CBCS SCHEME

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18EE742

Seventh Semester B.E. Degree Examination, Feb./Mar. 2022
Utilization of Electrical Power

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Explain the principle of dielectric heating and the factors on which dielectric loss in a dielectric material depends. **(08 Marks)**

b. Discuss the principle of arc welding and the difference between carbon and metallic arc welding. **(08 Marks)**

c. A three phase, 415 V, 45 kW resistance oven employs nickel-chrome wire for its heating elements. If the wire temperature is not to exceed 1200°C and the temperature of the charge is to be limited to 800°C, calculate the diameter and length of the wire. Assume radiating efficiency as 0.57 and resistivity of nichrome as $1.016\times10^{-6}\ \Omega$ and emissivity as 0.9. **(04 Marks)**

OR

2 a. Explain the principle of high frequency induction heating. What factors control the depth of penetration of heat? **(08 Marks)**

b. State Faraday's laws of electrolysis and explain any two applications of electrolysis. **(08 Marks)**

c. An insulating material 3 cm thick and 400 cm^2 in area is to be heated by dielectric heating. The material has a relative permittivity of 6 and a power factor of 0.05. Power required is 600 W at a frequency of 30 MHz. Determine the necessary voltage and the current required. If the voltage were to be limited to 800 V, what will be the frequency of the supply required? **(04 Marks)**

Module-2

3 a. State the laws of illumination and explain the term : (i) Plain angle (ii) Solid angle and establish the relationship between them. **(08 Marks)**

b. Explain with a neat diagram, principle of operation of a sodium vapour lamp. Mention its use. **(08 Marks)**

c. Two lamp posts are 20m apart and are fitted with lamps of luminous intensity 200 C.P each, at a height of 6 m above the ground. Calculate the illumination on the ground (i) under each lamp (ii) midway between the lamps. **(04 Marks)**

OR

4 a. What are the requirements of a good lighting? **(04 Marks)**

b. Write short notes on : (i) Flood lighting (ii) Street lighting. **(08 Marks)**

c. A lamp having a uniform C.P of 300 in all directions is provided with a reflector which directs 60 percent of the total light uniformly on to a circular area of 12m diameter. The lamp is 5m above the area. Calculate (i) the illumination at the centre and edge of the surface with and without reflector. (ii) The average illumination over a area without the reflector. **(08 Marks)**

Module-3

5 a. Assuming the quadrilateral speed time curve, derive equation for
(i) Total distance travelled by the train between two stops
(ii) Velocity at the time of braking. **(08 Marks)**

b. Define specific energy consumption and discuss the factors affecting it. **(08 Marks)**

c. A scheduled speed of 45 km/hr is required between two stops 1.5 km apart. Find the maximum speed over the run if the stop is of 20 seconds duration. The values of acceleration and retardation are 2.4 kmphps and 3.2 kmphps respectively. Assume a simplified trapezoidal speed time curve. **(04 Marks)**

OR

6 a. Define Tractive effort. Deduce expression for total tractive effort for propulsion of a train. **(08 Marks)**

b. Explain why a series motor is preferred for the electric traction. **(04 Marks)**

c. Explain with the help of suitable circuit diagrams,
(i) Shunt transition (ii) Bridge transition as applied to a pair of d.c traction motors. **(08 Marks)**

Module-4

7 a. Describe how plugging, rheostatic braking and regenerative braking are employed with d.c motors. **(12 Marks)**

b. Show how sag and tension are calculated in trolley wires. **(08 Marks)**

OR

8 a. Sketch the various arrangement of current collection used in electric traction. **(06 Marks)**

b. Explain the function of a negative booster in a tramway system. **(06 Marks)**

c. Discuss some of the mechanical braking arrangements used in electric traction. **(08 Marks)**

Module-5

9 a. With relevant block diagram, discuss the working principle of Hybrid Electric Vehicle. **(10 Marks)**

b. Discuss electric energy consumption in electric vehicle. **(10 Marks)**

OR

10 a. With neat diagram, explain the configuration of electric vehicles. **(10 Marks)**

b. Discuss electrical vehicle performance interms of maximum cruising speed, gradeability and acceleration. **(10 Marks)**

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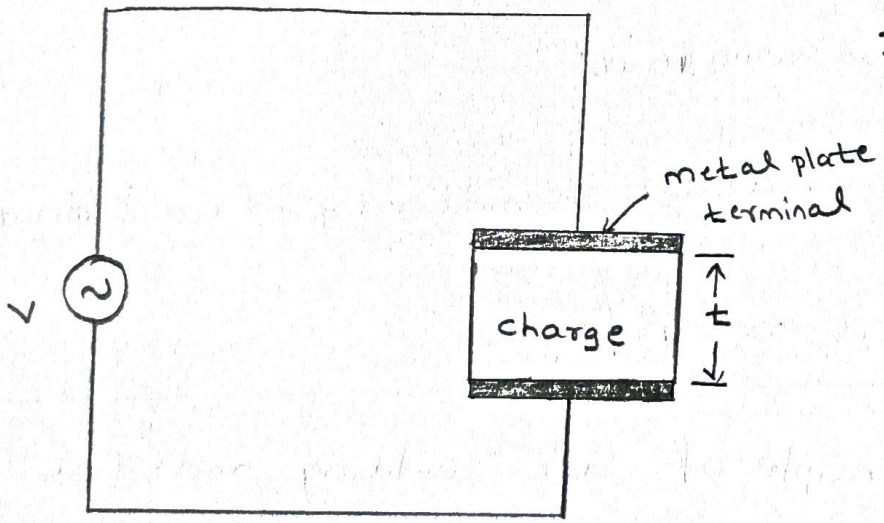
Module 1

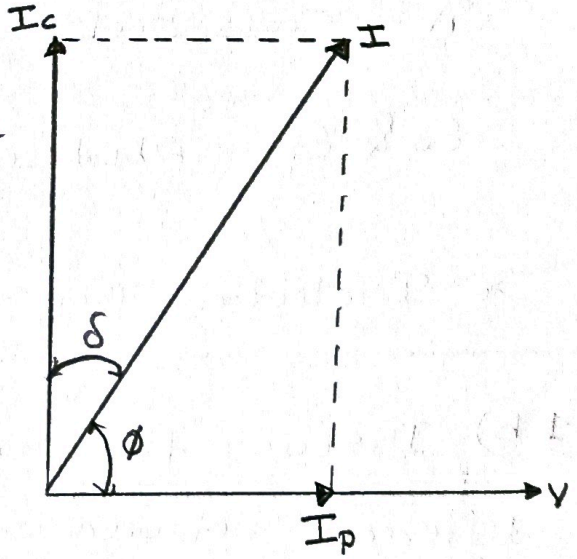
1a) Explain the principle of of dielectric heating and factor on which dielectric loss in a dielectric material depends. (8M)

Ans:- * Dielectric heating is also called as high frequency – capacitive heating.

* When a capacitor is subjected to a sinusoidal voltage, the current drawn by it is never leading the voltage by exactly 90°.

* The angle between the current & voltage is slightly less with the result that there is a small in-phase component of the current which produce power loss in the dielectric of capacitor.





* At ordinary frequency of 50Hz such loss may be small enough to be negligible but at high frequencies the loss becomes larger enough to heat the dielectric.

* The dielectric heating depends on frequency (f), charging current (Ic), voltage (V), power input (P). This can be illustrated through mathematical expression.

Power drawn from supply = $VI\cos\phi$

capacitive current $I_c = I = \frac{V}{X_c} = 2\pi f C V$

$P = V(2\pi f C V)\cos\phi = V^2 2\pi f C \cos\phi$

$\phi = (90 - \delta)$

$\cos\phi = \cos(90 - \delta) = \sin\delta = \tan\delta$

where δ is very small & its unit is radians

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

$C = \frac{\varepsilon_0 \varepsilon_r A}{t}$

t = thickness in meters.

A = Cross sectional area in m^2

ε_0 & ε_r = Absolute & relative permittivity of air & material

* Dielectric loss is $\propto V^2 f$.

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1 b) Discuss the principle of arc welding and the difference between carbon and metallic arc welding. (8 M)

Ans:- * Electric arc welding is the system which the metal is melted by the heat of an electric arc.

* Electric arc is luminous electrical discharge between two electrodes through ionized gas.

Metallic arc welding

* The arc establish between work & the filler metal electrode.
* Arc creates the molten metal pool to weld the particles.
* AC or DC supply used to create the arc. 60 to 70 V is essential to struck the arc & 17 to 25 V required to maintain short arc.
* Current requirement varies from 10 to 500 Amps.
* Arc blow introduced when DC supply employed, which may reduce the efficiency of welding.
* Consumbable flux coated electrode used in this welding.

Carbon arc welding

* It is differs from common shield metal arc welding in that it uses non consumable carbon graphite electrodes instead of consumable flux coated electrodes.
* Positive terminal connected to supply, where negative — connected to material to be welded.
* It is used for filling blow holes in the castings which are not subjected to any of the stresses.
* Temperature control is easy by varing the arc length.
* Used to weld high nickel alloy, galvanised sheets.

