SOLUTION FOR ELECTRICAL POWER UTILIZATION – 10 EE72

SEVENTH SEMESTER B E DEGREE EXAMINATION DEC 2017/JAN 18

ANSWER ANY FIVE FULL QUESTIONS

PART A

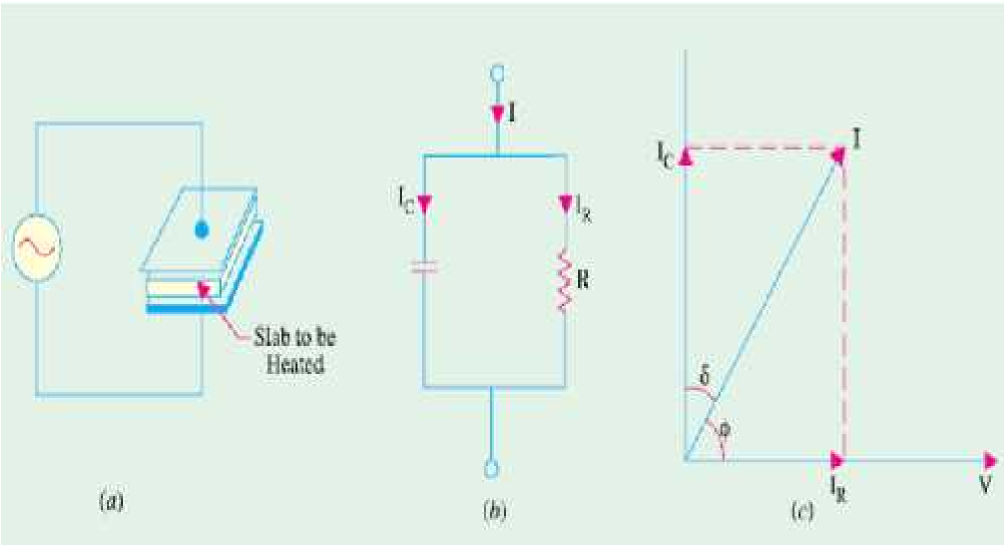
1. (a)Advantages of Electric heating
   - Cleanliness : Electrical energy is the cleanest form of energy. It does not produce ash or dust during heating. Cleaning costs are minimum as the material being heated is not contaminated.
   - Economical : Electrical energy is cheaper as it is produced on a large scale. The initial cost of electrical furnaces is cheaper and the maintenance cost is minimum because they occupy less space, storage space is not required and no chimney is required. The labour costs are minimum.
   - Higher efficiency : The efficiency of utilization of electrical energy is much higher as compared to other systems of heating because, it can be brought directly to the point where heat is required, thereby reducing the losses. The efficiency of electric heating is more than 75%, whereas it is 30% for solid fuels, 50% for oil heating and 60% for gas heating.
   - Ease of control : Simple, reliable and accurate control of temperature can be obtained by using manual or automatic switches. The desired temperature with an accuracy of +- 5% can be obtained in electrical heating which is not possible in other forms of heating.
   - Special Heating Requirement : Special heating requirements such as uniform heating of a material or heating one particular portion of the job without affecting its other parts or heating with no oxidation can be met only by electric heating.
   - Higher Efficiency : Heat produced electrically does not go away waste through the chimney and other by-products. Consequently, most of the heat produced is utilized for heating the material itself. Hence,

electric heating has higher efficiency as compared to other types of heating.

- Better Working Conditions. Since electric heating produces no irritating noises and also the radiation losses are low, it results in low ambient temperature. Hence, working with electric furnaces is convenient and cool.
- Heating of Bad Conductors. Bad conductors of heat and electricity like wood, plastic and bakery items can be uniformly and suitably heated with dielectric heating process.
- Safety. Electric heating is quite safe because it responds quickly to the controlled signals.
- Lower Attention and Maintenance Cost. Electric heating equipment generally will not require much attention and supervision and their maintenance cost is almost negligible. Hence, labour charges are negligibly small as compared to other forms of heating.

--------------------(6 Marks)

(b)Dielectric heating : Principle of Dielectric heating



When non – metallic parts such as wood, plastics are subjected to an alternating electrostatic field dielectric loss occurs. In dielectric heating these losses are made use of. The material to be heated is placed as a slab between metallic plates or electrodes connected to a high frequency AC supply. For producing sufficient heat, frequency between 10 and 30 MHz is used. Voltage applied will be in the range 600V – 3kV. The current drawn by the capacitor, when an ac supply voltage is applied across its two plates, does not lead the supply voltage by exactly 90^0 . There is always an in phase component of the current. Due to the in phase(active) component of the current, heat is always produced in the dielectric material placed in between the two plates of the capacitor. The electric energy dissipated in the form of heat energy in the dielectric material is known as dielectric loss. The dielectric loss is directly proportional to the frequency of AC supply given to the two plates of the capacitor. The dielectric loss is the molecular friction in the dielectric material when an AC electrostatic field is applied to it.

Expression for dielectric power loss :

- The material to be heated is considered as the imperfect dielectric of a condenser.
- The material is represented as a capacitance placed in parallel with a resistance.
- Let V =supply voltage in Volts, f = Supply frequency in Hz, C= Capacitance of the condenser in farads, Cosφ = pf of the load or charge
- Current through the Capacitor , Ic = V/Xc = V/(1/2πfC) = 2πfCV Amperes
- The current drawn from the supply, I is approximately equal to Ic = 2πfCV Amperes
- Power produced, P = VICosφ = V X 2πfCV X Cosφ = $2\pi fCV^2$Cosφ Watts

The capacity of a condenser is given by C = Є0 ЄrA/t farads where Є0 = absolute permittivity of vacuum. Єr is relative permittivity of dielectric ,Є0 = 8.854×10^{-12} F/m. t = thickness of dielectric in metres. A = surface area of the plates in m^2

--------------------(6 Marks)

(c)

