantages 1/2 Mark To Each Point, Total 2 Marks, Total 4 Marks)

Following are the advantages & disadvantages of electrical braking over mechanical braking system.

Ans: **Advantages:** (Any Four Points From The Following Or Equivalent Points Are Expected)

1. It is most reliable braking system.
2. Breaking actuation time is small as higher value of braking retardation is obtained.
3. Electrical braking is smooth & gradual.

	4. Life of electrical braking system is more. 5. There is less wear & tear of brake shoes, break block etc. so there is less maintenance cost. 6. Higher speeds are possible even when train is going down the gradient, as breaking system is reliable. 7. Trains having heavy loads can be stopped even when train going up the gradient. 8. Higher speeds of train is possible as braking system is reliable so pay load capacity increases. 9. In case of electric regenerative braking we can utilize 60 to 80% of kinetic energy to generate electricity which is not possible with mechanical braking. **Disadvantages:** (Any Four Points From The Following Or Equivalent Points Are Expected) 1. In addition to electrical braking there must be arrangement of mechanical braking for final stop. 2. Special arrangement of circuit and complication makes electrical braking system costly. 3. Operation in substation becomes complicated at the time of regenerative breaking when generated energy is surplus. 4. Initial cost is more due to other control equipments & circuitry.
a) ii)	**(ii) State any eight advantages of electric heating.**
Ans:	**Advantages of Electric heating:** **(Any Four Advantages expected : 1 Mark each, Total 4 Marks)** 1. It can be put into service immediately. 2. No standby losses. 3. High efficiency. 4. More economical than other conventional types of heating system. 5. Easy to operate and control. 6. No air pollution. 7. System is clean, as there is no waste produced. 8. No fuel transportation cost. 9. No space is required for storage of fuel and waste.

10. Noiseless operation.
11. Uniform heating is possible; heating at particular point is also possible.
12. Dielectric material can be heated.
13. Electrical heating equipments are generally automatic, so it requires low attention and supervision.
14. Protection against overheating can be provided by suitable switch gear.

b) 20 kW, 220 V resistance oven uses Nickel Chromium wire. If the temp. of charge is 727 °C and it is to be heated to 1127 °C, find the suitable length and diameter of wire.
Assume : Emissivity = 0.9, Radiant efficiency = 0.6 & Sp. resistance = 1.03 x 10-6 SZ m.

Ans:

(When Final answer of Numerical is correct Give Full Marks & if final answer is wrong give stepwise marks)

Given Data:

$T_1 = 1127^0C = 1127+273 = 1400^0K$ ---------- **(1/2 Mark)**

$T_2 = 727^0C = 727 +273 = 1000^0K$ ----------**(1/2 Mark)**

Radiation efficiency = 0.6, specific resistance of Ni-Cr = $1.03x10^{-6}$ ohm m, emissivity = 0.9.

$$H = 5.72\times10^4 \text{ k.e}\left[\left(\frac{T_1}{1000}\right)^4 - \left(\frac{T_2}{1000}\right)^4\right] \text{ w/m}^2$$ **OR**

$$\mathbf{H} = 5.72\times\ k.e\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]\ w/m^2$$ ---------- **(1 Mark)**

$$\mathbf{H} = 5.72\times\ 0.6\times0.9\left[\left(\frac{1400}{100}\right)^4 - \left(\frac{1000}{100}\right)^4\right]\ w/m^2$$

$$\mathbf{H} = 87771.3408 w/m^2$$ ---------- **(1 Mark)**

➢ $$\therefore \frac{l}{d^2} = \frac{V^2\ \pi}{4\ P\ \rho}$$ ---------- Equation No.1---------- **(1 Mark)**

$$\therefore \frac{l}{d^2} = \frac{(220)^2\,\pi}{4\times 20\times 1000\times 1.03\times 10^{-6}}$$

$$\therefore \frac{l}{d^2} = 1845543.68$$

$$l = 1845543.68d^2$$

--- Equation No.2 ---------- **(1 Mark)**

$$\frac{d}{l^2} = \frac{4\rho H}{V^2}$$

$$\frac{d}{l^2} = \frac{4\times 1.03\times 10^{-6}\times 87771.34}{(220)^2}$$

$$\frac{d}{l^2} = 7.471^{-6}$$

$$d = 7.474\times 10^{-6}\times [1845543.678d^2]^2$$

$$d = 2.5446\times 10^{7}\times d^4$$

$$\frac{d}{d^4} = 2.5446\times 10^{7}$$

$$\frac{1}{d^3} = 2.5446\times 10^{7}$$

$$d^3 = 39296.5\times 10^{-12}$$

Taking Cube root of both sides

$$d = 3.399\times 10^{-3} m$$ --- ---------- **(1Mark)**

$$d = 3.399 mm$$

Substitute Value of 'd' in Equation No.2 to calculate 'l' :

$$l = 1845543.68d^2$$

---------- **(1 Mark)**

$$l = 1845543.68\times [3.399\times 10^{-3}]^2$$

$$l = 21.209172\ m$$

---------- **(1 Mark)**

Answer : $\therefore$ *Length* $l = 21.209172$ *mtr*
$\therefore$ *Diameter* $d = 3.399$ *mm*

c)	**What is electric welding ? Describe electric arc welding in brief. How arc is formed in electric arc welding ?**
Ans:	**Meaning of electric welding :** **(2 Marks)**

It is the process of joining two similar or dis-similar metals by application of heat with or without application of pressure and addition of filler material.

Define electric arc welding:- **(2 Mark)**

- The processes in which two metal parts to be welded are brought to a molten state and then allowed to solidify is called as arc welding or stick welding.

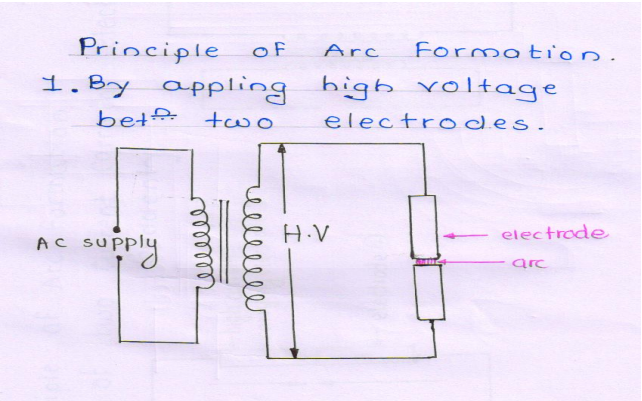
How arc is formed :- for following method

a) By applying High Voltage

b) By separation of two current carrying electrodes suddenly

Explanation:- (Any one Method is expected 4 Marks) **(4 Marks)**

a) By applying High Voltage:- Figure:



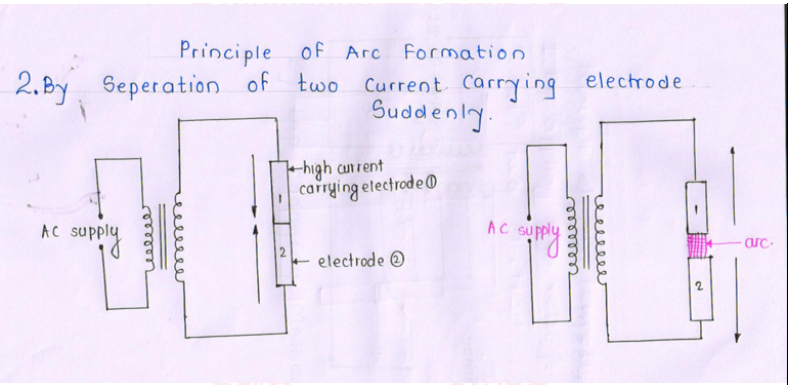
or equivalent figure

Operation:

- When very high voltage is applied across any two electrodes separated by small air gap then air between two electrodes gets ionized and ionized air is conducting, so current starts flowing from one electrode to another electrode in the form of spark (arc).
- This arc produces heat energy which is utilized for melting the charge.
- High Voltage is required to produce arc and to maintain arc high voltage is not necessary.
- Once arc is struck between two electrodes then low voltage is sufficient to maintain the arc.

b) By Separation of two current carrying electrodes suddenly:-

Figure:



or equivalent figure

Operation:-

- Another way to produce arc is to short circuit two current carrying electrodes as shown in fig (a) and suddenly withdraw them, then there will be spark between two electrodes as shown in figure (b)
- This arc then produce heat energy which is utilized for melting the charge.
- In this method high voltage is not necessary to produce the arc.
- **Characteristics of Arc:**
  1. Arc is conducting.
  2. Arc has negative temperature coefficient of resistance.

Q.4A) Attempt any THREE : 3 x 4 = 12 Marks

a) Compare DC and AC welding on any four points.

Ans:

(Any Four point Expected: 1 Mark each, Total 4 Marks.)

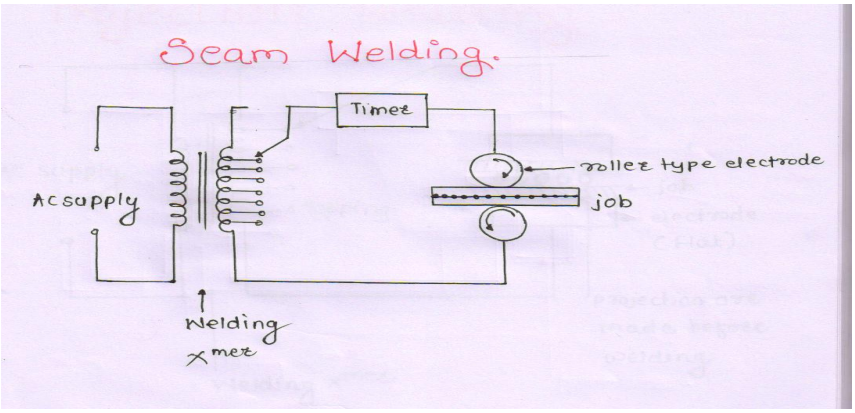
S.No	Points	DC Welding	AC Welding
1	Supply equipment used	DC differential Compound Generator, or Rectifier	Welding Transformer
2	Heating Effect	Uniform	Not Uniform
3	Temperature Obtain	More	Less
4	Possibility of Arc Blow	More Possibility	No Possibility
5	Stability of Arc	D.C Differential compound. Generator has dropping characteristics.	Use of series Reactor

6	Type of Electrode	Non Coated Electrode is used	Coated Electrode is compulsory
7	Voltage Required	50 to 60 volt	72 to 100 volt
8	Capital Cost	High	Low
9	Running cost	High	Low
10	Maintenance cost	High	Low
11	Stand by losses	High by 25%	Low
12	Efficiency	Low, 65%	High, 85%
13	Application	Carbon Arc Welding	Resistance Welding , Metal Arc Welding

b) Describe with neat sketch operation of seam type resistance welding.

Ans:

1) Seam Welding its neat labelled sketch: **(2 Mark)**



or equivalent figure

Explanation: **(2 Mark)**

Seam welding is nothing but series of continuous spot welding

Working:

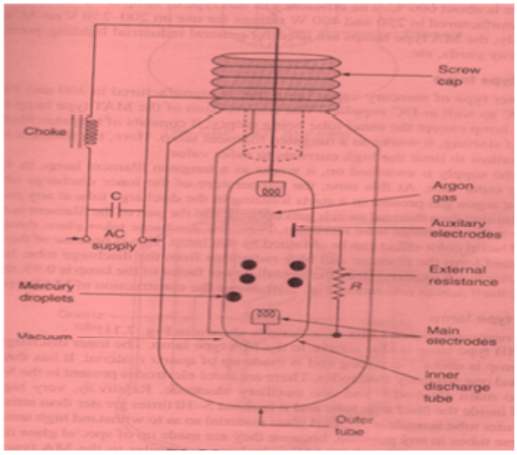
- Job is kept in between two electrodes under pressure. This pressure is kept constant throughout.
- In this type intermittent current is used, it means current is ON for definite time and OFF for another time interval with the help of timer.
- If current is continuously passes then heat produced may cause burning of job.
- Heat is produced due to I^2R losses where 'R' is the contact resistance.

- This heat is utilized to obtain welding temperature (to become a plastic state)
- When welding temperature is reached supply is cut down and external pressure is applied simultaneously across the job to complete weld.

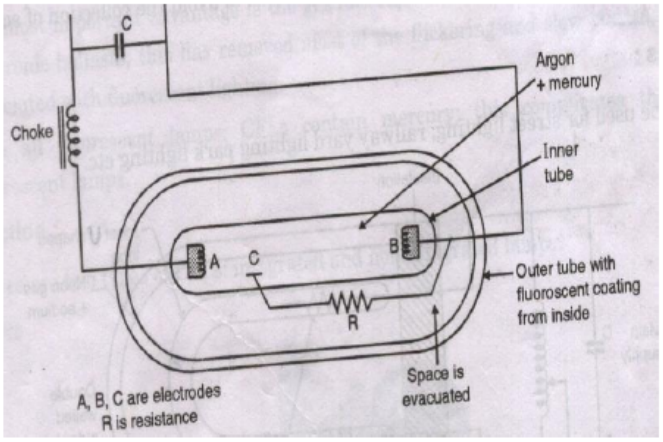
c) Describe the construction of high pressure mercury vapour lamp with neat sketch,

Ans:

Figure mercury vapour discharge lamp :- **(2 Mark)**



OR



Construction:- **(2 Mark)**

- It consists of an inner bulb generally of silicon, to withstand high temperatures.
- The bulb contains a small quantity of mercury and argon.
- It is protected by outer glass, this may be cylindrical or elliptical.
- The space between the two bulbs is filled with nitrogen at a pressure of half atmosphere.
- The discharge tube has three electrodes, namely two main electrodes A and B and one starting electrode.
- The starting electrodes are connected through a resistance of about 10-30 k ohm to the main electrode, located at the far end.
- The electrodes are of tungsten wire helices filled with electron emissive materials, usually barium and strontium carbonates mixed with thorium.