1c) A 3ϕ, 415V, 45kW resistance oven employes nickel chrome wire for its heating elements. If the wire temperature is not exceeds 1200°C & the temperature of the charge is to be limited to 800°C, calculate the diameter & length of the wire. Assume radiating efficiency as 0.57 & resistivity of nichrome as $1.016 \times 10^{-6}\ \Omega$ & emissivity as 0.9. (4M)

Ans:- Power per phase $P_{ph} = \frac{45}{3} = 15kW$

Voltage per phase $V_{ph} = \frac{415}{\sqrt{3}} = 239.6V$

$T_1 = 1200 + 273 = 1473K$

$T_2 = 800 + 273 = 1073K$

radiating efficiency $\eta_{rad} = 0.57$

resistivity of nichrome wire $\rho = 1.016 \times 10^{-6}\ \Omega m$

emissivity $e = 0.9$

$$H = 5.67\ \eta_{rad}\ e \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4 \right] W/m^2$$

$$= 5.67 \times 0.57 \times 0.9 \left[\left(\frac{1473}{100}\right)^4 - \left(\frac{1073}{100}\right)^4 \right] W/m^2$$

$$= 98377.38\ W/m^2$$

we know that $\frac{l}{d^2} = \frac{\pi V^2}{4\rho P}$

$$\frac{l}{d^2} = \frac{\pi \times (239.06)^2}{4 \times 1.016 \times 10^{-6} \times 15k}$$

$$\frac{l}{d^2} = 2945226 \quad \text{— I}$$

Total heat dissipated/sec = Electrical power input

$\pi d l H = P$

$\pi d \times l \times 98377.38 = 15000$

$d l = 0.04853$

$d^2 l^2 = 0.002355$ —— II

Multiplying (i) & (ii) we have

2a) Explain the principle of high frequency induction heating. What factors control the depth of penetration of heat. (8M)

Ans:- * High frequency induction heating is also called as coreless type induction heating.

* In this type of heating heavy iron core is not employed there is no continuous path for magnetic flux

* Primary winding sets up eddy current in the charge which tend to flow concentrically with those in the inductor.

* These eddy currents heat up the charge to its melting point & also set up electro-magnetic forces producing stirring action which is essential for obtaining uniform quality of metal.

* Flux density is low, to increase eddy current loss frequency is increased. ($P_e \propto B^2 f^2$

Factors affecting on depth of penetration of heat.

* Resistivity of the molten metal (R), frequency (f), relative permeability decides the depth of penetration (d)

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

$$d \propto \frac{1}{\sqrt{f}}$$

* Judicious selection of frequency ~~increa~~ decides the depth of penetration (d).

* Normally 10kHz to 40 kHz frequency employed.

2b) State Faraday's laws of electrolysis & any two application of electrolysis. (8M)

Ans:- Faraday's 1st law of electrolysis

Statement :- "The mass of a substance liberated from an electrolyte in a given time is proportional to the ~~q~~ — quantity of electricity passing through the electrolyte."

$$m \propto Q \propto It$$

$$m = ZIt$$

Z = A constant called electrochemical equivalent.

I = The steady current in amps.

t = Time for which current (I) flows through the electrolyte in seconds.

If $I = 1A$, $t = 1sec$, $Z = m$

Faraday's 2nd law of electrolysis

Statement :- "When the same quantity of electricity is passed through several electrolytes, the masses of the substance deposited are proportional to their respective chemical equivalents.

* Electrolysis used to seperate the metal from its ore.

* Electrolysis used to deposit metals, electro plating.

2c) An insulating material 3cm thick & 400 cm^2 in area is to be heated by dielectric heating. The material has relative permeability of 6 & power factor of 0.05. Power required is 600W, & frequency of 30MHz. Determine the necessary voltage & current required. If the ~~fo~~ voltage is to be maintained 600V, what will be the frequency of the supply required.

Ans:- $A = 400\ cm^2 = 400 \times 10^{-4}\ m^2$

$t = 3\ cm = 3 \times 10^{-3}$

$\cos\phi = 0.05$

$P = 600\ W$

$\varepsilon_r = 6$

$\varepsilon_0 = 8.854 \times 10^{-12}\ F/m$

$f = 30\ MHz$

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

$$C = \frac{\varepsilon_0 \varepsilon_r A}{t} = \frac{6 \times 8.854 \times 10^{-12} \times 400 \times 10^{-4}}{3 \times 10^{-3}}$$

$$C = 708.32 \times 10^{-12}\ F$$

$$V = \sqrt{\frac{P}{2\pi f C}}$$

$$V = \sqrt{\frac{600}{2\pi \times 30 \times 10^6 \times 708.32 \times 10^{-12}}}$$

$$V = 67.03\ Volts$$

$$X_C = \frac{1}{2\pi f C} = 7.489\ \Omega$$

$$I_C = I = \frac{V}{X_C} = \frac{67.03}{7.489} = 8.94\ Amps$$

$V_1 = 67.03V$ $f_1 = 30MHz$ $V_2 = 800V$ $f_2 = ?$

$$\frac{V_1}{V_2} = \frac{f_1}{f_2}$$

$$\frac{67.03}{800} = \frac{30MHz}{f_2}$$

$$f_2 = 358\ MHz$$

Module 2

3a) State the laws of illumination and explain the term (i) Plain angle ii] Solid angle and establish the relationship between them.

Ans:- Laws of illumination

* Illumination is directly proportional to the luminous intensity of the source.

$$E \propto I$$

* Inverse square law

" The illumination of a surface is inversely proportional to the square of the distance of the surface from the source."

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

r = distance between surface to source.

* Lamberts Cosine law

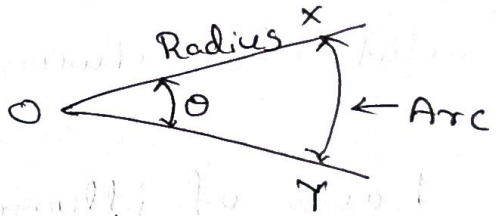
"Illumination is directly proportional to the cosine of the angle made by the normal to the illuminated surface with the direction of incident flux."

$$E = \frac{F \cos\theta}{A}$$

i] Plane angle

* It is subtended at a point & is enclosed by two straight lines lying in the same plane.

$$\theta = \frac{\text{Arc}}{\text{Radius}} \text{ 'radians'}$$

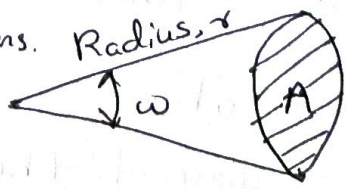


largest angle subtended at a point is 2π radians.

ii] Solid angle

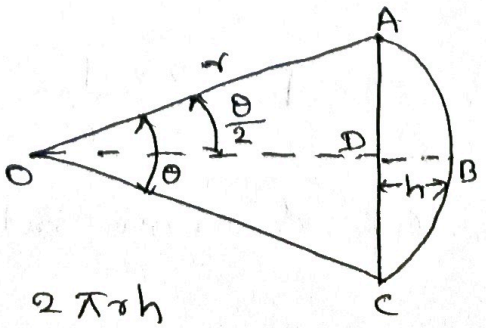
* It is the angle generated by the surface passing through the point in space & the periphery of the area.

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



* Relationship between ω & θ

Consider a curved surface of a spherical segment ABC of height 'h' & radius 'r'.



Surface area of segment ABC = $2\pi rh$

$$h(BD) = OB - OD = r - r\cos\frac{\theta}{2} = r\left(1-\cos\frac{\theta}{2}\right)$$

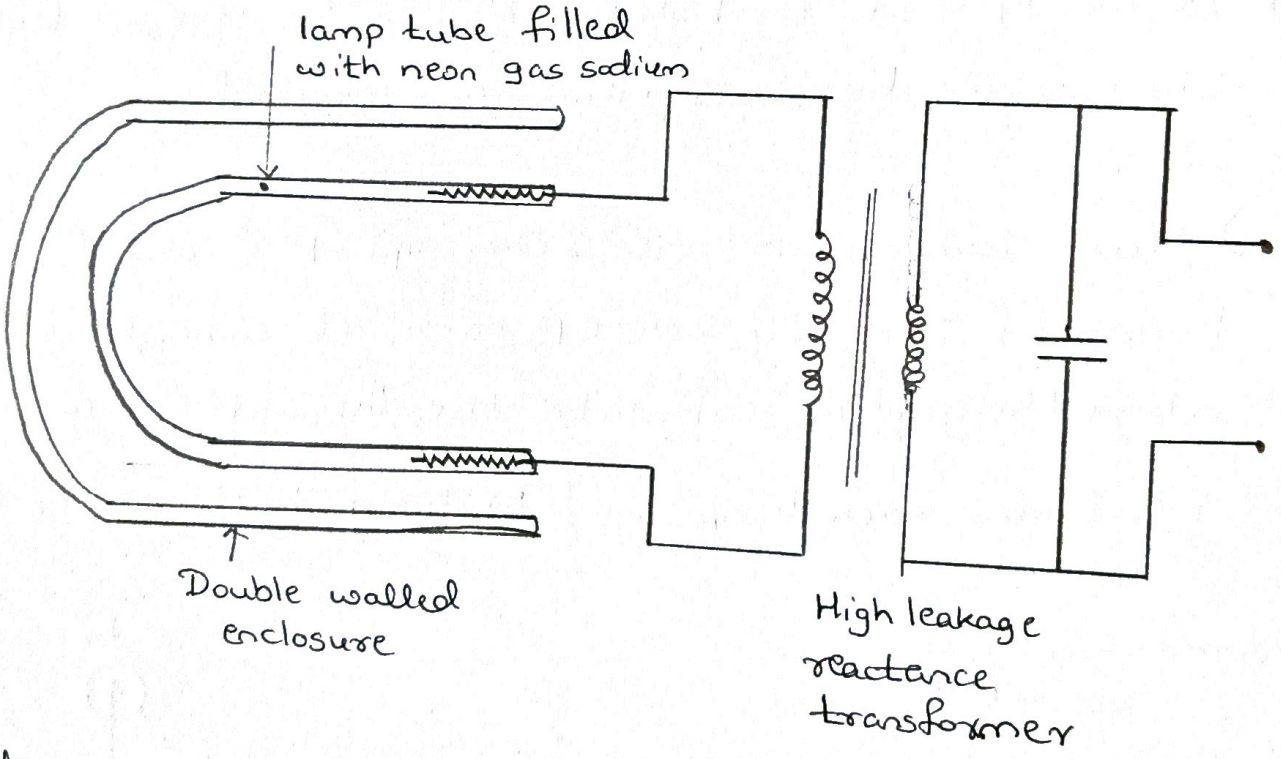
$\therefore$ Surface area of segment $ABC = 2\pi r^2\left(1-\cos\frac{\theta}{2}\right)$

