QP Code 691
Electrical Circuit Theory.

APRIL 2024

PART-A

1) Ohm's Law :

It is defined as " At a constant Temperature the current flow through a conductor is directly proportional to the voltage between the two ends of the conductor.

$$V = IR.$$

2) Given,

$C = 100\mu F$

$V = 500\,V$

To Find :

$E = ?$

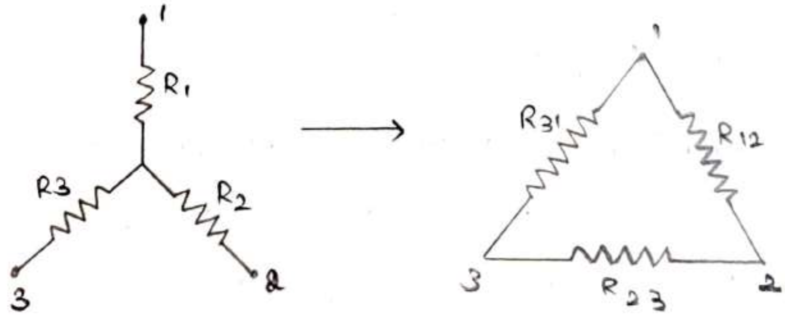
soln:

$$E = \frac{1}{2} V^2 \times C$$

$$E = \frac{1}{2} (500)^2 \times (100 \times 10^{-6})$$

$$E = 12.5\,J.$$

3) Star / Delta Transformation :

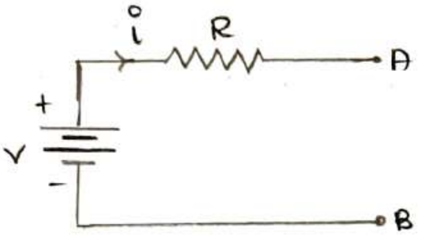


$$R_{12} = \frac{R_1R_2 + R_2R_3 + R_2R_1}{R_3}$$

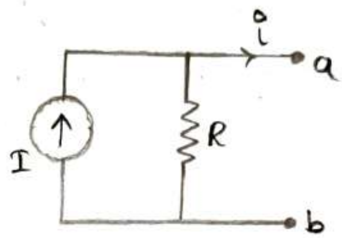
$$R_{23} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

$$R_{31} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

4) Current equivalent of voltage source :



voltage source



current source

5) Average value (or) Mean value :

The average value of all instantanoeus values for a period of time.

$$I_{av} = \frac{i_1 + i_2 + i_3 + \dots + i_n}{n}$$

$$V_{av} = \frac{V_1 + V_2 + V_3 + \dots + V_n}{n}$$

I_{av} (or) V_{av} for full cycle $= 0$.

RMS value (or) Effective value :

When an alternating current flow through a resistance for a certain time, certain amount of heat is produced.

A steady DC current flows through the same resistance for the same time same amount of heat is produced.

A steady DC current which has caused the same amount of heat is that of alternating current is called as RMS value.

$$I = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 + \dots + i_n^2}{n}}$$

$$V = \sqrt{\frac{v_1^2 + v_2^2 + v_3^2 + \dots + v_n^2}{n}}$$

b) i) Form factor:

The ratio of rms value to the average value of an alternating quantity is called form factor.

$$\text{Form factor} = \frac{\text{R.M.S value}}{\text{Average value}}$$

$$= 1.11$$

ii) Peak Factor:

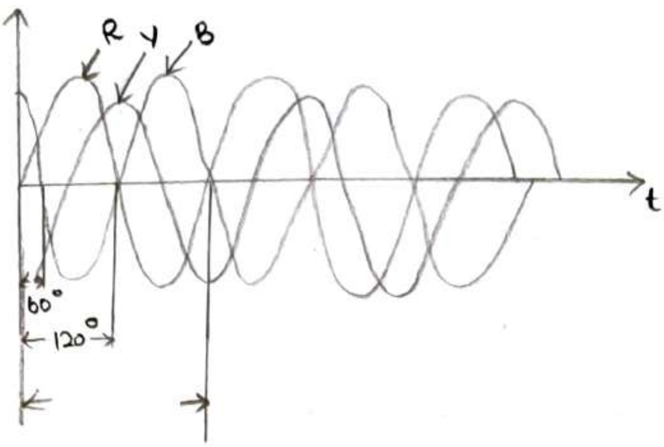
The ratio of maximum value to the rms value to alternating quantity is called peak factor.

