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 :** **(3x4=12)**
a)	**Define electric drive. State advantages and disadvantages of electric drive.**
Ans:	**Drive:** **(1 Mark)** 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 Three advantages expected: 1/2 each)** 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. **Following disadvantages of electric drive:** **(Any Three disadvantages expected: 1/2 each)** 1. It is used only where electricity is available. 2. On failure of supply (electricity) it cannot be used. 3. It is not self-contain.
b)	**Explain in brief the causes of failure of heating elements.**
Ans:	**Following of the different causes of failure of heating element:** **(4 Mark)** **i) Formation of hot spot:** 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)	**Define : i) Luminous flux ii) Luminous intensity iii) Space to height ratio iv) Utilization factor.**
Ans:	**(Each definition : 1 Mark)** **i) Luminous flux (F):-** The total energy radiated by a source of light in all directions in unit is called Luminous flux. And its **unit is Lumen** **OR**

Luminous flux is commonly called light output and is measured in lumens (lm).

ii) Luminous intensity:-

The luminous intensity in any particular direction is the luminous flux emitted by source per unit solid angle is called the luminous intensity of the source. And its **unit is Candela**

OR

$$I = \frac{\phi}{w} \quad (Where\ \ \phi = luminous\ \ flux, w = Solid\ \ Angle)$$

iii) Space-Height ratio:

$$Space\ \ height\ ratio = \frac{Space\ \ between\ \ lamps}{Height\ \ of\ \ lamps\ \ above\ \ working\ \ plane}$$

iv) Utilization factor:-

It is defined as the ratio of total lumens reaching the working plane to the total lumens given out by the lamp. Its value is always less than one.

d) State any four causes of low power factor.

Ans: **Following are the Causes of low power factor: - (Any four causes expected: 1 Mark each)**

1. Magnitude of Magnetizing Current (I_μ):-

   As magnetizing current increases, power factor reduces.

2. Due to use of Induction Motor:-

   Most of industrial drives, agriculture pumps, lift, irrigation pump set uses I.M. which works at lagging power factor, and so power factor reduces.

3. Due to use of Transformer: -

   All transformers works at lagging power factor, so power factor of system reduces.

4. Due to welding transformer: -

   Welding transformers are operated at low p.f. which reduces p.f. of the system.

5. Due to inductance of transmission & distribution Line: -

   In case of AC transmission & distribution lines, inductance is present which the main cause of low power factor is.

6. Series Reactor:-

   Series reactor is used in substation to minimize fault current causes low power factor.

	7. Industrial electrical heating furnaces:- Induction and arc furnace used in steel manufacturing industry works at low p.f. which reduces p.f. of the system. 8. Arc Lamp:- Arc lamp & electric discharge lamps operates at low p.f.so p.f. of the system reduces. 9. Equipments operated at light load:- P.f. falls if equipments like alternator, transformer, I.M. etc are not operated at full load. 10. Improper repairs and maintenance:- P.f. falls if proper maintenance or repairs of equipments are not done.
Q.1B)	**Attempt any ONE : (1x6=6)**
a)	**Define group drive and individual drive. State the advantages and disadvantages of each drive.**
Ans:	**(Each Definition: 1 Mark, Advantages: 2 Mark & disadvantages : 2 Mark)** **1. Definition of Group drive:-** In a group drive single large capacity electric drives is used to run number of machines through a long common shaft as shown in fig. is known as group drive. **2. Definition of Individual drive:-** In this type of drive each machine has its own separate electric drive (motor). It may be directly or indirectly coupled. **Advantages of Group Drive:-** **(Any two advantages expected: 1/2 Mark each)** **1. Initial Cost –** A cost of single motor of large capacity is less then cost of number of small capacity motors for same H.P. **2. Diversification of load –** All the machines and tools may not work at a time, so we can select main motor of slightly small capacity (HP) than the total requirements of individual machines. **3. Over load capacity –** Group drive has higher over load capacity. E.g. 100% overload on individual machine would cause only 8 to 10 % overload on main motor. **4. Space required –**

Less

5. Maintenance cost –

Maintenance cost of single motor of large capacity is less than maintenance cost of number of small motors of total HP.

6. Efficiency and Power Factor –

If group drive is run at nearly equal to full load than Efficiency and Power Factor of group drive will be higher

Disadvantages of Group Drive:- **(Any Two disadvantages expected: 1/2 Mark each)**

1. Flexibility:-

Flexibility is lost due to common shaft for number of machines.

2. Safety:-

It is less safe.

3. Reliability:-

Its reliability is less at the time of breakdown and maintenance of single large motor, Because, all the machines operations are required to be shut down at the time of breakdown and maintenance of single large motor.

4. Mechanical power transmission losses:-

Considerable power loss takes place for transfer of mechanical energy from shaft to machine.

5. Speed control:-

Speed control of individual machine is difficult, it requires special arrangement.

6. Addition / Alteration:-

Possibility of addition or alteration in existing system is limited.

7. **Efficiency and Power Factor: –**

If group drive is run at reduced load then Efficiency and Power Factor of group drive will be less.

Advantages of Individual Drive:- **(Any Two advantages expected: 1/2 Mark each)**

1. Flexibility:-

It has more flexibility that is machine can be placed in any desired position and can

be shifted whenever needed.

2. Safety:-

Working conditions are more safe.

3. Reliability:-

It has high reliability, because breakdown of single motor causes only one machine operation required to be shut down and not all machines.

4. Mechanical power transmission losses:-

Less power loss takes place for transfer of mechanical energy from shaft to machine.

5. Speed control:-

Speed control is easily possible.

6. Addition / Alteration:-

Possibility of addition or alteration in existing system is easily possible.

7. **Efficiency and Power Factor: –**

If it is run at full load than Efficiency and Power Factor of group drive will be high. If there is no load it can be stopped thus no load losses can be eliminated.

Disadvantages of Individual Drive:- **(Any Two disadvantages expected: 1/2 Mark each)**

1. Initial Cost –

Initial cost is high.

2. Diversification of load –

Diversification of load on individual machine is not possible.

3. Over load capacity –

Over load capacity is less.

4. Space required –

More

5. Maintenance cost –

Maintenance cost is more as number of drives are more.

6. Efficiency and Power Factor –

If it is run at reduced load then Efficiency and Power Factor of individual drive will be less.

b)	**Define electric arc welding. How arc is formed? State the characteristics of electric arc.**

Ans:

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

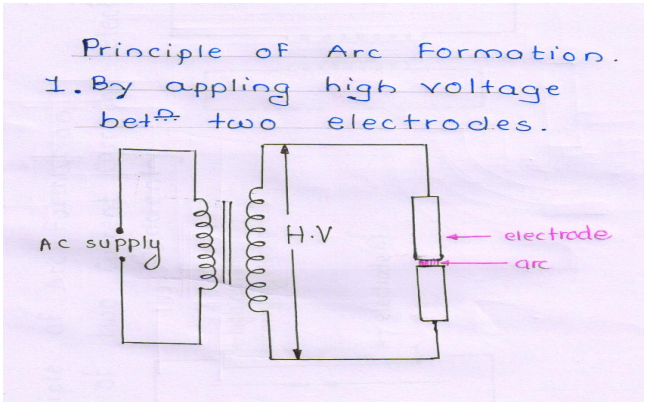
- The processes in which two metal parts to be welded are brought to a molten state and then allowed to solidify is called as arc welding or stick welding.
- At the time of welding external filler material is required. No mechanical pressure is required, so this type of welding is also known as non- pressure welding.
- Melting of metal is obtained due to heat developed by an arc struck between an electrode and metal to be welded (job)
- Temperature obtained by arc is very high (3500^0C to 6000^0C)

How arc is formed :- for following method

a) By applying High Voltage
b) By separation of two current carrying electrodes suddenly