$$\text{Solid angle } \omega = \frac{\text{surface area}}{(\text{Radius})^2} = \frac{2\pi r^2\left(1-\cos\frac{\theta}{2}\right)}{r^2}$$

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

3b) Explain with neat diagram, principle of operation of a sodium vapour lamp. Mention its use. (8M)

Ans:-



* Sodium Vapour lamp is of low luminosity, so the length of the lamp is large. To get the length U-tube is used.

* Two oxide-coated electrodes are sealed with the ends. Tube contain little sodium & neon gas. The U-tube is enclosed in double walled vaccume flask to keep the temperature within working range.

* Capacitor improve the power factor, which is reduced from leakage reactance transformer.

* Initially sodium is in solid powder form, through transform 380V applied which heats the filaments.

* Neon gas discharge intially, it rises the temperature, hence sodium powder get vapourised. To emmit 100% light it will take 10 to 15 min.

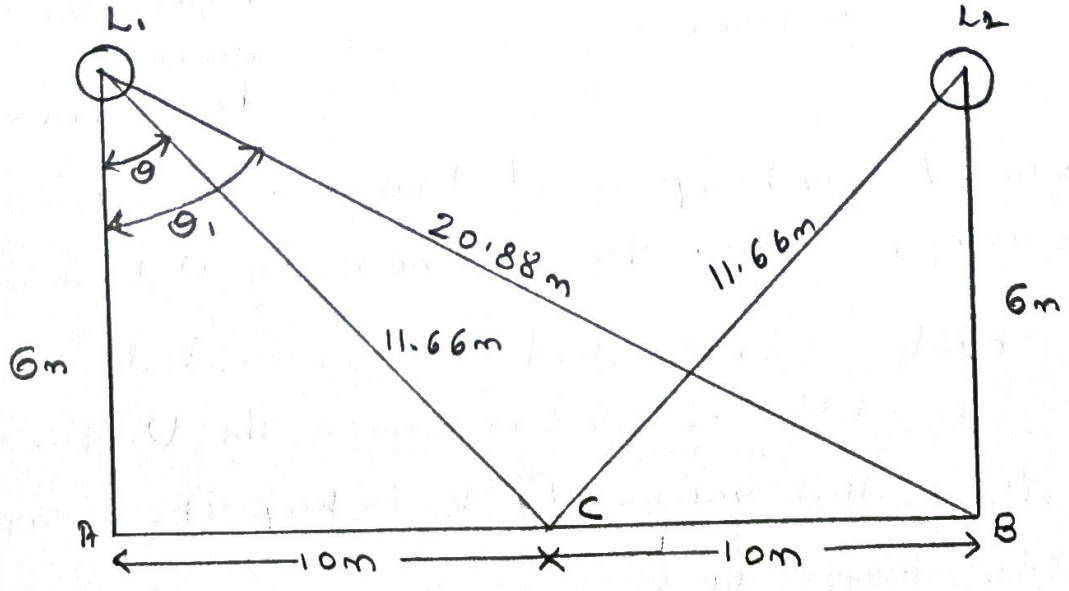
* Efficiency of sodium lamp is about 40-50 lumens/watt. Working hour is about 3000.

* It mainly used for highway & general outdoor lighting where colour discrimination is not required.

3c) Two lamp posts are 20m apart & are fitted with lamps of intensity 200 CP each, at a height of 6m above the ground. Calculate the illumination on the ground.

i] Under each lamp ii] Midway between the lamps. (4M)

- Ans:-



i] Illumination under each lamp

Illumination under either of the lamps, say under lamp (L_2)

E_B = Illumination due to lamp L_1 + Illumination due to lamp L_2

$$= \frac{CP}{h^2}\cos^3\theta + \frac{CP}{h^2}$$

$$= \frac{200}{6^2}\left(\frac{6}{20.88}\right)^3 + \frac{200}{6^2}$$

$$= 5.68 \text{ lux}$$

ii] Illumination midway between the lamps

E_C = Illumination due to L_1 + Illumination due to L_2

$$= \frac{CP}{h^2}\cos^3\theta + \frac{CP}{h^2}\cos^3\theta$$

$$= \frac{200}{6^2}\left(\frac{6}{11.66}\right)^3 + \frac{200}{6^2}\left(\frac{6}{11.66}\right)^3$$

$$= 1.537 \text{ lux}.$$

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4 a) What are the requirements of a good lighting? (4M)

Ans:- * Good lighting is one which provides visual comfort. Visual comfort enhance the efficiency of the workman.

* Good lighting should offer minimum glare & brightness - contrast.

* Light sources ~~be~~should be properly shielded by luminaries and mounted above the normal line of sight.

* Reflected glass is to be avoided, by mounting luminaries with respect to equipment, so that the reflected glare is directed away from the observer.

4b) Write short notes on : (i) Flood lighting (ii) street lighting

Ans:- (i) Flood lighting

* The flooding of large surfaces with light from powerful projectors is called "flood lighting".

* Flood lighting employed for the following purpose.

(i) To enhance the beauty of ancient monuments by night.

(ii) To illuminate advertisement boards & show-cases

(iii) To illuminate railway yards, sports stadiums, car parks, construction sites quarries etc.

* For small building uniform flood lighting is used.

* For large or tall buildings are illuminated non-uniformly.

* Narrow beam, Medium angle & wide angle projectors are employed in flood lighting.

(ii) Street Lighting

* The street light entails the following main objectives.

(i) To make the traffic & obstructions on the road clearly visible in order to provide safety & convenience.

(ii) To enhance the community value of the street

(iii) To make the street more attractive.

* Diffusion & specular reflection principle is used.

* In diffusion principle to avoid glare, the reflectors are made to have cut off between 30° to 45°, filament not visible to rider.

* In specular reflection principle, the reflectors are curved upwards, so that the light is thrown on the road at a very large angle of incidence.

* This method is more economical, in comparison to diffusion method of lighting. But it produces the glare.

* Spacing between the two lamps are normally 50m.

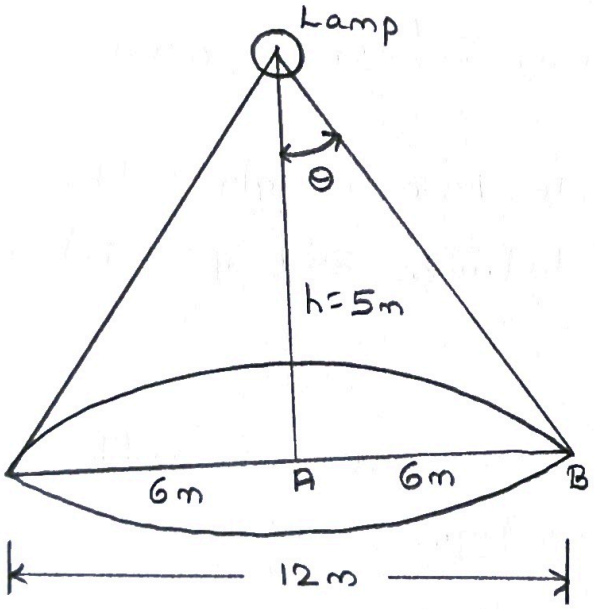
* Sodium vapour, Mercury vapour, LED lamps are used to illuminate the street.

4C) A lamp having a uniform CP of 300 in all directions is provided with a reflector which directs 60% of the total light uniformly on to a circular area of 12m diameter. The lamp is 5m above the area. Calculate

(i) The illumination at the centre & edge of the surface with & without reflector.

(ii) The average illumination over a area without the reflector.

Ans:-



Candle Power of the lamp, CP = 300

Height of the lamp, h = 5m

Diameter of the circular area = 12m

Efficiency of the reflector = 60%.

(i) The illumination at the centre & edge of the surface with & without reflector.

The illumination at the edge of the surface without reflect

$$= \frac{CP}{h^2}\cos^3\theta = \frac{300}{5^2} \times \left(\frac{5}{\sqrt{5^2+6^2}}\right)^3 = 3.15 \text{ lux}$$

With reflector

* With reflector the illumination at the edge & at the centre will be the same since the reflector directs the light uniformly on the surface.