$$\text{Peak Factor} = \frac{\text{maximum value}}{\text{RMS value}}$$

$$= 1.414$$

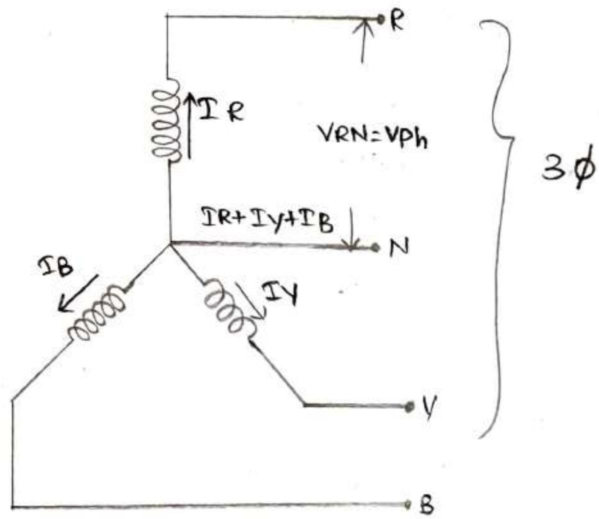
7) Phase sequence:

The order in which the voltages in three phases reach their maximum value is called phase sequence. This is determined by a direction of rotation of alternator.



Positive sequence = RYB

8)



$V_{RN} = V_{YN} = V_{BN} = V_{Ph}$

$V_{RY} = V_{YB} = V_{BR} = V_L$

In star connection,

$I_L = I_{ph}$

$I_R = I_{RY} = I_B = I_{ph}$

$V_L \neq V_{ph}$

$I_L = I_{ph}$

$$V_{RY}^2 = V_{RN}^2 + V_{YN}^2 + 2V_{RN} \cdot V_{YN} \cos 60^\circ$$

$$= V_{ph}^2 + V_{ph}^2 + \cancel{2} V_{ph} \cdot V_{ph} \cdot \frac{1}{\cancel{2}}$$

$$= V_{ph}^2 + V_{ph}^2 + V_{ph}^2$$

$$V_L^2 = 3V_{ph}^2$$

$$V_L = \sqrt{3V_{ph}^2}$$

$$V_L = \sqrt{3}\, V_{ph}.$$

9) Active materials used in Nickel cadmium cell.

* Nickel hydroxide $Ni(OH)_4$ for the +ve plate exactly as in the nickel iron cell.

* cadmium - (cd) for -ve plate. The cadmium reduced in the internal resistance of the cell.

* The electrolyte is potassium hydroxide (KOH), same as in the nickel-iron cell.

10) Ampere - hour efficiency:

It is the ratio of ampere-hour output to the Ampere-hour input.

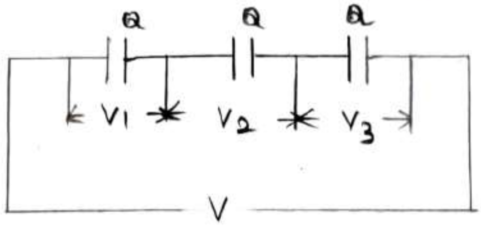
$$\text{Ah efficiency} = \frac{\text{Ampere - hour output}}{\text{Ampere - hour input}} \times 100$$

$$= \frac{\text{Ampere hours on discharge}}{\text{Ampere hours on charge}} \times 100.$$

PART-B

11. a) i) Equivalent capacitance of 3 capacitors in series :

(MARKS : 4)



In series combination, charge on all capacitors is the same but P.d across each is different.

$$\therefore V = V_1 + V_2 + V_3$$

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

(or)

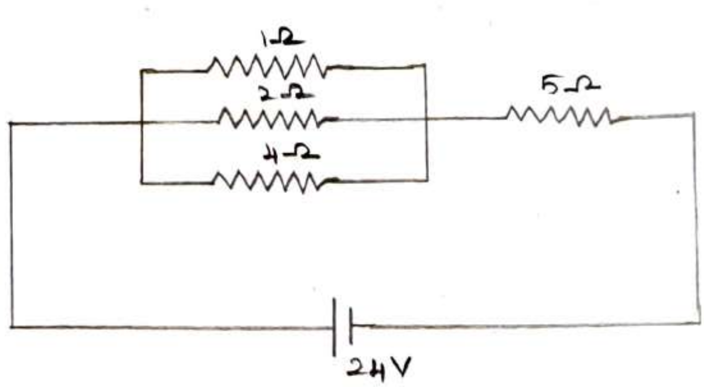
$$C = \frac{C_1 C_2 C_3}{C_1C_2 + C_2C_3 + C_3C_1}$$