1)c) Voltage, V = 230V

Power, P = 16 KW

Temperature of the element, $T_1 = 1170^\circ C$

Temperature of charge = $T_2 = 500^\circ C$

Radiating efficiency, K = 0.57

Emissivity, e = 0.9

Specific Resistance of Nichrome, $\rho = 1.09 \times 10^{-6}$ Ωm

$$\frac{l}{d^2} = \frac{\pi V^2}{4 \rho P} = \frac{\pi \times 230^2}{4 \times 1.09 \times 10^{-6} \times 16 \times 10^3} = \frac{166190.25}{0.06976}$$

$$= 2382314.364 \rightarrow (1)$$

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

$$= 5.72 \times 10^4 \times 0.57 \times 0.9 \left[\left(\frac{1170+273}{1000} \right)^4 - \left(\frac{500+273}{1000} \right)^4 \right]$$

$$= 116758.18 \, W/m^2$$

$$\pi d l H = 16 \, KW$$

$$dl = \frac{16 \times 10^3}{\pi H}$$

$$d^2 l^2 = \frac{256 \times 10^6}{\pi \times 116758.18} = 1.90 \times 10^{-3} \rightarrow (2)$$

$$① \times ② \Rightarrow \frac{l}{d^2} \times d^2 l^2 = l^3$$

$$\therefore l^3 = 2382314.364 \times 1.90 \times 10^{-3}$$

$$\therefore l = 16.54\ m$$

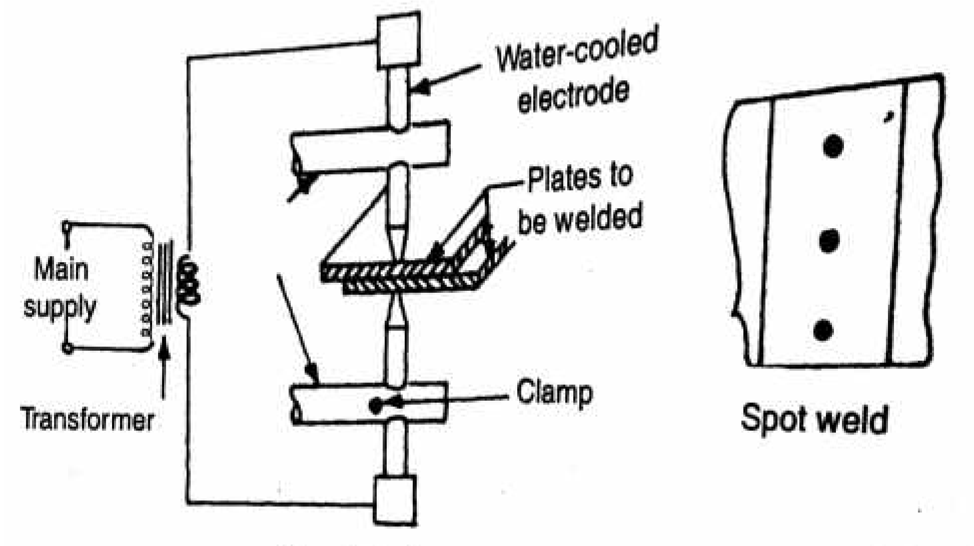
$$d^2 l^2 = 1.90 \times 10^{-3}$$

$$d^2 = \frac{1.90 \times 10^{-3}}{273.57} = 2.635 \times 10^{-3}\ m$$

--------------------------(8 Marks)

2. (a)Spot Welding

- Steel, copper, brass and light alloys can be joined by this method.
- This forms a cheap and satisfactory substitute for riveting.
- Spot welding is carried out by overlapping the edges of two sheets of metal and fusing them together between copper electrode tips at suitably spaced intervals by means of a heavy electrical current.



The resistance offered to the current as it passes through the metal raises the temperature of the metal between the electrodes to welding heat. The current is cut off and mechanical pressure is applied by the electrodes to forge the weld. Finally the electrodes open. When sheets of unequal thickness are joined, the current and pressure setting for the thinner sheets are used.

Applications :

- Spot welding is used for galvanized, tinned and lead coated sheets and mild steel sheet work.
- This technique is also applied to non – ferrous such as brass, aluminium, nickel and bronze.

--------------------(6 Marks)

(b)Faraday's Laws of Electrolysis

Faraday's First Law :

According to this Law, the chemical deposition due to the flow of current through an electrolyte is directly proportional to the quantity of electricity (coloumbs) passed through it.

Mass of chemical deposition, m α Q

m α It

m = ZIt

Here Q = Quantity of electricity

I = steady current in Amperes

t = time of current flow in seconds

Z = constant of proportionality called the electrochemical equivalent of the substance

Faraday's Second Law :

This law states that when the same quantity of electricity is passed through several electrolytes, the mass of the substances deposited are proportional to their respective chemical equivalents or equivalent weights.

Chemical Equivalent = Atomic weight/ Valency

-----------------(6 Marks)

(c)Elecrodeposition :

The process of depositing a coating of one metal over another metal or non-metal electrically is called the electro deposition. It is used for protective, decorative and functional purposes and includes such processes as electroplating, electro forming, electrotyping, electro facing, electro metallization, electro deposition of rubber and building up of worn out parts for repairs.

Factors affecting quality of electrodeposition :

Electro deposition depends on several factors. These are given below:

- Nature of electrolyte : The formation of smooth deposit largely depends upon the nature of electrolyte employed. The electrolyte from which complex ions can be obtained such as cyanides provides a smooth deposit.
- Current density : Electro deposition depends upon the rate at which crystals grow. At low current densities the deposits are coarse and crystalline in nature. For higher current densities, the metal deposit will be uniform and fine – grained. Also the deposit will be spongy and porous.
- Temperature : A low temperature of the solution favours formation of small crystals of metal and at high temperature large crystals are formed. A difference in temperature of 15 degree celsius results in a 50% decrease in strength of metal deposited.
- A high temperature may give beneficial results due to (a) increased solubility of salts (b) increased conductivity (c) decreased occlusion of hydrogen in the deposited metal.
- Conductivity : The use of a solution of good conductivity is important for economy in power consumption because it reduces the tendency to form rough deposits.
- Electrolytic concentration : Higher current density which is necessary to obtain uniform and fine grain deposit can be achieved by increasing the concentration of the electrolyte.
- Additional agents : The addition of acids or other substances to the electrolyte reduces its resistance. Some other agents take no direct part in the chemical reactions but influences the nature of deposit. Such additional agents are glue, gums, dextrose, gelatin, albumen , phenol ,sugar, glucose and rubber.
- Throwing power : This is the ability of the electrolyte to produce uniform deposit on an article of irregular shape. The distance between the various portions of cathode and anode will be different due to the irregular shape of the cathode. Due to unequal distance the resistance of the current path through the electrolyte for various portions of the cathode will be different.