Total lumens given out $F = 4\pi CP = 4\pi \times 300 \simeq 1200\pi$

Total lumens reaching the surface $= 0.6 \times F = 720\pi$

Total surface area $= \pi r^2 = 36\pi \, m^2$

$\therefore$ Average illumination with reflector $= \frac{720\pi}{36\pi}$

$= 20$ lux

ii) The average illumination over the area without the reflector.

Solid angle subtended by the area at the lamp

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

$= 2\pi (1 - \cos\theta)$

$= 2\pi \left(1 - \frac{5}{\sqrt{5^2+6^2}}\right)$

$= 4.021$ steradians

Total flux reaching the surface $= I\omega = 30 \times 4.021$

$= 120.637$ lumens

$\therefore$ Average illumination $= \frac{120.637}{\pi \times 36}$

$= 1.06$ lux

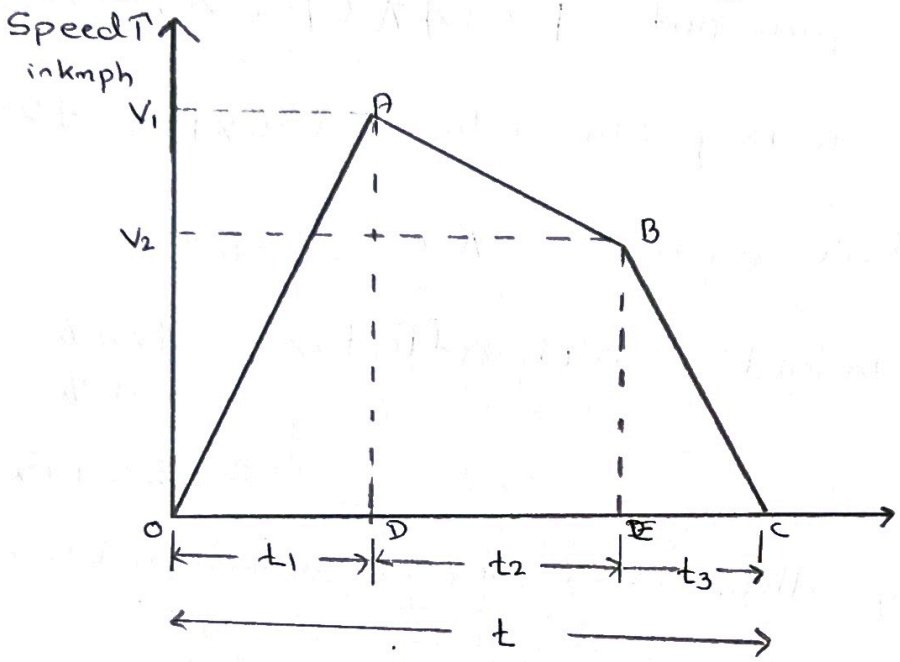
Module 3

5 a) Assuming quadrilateral speed time curve derive equation

i) Total distance travelled between two stops

ii) Velocity at the time of braking.

Ans:-



α = acceleration during starting period in

β_c = Retardation during coasting period

β = Retardation during braking period

V_1 = Maximum speed at the end of acceleration

V_2 = Speed at the end of coasting period

t = Total time of run

Time of acceleration $t_1 = \frac{V_1}{\alpha}$

Time of coasting $t_2 = \frac{V_1 - V_2}{\beta_c}$

Time of braking $t_3 = \frac{V_2}{\beta}$

D = Distance between two station.

Total distance travelled D = Area of OABC

D = Area of OAD + Area of ABED + Area of BEC

$= \frac{1}{2} V_1 t_1 + \left(\frac{V_1+V_2}{2}\right) t_2 + \frac{1}{2} V_2 t_3$

$= \frac{1}{2} V_1 (t_1+t_2) + \frac{1}{2} V_2 (t_2+t_3)$

$= \frac{1}{2} V_1 (t - t_3) + \frac{1}{2} V_2 (t - t_1)$

$= \frac{1}{2} t (V_1+V_2) - \frac{1}{2} V_1 V_2 \left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$

$D = \frac{1}{2} t (V_1+V_2) - V_1 V_2 k$

where $k = \frac{1}{2}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$

ii] Velocity at the time of braking (V_2)

$V_2 = V_1 - \beta_c t_2$

$= V_1 - \beta_c (t - t_1 - t_3)$

$= V_1 - \beta_c \left(t - \frac{V_1}{\alpha} - \frac{V_2}{\beta}\right)$

$= V_1 - \beta_c \left(t - \frac{V_1}{\alpha}\right) + \beta_c \frac{V_2}{\beta}$

$$V_2 = \frac{V_1 - \beta_c \left(t - \frac{V_1}{\alpha}\right)}{\left(1 - \frac{\beta_c}{\beta}\right)}$$

5 b) Define Specific energy consumption & discuss the factors affecting it. (8 M)

Ans:- Specific energy consumption is defined as the energy consumed (Wh) per tonne mass of the train per km length of the run.

$$E_{spc} = \frac{\text{Total energy consumed (Wh)}}{\text{Train mass (tonne)} \times \text{run length (km)}}$$

$$= \frac{\text{Specific energy output}}{\eta}$$

η = Overall efficiency of transmission motor & gear

$$= \eta_{motor} \times \eta_{gear}$$

$$E_{spc} = \left[0.01072 \cdot \frac{V_m^2}{\eta D} \cdot \frac{M_e}{M} + 27.25 \frac{G}{\eta} \frac{D'}{D} + 0.2778 \frac{\gamma}{\eta} \cdot \frac{D'}{D} \right]$$

Wh/t-km

For gradient case

$$E_{spc} = \left[0.01072 \frac{V_m^2}{\eta D} \cdot \frac{M_e}{M} + 0.2778 \frac{\gamma}{\eta} \cdot \frac{D'}{D} \right]$$

For level track

* The following factors influence on Espc

→ Acceleration (α)

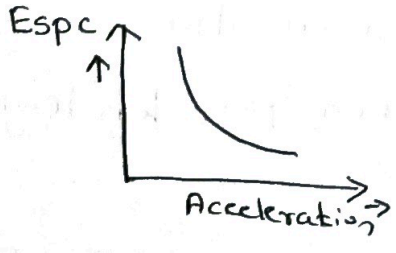
→ Retardation (β, β_c)

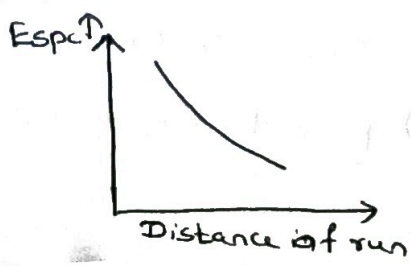
→ Maximum speed (V_m)

→ Track configuration (γ)

→ Distance between stops

→ Type of train & equipment





5C) A scheduled speed of 45 kmph is required between two stops 1.5 km apart. Find the maximum speed over the run of stop is of 20 seconds duration. The values of acceleration and retardations are 2.4 kmphps & 3.2 kmphps respectively. Assume simplified trapezoidal speed time curve. (4M)

Ans:- $D = 1.5\,km = 1500\,m$

$\alpha = 2.4$ kmphps $=$

$= \frac{2.4 \times 1000}{3600} = 0.667\ m/s^2$

$\beta = 3.2$ kmphps

$= \frac{3.2 \times 1000}{3600} = 0.888\ m/s^2$

$V_{sch} = 45\,km$

$V_{sch} = \frac{45 \times 1000}{3600} = 12.5\ m/s$

$t_s = 20$ sec

Schedule time of run (t_{sch})

$t_{sch} = \frac{D}{V_{sch}} = \frac{1500}{12.5} = 120$ sec

Actual time of run (t)

$t = t_{sch} - t_s = 120 - 20 = 100$ sec

$K = \frac{1}{2}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) = \frac{1}{2}\left(\frac{1}{0.667} + \frac{1}{0.888}\right) = 1.313$

Maximum Speed V_m

$V_m = \frac{t - \sqrt{t^2 - 4KD}}{2K}$

$= \frac{100 - \sqrt{100^2 - (4 \times 1.313 \times 1500)}}{2 \times 1.313} = 20.54\ m/s$

$= 74$ kmph

6a) Define Tractive effort, deduce expression for total tractive effort for propulsion of a train.