Since,

$$Q = CV \Rightarrow V_1 = \frac{Q}{C_1}, V_2 = \frac{Q}{C_2}, V_3 = \frac{Q}{C_3}$$

where, C is total capacitance of the series combination.

ii)



(CIRCUIT & CONSTRUCTION VALUE : (2))

Given,

$V = 24V$

Soln:

$$R_p = \frac{R_1R_2R_3}{R_1R_2+R_2R_3+R_3R_1} = \frac{1\times2\times4}{2+8+4} = \frac{8}{14} = 0.571\Omega$$

$R_{eq} = R_p + 5$

$= 5 + 0.571$

$R_{eq} = 5.571$ (MARK:2)

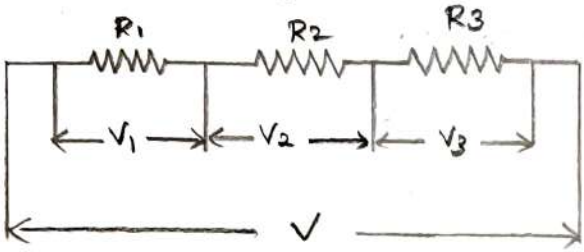
$$I = \frac{V}{R_{eq}} = \frac{24}{5.57} = 4.30A$$ (MARK:1)

$P = VI$

$= 24 \times 4.30$

$P = 103.2$ Watts (MARK:(3)

11. B)i) Equivalent Resistance of 3 Resistors in Series:



(MARK:4)

$V = V_1 + V_2 + V_3$

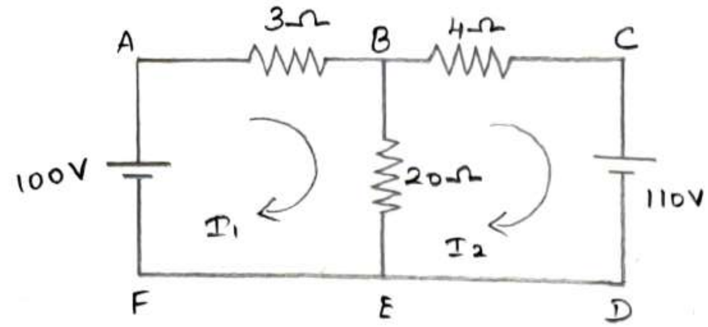
$V_1 = IR_1 + IR_2 + IR_3$

$= I(R_1 + R_2 + R_3)$

$= R_1 + R_2 + R_3 \Rightarrow R = R_1 + R_2 + R_3$

R is the total equivalent Resistance of the series circuit.

ii)



Branch current,

$AB = I_1$

$BC = I_2$

$BE = I_3$

soln:

Loop ABEFA,

$-3I_1 - 20(I_1 + I_2) + 100 = 0$

$-3I_1 - 20I_1 - 20I_2 + 100 = 0$

$(23I_1 + 20I_2) = 100$

$23I_1 + 20I_2 = 100 \rightarrow (1)$

(EACH EQUATION MARK :(1))

Loop BCDEB,

$4I_2 - 110 + 20(I_1 + I_2) = 0$

$4I_2 + 20I_1 + 20I_2 = 110$

$20I_1 + 24I_2 = 110 \rightarrow (2)$

$23I_1 + 20I_2 = 100 \rightarrow (1)$

$20I_1 + 24I_2 = 110 \rightarrow (2)$

eqn (1) x20

$460I_1 + 400I_2 = 2000$

eqn (2) x -23

$-460I_1 - 552I_2 = -2530$

STEPS AND ANSWER MARK :(5)

solve : $460I_1 + 400I_2 = 2000$

$-460I_1 - 552I_2 = -2530$

$-152I_2 = -530$

$$I_2 = \frac{-530}{-152}$$

$$\boxed{I_2 = 3.48\ A.}$$

sub I_2 in eqn (1)

$23 I_1 + 20(3.48) = 100$

$23 I_1 + 69.6 = 100$

$23 I_1 = 30.4$

$$I_1 = \frac{30.4}{23}$$

$$\boxed{I_1 = 1.32 A}$$

EACH BRANCH CURRENT : (3)