Throwing power can be improved by increasing the distance between anode and cathode and by reducing the voltage drop at cathode.

- Polarization : The rate of deposition of metal increases with the increase in electroplating current density up to a certain limit. Use of current density beyond this limit causes the electrolysis of water and hydrogen liberation on the cathode. This hydrogen evolved on the cathode covers the base metal which reduces the reduces the rate of metal deposition. This phenomenon is called polarization. With reverse current electroplating in which at regular intervals plating current is reversed sufficient electron concentration is established around the base metal and the polarization effect becomes negligible.

--------------------(8 Marks)

3. (a)Definitions :

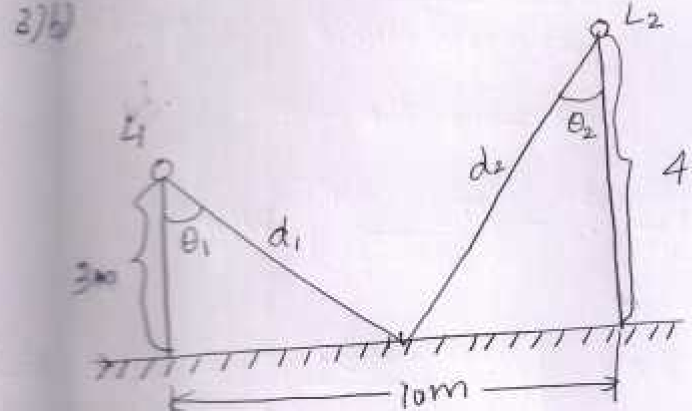
(i)Luminous flux : is defined as the total quantity of light energy emitted per second from a luminous body. It is represented by the symbol F and is measured in lumens (cd-sr).

(ii)Mean Horizontal Candle Power(MHCP) : it is defined as the mean of candle powers in all directions in the horizontal plane containing the source of light.

(iii)Coefficient of Utilization : It is defined as the ratio of total lumens reaching the working plane to total lumens given out by the lamp.

(b)

3) b)



Candle Power, $I = 100$ CP

$d_1 = \sqrt{5^2 + 3^2} = \underline{5.83m}$

$d_2 = \sqrt{5^2 + 4^2} = \underline{6.4m}$

(i) Illumination at a point midway between the lamp post $= \frac{I}{d_1^2} \cos\theta_1 + \frac{I}{d_2^2} \cos\theta_2$

$= \frac{100}{5.83^2} \left(\frac{3}{(5.83)}\right) + \frac{100}{6.4^2} \left(\frac{4}{6.4}\right)$

$= \underline{3.04 \text{ lux}}$

(2)

(ii) Illumination below the 3m lamp post

$= \frac{I}{h^2} = \frac{100}{3^2} = \underline{11.11 \text{ lux}}$

--(8 Marks) (c)Flood Lighting :

- The flooding of large surface with light from powerful projectors is called flood lighting
- Purpose is to enhance the beauty of ancient monuments
- To illuminate the advertisement board and show cases
- Railway yards , sports stadium , car parks, construction sites , quarries.
- For small building flood lights are placed near by buildings or posts at distance of 60 m
- Light should be perpendicular to building
- Tall buildings are illuminated non- uniformly .To avoid that flood lights should be suitably placed . If even shadows are formed it should enhance the beauty of the building

-----------------------(6 Marks)

4. (a)High Pressure Mercury Vapour Lamp :

Construction :

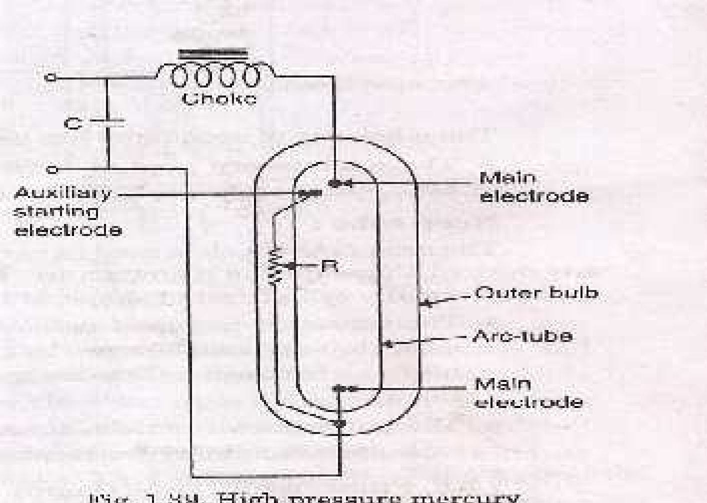


Fig. 1.39. High pressure mercury vapour discharge lamp.

- It consists of two bulbs – an arc tube containing the electric discharge and outer bulb which protects the arc tube from changes in temperature.
- The inner tube(arc tube) contains a small amount of mercury and argon gas.
- In addition to two main electrodes, an auxiliary starting electrode connected through a high resistance (about 50 k ohms) is also provided.
- The main electrodes consists of tungsten coils with electron emitting coating or elements of thorium metal.

Working :

- When the supply is switched ON, the initial discharge for a few seconds is established in the argon gas between the auxiliary starting electrode and the main electrodes.
- The heat produced due to this discharge through the gas is sufficient to vaporise mercury.
- The pressure inside the arc tube increases to about 1 to 2 atmospheres and potential difference across the main electrodes grows from about 20 to 150V.
- The operation takes about 5 to 7 minutes.
- During this time, discharge is established through the mercury vapours which emit greenish – blue light.
- The choke is provided to limit the current to a safe value.
- The choke lowers the power factor.
- Hence a capacitor C is connected across the circuit to improve the power factor.
- The efficiency of this type of lamp is 30 to 40 lumens/watt.

- These lamps are used for general industrial lighting, railway yards, ports, work areas, shopping centers where greenish – blue colour light is not objectionable.