Ans:- The tractive effort is defined as the effective force necessary to propel the train at the wheels of locomotive

* Tractive effort required for train propulsion is given by

$$F_t = F_a \pm F_g + F_r$$

F_a = Force required for giving linear acceleration to the train

F_g = " " to overcome the gravitational effect

F_r = " " " " resistance to the motion of train

i] Value of F_a

$F_a = M\alpha$ M = Dead mass of train

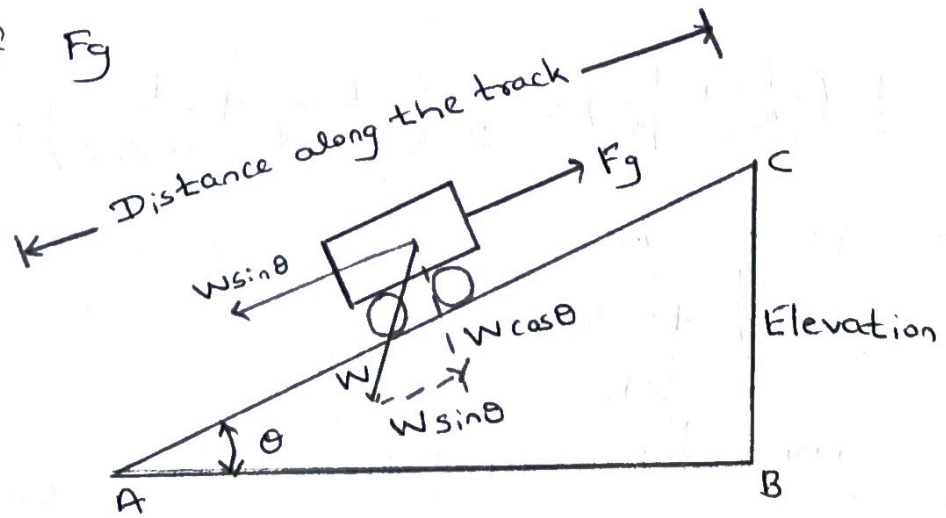
$F_a = M_e\alpha$ M_e = Effective mass of train

* when M_e in kg, α in m/s $F_a = M_e\alpha$

* When M_e in tonne, α in kmphps

$$F_a = 1000 M_e \times \frac{\alpha \times 1000}{3600} = 277.8\, M_e\alpha \text{ newton}$$

ii] Value of F_g



$F_g = W \sin\theta = Mg \sin\theta$

gradient $= \sin\theta = \dfrac{\text{Elevation (BA)}}{\text{Distance along track (AC)}}$

% gradient $G = 100 \sin\theta$

$$F_g = \frac{Mg\,G}{100}$$

* When M is in kg $F_g = 0.098\,MG$

* When M is in tonne $F_g = 0.098\,(1000M)\,G = 98\,MG$ newton

iii] Value of F_r

When M in kg, train resistance r in newton/tonne

$$F_r = Mr$$

When M in tonne, r in N/t

$$F_r = M r \text{ newton}$$

$$F_t = F_a \pm F_g + F_r$$

$$= (277.8\,M\alpha \pm 98MG + Mr) \text{ newton}$$

M in tonne — G is in metres / 100m of track length

α in kmphps — r is in newton/tonne

+ sign for up gradient

− sign for down gradient

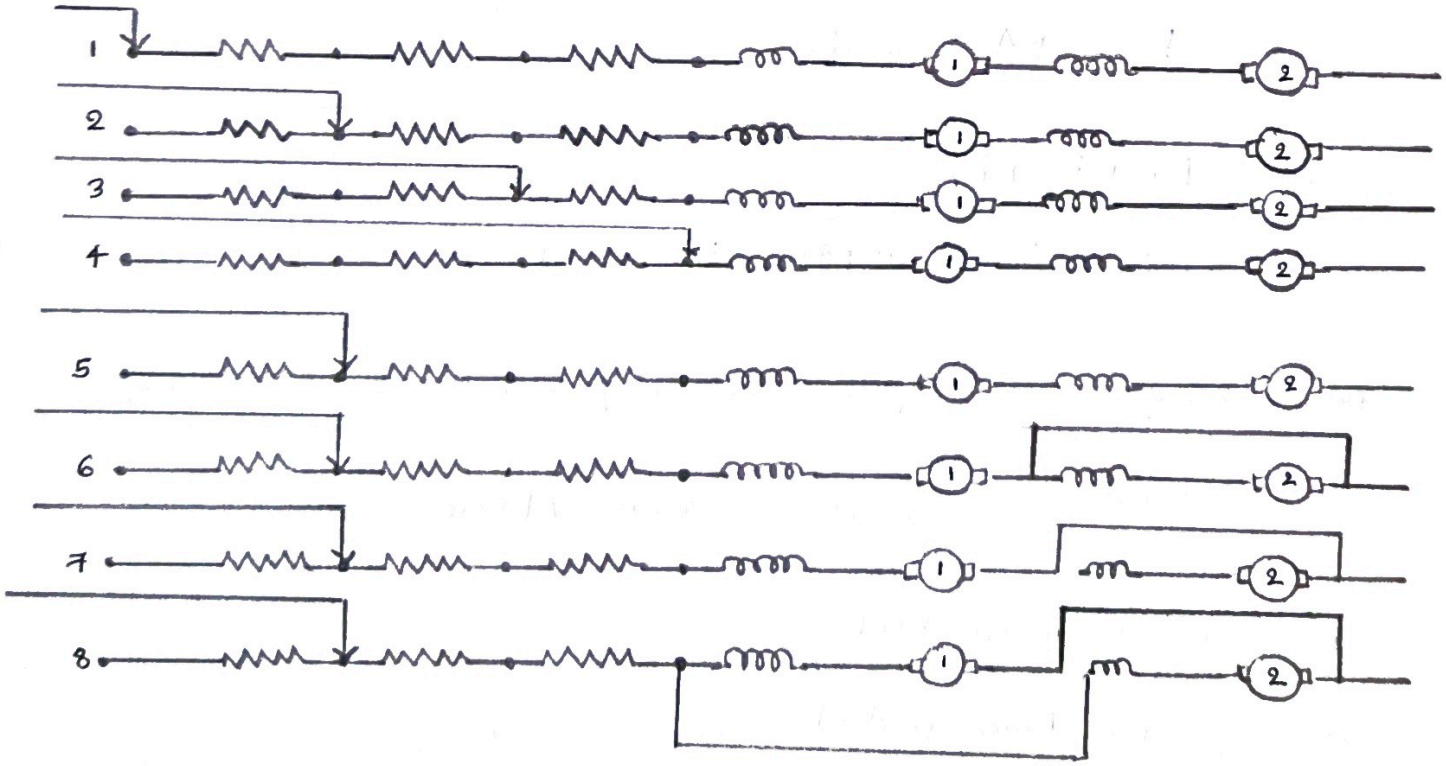
6b) Explain why a series motor is preferred for the electric traction (4M)

Ans:- DC motor is widely used in traction work due to following reason

* It has high starting torque & capability for high torque over loads.
* With an increase in torque, the flux also increases, so that same increases in torque, less increase in motor current.
* The speed- torque characteristic is also suitable for better sharing of loads between the motors.
* The motor commutation is satisfactory.

6c) Explain with the help of suitable circuit diagrams

i] Shunt transistion ii] Bridge transistion



1 to 4 series position

5 to 7 shunt transition

8 First parallel

* Step 1 to 4 explicates the series position. In the 1st step resistance during the starting is more. In the less input is applied to the motor. gradually they develops emf & produce rpm.

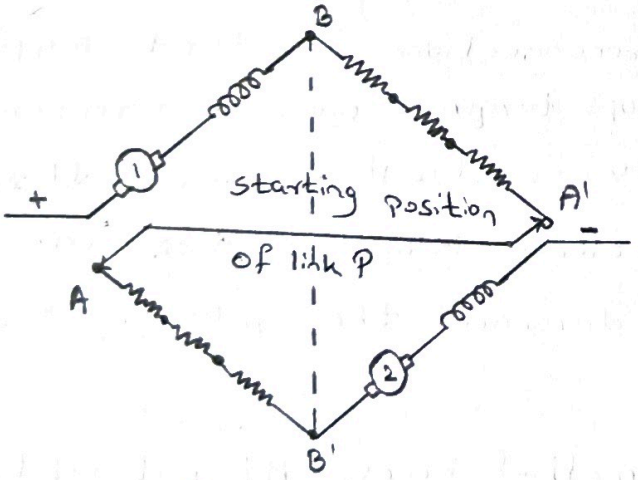
* In step 2 & 3 resistance reduced, more input applied & motor's ~~coz~~ developes more torque.

* In step 4 starting resistance reduced to zero, two motors achieves one speed. It's called full series position.

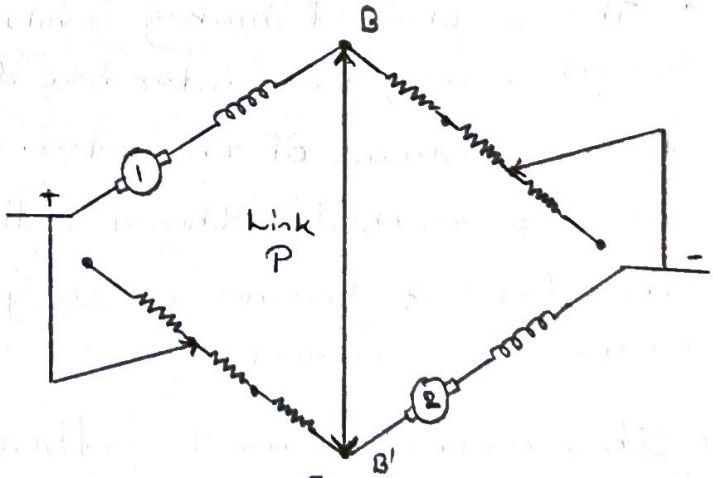
* To achieve high speed two motors connected in parallel, In step 5 starting resistance is reinserted. Later a field of one motor is disconnected, it reduces the torque production, so it causes jerking effect & create inconvineance to passanger.

* In step 8 two motors connected parallel.