Explanation:- **(4 Mark)**

a) By applying High Voltage:- Figure:



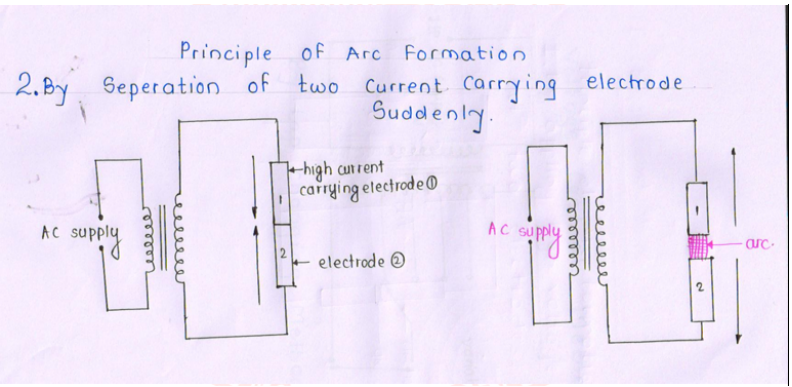
or equivalent figure

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.2 Attempt any FOUR : (4x4=16 Mark)

a) Compare electric braking over mechanical braking.

Ans: **(Any Four point expected: 1 Mark each)**

Sr.No.	Electric Braking	Mechanical Braking
1	It is most reliable braking system.	**In mechanical braking** heat is produced at break block & break shoes, which may be source of failure of break.
2	Breaking actuation time is small as higher value of braking retardation is obtained	Breaking actuation time is more as low value of braking retardation is obtained

3	Electrical braking is smooth & gradual.	Where as if mechanical breaks are not correctly adjusted then there are chances of sudden braking which is dis -comfortable to passenger.
4	Life of braking system is more.	Life of braking system is less.
5	There is less wear & tear of brake shoes, break block etc. so there is less maintenance cost.	There is more wear & tear of brake shoes, break block etc. so there is more maintenance cost.
6	Higher speeds are possible even when train is going down the gradient, as breaking system is reliable.	Higher speeds are not possible when train is going down the gradient, as breaking system is less reliable.
7	Higher speeds of train is possible as braking system is reliable so pay load capacity increases.	Higher speeds of train is not possible as braking system is not reliable so pay load capacity decreases.
8	In addition to electrical braking there must be arrangement of mechanical braking for final stop.	No additional arrangement is required
9	Special arrangement of circuit extra complication makes electrical braking system costly.	No special arrangement of circuit extra complication required so system is less costly.

b) Define electric heating. Classify the electric heating methods in detail.

Ans: **Define electric heating:-** **(Definition: 2 Mark & Classification: 2 Mark)**

Electric heating is nothing but heat energy is obtain or created by the use of electrical energy.

Electric heating are classified as below:

1) Power frequency electric heating:

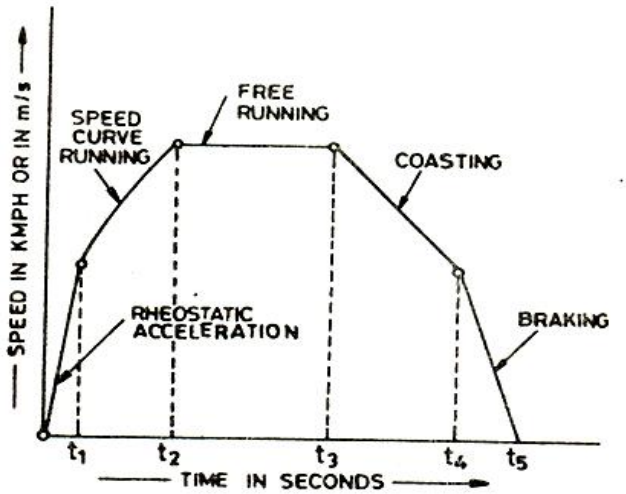
i) Resistance heating:

a) Direct resistance heating

b) Indirect resistance heating

	ii) Arc Heating: a) Direct arc heating (furnace) b) Indirect arc heating **2) <u>High frequency electric heating:</u>** iii) Induction Heating: a) Direct core type induction heating (furnace) b) Vertical core type induction heating or Ajax Wyatt induction heating c) Indirect core type induction heating d) Core less induction heating iv) Eddy Current heating v) Dielectric heating
c)	**State any six requirements of an ideal traction system.**
Ans:	**Ideal Traction system should processes following requirement:-** **(Any First Two point : 1 Mark each & Reaming any four point : 1/2 Mark each)** 1. It should be Pollution free. 2. It should have low capital, Running and maintenance cost. 3. It should have quick starting time. 4. It should have high starting torque. 5. It should have high rate of acceleration & retardation. 6. Highest speeds are possible. 7. It should have easy speed control method. 8. Its braking system should be reliable and causes less wear. 9. It should have better riding quality (less vibration) 10. It should be free from unbalance forces i.e. coefficient of adhesion should be more. 11. It should have lower centre of gravity.

	12. The locomotive should be self-contained and able to run on any route 13. There should be no standby losses. 14. It should have high efficiency 15. Regenerative braking should be possible. 16. The wear caused on the track should be minimum. 17. Equipment should be capable of overloads for short periods. 18. Capability of withstanding voltage fluctuations. 19. Parallel running usually more than one motor (2 or 4 motors) should be possible. 20. Traction system should be clean & long life. 21. There should be no interference to the communication lines running along the lines.
d)	**Write the different systems of track electrification.**
Ans:	**Following are the different track electrification system:** **(4 Marks)** **1. D.C. Supply system:-** 1. Direct current track electrification: ➢ 600V, 750V DC for tramways ➢ 1500V, 3000V DC for Train (Urban and sub-urban services) **2. 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)

e)	**Draw speed time curve. Show and list various time periods associated with it.**
Ans:	**Diagram of speed time curve with various time periods :** **(4 Marks)**  **or equivalent figure**
Q.3	**Attempt any TWO :** **(2 x 8 =16 Marks)**
a) i)	**Define: i) Continuous rating ii) Continuous maximum rating iii) Short time rating.**
Ans:	**Definition of Following:-** **i) Continuous Rating:-** **(1.5 Marks)** 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) Continuous maximum Rating:-** **(1.5 Marks)** This is an output which a motor can deliver continuously without exceeding the permissible temperature limit. It is similar to **Continuous rating but not allowing overload.** **iii) Short time Rating:-** **(1 Marks)** This is an output which a motor can deliver for a specific periods (short duration) e.g. 15min., 20min., 30min. etc. without exceeding the permissible temperature limit.
a) ii)	**Classify electric elevators on the basis of : i) Service ii) Capacity iii) Speed iv) Power unit.**
Ans:	**Classify electric elevators on the basis of :** **(1 Mark for each classification)** **i) According to Service :-** a) Passenger Elevators b) Freight (goods) Elevators

c) Combination of Elevators

ii) According to Speed of Elevator :-

a) Low speed Elevator
b) Medium speed Elevator
c) High speed Elevator

iii) According to capacity of Elevator :-

a) Light duty Elevator
b) Medium duty Elevator
c) Heavy duty Elevator
d) Extra Heavy duty Elevator

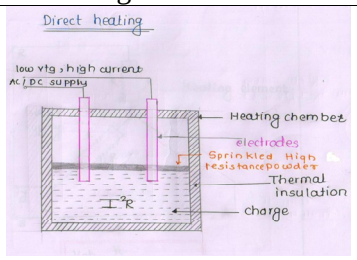
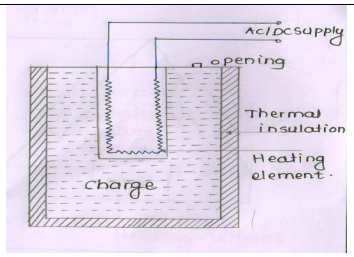
iv) According to power unit (elevator machine):-

a) Drum Elevator
b) Traction Elevator

b) i) Compare direct resistance heating and indirect resistance heating with suitable diagram.