OR Student may write

The construction & connection diagram is as shown in figure. As per this construction there are following components.

- **Choke:** The choke is acting as the ballast. At the time of supply voltage variation of current

flowing through the inner tube is maintained constant to keep uniform light intensity. Sometimes choke can be designed for to get the higher voltages & to apply the inner tube of mercury vapour lamp.

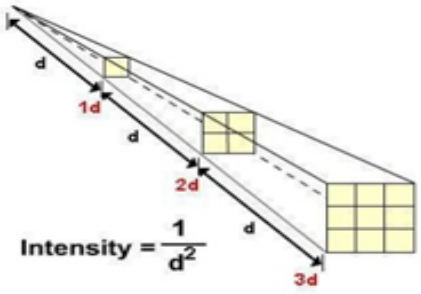
- **Starting resistance/limiting resistance:** Whenever current flows through the starting resistance there is a I2R loss which is converted into heat. If the temperature of this heat goes near about 6000C then there will be heating effect & inert gases ionization will be start.
- **Auxiliary electrode & Main electrode:** It is made by high resistive element. The ionization is taking place through the inert gases whenever current flows from auxiliary electrode to main electrode.
- **Inner Tube:** The various inert gases e.g. Argon, Nitrogen etc with mercury powder are filled in the inner tube at low pressure or high pressure.
- **Outer Tube:** The function of outer tube is to make the vacuum surrounding the inner tube to avoid thermal dissipation or to maintain 6000C surrounding the inner tube.
- **Power factor improvement Capacitor:** The function of power factor improvement capacitor is to improve the power factor 0.5 to 0.95

d) Give the two laws of illumination.

Ans: **(Inverse Square Law :- 2 Marks , Lamberts Cosine Law:- 2 Marks , Total 4 Marks.)**

1) Inverse Square Law:-

Intensity of illumination produced by a point source varies inversely as square of the distance from source.



$$E = \frac{I}{d^2}$$

Where,

I = intensity and d = Distance

2) Lamberts Cosine Law:

According to this law, Illumination at any point on a surface is proportional to the cosine of the angle between the normal at that point and the direction of luminous flux

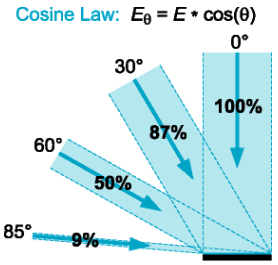


Fig. 6.3 Lambert's cosine law.

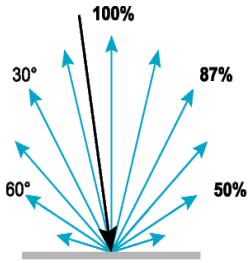


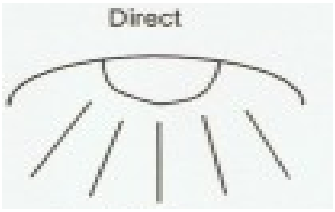
Fig. 6.5 Lambertian surface.

Q. 4 B) Attempt any ONE of the following : 6 Marks

a) Describe through illustration the following types of lighting scheme : (i) Direct, (ii) Indirect, (iii) Semi-direct, (iv) Semi-indirect.

Ans:

1. Direct lighting: **(1.5 Marks)**

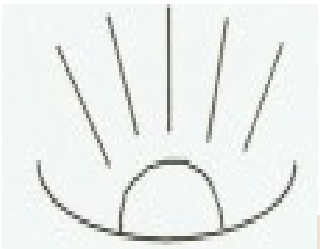


Direct: All the light goes downward or toward (90–100%)

Application:

The direct lighting scheme is widely used in drawing room, workshop and flood lighting etc.

2. Indirect lighting: **(1.5 Marks)**

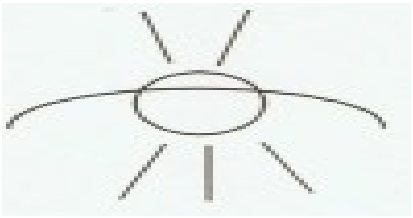


Indirect: All the light goes upward or away (90–100%)

Application:

Which is useful for drawing offices and composing rooms. It is also used for decoration purposes in cinema halls, hotels etc.

3. Semi direct lighting: **(1.5 Marks)**

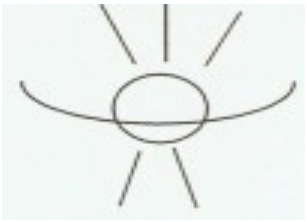


Semi–direct: Most light goes downward (60–90%)

Application:

It is mainly used for interior decoration.

4. Semi indirect lighting: **(1.5 Marks)**



or equivalent figure.

Semi–indirect: Most of the light goes upward or away (60–90%)

Application:

It is mainly used for interior decoration.

b) Describe with schematic diagram steps involved in series — parallel • control of traction motor.

Ans: **(Series steps--- 3 Marks, Parallel steps----- 3 Marks, Total 6 Marks)**

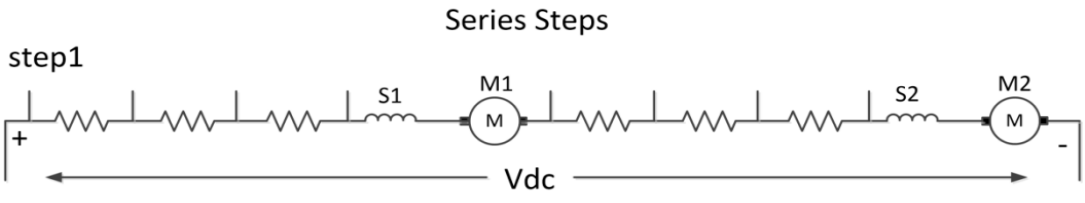
Series parallel control of DC series motor

1. For traction purpose, two motors are operated in following steps.

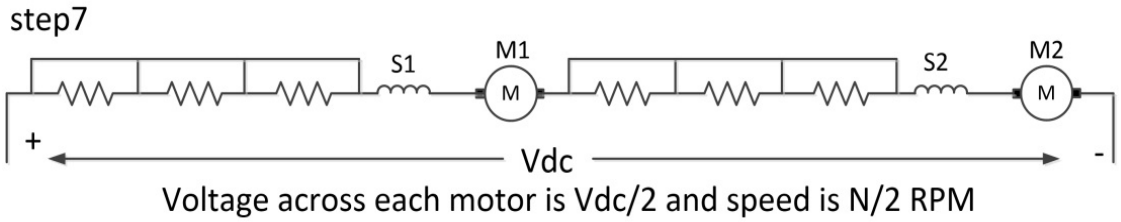
Series steps of traction motor:

Step 1 –

- Two traction motors M1 and M2 are connected in series and started with all starting resistances in series.