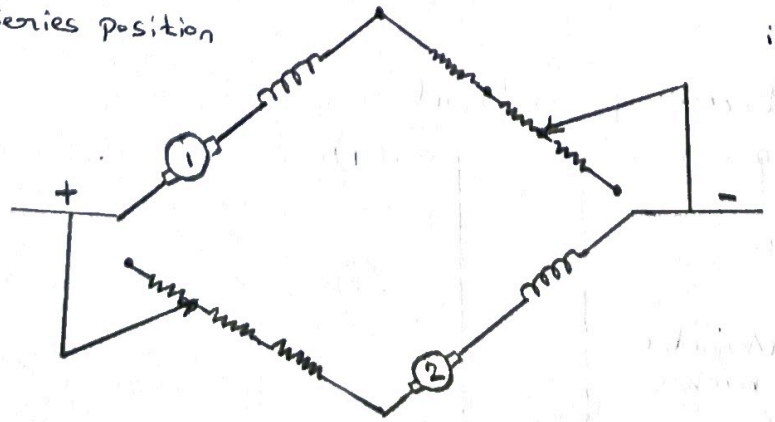
ii] Bridge transition method



i] Series position



ii] Transition step



iii] First parallel position

* In the 1st starting position the motors are in series & the rheostats are completely in circuit as indicated by the rheostats arm P at AA'. A & A' are moved in the direction of the arrow heads & in position BB' the motors are in full series.

* In the transition step, the rheostats are reinserted by connecting to positive & negative of the supply shown in fig (ii).

* In the 1st parallel step, the link P is removed & the motors are connected in parallel with the starting resistance in their circuit fig (iii)

* The merits of this method is that duration, the motors are always connected to the supply & as the resistances are so adjusted that the value of current remains same, the torque does not change & hence uniform acceleration is obtained without causing inconvenience to the passengers.

Module 4

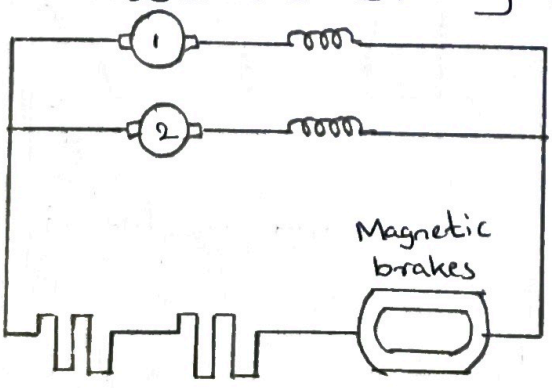
7a) Describe how plugging, rheostatic braking & regenerative braking are employed with DC motors.

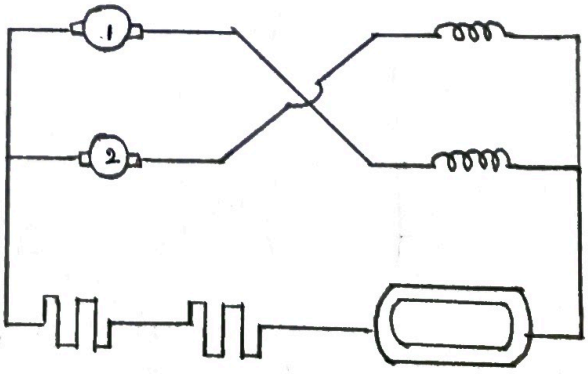
Ans:- Plugging Braking method

* This method of braking involved reconnection of motor to supply in such a way that motor now develops torque in opposite direction to the movement of the rotor. System speed will decrease till zero speed is reached & then it will accelerate in opposite direction. — Therefore, it becomes necessary to disconnect the supply as soon as system comes to rest.

* This method is most inefficient method, because KE not utilized.

Rheostatic Braking method





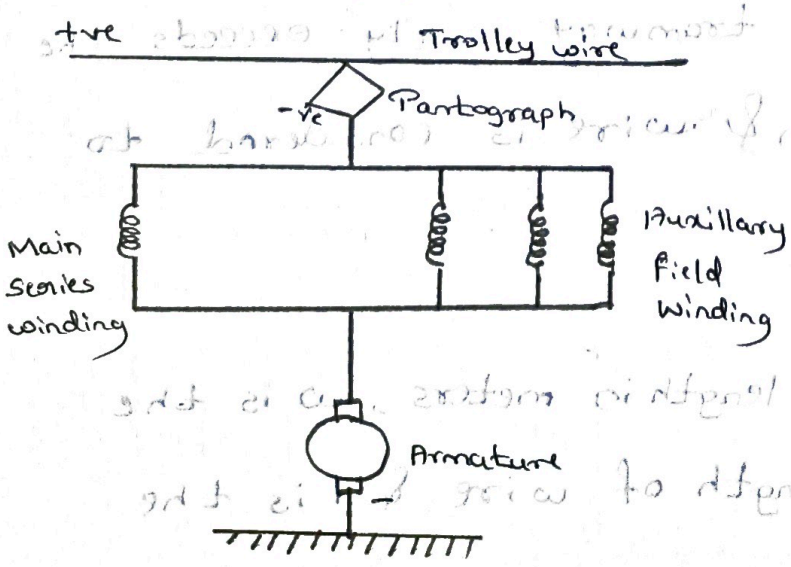
* In traction work when two or three series motors are used. These motors are connected in parallel across a resistance. The K.E of the vechicle is used in driving the motors are generators which dissipate this energy in the form of heat in rheostats to which they are connected.

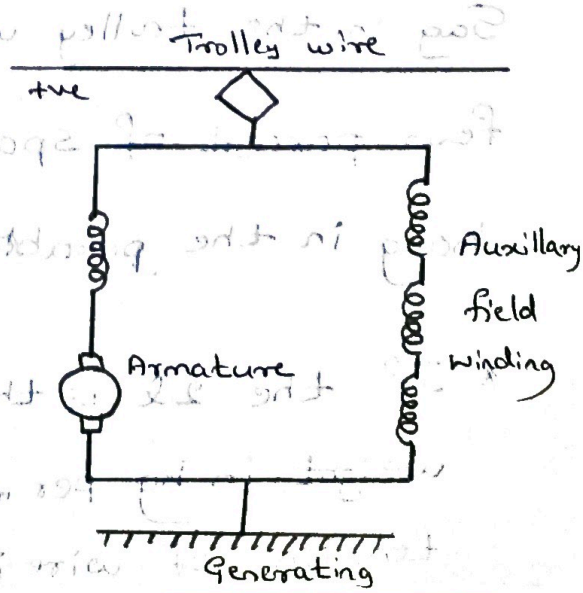
* Two machines are in parallel, amount to two series generator in parallel & in order that they may self-excited, an equiliser connection. If this connection were not used, the machine that would builld first would send a current through the other in the opposite direction with the result that the second machine would excite with reversed voltage. The two machines would be short-circuited on themselves & might even burnt out on account of large currents. The equiliser prevents such a condition

* Cross-connection :- Another method of avoiding the above mentioned situation is cross-connecting fields of the two machines in figure. Suppose the voltage of machine-1 is greater than that of machine-2. It will send a greater current through field of the machine 2 causing it to excite to a higher voltage & its own excitation will be kept down because of the lesser induced emf of machine-2.

Regenerative Braking method

* French Method



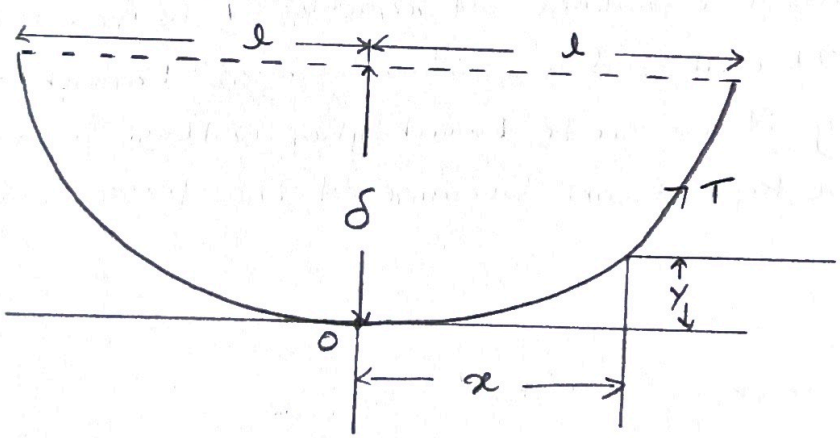


* During regenerative braking the auxiliary field windings are placed in series with each other & switched over in parallel across the armature & the main series field. The machine acts as a compound generator with slight differential compounding. When there is a change in the line voltage, the shunt excitation being sensitive to such changes, immediately causes the emf of the generator to increase or decrease thus providing the necessary balance.

* In case of locomotive where four or six series motors are used, there need not be any auxiliary windings. During normal working all the motors are in series with their respective field windings but during regeneration, the motor armature are in parallel with field windings of all other motors except one. This arrangement is now similar to the previous one.

7b) Show how sag and tension are calculated in trolley wire.

Ans:-



Sag in the trolley wire of tramway rarely exceeds the few percent of span length & wire is considered to hang in the parabola.

* If the 2l is the span length in meters, w is the weight in kg per meter length of wire & T is the tension of wire in kg.