$I_1 = \frac{\Delta I_1}{\Delta} = \frac{200}{152} = 1.315 A$

$I_2 = \frac{\Delta I_2}{\Delta} = \frac{530}{152} = 3.486 A$

$I_2 = 3.486,\ I_1 = 1.32 A.$

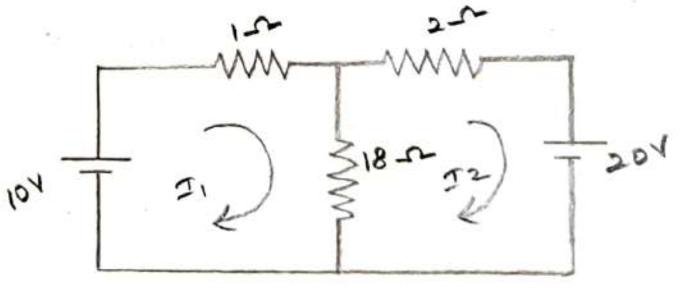
$I_3 = I_1 - I_2$

$= [1.315] - [3.486]$

Branch $_{BE}$ $(I_3) = -2.171 A.$

Branch $_{AB}$ $(I_1) = 1.315 A$, Branch $_{BC}$ $(I_2) = 3.486$,

(A)
12) i)



soln:

Δ MARK : (2)

$$\Delta = \begin{bmatrix} 19 & -18 \\ -18 & 20 \end{bmatrix} = (380) - (324)$$

$\Delta = 56$

$\Delta I_1 = \begin{bmatrix} 10 & -18 \\ -20 & 20 \end{bmatrix} = 200 - 360$ ΔI_1 MARK (2)

$\boxed{\Delta I_1 = -160}$

$\Delta I_2 = \begin{bmatrix} 19 & 10 \\ -18 & 20 \end{bmatrix} = (-380) - (-180)$

$= -380 + 180$

$\boxed{\Delta I_2 = -200}$ ΔI_2 MARK : (2)

$I_1 = \frac{\Delta I_1}{\Delta} = \frac{-160}{56} = -285 A$

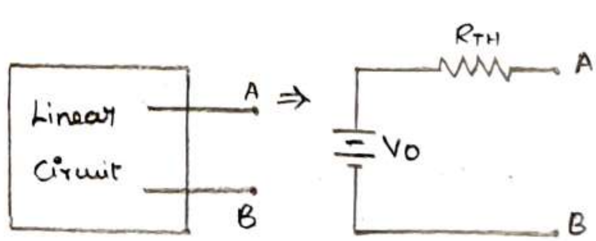
$I_2 = \frac{\Delta I_2}{\Delta} = -\frac{200}{56} = -3.571$ ANSWER : (4)

∴ Current flow through 1Ω Resistor $= I_1 - I_2$
$= 2.85 - (-3.571)$
$= -2.85 + 3.521$

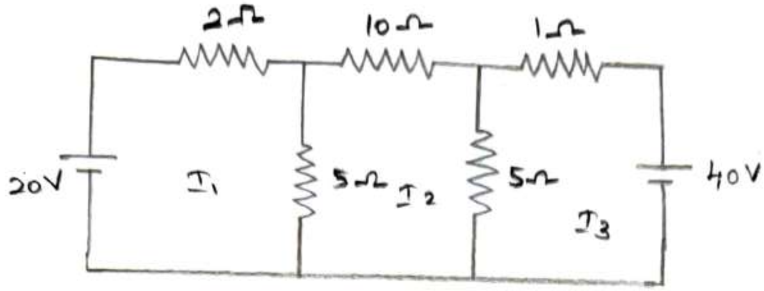
∴ I Through 18Ω resistor = 0.721 A

(ii) Thevenin's Theorem: MARK : (4)

A linear two terminal network can be replaced by a voltage source Vo in series with the resistance RTH.