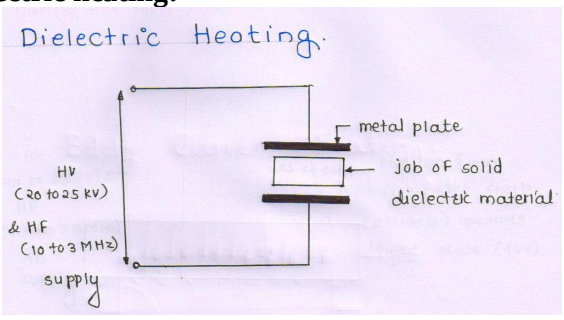
Ans:

Sr.No.	Point	Direct resistance heating	Indirect resistance heating
1	Working Principle	When current is passed through charge heat is produced due to I^2R losses taking place in the charge. Where, R is the resistance of the charge and I be the current passed through charge.	1. When current is passed through heating element then heat is produced due to I^2R losses taking place in the heating element. 2. Heat is transferred towards charge mainly be radiation or sometimes by conduction.
2	Heat is transfer loss.	There is no heat is transfer loss.	There is heat is transfer loss.
3	Temperature obtained:	Temperature obtained is more than in direct resistance heating as heat is directly produced in charge	Temperature obtained is less than direct resistance heating as heat is not directly produced in charge
4	Definition:	As heat is produced in the charge itself hence its name is direct resistance heating.	As heat is produced in the heating element and then it is transferred towards charge which is to be heated. Hence its name is indirect resistance furnace/oven.

5	Efficiency:	It has high efficiency.	Overall efficiency is less than direct resistance heating due to heat transfer loss.
6	Application:	1.This type of heating used for industrial purpose 2.Salt bath heating: This utilized for the purpose of carbonizing, tempering, quenching and hardening of steel tools 3. Heating of water in boiler	It is used for Room heater, Electric Iron, Hair dryer, Hot plate, Electric water heater, Electric toaster and Electric oven etc
7	Diagram		
8	Heating element used:	Electrodes are made up of carbon or graphite.	Names of Material used for manufacturing of heating element i) Nichrome ii) Constantan or Eureka iii) Nickel-chromium iv) Iron-chromium-Aluminimum v) Silicon carbonate

b) ii) Explain the principle of dielectric heating.

Ans: **Figure of dielectric heating:**



or equivalent figure

Principle of Dielectric heating:

For heating non-metallic material (dielectric material) for e.g. Glass, plastic, wood, etc. dielectric heating is used.

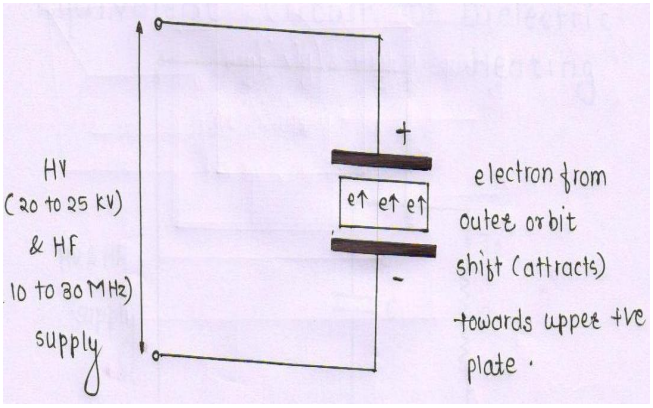
Material to be heated is placed between two metallic plates as shown in figure (1) across which a high voltage (20 to 25 KV) and high frequency (10 to 30 MHz) AC supply is

given.

Material is heated due to dielectric loss taking place inside the job.

Operation :-

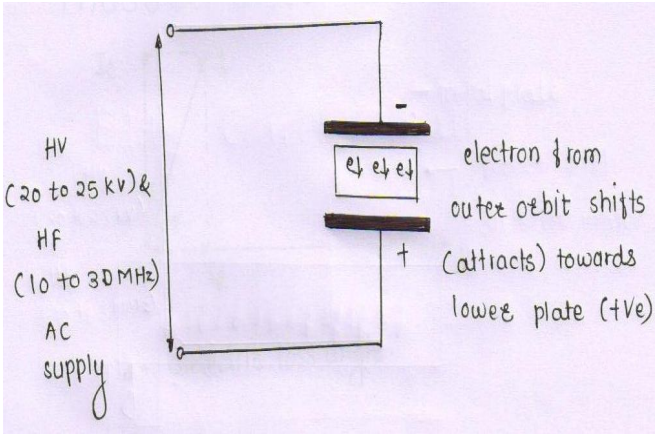
1. **During (+) ve half cycle:**



or equivalent figure

Material to be heated is placed between two metallic plates, if upper plate is **+ Ve**, most of electrons from its outer orbit (of job) gets attracted towards **+ Ve** plate.

2. During (-) ve half cycle:



During **- Ve** half cycle field is reversed i.e. bottom plate becomes **+ Ve**. At that time most of electrons from its outer orbit gets attracted towards bottom electrode.

Effect:-

Due to inter atomic friction caused by repeated (due to frequency) deformation and rotation of atomic structure, Dielectric loss takes place inside the job which produces heat.

c) A electric motor has load variations as given below :
i) Torque 250 Nm for 20 min. ii) Torque 150 Nm for 10 min.
iii) Torque 300 Nm for 10 min. iv) Torque 200 Nm for 20 min. If speed of the motor is 750 rpm find the power rating of the motor.

Ans:

i) 250 Nm for 20 min. Speed of motor : 750 rpm

ii) 150 Nm for 10 min. Rating of motor (KW) =?

iii) 300 Nm for 10 min.

iv) 200 Nm for 20 min.

Duty Cycle (T) $= t_1 + t_2 + t_3 + t_4$ ---------- **(1 Marks)**

$= 20+10+10+20$

$= 60$ Min. ---------- **(1 Marks)**

$$rating\ of\ motor\ (Torque) = \sqrt{\frac{T_1^2 \times t_1 + T_2^2 \times t_2 + T_3^2 \times t_3 + T_4^2 \times t_4}{T}}$$ ---------- **(1 Marks)**

$$rating\ of\ motor\ (Torque) = \sqrt{\frac{250^2 \times 20 + 150^2 \times 10 + 300^2 \times 10 + 200^2 \times 20}{60}}$$

$$rating\ of\ motor\ (Torque) = \sqrt{\frac{3175000}{60}}$$

$$rating\ of\ motor\ (Torque) = \sqrt{52916.6666}\ Nm$$

$$rating\ of\ motor\ (Torque) = 230.0362\ Nm$$ ---------- **(1 Mark)**

$$\therefore rating\ of\ motor\ (watt) = \frac{2\pi N T}{60}$$ ---------- **(1 Mark)**

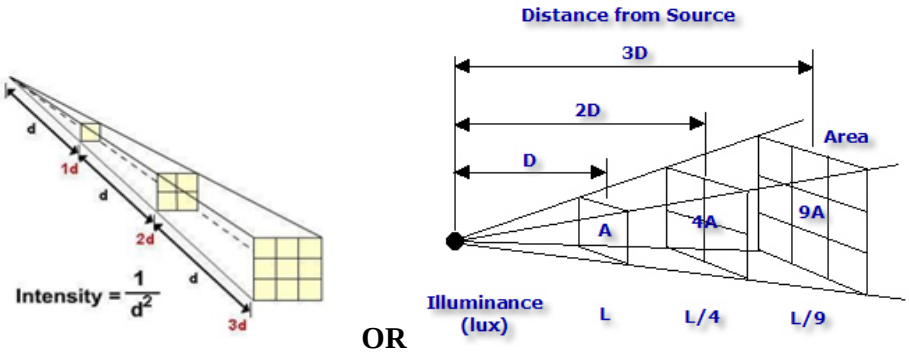
$$rating\ of\ motor\ (watt) = \frac{2\pi \times 750 \times 230.0362}{60}$$

$$rating\ of\ motor\ (watt) = 18057.8439\ Watt$$ ---------- **(1 Mark)**

$$rating\ of\ motor\ (Kw) = \frac{18057.8439}{1000}$$

$$rating\ of\ motor\ (kw) = 18.057\ kW$$ i.e.