Then by taking moments about one of the supports, we ge

$$T\delta = w l \times \frac{l}{2}$$

$$\delta = \frac{wl^2}{2T}$$

The equation of parabola is given by the expression.

$$y = \frac{\delta x^2}{l^2} = \frac{w}{2T} x^2$$

$$\frac{d\delta}{dx} = \sqrt{1 + \left(\frac{dy}{dx}\right)^2}$$

or

$$\frac{d\delta}{dx} = \sqrt{1 + \left(\frac{wx}{T}\right)^2}$$

$$\int d\delta = \int \left(1 + \frac{w^2 x^2}{T^2}\right)^{1/2} dx$$

$$\delta = \int \left(1 + \frac{w^2 x^2}{T^2}\right)^{1/2} dx$$

$$= x + \frac{w^2 x^2}{6T^2}$$

when $x = l$, i.e half of the span, the length of conductor in half of span

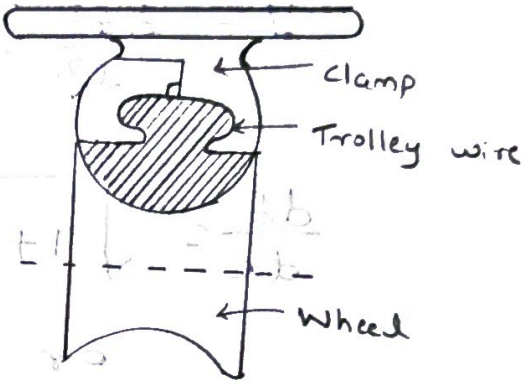
$$\delta = \frac{wl^2}{2T}$$

8a) Sketch the various arrangement of current collection used in electric traction. (6M)

Ans:- There are 3 types of current collecting devices are employed, they are

a) Trolley collector

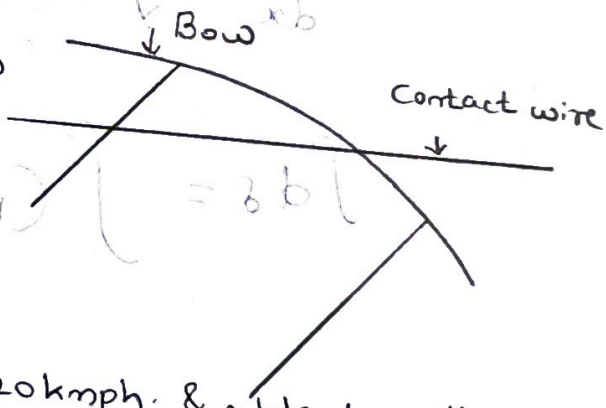
* Its used in tramways & trolley buses & mounted on the roof of the vehicle.



* Trolley collector employed upto speed of 32kmph.

b) Bow collector

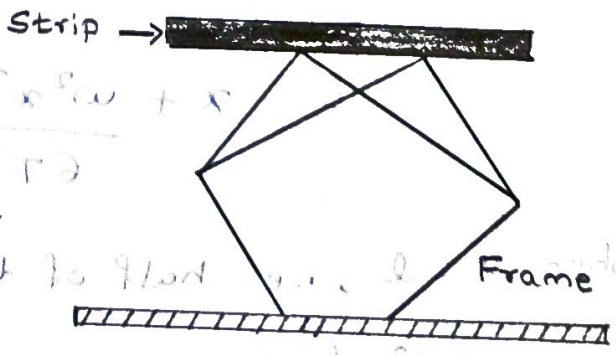
* It consists of a light metal strip or bow & the framework is mounted on the roof of car.
* Bow is made up of copper material.



* It is suitable for speed up to 120kmph. & able to collect 3kA.

c) Pantograph Collector

* It is mounted on a pentgonal framework which can be raised or lowered by compressed air or spring.



* It is used where the vehicles run at high speeds & able to collect 2k to 3kA.

8b] Explain the function of negative booster in a tramway system? (6M)

Ans:- Negative boosters are employed to conform to the regulation that the potential difference between any two points of the rail return shall not exceed 7V.

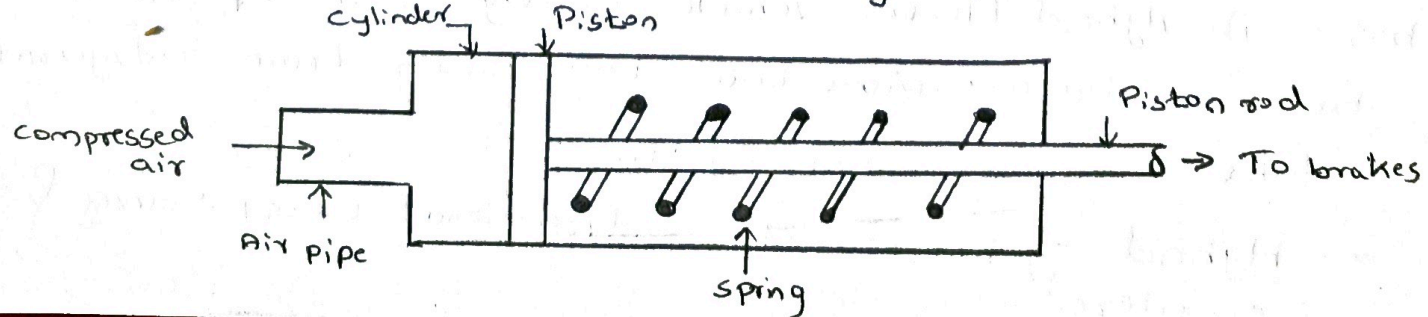
* Two boosters, positive & negative, are used which are mechanically coupled together & driven by a DC motor. The positive booster is connected to the trolley wire & negative booster is connected to the track rail. The 'positive booster' adds voltage to the line while the 'negative booster' lowers the potential of the point it is connected to.

* As we go along trolley wire away from the generating station / sub-station, the potential drop increases & the voltage of the the trolley wire falls. Since the current return via the track rail, points away from the generating station acquire high potentials.

* When the load is sufficiently far away from the generating station, the trolley wire is fed by the positive booster. The current in the positive booster provides the excitation for the negative booster. The feeder current as it flows through the booster maintains the voltage of the trolley within limits.

8c) Discuss some of the mechanical braking arrangements used in electric traction. (8M)
(M01)

Ans:- The compressed air brakes system



* It consists of a reservoir of compressed air, a brake cylinder, compressed air pipe, a valve, spring, piston & piston rod. The piston is connected to brake shoes through piston rod & levers. The brakes are kept in off position by means of spring provided for that.

* While applying brakes, compressed air allow to enter in to brake cylinder through the air pipe & valve, which presses the piston against the force of springs.

* The brakes are released by exhausting the air. The ~~combined~~ compressed air pressure is about 5.5 bar.

The vacuum brake system

* In this brake system force is applied by piston when vacuum underside piston is destroyed.

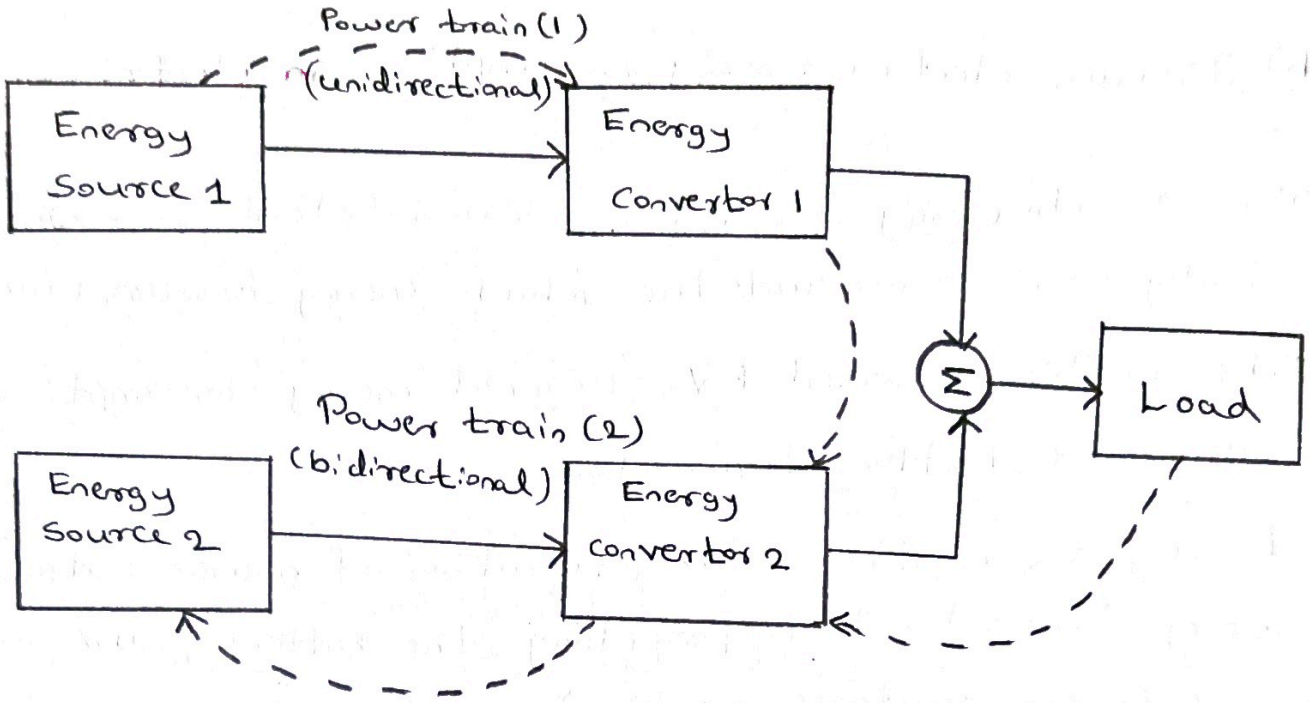
* When brakes are applied, vacuum broken from underside by admitting air at atmospheric pressure. piston moves up & applies the brake. The brakes may be released by either recreating the vacuum or by making the pressure equal on both side of the position.