- The starting resistances are cut out one by one gradually from step 1 to step 7 and finally two motors are in series without any resistance.
- In series connection the supply voltage V is divided in two motors. (Both motors get half or (V/2) volts). So speed is also half. (N/2)

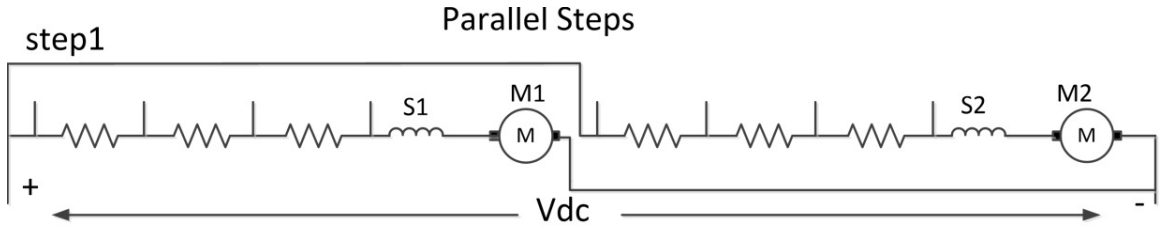


Voltage across each motor is Vdc/2 and speed is N/2 RPM

Parallel steps of traction motor:

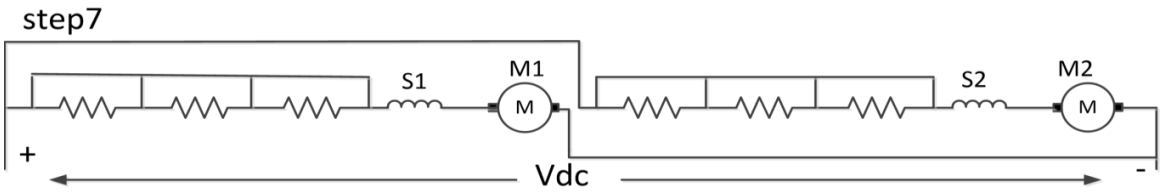
Step 1 –

- After completion of series last step motors are now connected in parallel again with series resistance otherwise motor will draw very high current and may damage itself.



Step 2 to 7 –

- Both motors are now connected in complete parallel and starting resistances are cut out one by one 2 To 7
- In parallel connection, voltage across M1 and M2 will be full i.e. V (voltage is always same in parallel).
- Voltage across each motor = V and speed of each motor = N
- So, voltage is now increased from (V/2) to V.
- Hence, speed also increases from (N/2) to N and motor runs with full speed.



Voltage across each motor is Vdc and speed is N RPM

Advantages:

1. This method has highest starting efficiency then rheostat method.

   Starting efficiency of plain rheostat method = 50 %. By this method for two motor it is 66.66% & for 4 motors it is 72.72% and for 6 motors it is 75%

2. Different economical speeds are obtained:
   - For 2 Motor = 1 :2
   - For 4 Motor = 1:2:4
   - For 6 Motor = 1:2:3

3) For same power input torque of different magnitude is obtained.

Disadvantages:

1. If proper transition method is not used then
   - There is loss of torque when motors are disconnected from supply
   - There will be jerk when motors are reconnected in parallel

Q.5	**Attempt any FOUR :**	**4 x 4 = 16 Marks**
a)	**Write different systems of track electrification.**	

Ans: **(Any Four Systems Of Track Electrification From The Following Are Expected 1 Mark To Each Systems Of Track Electrification, Total 4 Marks)**

Following are the different track electrification system

D.C. Supply system:-

1. Direct current track electrification:
   - 600V, 750V DC for tramways

	➢ 1500V, 3000V DC for Train (Urban and sub-urban services) **A.C. Supply system:-** 2. 1-Ph, 25KV,standard frequency AC supply system: ➢ 1-Ph, 25 KV, 50 Hz 3. 1-Phase, low frequency AC Supply system: ➢ 1-Ph, 15/16 KV, 16.2/3 Hz or 25 Hz 4. 3-Ph, Low frequency AC supply system; ➢ 3-Ph, 3.3/3.7 KV, 16 2/3 Hz or 25 Hz **Composite system:-** 5. 1-Ph AC (1-ph, 25KV) – DC Supply System 6. Kando System (1-Ph AC – 3-Ph AC)
b)	**Write eight desirable characteristics of traction motor.**
Ans:	**(Any Eight Points From The Following Or Equivalent Points Expected 1/2 Mark Each, Total 4 Marks)** **Desirable characteristics of ideal traction motors:-** 1) It should be robust in construction to withstand against continuous vibrations. 2) Weight of motor per HP should be minimum in order to increase pay load capacity. 3) It must be small in overall dimensions, especially in overall diameter. 4) It must have totally enclosed type enclosure to provide protection against entry of dirt, dust, mud, water etc. in drive. 5) When motors are running in parallel they should share almost equal load. (even when there is unequal wear & tear of driving wheels) 6) It should have high starting torque. 7) It should possess high rate of acceleration & retardation. 8) It should be variable speed motor. 9) Its speed-torque characteristics should be such that it should produce high torque at low speed

and low toque at high speed.

10) Motor must be capable of taking excessive overload in case of emergency.
11) It should have simple speed control methods.
12) Electrical braking system should be reliable, easy to operate and control, especially regenerative braking is possible.
13) Motor should draw low inrush current (Starting current,and if supply is interrupted and restore again.)
14) It should withstand for voltage fluctuation without affecting its performance.
15) It should have low initial cost.
16) It should have less maintenance cost.
17) It should have high efficiency.
18) It should have long life.

c) A train has schedule speed of 60 kmph between stops which are 6 km apart. Determine crest speed over the run assuming : (i) Duration of stops as 60 sec. (ii) Acceleration as 2 kmphps (iii) Retardation as 3 kmphps. The speed time curve is trapezoidal.