---------------------------(8 Marks)

(b)

4(a) Space height ratio = $\frac{\text{horizontal distance between lamps}}{\text{Mounting height}}$

Illumination, E = 200 lux

Let Mounting height = 5m

Take space - height ratio = 1m

$\therefore$ Space height ratio = $1 = \frac{x}{5}$

$\therefore$ horizontal distance between the lamps = 5m

Dimension of the hall = 30m x 20m

Gross lumens, $N \times O = \frac{EA}{UF \times MF}$

Coefficient of Utilisation, UF = 0.75

Depreciation factor, DF = 0.8

Maintenance factor, $MF = \frac{1}{DF} = \frac{1}{0.8} = \underline{\underline{1.25}}$

Gross lumens, $N \times O = \frac{200 \times 30 \times 20}{0.75 \times 1.25}$

$= \frac{12 \times 10^4}{0.9375} = 128 \times 10^3$

Efficiency of lamp = 25 lumen/watt

--------------------------------(8 Marks) (c)CFL Lamps : Performance Features

- Electronic ballasts contain a small circuit board with rectifiers, a filter capacitor and two switching transistors connected as a high frequency resonant series dc to ac inverter.
- The resulting high frequency (about 40 kHz) is applied to the lamp tube.
- The resonant converter tends to stabilize the lamp current and therefore the light is produced over a range of input voltages.
- CFLs are designed to operate within a specified temperature range.
- Temperatures below the range causes reduced output.
- Most of the CFLs are for indoor use.
- Outdoor CFLs need installation in enclosed fixtures so as to minimize the adverse effects of low temperature.

LED Lamps : Performance Features

- LED Lamp is a Light Emitting Diode(LED) product which is assembled into a lamp for use in lighting fixtures.
- LED lamps have a life span and electrical efficiency which are several times longer than incandescent lamps and fluorescent lamps.
- LEDs come to full brightness without the need of warm up time.
- The initial cost of LED is usually higher.
- Some LED lamps are made to be a direct compatible drop in replacement for incandescent lamps and fluorescent lamps.
- Most of the LEDs do not emit light in all directions.
- LED chips need controlled direct current(DC) electrical power and an appropriate circuit as an LED driver is required to convert the AC current from the supply to the regulated voltage DC used by the LEDs.
- LEDs are adversely affected by high temperature.

- Therefore LED lamps typically include heat dissipation elements such as heat sinks.

--------------------(4 Marks)

PART B

5. (a)Types of Railway services :

Railways offer the following three types of passenger services :

1. City or Urban service : In this type of service, there are frequent stops, the distance between stops being nearly 1 km. It is essential to have high acceleration and retardation.
2. Suburban service : Here the distance between stops averages from 3 to 5 km over a distance of 25 to 30 km from the city. In this case also, high rates of acceleration and retardation are necessary.
3. Main Line service : In this case, operation is over long routes and stops are infrequent. Here operating speed is high and acceleration and braking periods are relatively less important.

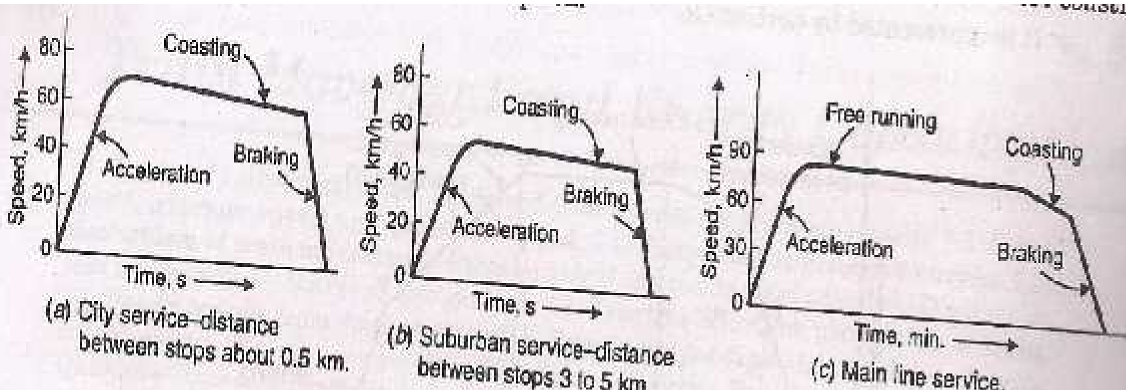


Fig. 7.2. Typical speed-time curves.

----------------(4 Marks)

(b)

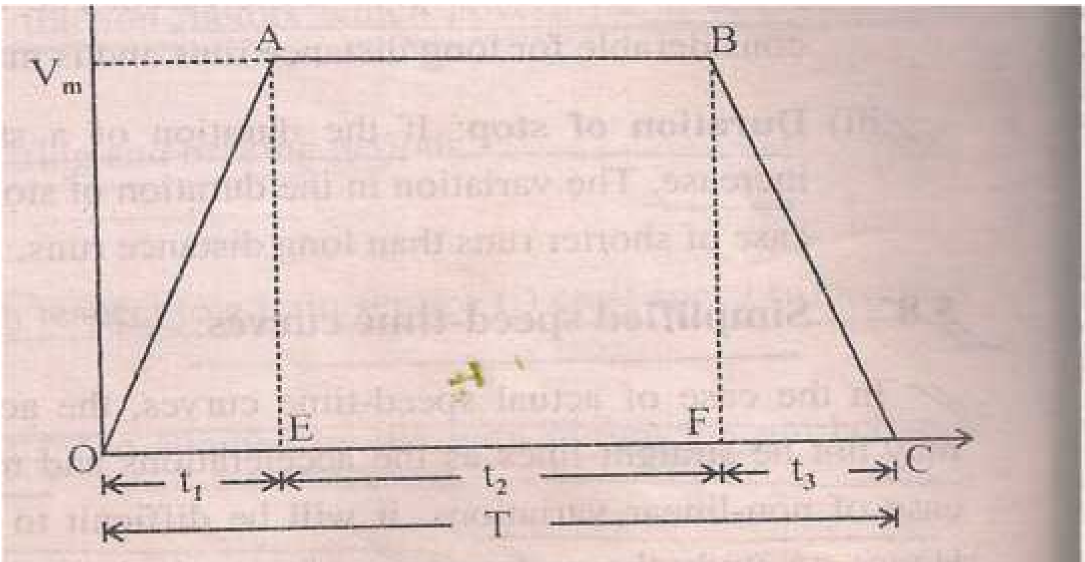


Fig.5.3

Then, t_1 = time of acceleration in seconds = $\frac{V_m}{\alpha}$ V= at

t_3 = time of braking retardation in seconds = $\frac{V_m}{\beta}$

t_2 = time of free run in seconds = $T - (t_1 + t_3) = T - \left(\frac{V_m}{\alpha} + \frac{V_m}{\beta}\right)$