Module 5

9 a) With relevant block diagram, discuss the working principle of Hybrid Electric Vehicle. (10M)

Ans:- An Hybrid Electric vehicle usually consists of no more than two power trains. More than two power train configuration will be complicate the system.

* Hybrid system consists bidirectional energy source & converters.



——————→ Power flow while propelling

– – – – – – → Power flow while charging from source (2)

There are many available patterns of combining the power flow to meet load requirements as follows:

1] Power train 1 (PT_1) delivers power to the load.

2] Power train 2 (PT_2) delivers power to the load.

3] Both PT_1 & PT_2 delivers power to load at same time

4] PT_2 obtains power from load (regenerative braking)

5] PT_2 obtain power from PT_1

6] PT_2 obtain power from PT_1 & load at same time.

7] PT_1 delivers load & to ~~flow~~ PT_2 at same time.

8] PT_1 delivers power to PT_2, & PT_2 delivers power to load.

9] PT_1 delivers ~~load to~~ power to load; ~~PT_2 de~~ load delievers power to PT_2.

9 b) Discuss electric energy consumption in electric vehicle. (10M)

Ans:- * The energy consumption per unit distance in kWh/km is generally used to evaluate the vehicle energy consumption.

* The battery powered EV's original energy consumption in kWh, measured at battery terminals.

* Energy consumption in an integration of power output at the battery terminals. For propelling, the battery power output is equal to the resistance power & any power losses in transmission & motor drive including losses in electronic devices. To find power loss efficiency of motor (η_m) & transmission (η_t) is considered.

* The battery power output is given by

$$P_{b\text{-}out} = \frac{V}{\eta_t V_m}\left(M_v g(f_r + i) + \frac{1}{2}\rho_a C_D A_f V^2 + M\delta\frac{dV}{dt}\right)$$

Here non traction load not included.

* When regenerative braking is effective on an EV, a part of that braking energy - wasted in conventional ~~braking~~ vehicles - can be recovered by operating the motor drive as a generator & restoring in to the batteries.

* The regenerative braking power at battery terminals given by

$$P_{b\text{-}in} = \frac{\alpha V}{\eta_t \eta_m}\left(M_v g(f_r + i) + \frac{1}{2}\rho_a C_D A_f V^2 + M\delta\frac{dV}{dt}\right)$$

* road grade(i) & acceleration $\frac{dV}{dt}$ both of them are in negative, α ($0 < \alpha < 1$) is the % of total braking energy

that can be applied by the electric motor.

* The net energy consumption from the battery is given by

$$E_{out} = \int_{traction} P_{b\text{-}out}\, dt + \int_{braking} P_{b\text{-}in}\, dt$$

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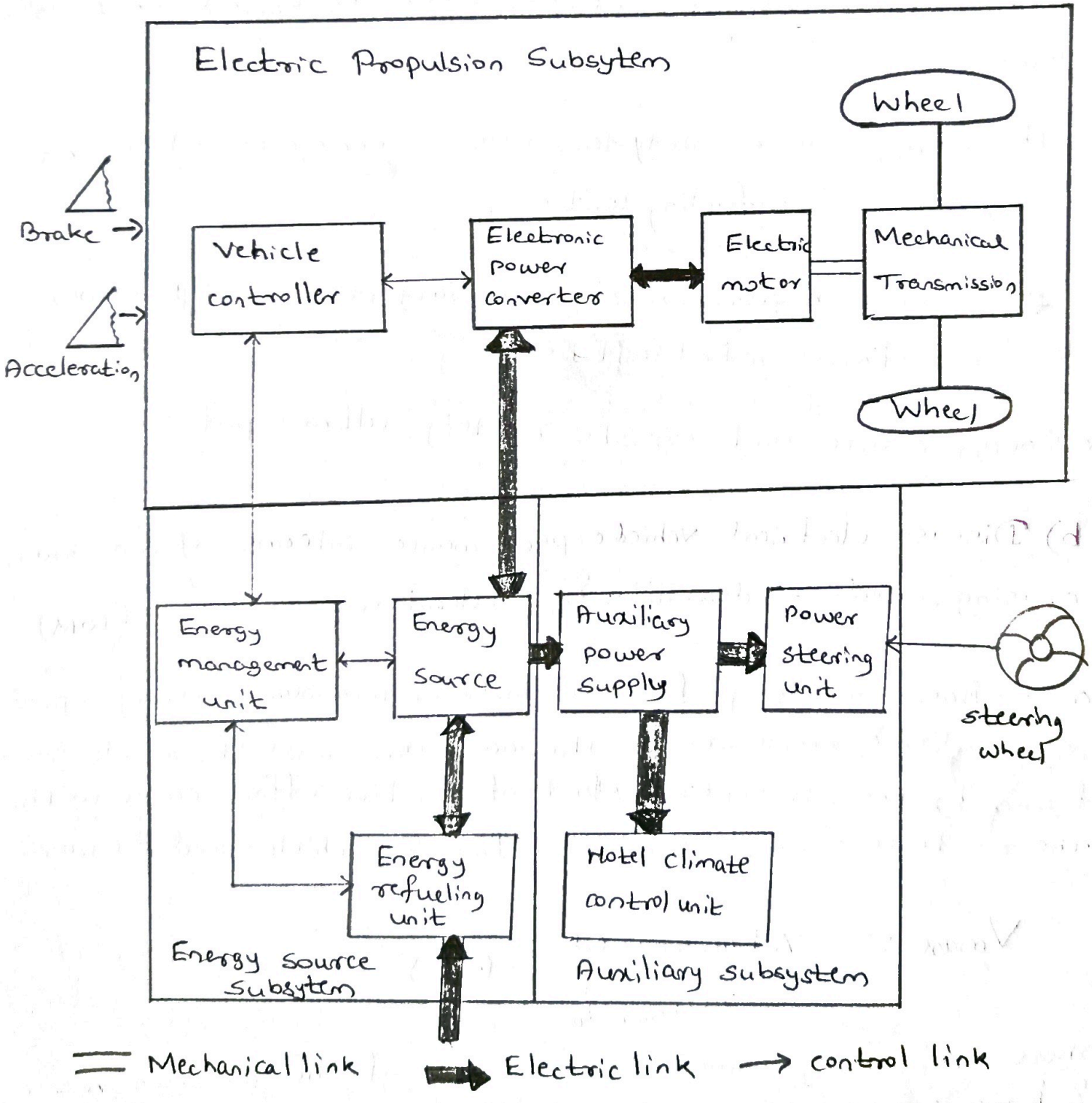
10 a) With neat diagram explain the configuration of EV's. (10M)

Ans:-



* The drive train consists of 3 major subsystemes

1] The electric propulsion subsystem

2] Energy source subsystem

3] Auxiliary subsystem

* Basical on the brakes & acceleration system all subsystem works.

* The electric propulsion subsystem consists, vehicle controller, electronic power converter, electric motor, Mechanical transmission system.

* The energy source subsystem consists charge controlling unit, energy source & refueling unit.

* Auxiliary subsyten consists auxiliary power supply, power steering & climate control unit, steering.

* Energy source unit consists battery, ultra capictor.

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10 b) Discuss electrical vehicle performance interms of maximum crusing speed, gradeability & acceleration. (10M)

Ans:- Basic vehicle performance includes maximum crusing speed, gradeability & acceleration. The maximum speed of vehicle can be found by the intersection point of tractive effort curve with the resistance curve, in tractive effort v/s vehicle speed diagram.

$$V_{max} = \frac{\pi N_{m\,max}\, r_d}{30\, i_{g\,min}\, i_o} \text{ (m/s)}$$

where N_{mmax} is allowed maximum rpm of the traction motor & i_{gmin} is minimum gear ratio of the transmission.

* Gradeability is determined by net tractive effort of the vehicle.

$$F_{t\text{-}net} = F_t - F_r - F_a$$

* Mid & high speed gradeability is smaller than gradeability at low speed.

* The maximum gradeability ~~at low speed~~ that the vehicle can overcome at the given speed is calculated by

$$i = \frac{F_{t\text{-}net}}{M_v g} = \frac{F_t - (F_r + F_w)}{M_v g}$$

$F_t \rightarrow$ Tractive effort on driven wheel

$F_r \rightarrow$ Tire rolling resistance

$F_w \rightarrow$ Aerodynamic drag

$$\sin\alpha = \frac{d - f_r\sqrt{1 - d^2 + f_r^2}}{1 + f_r^2}$$

$d = (F_t - F_w)/M_v g$, which is called vehicle performance factor

* Acceleration performance of vehicle is evaluated by the time used to accelerate the vehicle from low speed V_1 ($V_1 = 0$) to higher speed.

* The acceleration time for an EV is given by

$$t_a = \int_{V_b}^{V_f} \frac{M_v \delta}{P_t/V_b - M_v g f_r - (1/2)\rho_a C_D A_f V^2} dV + \int_{V_b}^{V_f} \frac{M_v \delta}{P_t/V - M_v g f_r - (1/2)\rho_a C_D A_f V^2} dV$$

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