$$\therefore rating\ of\ motor\ (kw) = 18\ kW$$ ---------- **(2Mark)**

Q.4 A)	**Attempt any THREE :** **(3 x 4 =12 Marks)**
a)	**Define welding. State the requirements of good weld.**
Ans:	**Define welding**: **(Definition: 2 Marks & Requirement: 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. **The good welding has following requirements:-** **(Any Two requirement expected: 1 Marks each)** 1) Welding joints must be strong and reliable 2) Joint (welding) is made by proper welding technique. 3) Surface of job should be uniformly welded. 4) Welding Should be free from following defects like:- i) Cracks (cold crack or hot crack) ii)overlap iii) porous iv) blow holes v) incomplete penetration vi)Excess penetration vii) incomplete fusion viii)Suck buck ix)under flush x)burn through 5) Even counter & width of surface welding.
b)	**State the laws of illumination.**
Ans:	**Laws of illumination:-** **(Each laws explanation: 1 Mark & each Figure : 1 Mark)** **1. Inverse Square Law:-** Intensity of illumination produced by a point source varies inversely as square of the distance from source.  **OR** $E = \frac{I}{d^2}$ 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

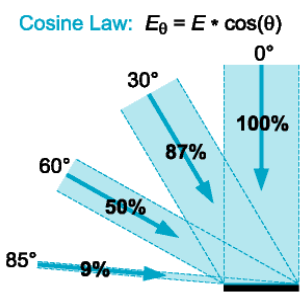


Fig. 6.3 Lambert's cosine law.

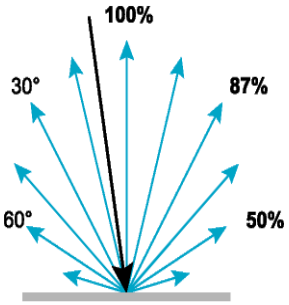


Fig. 6.5 Lambertian surface.

c) Compare block rate tariff and flat rate tariff (any four points)

Ans: **(Any Four Point expected: 1 Mark each)**

S.No	Block rate tariff	Flat rate tariff
1	In case of block rate tariff there are blocks of units consumed	In case of **flat rate tariff** there are no blocks of units consumed
2	Each block tariff rate/unit (KWH) is different	There is flat rate/unit for actual energy consume
3	Plus consumer has to pay fix charges.	No fix charges have to be paid by consumer.
4	Even if consumer has not consume the energy he has to pay fix charges	If consumer has not consume the energy he has not require to pay fix charges
5	Rate Schedule:	Number of units consume = Current Reading – Previous Reading of energy meter.

Consumption slab (kWh)	Fixed/Demand Charges	Energy Charges (Rs.kWh)
0-100 units	Single Phase: Rs..../Month Three Phase: Rs..../Month	
101-300 units		
301-500 units		
501-1000 units		
Above 1000 units (balance units		

6	The consumers which consume less energy (KWH) shall have to pay fewer charges., The consumers which consume more energy (KWH) shall have to pay more charges.	No such discrepancy in this type of Tariff
7	Due to block rate tariff consumer will use minimum energy to reduce its energy bill. So this type of tariff is helpful from energy conservation point of view.	This type of tariff is useful to consumers whose power consumption is less

d) State any four advantages of good power factor for electric supply system.

Ans:

Advantages of good power factor for electric supply system:

(Any Four Advantages are expected: 1 Mark each)

We know that,

$$P = \sqrt{3}\ V_L\ I_L\ Cos\phi$$

- For same power to be transmitted at same voltage over a same distance

$$I\ \alpha\ \frac{1}{Cos\phi}\ \alpha\ \frac{1}{P.f}$$

- From above equation it is seen that as power factor increases current decreases, due to decreases in current, system has following advantages

(Any Four advantages expected)

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

Q. 4B)	**Attempt any ONE** **06 Marks**
a)	**Define resistance welding. State the types of resistance welding and explain any two in brief.**
Ans:	**Definition of Resistance welding :-** **(1 Mark)**

In resistance welding, sufficiently heavy current at low voltage is passed directly through two metals in contact to be welded.

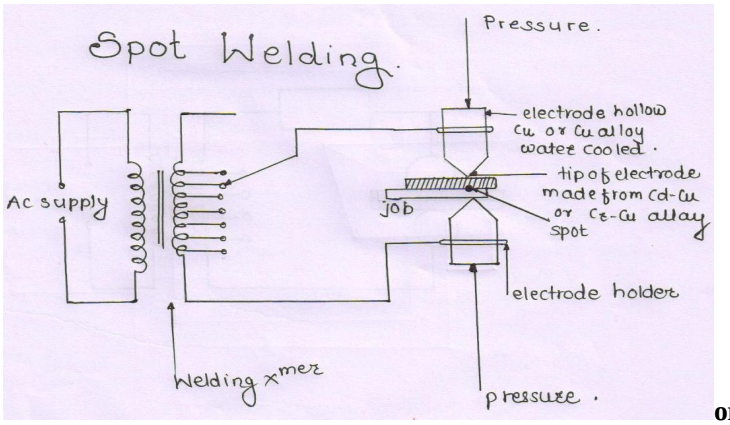
Heat is produced due to I^2R losses where 'R' is the contact resistance. This heat is utilized to obtain welding temperature (to become a plastic state)

Types of Resistance Welding: **(Any Four Type expected: 2 Mark)**

1. Spot Welding
2. Seam Welding
3. Projection Welding
4. Upset Butt welding
5. Flash Butt welding

Explanation of Types of Resistance Welding:- **(Any Two Type expected: 3 Mark)**

1) Spot Welding:



or equivalent figure

Explanation

Spot welding means the joining of two metal sheets at suitable spaced interval.

It consists of:

- Transformer used for spot welding is designed for low voltage and high current secondary.
- Transformer is oil cooled and portable
- There are two electrodes one is fixed and other is movable
- The electrodes are hollow and water cooled.
- Electrodes are made from copper or copper alloys and tips of electrodes are made from Cd-Cu or Cr-Cu.

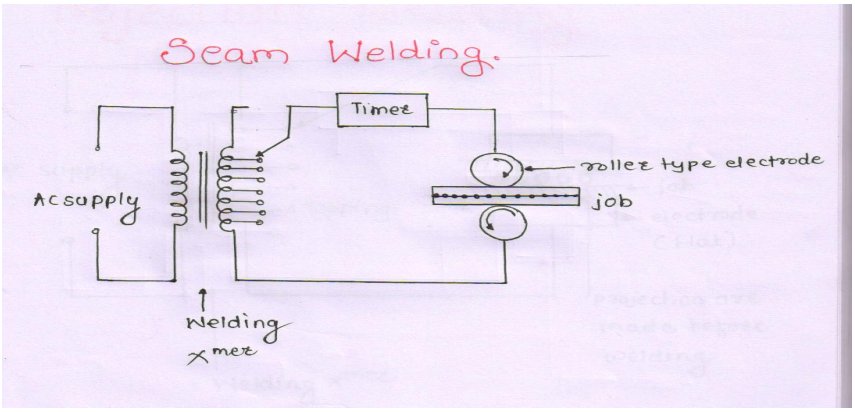
Working:

- As shown in fig. Job to be welded is placed one over the other between two electrodes

under pressure

- Sufficiently heavy current at low voltage is passed directly through two metals in contact to be welded.
- 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.
- Magnitude of current varies from 1000A to 10000A.and the voltage between electrodes is usually less than 2V.
- The period of flow of current and magnitude of current depends upon thickness of sheet (job) to be welded.