The distance of run between two stops is given by the area under the curve

$\therefore$ D = area of triangle OAE + area of rectangle ABFE + area of triangle FBC

$$= \frac{1}{2} V_m \frac{t_1}{3,600} + V_m \frac{t_2}{3,600} + \frac{1}{2} V_m \frac{t_3}{3,600}$$

[**Note**: As V_m is in kmph, t_1, t_2 and t_3 must be in hours]

$$= \frac{1}{2} \times \frac{V_m}{3,600} \cdot \frac{V_m}{\alpha} + \frac{V_m}{3,600}\left[T - \left(\frac{V_m}{\alpha} + \frac{V_m}{\beta}\right)\right] + \frac{1}{2} \times \frac{V_m}{3,600} \cdot \frac{V_m}{\beta}$$

$$= \frac{V_m^2}{7,200\alpha} + \frac{V_m}{3,600} T - \frac{V_m^2}{3,600\alpha} - \frac{V_m^2}{3,600\beta} + \frac{V_m^2}{7,200\beta} = \frac{V_m}{3,600} T - \frac{V_m^2}{7,200\alpha} - \frac{V_m^2}{7,200\beta}$$

i.e. $\frac{V_m^2}{7,200}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) - \frac{V_m}{3,600} T + D = 0$ Put $K = \frac{1}{\alpha} + \frac{1}{\beta}$

i.e. $\frac{V_m^2}{7,200} K - \frac{V_m}{3,600} T + D = 0$ i.e. $KV_m^2 - 2TV_m + 7,200D = 0$ (5.1)

$$\therefore V_m = \frac{2T \pm \sqrt{4T^2 - 4K \times 7,200D}}{2K} = \frac{T}{K} \pm \sqrt{\left(\frac{T}{K}\right)^2 - \frac{7,200D}{K}}$$

In the above equation, if positive sign is used, it gives abnormal values of V_m. Therefore only negative sign is used.

$$\therefore V_m = \frac{T}{K} - \sqrt{\left(\frac{T}{K}\right)^2 - \frac{7,200D}{K}} \quad (5.2)$$

From equation (5.1), the distance between two stops can be calculated, if all the other quantities are known.

We know that, from equation (5.1), $KV_m^2 - 2TV_m + 7,200D = 0$

i.e. $K = \frac{2T}{V_m} - \frac{7,200D}{V_m^2}$ but $T = \frac{3,600D}{V_a}$

$$= \frac{2}{V_m}\left(\frac{3,600D}{V_a}\right) - \frac{7,200D}{V_m^2} = \frac{7,200D}{V_m V_a} - \frac{7,200D}{V_m^2} = \frac{7,200D}{V_m^2}\left[\frac{V_m}{V_a} - 1\right] \quad (5.3)$$

------------------------(8 Marks)

Part B

5(b) Average speed, $V_a = 40\,Km/hr$

Distance between stops, $D = 1500m = 1.5Km$

Acceleration, $\alpha = 2\,Kmphps$

Braking Retardation, $\beta = 3\,Kmphps$

$$V_a = \frac{3600D}{T} = \frac{3600 \times 1.5}{T} = 40$$

$$\therefore T = \frac{3600 \times 1.5}{40} = \underline{\underline{135 \text{ seconds}}}$$

$$K = \frac{1}{\alpha} + \frac{1}{\beta} = \frac{1}{2} + \frac{1}{3} = \underline{\underline{0.833}}$$

Maximum speed, $$V_m = \left(\frac{T}{K}\right) - \sqrt{\left(\frac{T}{K}\right)^2 - \frac{7200D}{K}}$$

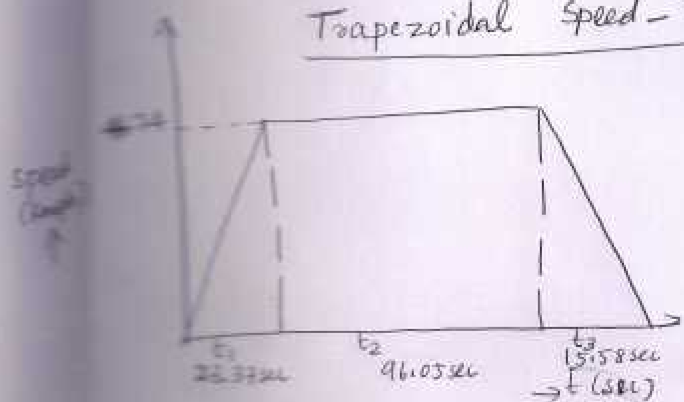
$$= \frac{135}{0.833} - \sqrt{\left(\frac{135}{0.833}\right)^2 - \frac{7200 \times 1.5}{0.833}}$$

$$= \underline{\underline{46.74}}\ km/hr$$

$t_1 = \frac{V_m}{\alpha} = \underline{\underline{23.37 \text{ seconds}}}$ $\qquad t_3 = \frac{V_m}{\beta} = \underline{\underline{15.58 \text{ seconds}}}$

$t_2 = T - (t_1 + t_3) = 135 - (23.37 + 15.58) = \underline{\underline{96.05 \text{ seconds}}}$

Trapezoidal Speed-Time Curve



---------------(8 Marks)

6. (a)Power output from driving axle

Power output, P = Rate of doing work

= Tractive effort xdistance/Time

P = Tractive effort x velocity = Ft x v

Where Ft = tractive effort , v = train velocity

- If *Ft* is the tractive effort and v is the train velocity, then output power = *Ft* × v
- **(i)** If *Ft* is in newton and v in m/s, then output power = *Ft* × v watt
- **(ii)** If *Ft* is in newton and v is in km/h , then converting v into m/s, we have

$$\text{output power} = F_t \times \left(\frac{1000}{3600}\right) v \text{ watt} = \frac{F_t v}{3600} \text{ kW}$$

If η is the efficiency of transmission gear, then power output of motors is

$$= F_t \, . \, v/\eta \text{ watt} \qquad \text{— v in m/s}$$

$$= \frac{F_t v}{3600\,\eta} \text{ kW} \qquad \text{— v in km/h}$$

------------------(6 Marks)

6)b) Weight of the train, $W = 250$ tonnes

Diameter of driving wheels, $D = 80cm = 0.8m$

Percentage gradient, $G = \frac{40}{1000} \times 100 = 4\%$

Tractive resistance, $r = 50 N/Tonne = r$

Gear ratio, $\gamma = 4$

Gear transmission efficiency $= 87\% = 0.87 = \eta$

Equivalent accelerating weight of the train, $W_e = 1.12 \times 250 = 280$ tonnes