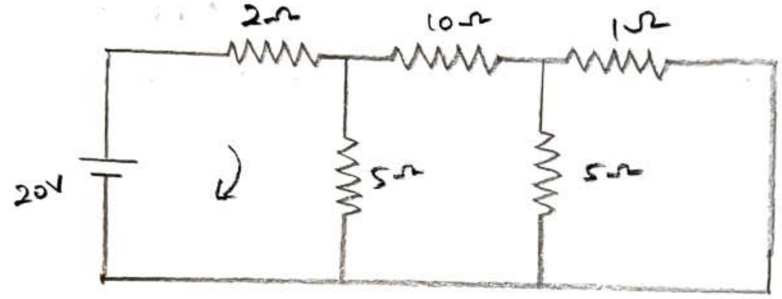


12)B) Superposition theorem : MARK :(6)



case - I

20V source is active, 40V source is short circuited.



$$R = \begin{bmatrix} 7 & -5 & 0 \\ -5 & 20 & -5 \\ 0 & -5 & 6 \end{bmatrix} \quad V = \begin{bmatrix} 20 \\ 0 \\ 0 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} 7 & -5 & 0 \\ -5 & 20 & -5 \\ 0 & -5 & 6 \end{bmatrix} = \begin{bmatrix} 7 & -5 & 0 & 7 & -5 \\ -5 & 20 & -5 & -5 & 20 \\ 0 & -5 & 6 & 0 & -5 \end{bmatrix}$$

$$= 840 - (175 + 150)$$

$$\Delta = 515$$

$$\Delta I_2 = \begin{bmatrix} 7 & 20 & 0 \\ -5 & 0 & -5 \\ 0 & 0 & 6 \end{bmatrix}$$

$$= \begin{vmatrix} 7 & 20 & 0 & 7 & 20 \\ -5 & 0 & -5 & -5 & 0 \\ 0 & 0 & 6 & 0 & 0 \end{vmatrix}$$

$= -(-600)$

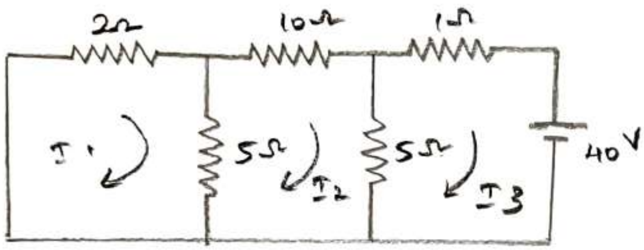
$\Delta I_2 = 600$

$I_2 = \frac{\Delta I_2}{\Delta} = 1.17A$

Case -II

MARK : (6)

40V source is Active, 20V source is short circuited.



$R = \Delta = \begin{bmatrix} 7 & -5 & 0 \\ -5 & 20 & -5 \\ 0 & 5 & 6 \end{bmatrix}$ $V = \begin{bmatrix} 0 \\ 0 \\ -40 \end{bmatrix}$

$R = 515$

$\Delta I_2' = \begin{bmatrix} 7 & 0 & 0 \\ -5 & 0 & -5 \\ 0 & -40 & 6 \end{bmatrix} = \begin{bmatrix} 7 & 0 & 0 & 7 & 0 \\ -5 & 0 & -5 & -5 & 0 \\ 0 & -40 & 6 & 0 & -40 \end{bmatrix}$

$\Delta I_2' = 1400$

$I'_2 = \frac{\Delta I_2'}{\Delta} = \frac{-1400}{515} = -2.72A.$

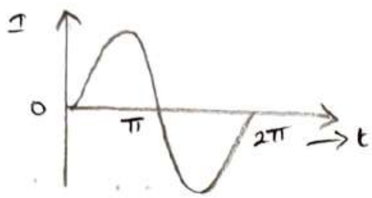
∴ current flow through 10Ω resistor = $I_2 + I_2'$

$$I_2 + I_2' = 1.17 + (-2.71)$$

$$= -1.55A$$

13.A) i)

(MARK : 6)



$i = I_m \sin\theta$

where, I_m is the maximum value

$$\text{Average value} = \frac{\text{Area under the curve}}{\text{Base length}}$$

$$I_{av} = \int_0^{\pi} \frac{I_m \sin\theta \, d\theta}{\pi}$$

$$= \frac{I_m}{\pi} \left| -\cos\theta \right|_0^{\pi}$$

$$= \frac{I_m}{\pi} \left[-(\cos\pi - \cos 0) \right]$$

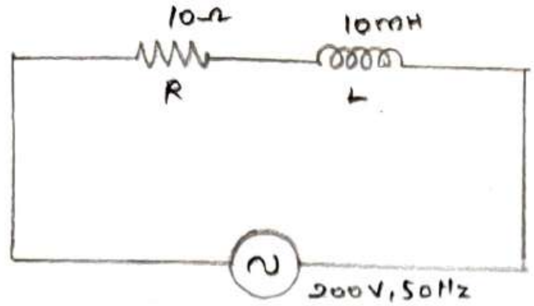
$$= \frac{I_m}{\pi} \left[-(-1-1) \right]$$

$$= \frac{2I_m}{\pi} \text{ (or)}$$

$$I_{av} = 0.637 I_m$$

Similarly, $V_{av} = 0.637 V_m$.