2) Seam Welding:



or equivalent figure

Explanation:

Seam welding is nothing but series of continuous spot welding

It consists of:

- Transformer used for seam welding is designed for low voltage and high current secondary.
- Transformer is oil cooled
- There are two electrodes, in this type beam or roller type electrodes are used.

Working:

- Job is kept in between two electrodes under pressure. This pressure is kept constant

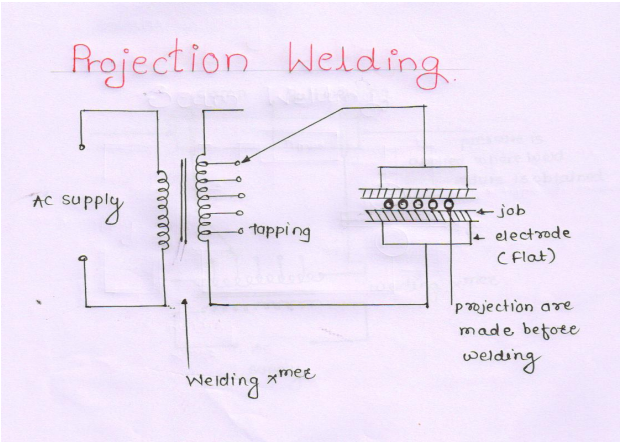
throughout.

- 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.

There are three types of seam welding:

1. Lap seam welding
2. Mesh seam welding
3. Metal finished seam welding

3) Projection Welding:



or equivalent figure

Explanation:

It is modified form of spot welding, before welding projections are made to job on both or one part to be welded by mechanical means. Hence it is called as a Projection Welding.

It consists of:

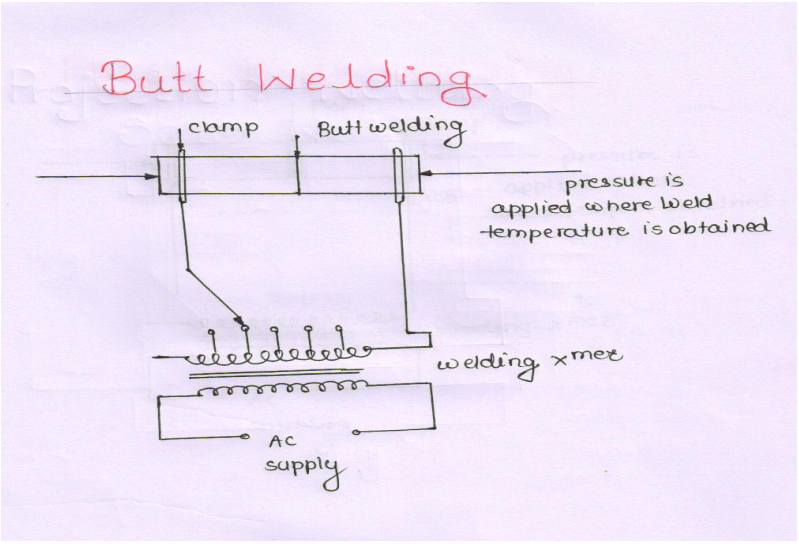
- Transformer used for projection welding is designed for low voltage and high current secondary.
- Transformer is oil cooled

- There are two electrodes .In this type flat electrodes are used as shown in figure.
- Therefore it is possible to join several welding points (spots) simultaneously

Working:

- Job is kept in between two electrodes under pressure. This pressure is kept constant throughout.
- Sufficiently heavy current at low voltage is passed directly through two metals in contact to be welded.
- 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.

4. Upset Butt Welding:



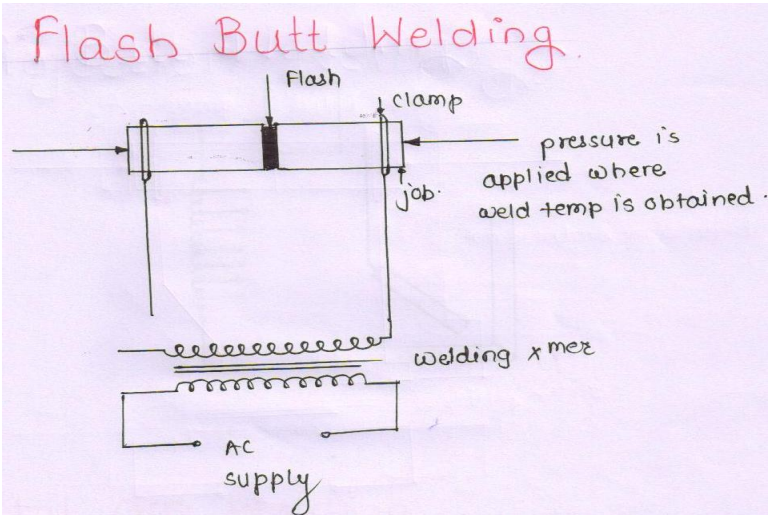
or equivalent figure

Explanation:

- Transformer used for welding is designed for low voltage and high current secondary.
- Transformer is oil cooled
- The job is clamped as shown in fig. two parts which are to be welded are brought together
- Sufficiently heavy current is passed through joints by welding transformer,

- which creates necessary heat at joints due to I^2R
- When welding temperature is reached supply is cut down.
- And external pressure is applied simultaneously across the job to complete weld

5) Flash Butt welding: -



or equivlent figure

Explanation:

- The job is clamped as shown in fig. two parts which are to be welded are brought near to each other by keeping small air gap,
- When welding transformer is made ON, due to heavy currents flash (arc) is produced between joints.
- This arc will produce heat which will create welding temperature.
- When welding temperature is reached, supply is cut down and at the same time mechanical pressure is applied for final weld.

Advantages:

1) Due to flash (arc) surface to be welded becomes clean and pure.
2) Weld obtained is better than butt welding.
3) It requires less power than butt welding.

b) **A factory has a maximum demand of 250 kW with a load factor of 0.6. The following tariffs are offered.**
a) Two part tariff Z 70/kW of M.D./Year + 4 paise/kWh. b) A flat rate of 10 paise/kWh. Calculate tariff in both the cases and state with the reason which of the two will be cheaper.