Total torque developed, $T = 4 \times 6000 = 24000$ Nm

Tractive effort, $F_t = \frac{\eta T 2\gamma}{D} = \frac{0.87 \times 24000 \times 2 \times 4}{0.8}$

$= 208800 N$

Let the acceleration of the train be α Kmphps

$\therefore F_t = 277.8 W_e \alpha + 98.1 WG + Wr$

$208800 = 277.8 \times 250 \times \alpha + 98.1 \times 250 \times 4 + 250 \times 50$

$208800 = 69450\alpha + 98100 + 12500$

$\therefore \alpha = \frac{208800 - 110600}{69450} = 1.414$ Kmphps

Time taken for the train to attain a speed of 50Kmph, $t = \frac{V_m}{\alpha} = \frac{50}{1.414} = 35.36$ seconds

----------------------(10 Marks)

(c)Definition :

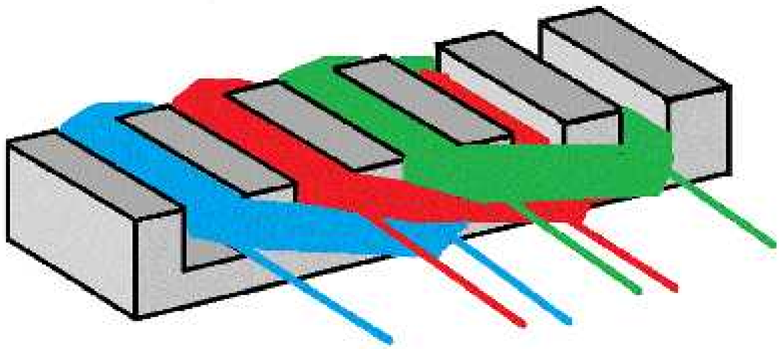
(i)Dead weight : The total weight of locomotive and train to be pulled by the locomotive is called dead weight. It is the gross weight of the train, including the locomotive moving the track.

(ii)Coefficient of adhesion : Adhesion between two bodies is due to interlocking of the irregularities of their surfaces in contact. The adhesive weight of a train is equal to the total weight to be carried on the driving wheels.

--------------------(4 Marks)

7. (a)Working principle of Linear Induction motor :

- A linear Induction motor is a special type of Induction motor which provides linear motion and works on the same principle as that of conventional Induction motor.
- Whenever a relative motion occurs between the field and the short circuited conductors, currents are induced in them.
- This results in electromagnetic forces and under the influence of these forces according to Lenz's law, the conductors try to move in such a way as to eliminate the induced currents.
- Here the field's movement and the conductor motion is linear.



Linear Induction Motor

- When the 3 phase primary winding of the motor is energized from a balanced 3 phase source, a magnetic field moving in straight line from one end to the other at a linear synchronous speed Vs is produced.
- $V_s = 2 \tau f$ m/s

  where τ = Pole pitch (metres)

  f = Supply frequency (Hz)
- Slip of the motor, $s = (V_s – V)/V_s$

  where Vs = Linear synchronous speed

  V = Actual speed of the rotor plate
- Thrust or Tractive effort , F = P2/Vs

  where P2 = Actual power supplied to the rotor
- Copper loss in rotor = sP2
- Mechanical Power developed, $P_{mech} = (1 – s)P_2$

----------------------------(6 Marks)

(b)Bridge transition control of DC motors :

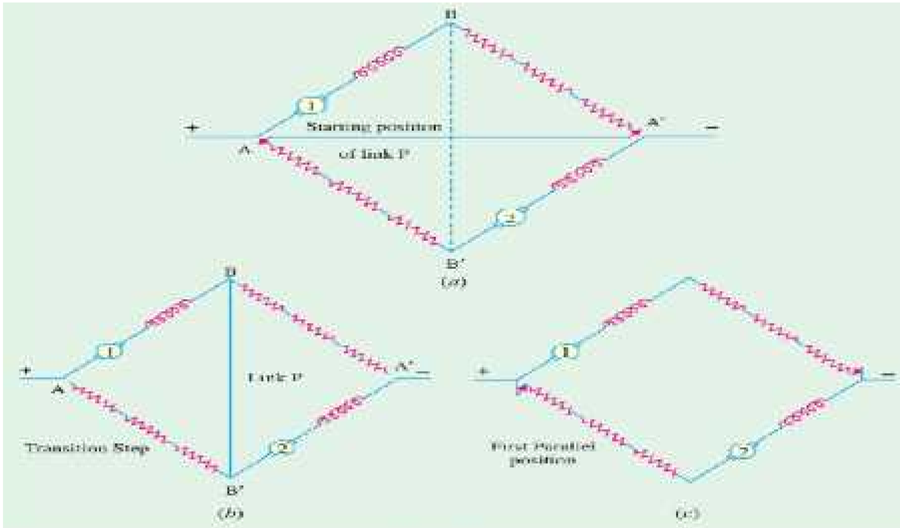


Fig. 43.32

- The motor and the starting rheostats are connected in the form of a Wheatstone bridge.
- In the first starting position the motors are in series and the rheostats are completely in the circuit as indicated by the rheostat arm P at AA'.
- A and A' are moved in the direction of the arrow heads and in position BB' the motors are in full series.
- In the transition step, the rheostats are reinserted by connecting to positive and negative of the supply.
- In the first parallel step, the link P is removed and the motors are connected in parallel with the starting resistances in their circuits.
- The advantage of this method is that during transition the motors are always connected to the supply and as the resistances are so adjusted that the value of current remains the same, the torque does not change and hence uniform acceleration is obtained without causing inconvenience to the passengers.
- This method is used for railway traction.

For shunt transition and bridge transition series parallel drum type controllers are used. The controllers incorporate arrangements for starting, reversing and braking of the motors also.

