Assignment - 3

Electrostatics and Capacitance

DATE :

Q-1 Define following Terms

1) Electric Field :-

→ Space around the test charge in which it experiences a force is known as electric field.

6) Electric Dielectric ~~field~~ strength :-

→ The maximum electric field that a dielectric medium can with stand without breakdown is called its dielectric strength.

3) Relative Permittivity :-

→ Relative permittivity or dielectric constant is the ratio of the absolute permittivity of a medium to the permittivity of free space. It is denoted by K or ε_r.

Ex K or $\varepsilon_r = \dfrac{\varepsilon}{\varepsilon_0}$

4) Electric field Intensity :-

→ It is defined as force acting per unit charge.

$\vec{E} = \dfrac{\vec{F}}{q_0}$ SI unit → NC^{-1}

→ $[M^1 L^1 A^{-1} T^{-3}]$

DATE :

5) Potential and Potential Difference

→ Electric Potential :

→ It is defined as the amount of work done when a unit positive charge is moved from infinity to a point.

$$V = \frac{W}{q}$$

→ Electric Potential Difference :-

→ It is defined as the work done per unit charge in moving a unit positive charge from one point to other point.

7) Electric Flux :

→ Electric flux is the number of electric field lines passing through a given area.

→ SI unit $NC^{-1}m^2$ or $V\text{-}m$

8) Break down potential :

→ Break down potential is the maximum potential Difference befor sparking.

2) Electric field strength :- (E)

→ The electric field strength vector E at any point in an electric field ~~as the~~ is defined as the force per unit positive (test) charge placed at that point in the field.

$$E = \frac{F}{q} \quad (NC^{-1})$$

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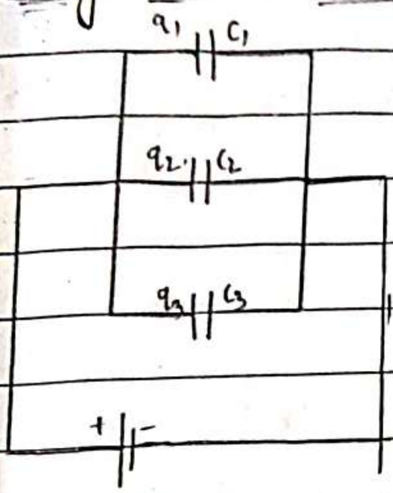
Q.2 Derive the expression for Equivalent Capacitance of A group of Capacitors when.

1) They are connected In Parallel.



Here, q_1, q_2 & q_3 are charge of capacitor C_1, C_2 & C_3

In parallel, charge will be different & potential remain same.

So, $Q_1 = C_1 V$; $Q_2 = C_2 V$; $Q_3 = C_3 V$

$\therefore$ Total charge $Q = Q_1 + Q_2 + Q_3$

$$= C_1 V + C_2 V + C_3 V$$

$$Q = V(C_1 + C_2 + C_3)$$

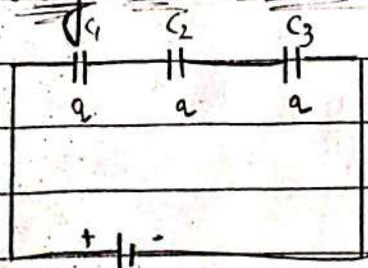
$$\therefore \frac{Q}{V} = C_1 + C_2 + C_3 \quad \{\because Q = C_p V\}$$

$$\therefore \boxed{C_p = C_1 + C_2 + C_3}$$

for n no. of capacitor

$$\therefore \boxed{C_p = nC} \text{ (max)}$$

2) They are connected in series :-



Here, q is charge of capacitor C_1, C_2 & C_3.

- In series, charge will be constant & potential will different.

- V_1, V_2, V_3 be the Potential Difference at C_1, C_2 & C_3.

$$V_1 = \frac{Q}{C_1} \; ; \; V_2 = \frac{Q}{C_2} \; ; \; V_3 = \frac{Q}{C_3}$$

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

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

$$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

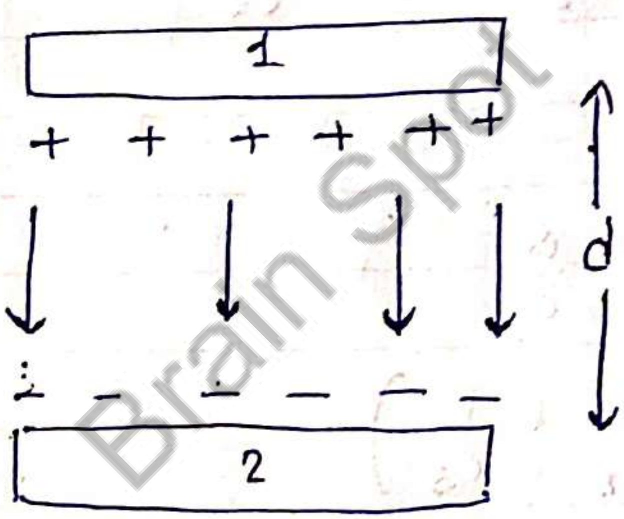
$$\frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

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

- for n capacitor

$$\boxed{C_p = \frac{C}{n}}$$

I



II

surface charge density - σ

<u>Parallel Capacitor</u>

DATE :

Q-3 Prove for capacitance of a parallel capacitor $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$.