Ans:

- **No. of Units consume in One Year**

$= Load\ \ Factor \times M.D(KW) \times 8760$ ---------- **(1/2 Mark)**

$= 0.6 \times 250 \times 8760$

$= 1314000\ Kwh$ ----------**(1 Mark)**

- **Case-I: Energy Bill :-**

$= (Tariff\ \ given\ \ Rs.70\ of\ M.D./\ year + Rs.4\ paise\ /\ Kwh)$ ------ **(1/2 Mark)**

$= ((250 \times 70) + (1314000 \times 4/100))$

$= (Rs.17500 + Rs.52560)$

= 70060 Rs. ---------- **(1 Mark)**

- **Case-II: Energy Bill :-**

$= (Tariff\ \ given\ \ flat\ rate\ of\ 10\ Paise\ /\ Kwh)$ ---------- **(1 Mark)**

$= (1314000 \times 10/100))$

= 131400 Rs. ---------- **(1 Mark)**

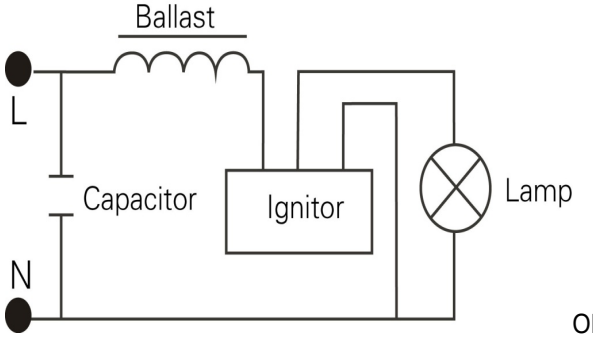
- **According to energy bill Case-I is economical** ---------- **(1 Mark)**
- **For industrial consumer Case-I is economical**

Q.5 **Attempt any FOUR :** **(4 x4=16 Marks)**

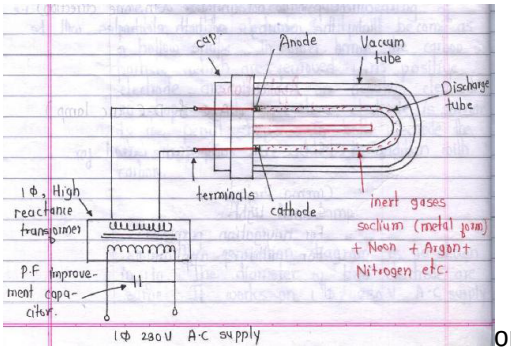
a) **Explain in brief the construction and working of sodium vapour lamp.**

Ans: **Sodium Vapour Lamp diagram:**

(Figure: 1 Mark, Construction: 1.5 Marks & Working : 1.5 Marks)



OR



or equivalent figure

Construction

- HPS lamps consist of an arc tube (inner) enclosed by an outer tube.
- Vacuum is created between the inner & outer glass tube to prevent heat loss.
- The arc tube is made from a special glass that can withstand to high temperatures
- Arc tube is U Shape
- The arc tube contains xenon / neon gas (starting gas), sodium and mercury and two electrodes.
- IT require a ballast to give high voltage at staring to produce the arc *(The ballast provides a high-voltage pulse (2,500 V) for one microsecond for lamp start.)*
- There is an igniter which sends a pulse to start the discharge.
- To improve the power factor a capacitor is connected across the supply. (P.F. is low @ 0.3 lag.)
- HPS lamps do not have starting electrodes.

Working Principle:

- When the lamp is turned on, a high voltage at staring is applied across two electrodes, to initiate an arc which discharges and vaporizes xenon /neon gas (starting gas), sodium and mercury.
- The energized metal atoms emit light.
- After 2 to 5 minutes lamp will glow 100 %.
- For running the lamp low voltage of about 165 v is sufficient.
- The color of light produce is yellowish.

b) Compare ac welding to dc welding (any four points).

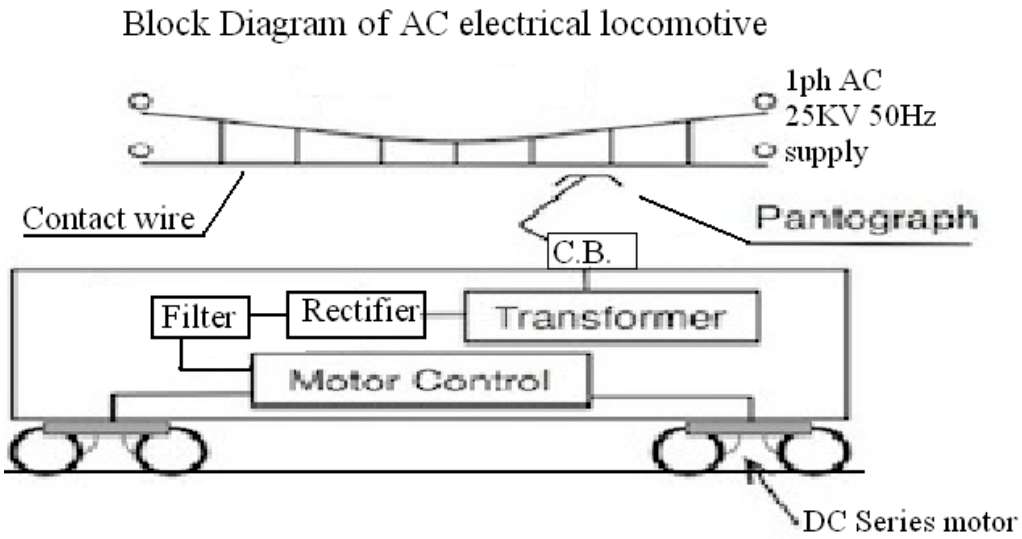
Ans: **(Any Four point Expected: 1 Mark each)**

S.No	Points	AC Welding	DC Welding
1	Supply equipment used	Welding Transformer	DC differential Compound Generator, or Rectifier
2	Heating Effect	Not Uniform	Uniform
3	Temperature Obtain	Less	More
4	Possibility of Arc Blow	No Possibility	More Possibility

5	Stability of Arc	Use of series Reactor	D.C Differential compound. Generator has dropping characteristics.
6	Type of Electrode	Coated Electrode is compulsory	Non Coated Electrode is used
7	Voltage Required	72 to 100 volt	50 to 60 volt
8	Capital Cost	Low	High
9	Running cost	Low	High
10	Maintenance cost	Low	High
11	Stand by losses	Low	High by 25%
12	Efficiency	High, 85%	Low, 65%
13	Application	Resistance Welding , Metal Arc Welding	Carbon Arc Welding

c) Draw a neat labelled diagram ofAC electric locomotive. State the function of each part.

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



Explanation:

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:

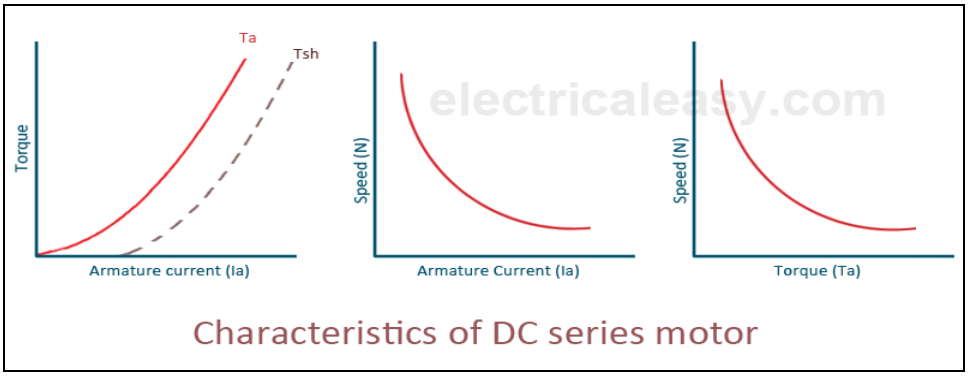
It gives mechanical power to run the train DC series motor is used as traction motor.

d) "DC series motor is used for traction purpose". Justify your answer with any four 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

Advantages:

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) Write any six desirable characteristics of traction motors.

Ans: **(Any First Two point : 1 Mark each & Reaming any four point : 1/2 Mark each)**

Traction motor should posses Following Characteristics :

A) Mechanical Properties or characteristics:

1) It should be simple in design
2) It should be robust in construction to withstand against continuous vibrations.
3) Weight of motor per HP should be minimum in order to increase pay load capacity.

4) It must be small in overall dimensions, especially in overall diameter.

5) It must have totally enclosed type enclosure to provide protection against entry of dirt, dust, mud, water etc. in drive.

6) When motors are running in parallel they should share almost equal load. (even when there is unequal wear & tear of driving wheels)

7) It should have high coefficient of adhesion.

8) It should have lower center of gravity.

C) Electrical Properties or characteristics:

9) It should have high starting torque.