-------------------(6 Marks)

(c)

7)c) Given $M = 400$ tonnes

$V_1 = 60$ km/h

$V_2 = 40$ km/h

$S = 2$ km

$G = 1.5\%$, $r = 50$ N/tonne

$\frac{M_e}{M} = 1.1$, $\eta = 75\%$

(i) Electrical energy returned to the line

$$= \eta\left[0.01072 \frac{M_e}{M}(V_1^2 - V_2^2) + S(27.25G - 0.2778r)\right]$$

$$= 0.75\left[0.01072 \times 1.1(60^2 - 40^2) + 2(27.25 \times 1.5 - 0.2778 \times 50)\right] \text{ Wh/tonne}$$

$$= 58.16 \text{ Wh/tonne} = 58.16 \times 400 \times 10^{-3} = \underline{\underline{23.26 \text{ kWh}}}$$

(ii) Average power returned to the line

$$\text{Average speed} = \frac{60 + 40}{2} = 50 \text{ km/h}$$

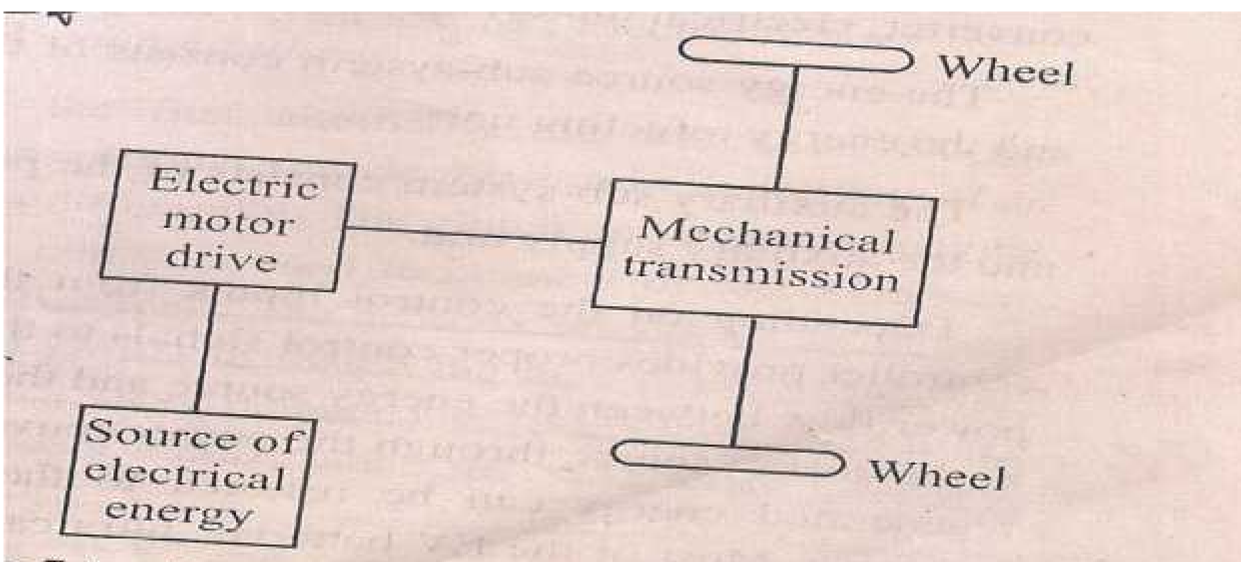
$$\text{Time taken} = \frac{\text{Distance}}{\text{Average speed}} = \frac{2}{50} = \underline{\underline{0.04 \text{ h}}}$$

$$\text{Hence power returned} = \frac{23.26}{0.04} = \underline{\underline{581.5 \text{ kW}}}$$

---(8 Marks)

8. (a)General electric vehicle configuration with block diagram :

The primary electric vehicle power train was mainly converted from the then existed Internal combustion engine vehicle(ICEV) in which internal combustion engine and the fuel tank are replaced by an electric motor drive and the battery pack, while retaining all other components.



g.7.1 : Primary electric vehicle power train

The drawback of such a system are heavy weight, lower flexibility and unsatisfactory performance and such EVs have become obsolete. A modern EV is built based on original body and frame designs. This satisfies the structure requirements unique to EVs and gives greater flexibility of electric propulsion.

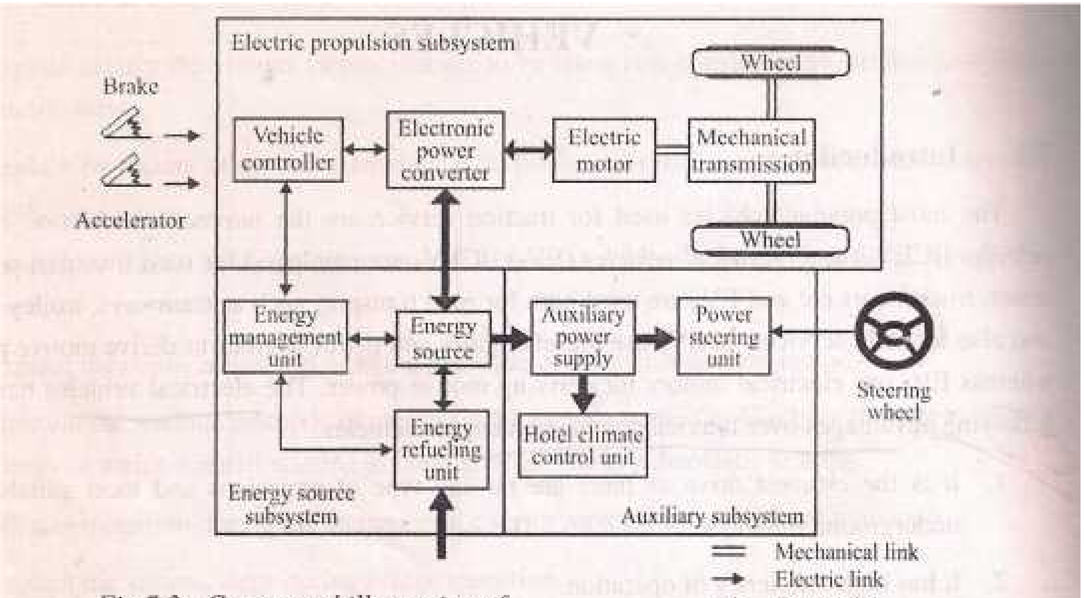


Fig.7.2 : Conceptual illustration of general EV configuration

The electric drive consists of three major sub systems :