iii)



$X_L = 2\pi f L$

$= 2\times 3.14 \times 50 \times 10 \times 10^{-3}$

$X_L = 3.14$ MARK :(2)

$Z = \sqrt{R^2 + X_L^2}$

$= \sqrt{10^2 + 3.14^2}$

$Z = 10.48\,\Omega$ MARK : (2)

$I = V/Z$

$I = 200/10.48 = 19.08A$ MARK : (2)

$\phi = \cos^{-1}\left[R/Z\right]$

$= \cos^{-1}\left[10/10.48\right]$

$\cos\phi = 0.954$

$\phi = \cos^{-1}(0.954) = 17.44$ MARK :(2)

13.B)

$E = 100 \sin 314 t$

$E = E_m \sin \omega t$

$\omega t = 314 t$, $\omega = 2\pi f$

$2\pi f = 314$

$f = \frac{314}{2\pi} = 49.97$ MARK :(4)

$\therefore f = 50 Hz$ $E_m = 100$ volts.

$E_{av} = \frac{2E_m}{\pi} = \frac{2 \times 100}{\pi}$

$E_{av} = 63.66$ volts. MARK: (1)

Rms value $= \frac{E_m}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.72$ volts

$E_{rms} = 70.72$ volts MARK: (1)

$E = 100 \sin 314 \left(\frac{1}{500}\right)$

$= 99.99$

MARK: (2).

$\therefore E = 100$ volts at time, $t = \frac{1}{200}$ seconds.

14.A) i)

Δ connection

Given

$8 + j6$, 230V

To find,

$I_L = ?$

$\cos\phi = ?$

Power = ?

Volt ampere = ?

Soln:

$Z_{ph} = \sqrt{R^2 + X_L^2} = \sqrt{8^2 + 6^2}$ $Z_{ph} = 10\Omega$

$V_L = V_{ph}$ in Δ

$V_L = V_{ph} = 230V$

$I_p = \frac{V_{ph}}{Z_{ph}} = \frac{230}{10} = 23A$

$I_L = \sqrt{3}\, I_{ph}$

$= \sqrt{3} \times 23A$

$I_L = 39.83A$ MARK :(3)

$\cos\phi = \frac{R_P}{Z_{ph}} = \frac{8}{10} = 0.8$

$\cos\phi = 0.8$ MARK : (2)

Power $= \sqrt{3}\, V_L I_L \cos\phi$

$= \sqrt{3} \times 230 \times 39.83 \times 0.8$

$P = 12693.71$ watts. MARK : (2)