10) It should possess high rate of acceleration & retardation.

11) It should be variable speed motor.

12) Its speed-torque characteristics should be such that it should produce high torque at low speed and low toque at high speed.

13) Motor must be capable of taking excessive overload in case of emergency.

14) It should have simple speed control methods.

15) Electrical braking system should be reliable, easy to operate and control, especially regenerative braking is possible.

16) Motor should draw low inrush current (Starting current, and if supply is interrupted and restore again.)

17) It should withstand for voltage fluctuation without affecting its performance.

18) It should have high power to weight ratio.

C) General Properties or characteristics:

19) It should have low initial cost.

20) It should have less maintenance cost.

21) It should have high efficiency.

22) It should have long life.

Q.6 **Attempt any TWO of the following :** **16 Marks**

a) **A resistance oven employing Nichrome wire is to be heated from 220V, 1-phase, supply and is rated at 16 kW. If temperature of element is to be limited to 1170°C and average temperature of charge is 500°C, find diameter and length of wire. Radiating efficiency, K = 0.57 Emissivity e = 0.9, Specific resistance of Nichrome = 109×10^6 ohm cm..**

Ans:

Given Data:

$T_1 = 1170^0C = 1170+273 = 1443^0K$

$T_2 = 500^0C = 500 +273 = 773^0K$

Radiation efficiency = 0.57, specific resistance of Ni-Cr = 1.016×10^{-6} ohm m, emissivity = 0.9.

(NOTE :_**This problem is solved by taking value Specific resistance of Ni-Cr = 1.016×10^6 and also by taking value Specific resistance of Ni-Cr = 1.016×10^{-6} : Give marks to both answers)**

Solution By take Specific resistance of Ni-Cr = 1.016×10^6 :

$$\mathbf{H} = 5.72 \times 10^4 \; k.e\left[\left(\frac{T_1}{1000}\right)^4 - \left(\frac{T_2}{1000}\right)^4 \right] \; w/m^2$$ **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)**

$$\mathbf{H} = 5.72 \times \; 0.57 \times 0.9\left[\left(\frac{1443}{100}\right)^4 - \left(\frac{773}{100}\right)^4 \right] \; w/m^2$$

$$\mathbf{H} = 11.4749 \times 10^4 \; w/m^2$$ ---------- **(1 Mark)**

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

$$\therefore \frac{l}{d^2} = \frac{(220)^2\ \pi}{4\times16\times1000\times1.09\times10^6}$$

$$\therefore \frac{l}{d^2} = 2.179660\times\ 10^{-6}$$

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

Heat Dissipated = Electrical Power I/p

$$\pi\ d\ l\ H = P$$

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

$$\pi\ d\ l\ 11.6749\times10^4 = 16000$$

$$d\ l\ = 0.043623$$

----------Equation No.3 ---------- **(1 Mark)**

$$\therefore \frac{l}{d^2} = 2.179660\times\ 10^{-6}$$

$$\therefore l = d^2\times2.179660\times10^{-6}$$

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

By Simplify :

$$\therefore 2.179\times10^{-6}\times d^2\times d = 0.043623$$

$$\therefore d^3 = \frac{0.043623}{2.179\times10^{-6}}$$

$$\therefore d^3 = 20022.94$$

$$\therefore d = 27.1545\quad mtr$$

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

Substitute Value of 'd' in Equation No.3 to calculate 'l' :

$$\therefore d\ l\ = 0.043623$$

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

$$\therefore l\ = \frac{0.043623}{27.154}$$

$$\therefore l\ = 1.60\times10^{-3}\ mtr$$

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

Answer:-

$\therefore l = 1.6\times10^{-3}\ m$ $\therefore$ *Diameter* d = $2\ 7.15\ mtr$

OR Student may solve this type

Solution By take Specific resistance of Ni-Cr = 1.016 x 10^{-6} :

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

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)**

$$\mathbf{H} = 5.72\times\ 0.57\times0.90\left[\left(\frac{1443}{100}\right)^4-\left(\frac{773}{100}\right)^4\right]\ \ w/m^2$$

$$\mathbf{H} = 11.4749\times10^{4}\ \ w/m^2$$

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

$\Rightarrow$ *Thickness* : $0.3\,mm$ $\therefore 0.3\times10^{-3}\ m$

➢

$$\therefore \frac{l}{d^2}=\frac{V^2\ \pi}{4\ P\ \rho}$$

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

$$\therefore \frac{l}{d^2}=\frac{(220)^2\ \pi}{4\times16\times1000\times1.09\times10^{-6}}$$

$$\therefore \frac{l}{d^2}=2179660$$

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

Heat Dissipated = Electrical Power I/p

$$\pi\ d\ l\ H = P$$

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

$$\pi\ d\ l\ 11.6749\times10^{4}=16000$$

$$d\ l\ = 0.043623$$

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

By Simplifying :

$$\therefore\ d^2\ l^2\ = 1.90297\times10^{-3}$$

$$\therefore\ d^2\ = \frac{1.90297\times10^{-3}}{l^2}$$

Substitute Value of d^2 in Equation No.1 :

$$\therefore \frac{l}{\frac{1.90297\times10^{-3}}{l^2}}=2179660$$

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

$\therefore l^3 = 2179660 \times 1.90297 \times 10^{-3}$

$\therefore l = 16.06\ m$

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

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

$\therefore \quad \frac{l}{d^2} = 2179660$ ---------- **(1/2 Mark)**

$\therefore \quad d = 2.7144 \times 10^{-3}\ mtr$

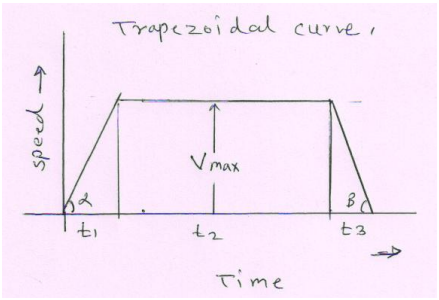
$\therefore \quad d = 2.714\ mm$

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

Answer : $\therefore$ *Length* $l = 16.06\ mtr$ $\therefore$ *Diameter* $d = 2.714\ mm$

b) **A trapezoidal time curve of train consists of : i) Uniform acceleration of 6 kmphps for 25 seconds ii) Free running for 10 minutes iii) Uniform deceleration of 6 kmphps to stop the train iv) A stop time of 5 minutes.**
Find the distance between the stations, average and scheduled speed.

Ans: **Given Data:**



t_1= 25 sec t_2= 10 min = 600 sec T_{stop}= 5 min = 300 sec
acceleration α = 6 km phps retardation β = 6 km phps

- $\alpha = \frac{V_{max}}{t_1}$ ---------- **(1/2 Mark)**

$V_{max} = t_1 \times \alpha = 25 \times 6$

$V_{max} = 150\ Km/hr$ ----------Answer---------- **(1/2 Mark)**

- $\beta = \frac{V_{max}}{t_3}$ ---------- **(1/2 Mark)**

$$t_3 = \frac{V_{max}}{\beta} = \frac{150}{6}$$

$t_3 = 25$ sec ----------Answer---------- **(1 /2 Mark)**

- Distance covered during Acceleration ($D\alpha$) =

$$D\alpha = \frac{V_{max}^{\ 2}}{7200\,\alpha}$$ ---------- **(1/2 Mark)**

$$D\alpha = \frac{(150)^{\ 2}}{7200 \times 6}$$

$D\alpha = 0.52083 \ \ km$ ----------Answer---------- **(1/2 Mark)**

Distance covered during Retardation ($D\beta$) =

$$D\beta = \frac{V_{max}^{\ 2}}{7200\ \beta}$$ ---------- **(1/2 Mark)**

$$D\beta = \frac{(150)^2}{7200 \times 6}$$

$D\beta = 0.52083$ km----------Answer------- **(1/2 Mark)**

$$\therefore \ \ D\ Free\ \ running\ = \frac{t_2 \times V_{max}}{3600}$$ ---------- **(1/2 Mark)**