Ans:

Given data:

$V_{sch} = 60\ Km/hr \qquad D = 6KM \quad T_{Stop}\ 50\text{sec} \quad \alpha = 2km/hr - \text{sec} \quad \beta = 3km/hr.\text{sec}$

Solution;

$$V_{sch} = \frac{3600D}{Schedule\ \ Time\ (T_{sch})}$$ ---------- **(1 /2 Mark)**

$$\therefore Schedule\ Time\ (T_{sch}) = \frac{3600 \times D}{V_{sch}}$$

$$\therefore Schedule\ Time\ (T_{sch}) = \frac{3600 \times 6}{60}$$

$$\therefore Schedule\ Time\ (T_{sch}) = \frac{21600}{60}$$

$$\therefore Schedule\ Time\ (T_{sch}) = 360\ \text{sec}$$ ---------- **(1 /2 Mark)**

- $Schedule\ Time\ (T_{sch}) = Actual\ Time\ of\ \ Run\ (T) + Stop\ time\ (T_{stop})$

$$\therefore Actual\ Time\ of\ \ Run\ (T) = Schedule\ Time\ (T_{sch}) - Stop\ time\ (T_{stop})$$

$$\therefore Actual\ Time\ of\ \ Run\ (T) = 360 - 60$$

$$\therefore Actual\ Time\ of\ \ Run\ (T) = 300\ \text{sec}$$ -------- ---------- **(1/2 Mark)**

➢ **Maximum Speed**

$$V_{max} = \frac{T - \sqrt{T^2 - 4K3600D}}{2K}$$

But, $K = \frac{\alpha + \beta}{2(\alpha \times \beta)}$ ---------- ---------- **(1/2 Mark)**

$$K = \frac{2+3}{2(2\times 3)}$$

$K = 0.4167$

---------- ---------- **(1/2 Mark)**

Now,

$$V_{max} = \frac{T - \sqrt{T^2 - 4K3600D}}{2K}$$ ---------- **(1/2 Mark)**

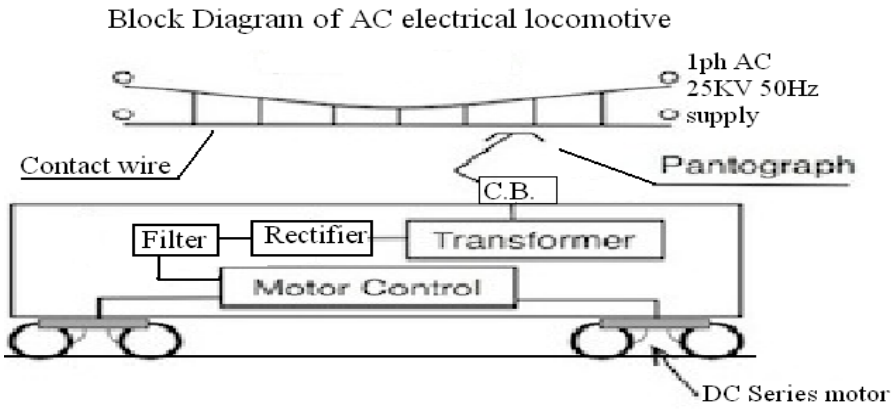
$$V_{max} = \frac{300 - \sqrt{(300)^2 - 4\times 0.4167\times 3600\times 6}}{2\times 0.4167}$$

$$V_{max} = \frac{300 - 232.372}{2\times 0.4167}$$

$V_{max} = 81.1471\ Km/hr$ -- ----------**(1 Mark)**

d) Draw a neat labelled block diagram of AC electric locomotive. State the function of each part.

Ans: **labelled diagram of AC electric locomotive:** **(Diagram: 2 Marks & Function: 2 Marks)**



Function of AC electric locomotive Parts:

1) Overhead contact wire:

Supply of 1-ph, 25KV, 50Hz, AC is given to overhead conductor.

2) Current collecting device:

It collects current from overhead contact wire and passes it to tap changing transformer through circuit breaker.

3) Circuit breaker (C.B):

- It is connected in between current collecting devices and tap changing transformer.

  SF6 circuit breaker is used.
- To disconnect locomotive equipments whenever there is fault.
- It opens automatically when train passes neutral zone (from zone No.1 to Zone No.2)

4) On load tap changing transformer:

It changes the tap without disconnecting the load on transformer. Its purpose is to vary the voltage for speed control of traction motor.

5) Traction Transformer:

It step down input voltage 25 KV to working voltage of traction motor (1500V/3000V).

6) Rectifier:

It converts secondary voltage of transformer into DC supply.

7) Filter circuit (smoothing reactor):

It is used to obtain pure DC supply.

8) Motor control unit: It controls operation of traction motor.

9) Traction Motor:

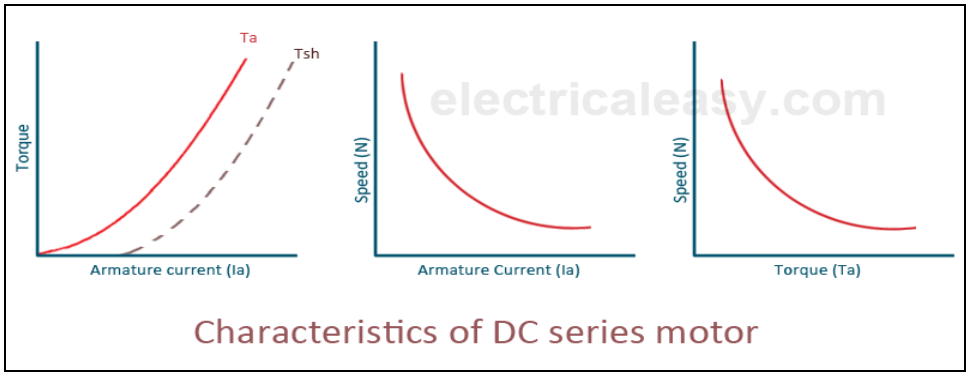
It gives mechanical power to run the train i.e. DC series motor which is used as traction motor.

e) "DC series motor is used for traction purpose." Justify your answer with any six characteristics.

Ans: **(4 Marks)**

Due to following characteristics and advantages, DC series motor is suitable for traction purpose:

1) **Characteristics:** We know that,



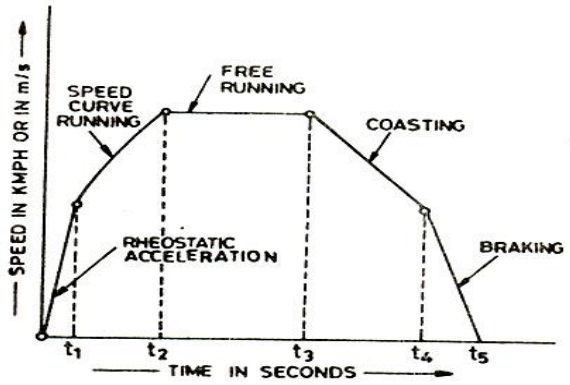
Characteristics of DC series motor

Due To Following Reasons DC Series Motor Is Used For Traction Purpose:-

1. DC Series motor robust in construction and capable to withstand against continuous vibration.
2. DC series motor weight is 1.5 times less than 1-Ph AC series motor for same H.P.
3. DC Series motor has high starting torque.
4. DC Series motor has high rate of acceleration and retardation.
5. DC Series motor is variable speed motor. Due to these characteristics motor is protected against overload.
6. DC Series motor speed-torque characteristics are such that as torque increases speed decreases.
7. DC series motor has develops high torque at low speeds, low torque at high speed, this is the basic requirement of traction unit.
8. Commutating property of series motor is good so we get sparkles commutation.
9. Torque is unaffected by variation in supply voltage.
10. DC Series motor maintenance cost is less.
11. When DC series motor are running in parallel the all motors share almost equal load.
12. Torque obtained by DC series motor is smooth and uniform, so it improves riding quality.