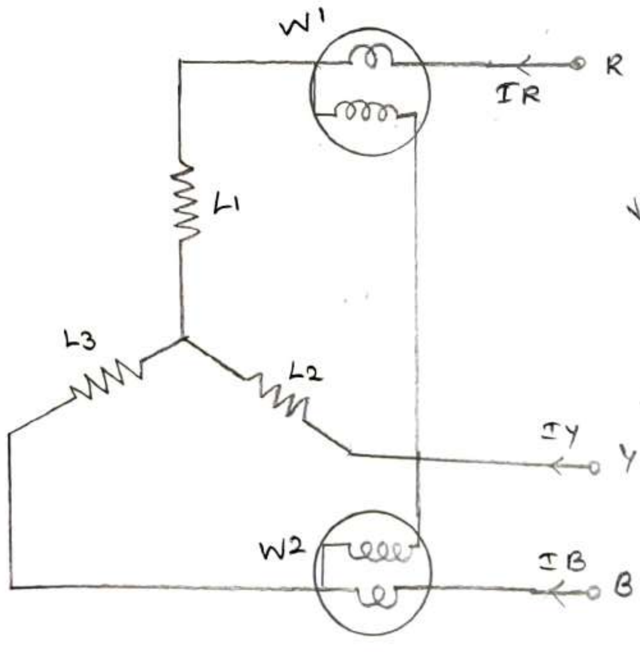
Volt ampere $= \sqrt{3}\, V_L I_L$

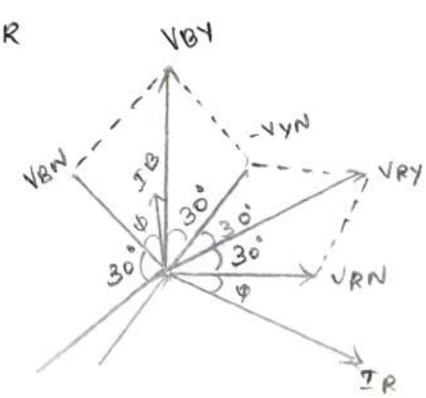
$= \sqrt{3} \times 230 \times 39.83$

Volt Ampere = 15867.14 Volt Ampere. MARK : (3)

ii) 3ϕ power measurement by two wattmeter method :

MARK: (4)





14.B)i) $W_1 = 3000W$ To find,

$W_2 = 8000W$ Input power = ?

Output power = ?

Soln:

Input power $= W_1 + W_2$

$= 8000 + 3000$

Input power = 11000 Watts. MARK: (4)

$$\tan\phi = \sqrt{3}\left[\frac{W_2 - W_1}{W_1 + W_2}\right]$$

$$= \sqrt{3}\left[\frac{8000 - 3000}{3000 + 8000}\right]$$

$$= \sqrt{3}\left[\frac{5000}{11000}\right]$$

$$= \sqrt{3}\,(0.4545)$$

$\tan\phi = 0.787$

$\phi = \tan^{-1}(0.787)$

$\phi = 38.20°$ $\therefore \phi = 38.20°$

Power factor $= \cos\phi = \cos 38.20°$ MARK: (6)

Power factor = 0.785

Bii) Positive Sequence: MARK: (4)

In 3ϕ system, positive sequence refers to the sequence of voltage or currents where the phase sequence is the same as the natural order (ABC).

Negative sequence :

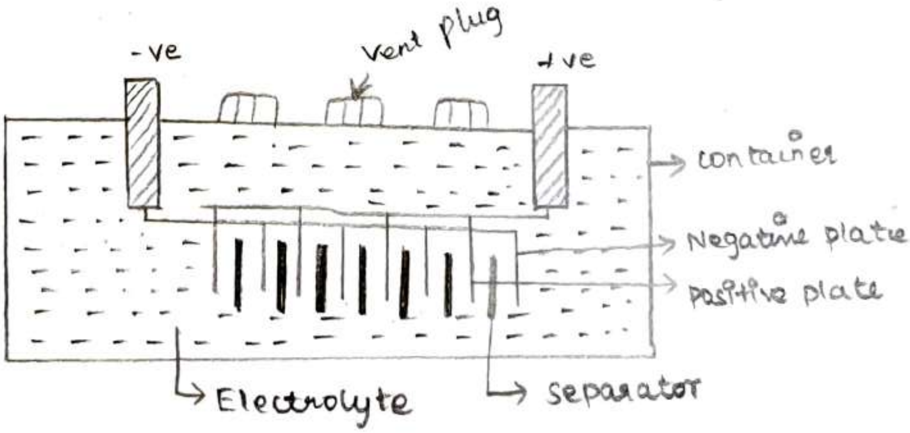
Negative sequence refers to a sequence where the Place sequence is reversed (CBA)

Positive sequence is characteristics is balanced operation while negative sequence can indicate unbalance or faults in the system.

15) A) Lead Acid Battery : DIAGRAM & EXPLANATION MARK : (14)

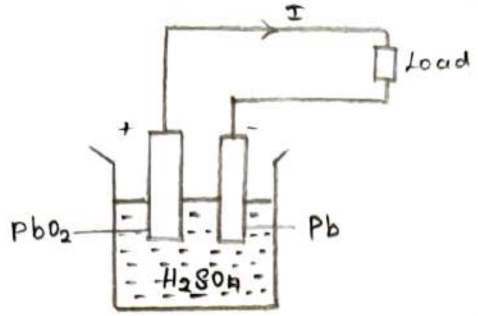
A Battery consist of a number of cells and each cell of the battery consist of the following components.

* Container.
* positive plate.
* negative plate.
* Separator.
* Electrolyte.
* cell cover and vent plug.
* cell connections.
* Battery Terminals.