$$D\ Free\ \ running\ = \frac{600 \times 150}{3600}$$

$D\ Free\ \ running\ = 25\ Km$ ----------Answer-------- **(1/2 Mark)**

$$Distance\ 'D'\ = D\alpha + D\beta + \ D\ Free\ \ running$$

$$Distance\ 'D'\ = 0.52083 + 0.52083 + \ 25$$

$Distance\ 'D'\ = 26.04168\ \ Km$ ----------Answer------- **(1/2 Mark)**

OR Student may solve by using following formula also

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

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

$Time\ 'T' = t_1 + t_2 + t_3 = 25 + 600 + 25$

$Time\ 'T' = 650\ Sec$ ----------Answer-------- **(1 /2 Mark)**

➢ $V_{av} = \frac{3600\ D}{Time}$ ---------- **(1/2 Mark)**

$V_{av} = \frac{3600 \times 26.04168}{650}$

$V_{av} = 144.2308\ Km/hr$ ----------Answer--- **(1 /2 Mark)**

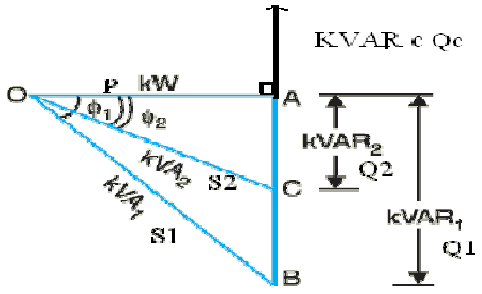
➢ $V_{schv} = \frac{3600\ D}{T + T_{stop}}$ ---------- **(1/2 Mark)**

$V_{schv} = \frac{3600 \times 26.04168}{650 + 300}$

$V_{schv} = 98.6842\ Km/hr$ ----------Answer------ **(1 /2 Mark)**

c) i) 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

$\text{Cos}\phi_1$ = Initial Power factor

$\text{Cos}\phi_2$ = 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**:**

$$Q_1 = P \tan \phi_1$$

$$\text{Cos } \phi_1 = \frac{P}{S_1}$$

$$S_1 = \frac{P}{\text{Cos } \phi_1}$$

$$\therefore \text{KVA}_1 \ (S_1) = P \sec \phi_1$$

2) After improving Power factor**:**

$$Q_2 = P \tan \phi_2$$

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

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

$$\therefore \text{KVA}_2 \ (S_2) = P \sec \phi_2$$

3) Saving in KVA charges**:**

$$= \text{Rs X } (S_1 - S_2)$$

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

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

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.

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

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

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

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

$$\therefore Rs\ X\ \tan\phi_2 = Rs\ Y\ \sec\phi_2$$

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

$$\therefore Rs\ X\ \sin\phi_2 = Rs\ Y$$

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

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

c) ii) State the methods of power factor improvement. Explain any one of them.

Ans: **Methods of power factor improvement:-** **(2 Marks)**

1) By use of static capacitor (Condenser)

2) By use of over excited synchronous motor (Synchronous condenser)

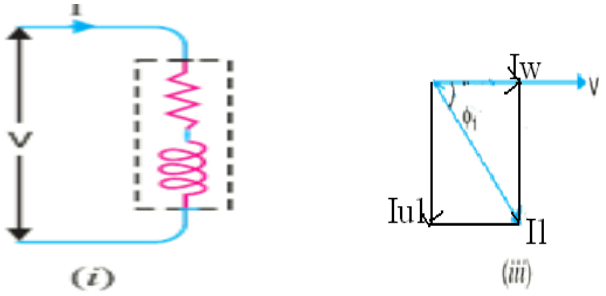
3) By use of over excited Schrage motor

4) By use of phase advancer.

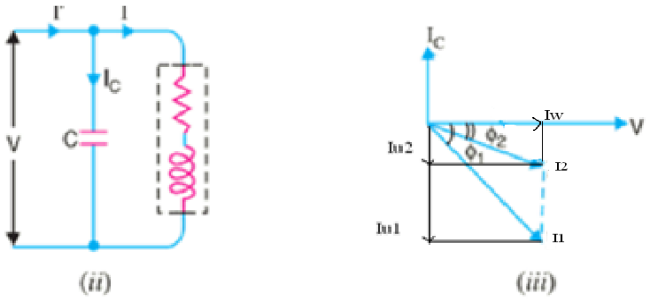
Explanation:

1) The static capacitor method of power factor improvement. **(2 Marks)**

Before connecting capacitor Phasor diagram



After connecting capacitor phasor diagram



$Cos\phi_1$ = Initial Power factor

$\cos\phi_2$ = Improved Power factor

Calculation from current vector diagram:

$$I_C = I\mu_1 - I\mu_2$$

$$\therefore I_C = [Iw \tan\phi_1] - [Iw \tan\phi 2]$$

Now, $I_C = \frac{V}{X_C}$ $\therefore X_C = \frac{V}{I_C}$ $\therefore X_C = \frac{1}{2 \times \pi \times f \times c}$

$$\therefore C = \frac{1}{2 \times \pi \times f \times X_C}$$

Magnitude of new current:

$$I_2 = \sqrt{(I_w)^2 + (I\mu_2)^2}$$

Calculation from power triangle: Where ,

P = Active power KW

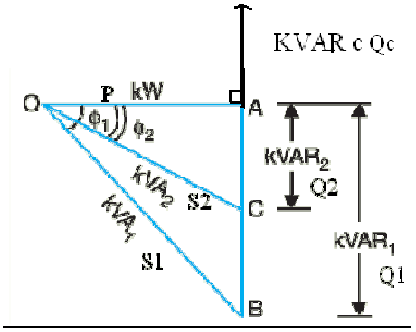
Q_1, Q_2 = Lagging reactive power before & after improving power factor

Q_C = Leading Reactive power drawn by Capacitor

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

$\cos\phi_1$ = Initial Power factor

$\cos\phi_2$ = Improved Power factor



$Q_C = Q_1 - Q_2$

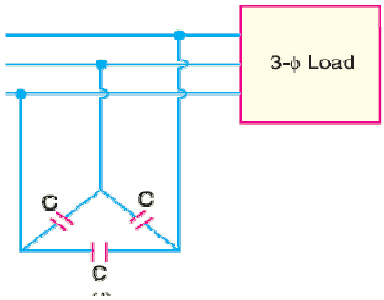
$Q_C = [P \tan\phi_1] - [P \tan\phi_2]$ KVAr rating of capacitor

Observation:

- From above vector diagram & power triangle calculations, if capacitor is connected across load than following observations are observed.

S.No.	Parameter	Effect
1	Power factor	Improves
2	Magnetizing current ($I\mu$)	Reduces
3	Total current	Reduces
4	Lagging reactive power (KVAr)	Reduces
5	Apparent power (KVA)	Reduces

- **Connection diagram to connect capacitor to improve power factor (Delta connection)**

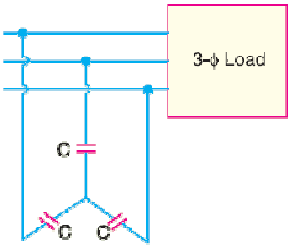


or equivalent figure

$$(Cph) = \frac{KVAR}{3\,\omega\,V^2}\ \text{Farad}$$

$$\omega = 2\pi\ f$$

- **3-ph Star connected Capacitor Bank:**



or equivalent figure

$$(\text{Cph})_{\lambda} = \frac{\text{KVAR}}{\omega\ \text{V}^2}\ \text{Farad}$$

$$\omega = 2\pi\ f$$