- capacitor is a device used to store charge.
- The amount of charge Q a capacitor can store depends on two major factors - the voltage applied and the capacitor's physical characteristics, such as its size.

- The capacitor c is the amount of charge stored per volt, or

$$C = \frac{Q}{V}$$

- The capacitance of a parallel plate capacitor is

$$C = \frac{\varepsilon_0 A}{d}$$

where, ε_0 is called the permittivity of free space.

- A parallel plate capacitor with a dielectric bt^n its plates has a capacitance given by

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

where, ε_0 is the dielectric constant of a material

DATE :

(4) Explain charging of capacitor.

→ When the key is pressed, the capacitor begins to store charge. If at any time during charging, I is the current through the circuit and Q is the charge on the capacitor, then potential difference across resistor IR, and,

potential difference ~~across~~ btⁿ the plates of the capacitor $= \frac{Q}{C}$

→ Since the sum of both these potentials is equal to $\mathcal{E}$,

$$\therefore \boxed{RI + \frac{Q}{C} = \mathcal{E}} \quad \text{—— (1)}$$

→ As the current stops flowing when the capacitor is fully charged,

when $Q = Q_0$ & $I = 0$

from (1),

$$\boxed{\frac{Q_0}{C} = \mathcal{E}} \quad \text{—— (2)}$$

→ from (1) & (2)

$$RI + \frac{Q}{C} = \frac{Q_0}{C} \Rightarrow \frac{Q_0}{C} - \frac{Q}{C} = RI$$

DATE :

$$\therefore \frac{Q_0 - Q}{C} = RI$$

$$\therefore \boxed{\frac{Q_0 - Q}{CR} = I} \quad \text{---} (3)$$

since $I = \frac{dQ}{dt}$, from eq^n (3),

$$\frac{Q_0 - Q}{CR} = \frac{dQ}{dt}$$

$$\therefore \frac{dQ}{Q_0 - Q} = \frac{dt}{CR}$$

when $t = 0$, $Q = 0$ and when $t = t$, $Q = Q$
Integrating both sides within proper limits, we get

$$\therefore \int_0^Q \frac{dQ}{(Q_0 - Q)} = \int_0^t \frac{dt}{CR} = \frac{1}{CR}\int_0^t dt$$

$$\therefore \left[-\log(Q_0 - Q)\right]_0^Q = \frac{1}{CR}\left[t\right]_0^t$$

$$\therefore -\log(Q_0 - Q) + \log Q_0 = \frac{t}{CR}$$

$$\therefore \log(Q_0 - Q) - \log Q_0 = -\frac{t}{CR}$$

$$\therefore \log\left(\frac{Q_0 - Q}{Q_0}\right) = -\frac{t}{CR}$$

Teacher's Sign. :

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$$\therefore \frac{Q_0 - Q}{Q_0} = e^{-t/CR}$$