Working :

Chemical Reaction During Discharging :



* When the cell is fully charged its positive plate or Anode is PbO_2 which is dark chocolate brown in colour and the negative plate or cathode is Pb which is grey in colour.

* During Discharging it stands current through the external load.

* As the current with in the cell is flowing from cathode to anode, H_2 ions move towards the anode and SO_4 ions move towards the cathode.

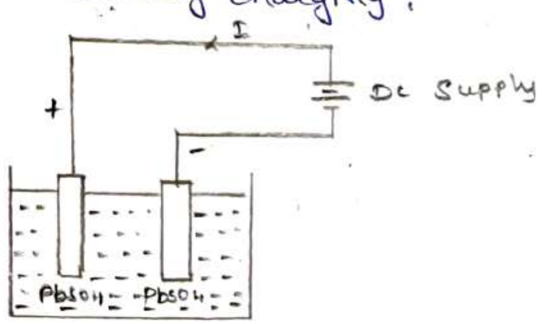
At Anode,

$$PbO_2 + H_2 + H_2SO_4 \longrightarrow PbSO_4 + 2H_2O.$$

At cathode,

$$Pb + SO_4 \longrightarrow PbSO_4$$

Chemical Reactions During charging :



* To recharge a discharged cell, direct current is passed through the cell in the reverse direction by connecting the anode to the +ve terminal of dc.

* During charging the H_2 ions move towards the cathode and SO_4 ions move towards the Anode.

At Cathode,

$$PbSO_4 + H_2 \rightarrow Pb + H_2SO_4$$

At Anode,

$$PbSO_4 + 2H_2O + SO_4 \rightarrow PbO_2 + 2H_2SO_4$$

Application :

* It is used in emergency lights in hospital and substations.

* Used in Automobiles for starting and lighting purpose.

* Used as power source in industries mines etc.

* Used as power source for submarines.

* Maintenance free batteries.

15) B) i) Care and maintenance of Batteries : (ANY 7 POINTS MARK : (7))

* Install the battery firmly.

* Tighten all connections periodically.

* Keep the battery dry and clear to avoid discharging

through moisture.

* Keep the battery surface free of any electrolyte

* Apply petroleum jelly to terminals to prevent corrosion.

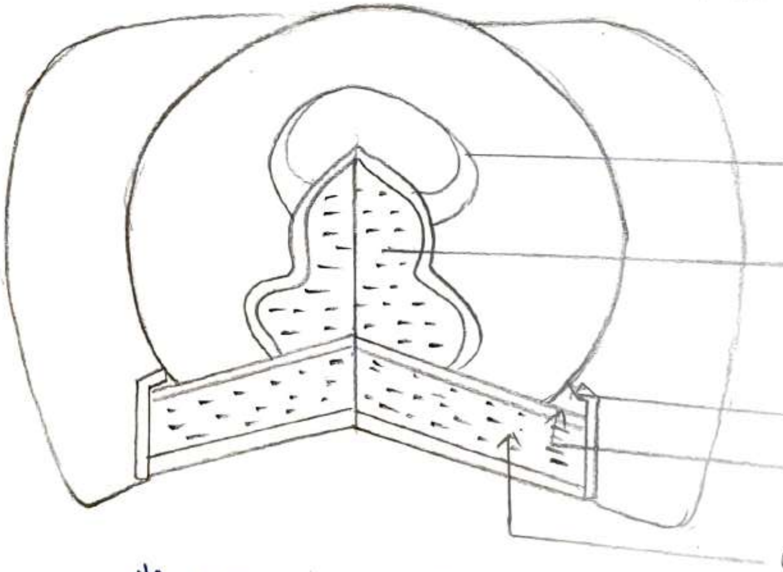
* The level of the electrolyte must be kept above the top of plate.

* The cell should be recharged as soon as possible after discharge.

* Do not charge the battery at high rate.

iii) Mercury cells :

MARK :(7)



* Mercury cell is a primary cell.

* It can not be recharged and reused.

* It is suitable for low current devices.

* It is used in the shape of button cell for hearing aids, watches, cameras etc..

* The cell produced about 1.35V.

Advantage :

* Low cost .
* Long Life .

Disadvantage :

* It contained toxic mercury which pollute the environment .
* It cannot be recharged .

Prepared by,
M. A. Suresh Babu
Lecturer (Sr. Sc)/EEE
Thiagarajar Poly. College,
Salem.