e)	**Draw speed time curve. Show and list various time periods associated with it.**
Ans:	**Typical speed time curve for main traction line :**

(Total, 4 Mark)



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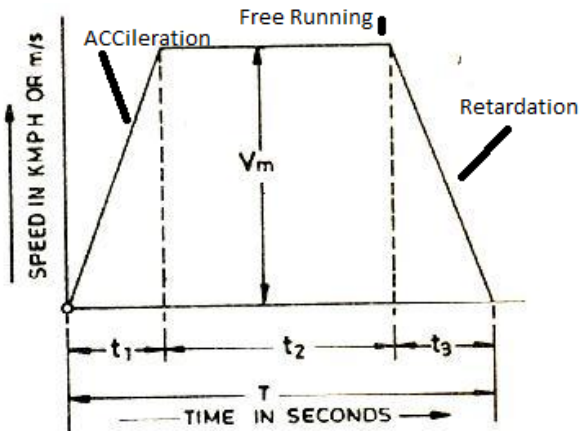


Speed Time Curve list various time periods:-

There are five periods in the run of train as shown in speed time curve.

i) Constant acceleration period (o to A)

ii) Acceleration on speed –Time curve (A to B) For T_2 sec.

iii) Free Running or constant period (B to C) For T_3 sec.

iv) Coasting period (C to D) For T_4 sec.

v) Braking period (D to E) For T_5 sec.

Q.6	**Attempt any TWO :** **8 x 2 = 16 Marks**
a) i)	**A 400 V, 50 Hz, 3 Phase line delivers 200 kW at 0.7 p.f. lagging. It is desirable to improve the line power factor to unity by using shunt capacitors. Calculate value of capacitance of each unit if they are connected in delta.**

Ans:

Volt : line volts V = 400V, f= 50 Hz P= 200kW $\cos\phi_1$=0.7 $\cos\phi_2$ =1

$\therefore$ Cos $\phi_1 = 0.7$ $\therefore \phi_1 = 45.5729^0$

$\therefore \tan\phi_1 = \tan 42.5729^0$

$\tan\phi_1 = 1.020$ ---------- **(1/2 Mark)**

$\tan\phi_2 = 0$ ---------- **(1/2 Mark)**

$Q_1 = P \tan\phi_1$
$= 200 \times 1.020$
$= 204$ KVAR ---------- **(1/2 Mark)**

$Q_2 = P \tan\phi_2$
$= 200 \times 0$
$= 0$ KVAR ---------- **(1/2 Mark)**

$Q_C = Q_1 - Q_2$
$= P \tan\phi_1 - P \tan\phi_2$ ----------**(1/2 Mark)**
$= 204-0$
$= 204$ KVAR ---------- **(1/2 Mark)**

$\therefore$ Capacitor when connected in Delta:-

$$C \text{ per phase} = \frac{Q_C}{3\omega V^2}$$ ---------- **(1/2 Mark)**

$$C \text{ per phase} = \frac{204\times10^3}{3\times 2\pi\times 50\times 400^2}$$

$$C \text{ per phase} = \frac{204\times10^3}{3\times 50.265\times10^6}$$

$$C \text{ per phase} = 1.3528\times10^{-3} F$$ ---------- **(1/2 Mark)**

a) ii)	**State four requirements of tariff.**
Ans:	**(Any Four Requirements From The Following Or Equivalent Points Are Expected , Total 4 Marks)** **Following are the requirements of Tariff :-** 1. It should be easy to understand to consumer. 2. Easy to calculate. 3. Tariff should be attractive i.e. It should not be too high or too low. It should be reasonable. 4. Tariff should be economical as compare to other types of energy sources. 5. Tariff should be different for different types of consumers. 6. Tariff must be fair, so that different types of consumers are satisfied with rate of electrical energy charges. 7. Tariff should be framed into two parts i.e. fixed charges + running charges. 8. Tariff should be high during peak load period. 9. Tariff should be low during off load period. 10. For industrial consumer, in addition to basic tariff incentives and penalty related to PF and LF should be considered.
b) (i)	**What are different tariffs used by electricity supply authority ? Describe any two in brief.**
Ans:	**Types of Tariff:-** **(Any Four Types expected: 1/2 each, Total 2 Marks)** 1) Flat-demand Tariff 2) Simple-demand Tariff or Uniform Tariff 3) Flat-rate Tariff 4) Step-rate Tariff 5) Block-rate Tariff 6) Two-part Tariff 7) Maximum demand Tariff 8) Three-part Tariff

9) Power factor Tariff :- a) KVA maximum demand Tariff

b) Sliding Scale Tariff or Average P.F. Tariff

c) KW and KVAR Tariff

10) TOD (Time of Day) Tariff

11) ABT:-This tariff system is called availability based tariff. As its name suggest it is a tariff system which depends on the availability of power.

Explanation of Types of Tariff (Any TWO Types explanation Expected: 1 Mark each, Total 2 Marks)

1) Block Rate Tariff:-

- In case of block rate tariff there are blocks of units consumed and each block tariff rate/unit (KWH) is different plus consumer has to pay fix charges e.g.
- If generation is less than utilization than tariff rate/unit in each block goes on increasing and vice versa. e.g.

2) Two Part Tariff:-

- In this type of tariff energy bill is split into two parts.

ENERGY BILL= FIXED CHARGE which depends on load (KW) +RUNNING CHARGE which depends on actual energy consume (KWH)

- Fixed charge which depends on load (KW) which is declared by consumer on test report.
- There is no separate meter is installed to measure load.
- Only one energy meter is used to measure number of units consumed.
- This type of tariff system is used for residential and commercial consumers.(up to 20 KW)
- This type of tariff is not used for industrial consumers.
- **Advantages:**

1. It recovers fixed charges which depends on load (KW), so it automatically recovers capital investment of Supply Company

- **Disadvantages:**

1. The consumer has to payfix charges per month whether he has to consume or not consume the electrical energy.

- **Application:**

1. This type of tariff system is used for residential and commercial consumers. (Up to 20 KW)

2. This type of tariff is not used for industrial consumers.

3) Maximum Demand Tariff/KVA Maximum Demand Tariff / Load factor tariff:-

- This is basic tariff for all industrial / commercial consumers with contract demand above 80 KW/ 100KVA/107 HP
- It is similar to two part tariff except that maximum demand (KVA) is actually measured by installing maximum demand meter(in KVA)
- M.D. Meter (it is an electromagnetic or electronic trivector meter) is installed in the premises of consumer, in addition to energy meter.

Maximum Demand Tariff / Load factor Tariff =

$$M.D.(KVA) \times Rs\ 'X'\ permonth + \{Number\ of\ units\ (KWH)\ Actual\ consumer\} \times Rs\ 'Y''$$

Application: -This type of tariff is applicable to industrial consumer/H.T/ commercial consumers with contract demand above 80 kw/ 100Kva/107 hp consumer.