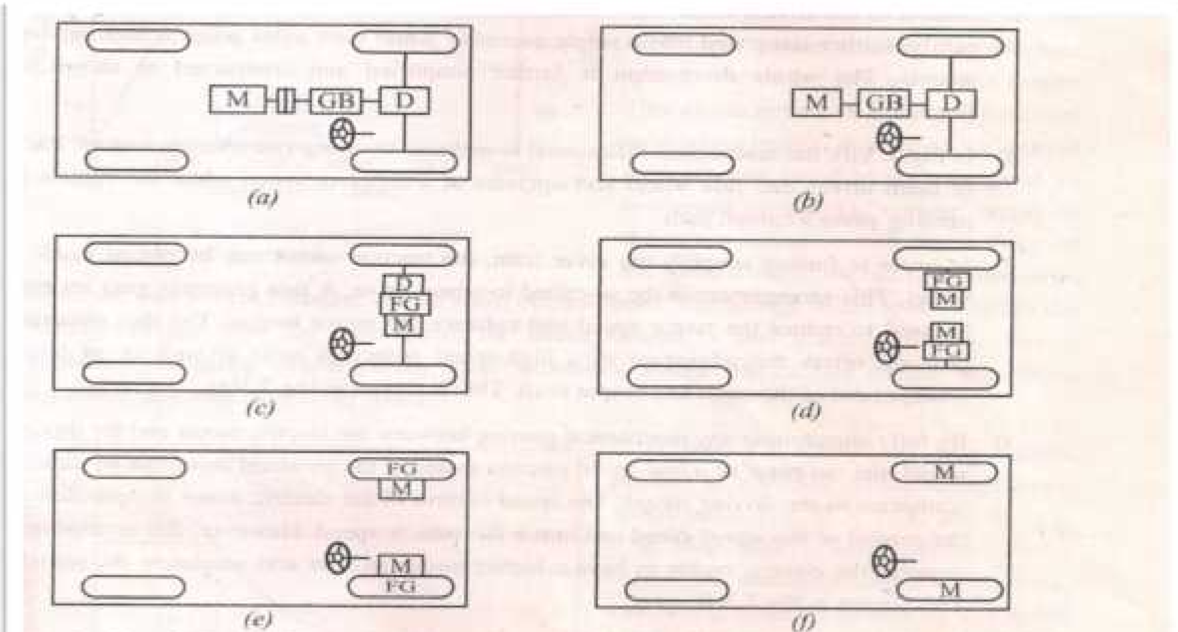
(i)the electric propulsion sub system

(ii)energy source sub system

(iii)auxiliary sub system

Depending on the control inputs from the accelerator and brake pedal, the vehicle controller provides proper control signals to the electronic power converter, which regulates the power flow between the energy source and the motor. If there is any power flow from the motor to the energy source through the power converter, it is due to the regenerative braking and this regenerated energy can be restored to the energy source provided the energy source is receptive. Most of the EV batteries, ultra capacitors and flywheel possess the ability to accept the regenerated energy. The energy management unit cooperates with the vehicle controller the regenerative braking and its energy recovery.

There are a variety of EV configurations due to the variations in electric propulsion characteristics and energy sources :



C : Clutch, D : Differential, FG : Fixed gearing, GB : Gearbox, M : Electric motor

Fig.7.3: Possible EV configurations

(a)This shows the configuration of the first alternative, in which an electric propulsion replaces the IC engine of a conventional vehicle drive train. It consists of an electric motor, a clutch, a gear box and a differential. The clutch is used to connect or disconnect the power of the electric motor from the driven wheels. The gear box provides a set of gear ratios to modify the speed – power (torque) profile to match the load requirement.

(b)This shows the configuration which consists of an electric motor that has constant power in a long speed range, a fixed gearing can replace the multispeed gear box and reduce the need for a clutch. The configuration not only reduces the size and weight of the mechanical transmission, but also simplifies the drive train control because gear shifting is not needed.

(c)Similar to the drive train in (b), the electric motor, fixed gearing and the differential can be further integrated into a single assembly while both axles point at both driving wheels. The whole drive train is further simplified and connected.

(d)Here the mechanical differential is replaced by using two traction motors. Each of them drives one side wheel and operates at a different speed when the vehicle is running along a curved path.

(e)In order to further simplify the drive train, the traction motor can be placed inside a wheel. This arrangement is the so called in – wheel drive. A thin planetary gear set may be used to reduce the motor speed and enhance the motor torque. The thin planetary gear set offers the advantage of a high speed reduction ratio as well as an inline arrangement of the input and output shaft.

(f)By fully abandoning any mechanical gearing between the electric motor and the driving wheel, the out – rotor of a low speed electric motor in the in-wheel drive can be directly connected to the driving wheel. The speed control of the electric motor is equivalent to the control of the wheel and hence the vehicle speed. This arrangement requires the electric motor to have a higher torque to start and accelerate the vehicle.

------------------(12 Marks)

(b)Regenerative braking with reference to DC motors :

In Regenerative Braking, the power or energy of the driven machinery which is in kinetic form is returned back to the power supply mains. This type of braking is possible when the driven load or machinery forces the motor to run at a speed higher than no load speed with a constant excitation. Under this condition, the back emf E_b of the motor is greater than the supply voltage V, which reverses the direction of motor armature current. The machine now begins to operate as a generator and the energy generated is supplied to the source. Regenerative braking can also be performed at very low speeds if the motor is connected as a separately excited generator.

The excitation of the motor is increased as the speed is reduced so that the Two equations shown below are satisfied.

$$E_b = \frac{nP\varphi Z}{A} \quad \text{and} \quad V = E_b - I_a R_a$$

Regenerative braking for Shunt motor :

$$-I_a = \frac{V - E_b}{R_a}$$

When the load is lowered by a crane, hoist or lift causes the motor speed to be greater than the no-load speed. The back EMF becomes greater than the supply voltage. Consequently, armature current Ia becomes negative. The machines now begin to operate as a generator.

Regenerative braking for Series motor :

In case of DC Series Motor an increase in speed is followed by a decrease in the armature current and field flux. The back EMF Eb cannot be greater than the supply voltage. Regeneration is possible in DC Series Motor since the field current cannot be made greater than the armature current.

Regeneration is required where DC Series Motor is used extensively such as in traction, elevator hoists etc. For example – In an Electro-locomotive moving down the gradient, a constant speed may be necessary. In hoist drives the speed is to be limited whenever it becomes dangerously high.

One commonly used method of regenerative braking of DC Series Motor is to connect it as a shunt motor. Since the resistance of the field winding is low, a series resistance is connected in the field circuit to limit the current within the safe value.

------------------------(8 Marks)