- Measurement of KVA M.D.:-

  Actual Maximum Demand recorded in the month during 06am.To10pm. Is considered for billing.
- Incentives and Penalties to M.D. tarrif :-

Incentives :-

1) If consumer is used M.D. above 75 % to 85 % of saction contract demand than , consumer will gate 0.75 % rebeat on the energy bill.
2) If consumer is used M.D. above 85 % to 100 % of saction contract demand than , consumer will gate 1 % rebeat on the energy bill.

Penalties :-

1) If consumer is used M.D. above 100 % of saction contract demand than , consumer has to pay

more demand charges 150 % for use of extra M.D.

2) If consumer is used M.D. below 50 % of saction contract demand than , consumer has to pay minimum demand charges 50 % of saction contract demand.

Advantages:-

1) Each industrial consumer is trying to use M.D. above 75 % to 100 % of sanction contract demand to get discount in energy bill. So it will improve load factor of industry.
2) Industrial consumers were not utilizing their load simultaneously to avoid Penalties on exceed of M.D. than saction contract demand. So it will improve diversity factor.
3) Industrial consumer is trying to improve power factor to reduce maximum demand charges.

Since $KVA \propto I \propto 1/pf$

4) As each industry run at high load factor, diversity factor and power factor then overall load factor, diversity factor and power factor of power system increases.
5) Which will automatically beneficial from the economics of power system and energy conservation point of view.

4) Power Factor Tariff:-

In addition to basic tariff (Maximum Demand Tariff/KVA Maximum Demand Tariff / Load factor tariff) **the tariff in which P.F. of industrial consumer is taken into consideration.**Is known as Power Factor Tariff.

- If the P.F. of consumer is less than P.F. declare by Supply Company (say below 0.9 Lag.) than penalty will be charged in energy bill.
- If The P.F. of consumer is more than P.F. declare by Supply Company (say above 0.95lag.) than discount will be given in energy bill.
- As usual consumer has to pay actual energy consumption charges
- Application :-

  This type of tariff is applicable to industrial consumer/H.T/ commercial consumers with contract demand above 80 kw/ 100Kva/107 hp consumer.

- Incentives and Penalties to Power factor tarrif :-

Power factor incentive:- e.g.

Power Factor	Percentage of incentive
0.95	0% of energy bill
Above 0.96	1% of energy bill
Above 0.97	2% of energy bill
Above 0.98	3% of energy bill
Above 0.99	4% of energy bill
At unity P.F.	5% of energy bill

Power factor penalty:- e.g.

Power factor lagging	Percentage of penalty
For0.90Power factor lagging	0% of energy bill
For 0.89 Power factor lagging	2% of energy bill
For 0.88 Power factor lagging	3% of energy bill
For 0.87 Power factor lagging	4% of energy bill
For 0.86 Power factor lagging	5% of energy bill
For 0.85 Power factor lagging	6% of energy bill
For 0.84 Power factor lagging	7% of energy bill
For 0.83 Power factor lagging	8% of energy bill
For 0.82 Power factor lagging	9% of energy bill
For 0.81 Power factor lagging	10% of energy bill

There are three types of P.F. tariff ;-

a) KVA maximum demand Tariff: (All ready explain above)

b) Sliding Scale Tariff or Average P.F. Tariff:

- If the P.F. of consumer is less than P.F. declare by Supply Company (say below 0.9 Lag.) than penalty will be charged in energy bill.
- If The P.F. of consumer is more than P.F. declare by Supply Company (say above 0.95lag.) than discount will be given in energy bill.
- As usual consumer has to pay actual energy consumption charges

c) KW and KVAR Tariff:

- In this type both active (KW) & reactive power (KVAr) supplied are charged separately and actual energy consumption charges
- A consumer having low power factor draw more reactive power and shall have to pay more charges and vice-versa.
- So consumer is trying to improve power factor to reduce KVAr charges in energy bill, so power factor of power system increases.

$$Energy\ \ Bill = \{Rs\ 'A'(KW)\ Charges\} + \{Rs\ 'B'(KVAR)\ Charges\} + \{Rs\ 'C'(KWH)\ Charges\}$$

5) Time of Day (TOD) Tariff or OFF-load Tariff:-

- **In addition to basic tariff** (Maximum Demand Tariff / KVA Maximum Demand Tariff / Load factor tariff also the tariff in which P.F. of industrial consumer is taken into consideration.**)** Consumer has to pay energy consumption charges according to time for which energy is consumed.
- TOD energy meter is installed in the consumer premises.
- This meter is specially designed to measure energy consumption w.r.t. time.
- This type of tariff is such that energy consumption charges/unit are less at during OFF-load period

- Energy consumption charges/unit are more during PEAK -load period
- This type of tariff is introduced to encourage industrial consumers to run their maximum load during OFF-load period.
- e.g.

Sr.No	Block	Rate / KWH Rs	Remark
1	8.00 am to 12.00 noon	Rs. 6.00 per unit+0.80 Rs. Per unit	Peak load period
2	12.00 noon to 6.00 pm	Rs. 5.00 per unit+ 0 Rs. Per unit	Base load
3	6.00 pm to 10.00 pm	Rs. 6.00 per unit+ 1.10 Rs. Per unit	Peak load period
4	10.00 pm to 8.00 am	Rs. 5.00 per unit – 1.50 Rs. Per unit	OFF load period

Application :-

This type of tariff is applicable to industrial consumer/H.T/ commercial consumers with contract demand above 80 kw/ 100Kva/107 hp consumer.

6) Three part Tariff:-

- Fixed charges per month depend on connected load.
- Semi-fixed charges depend on KVA maximum demand.
- Running charges depend on actual energy consume.

b) (ii) State any four advantages of good power factor for electric supply.

Ans: **Following Advantages of good power factor for electric supply:**

(Any Four Advantages are expected: 1 Mark each, Total 4 Marks)

1. Cross section of conductor reduces:

$$\text{Cross section of conductor } \alpha\ I\ \alpha\ \frac{1}{P.f}$$

As P.F. increases current reduce so; cross section of conductor and its weight reduces hence its cost reduces

2. Design of supporting Structure:

As weight of conductor reduces design of supporting structure (tower) becomes lighter, so its cost reduces.

3. Cross section of terminal (contacts) reduces:

As power factor increases, current reduces. hence cross section of switchgear bus bar and contacts etc decreases.

4. Copper losses reduces:

As power factor increases current reduces. So copper losses reduces. As a effect efficiency increase.

5. Voltage drop reduces:

As P.F. increases, current decreases. So voltage drop decreases, So regulation gets improved (better)

6. Handling capacity (KW) of equipment increases:

As power factor increases, handling capacity of each equipment such as Alternator, transformer increases

7. KVA rating of equipments reduces:

As P.F. increases, current decreases. So KVA rating of all equipments for eg- alternator, transformer etc decreases, so its capital cost reduces.

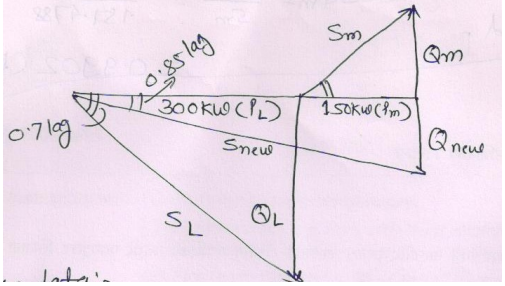
8. Cost per unit (KWH) reduces:

From all above advantages, it is seen that cost of generation, transmission & distribution decreases, so cost/unit reduces.

Also performance i.e. efficiency & regulation gets improved at high power factor

c) (i) A Factory takes 300 kW at 110 V from a 3 phase supply and power factor of 0.7 lagging. A synchronous motor is installed which takes an additional 150 kW. What must be the kVA rating of this motor to raise the power factor of the system to 0.85 lagging ?

Ans:



or equivalent diagram **Given Data:**

P_L = 300 KW $Cos\phi = 0.7\ lag$ $Sin\phi = 0.7$ $tan\phi = 1$

Power factor improved to 0.85 *lag* $\tan\phi_{new} = 0.6197$ $P_m = 150_{KW}$

- Reactive Power taken by load (Q_L) = $P_L \tan\phi$ ---------- **(1/2 Mark)**

  = 300 x 1

  = 300 *KVAR* (*lag*) ---------- **(1/2 Mark)**

- Reactive Power taken after synchronous motor is connected (Q_{new}) =

  $=(P_{L+} P_m) \tan\phi_{new}$ ---------- **(1/2 Mark)**

  = (300 +150) x 06197

  = 450 x 06197

  = 278.8849 *KVAR* (*lag*) ---------- **(1/2 Mark)**

- Reactive Power taken by synchronous motor to improve P.f =

  $= ((\phi_L - \phi_{new})$

  = 300 - 278.8849

  = 21.115 *KVAR* (*leading*) ---------- **(1/2 Mark)**

- *KVA Rating of Synchronous Motor* $S_m = \sqrt{(P_m + \phi_m)^2}$ - ---------- **(1/2 Mark)**

  $S_m = \sqrt{(150)^2 + (21.115)^2}$

  $S_m = \sqrt{22945.845}$

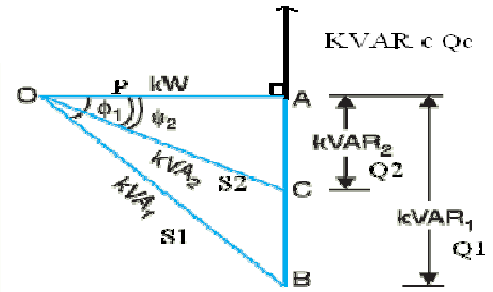
  $S_m = 151.4788$ *KVA* ---------- **(1/2 Mark)**

- *Power Factor of Synchronous Motor* $Cos\phi_m = \frac{P_m}{S_m} = \frac{150}{151.4788}$

  Power Factor of Synchronous Motor $Cos\phi_m = 0.9902$ *leading* ---------- **(1/2 Mark)**

c) (ii)	**Derive the equation of most economical power factor.**

Ans: **Derivation:** **(4 Mark)**



Let,

P = Active power KW

S_1, S_2 = KVA Maximum demand before and after improving power factor

Q_1, Q_2 = Lagging reactive power before & after improving power factor

Q_C = Leading Reactive power drawn by Capacitor

$\cos\phi_1$ = Initial Power factor

$\cos\phi_2$ = Improved Power factor

Rs X = Tariff charges towards M.D. (KVA) /year

Rs Y = Expenditure towards KVAr to be neutralized per year (Expenditure towards P.F. improving apparatus)

1) Before improving Power factor:

$$Q_1 = P \tan \phi_1$$

$$\cos \phi_1 = \frac{P}{S_1}$$

$$S_1 = \frac{P}{\cos \phi_1}$$

$$\therefore KVA_1\ (S_1) = P \sec \phi_1$$

2) After improving Power factor**:**

$$Q_2 = P \tan \phi_2$$

$$\text{Cos}\ \phi_2 = \frac{P}{S_2}$$

$$S_2 = \frac{P}{\text{Cos}\ \phi_2}$$

$$\therefore KVA_2\ (S_2) = P \sec \phi_2$$

3) Saving in KVA charges**:**

$$= Rs\ X\ (S_1 - S_2)$$

$$= Rs\ X\ (P \sec \phi_1 - P \sec \phi_2)$$

$$= Rs\ X\ .P\ (\sec \phi_1 - \sec \phi_2)$$

4) Expenditure towards KVAr to be neutralized**:**

$$= Rs\ Y\ (Q_1 - Q_2)$$

$$= Rs\ Y\ (P \tan \phi_1 - P \tan \phi_2)$$

$$= Rs\ Y x P\ (\tan \phi_1 - \tan \phi_2)$$

5) Net Saving**:**

= Saving in KVA charges - Expenditure towards KVAr to be neutralized.

$$= [Rs\ X\ .P\ (\sec \phi_1 - \sec \phi_2)] - [Rs\ Y\ (P \tan \phi_1 - P \tan \phi_2)]$$

Saving will be maximum when differentiate above equation with respect to ϕ_2 and equate to zero.

$$\frac{ds}{d\phi_2} = \frac{d}{d\phi_2}\left[\text{Rs X P}(\sec\phi_1 - \sec\phi_2)\right] - \left[\text{Rs Y P}(\tan\phi_1 - \tan\phi_2)\right]$$

$$= 0 - \text{X P}\sec\phi_2 \times \tan\phi_2 - 0 + \text{Y P}\sec^2\phi_2$$

$$0 = -\text{Rs X P}\sec\phi_2 . \tan\phi_2 - 0 + \text{Rs Y P}\sec^2\phi_2$$

$$\text{Rs X P}\sec\phi_2 . \tan\phi_2 = \text{Rs Y P}\sec^2\phi_2$$

$$\therefore \text{Rs X}\ \tan\phi_2 = \text{Rs Y}\ \sec\phi_2$$

$$\therefore \text{Rs X}\ \frac{\sin\phi_2}{\text{Cos}\phi_2} = \text{Rs Y}\ \frac{1}{\text{Cos}\phi_2}$$

$$\therefore \text{Rs X}\ \sin\phi_2 = \text{Rs Y}$$

$$\therefore\ \sin\phi_2 = \text{Rs}\ \frac{\text{Y}}{\text{X}}$$

6)

$$\therefore\ \sin^2\phi_2 + Cos^2\phi_2 = 1$$

$$Cos^2\phi_2 = 1 - \sin^2\phi_2$$

Most economical power factor = $Cos\ \phi_2 = \sqrt{1-(Y/x)^2}$

Most economical power factor at which maximum saving will occurs

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