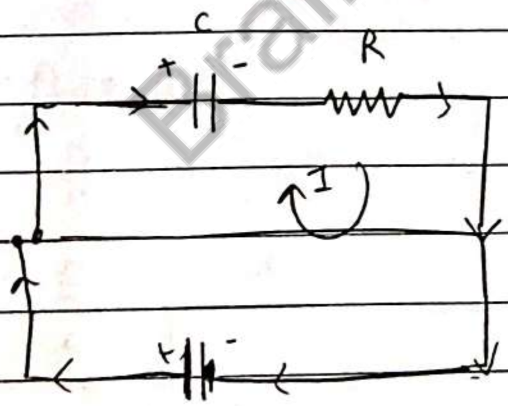
$$\therefore Q_0 - Q = Q_0 e^{-t/CR}$$

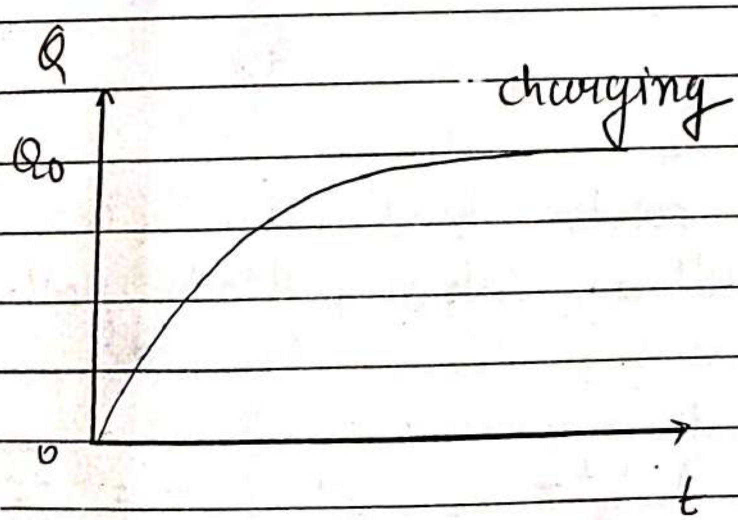
$$\therefore Q = Q_0 (1 - e^{-t/CR})$$

$$\therefore \boxed{Q = Q_0 (1 - e^{-t/\tau})} \quad \text{—— (4)}$$

where $\tau = CR$

↳ Eqⁿ (4) gives is the value of charge on the capacitor at any time during charging.





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(5) Explain discharging of capacitor.

ans When the key K is released, the circuit is broken without introducing any additional resistance

→ The battery is now out of the circuit and the capacitor will discharge itself through R. If I is the current of at any time during discharge,

then putting $\varepsilon = 0$ in $RI + \frac{Q}{C} = \varepsilon$; we get,

$$RI + \frac{Q}{C} = 0$$

$$\therefore R\frac{dQ}{dt} + \frac{Q}{C} = 0$$

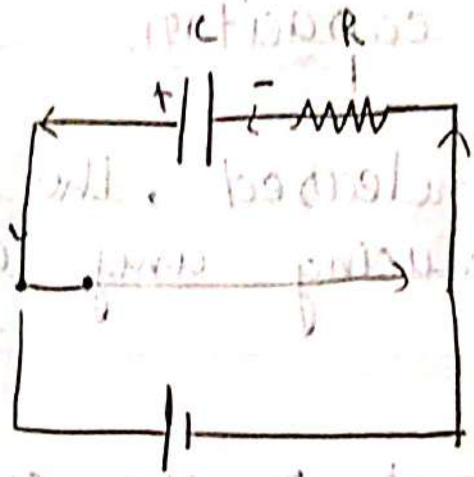
$$\therefore R\frac{dQ}{dt} = -\frac{Q}{C}$$

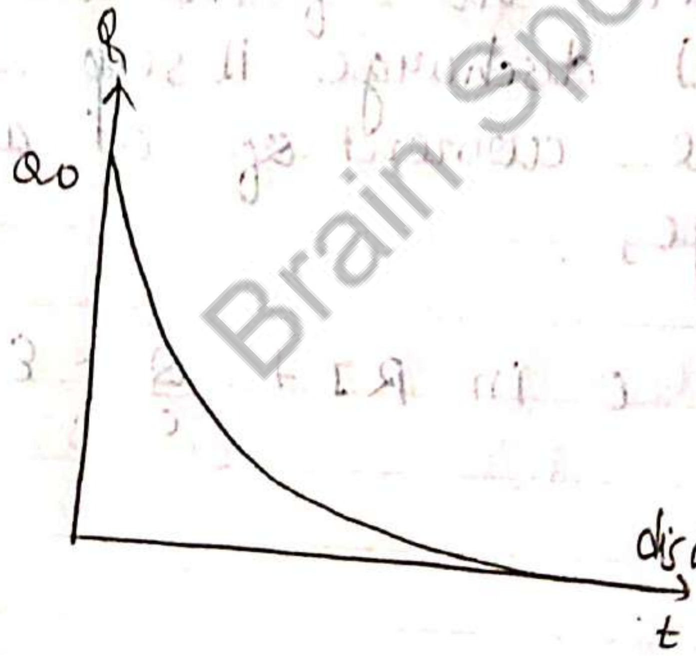
$$\therefore \frac{dQ}{Q} = -\frac{dt}{CR}$$

→ When $t = 0$, $Q = Q_0$ and when $t = t$, $Q = Q$
Integrating both sides within proper limits, we get.

$$\int_{Q_0}^{Q} \frac{dQ}{Q} = -\int_{0}^{t} \frac{dt}{CR} = \frac{-1}{CR}\int_{0}^{t} dt$$

Teacher's Sign. :





discharging

DATE :

$$\therefore \left[\log Q\right]_{Q_0}^{Q} = -\frac{1}{CR}\left[t\right]_0^t$$

$$\therefore \log Q - \log Q_0 = -\frac{t}{CR}$$

$$\therefore \log \frac{Q}{Q_0} = -\frac{t}{CR}$$

$$\therefore \frac{Q}{Q_0} = e^{-t/CR}$$

$$\therefore \boxed{Q = Q_0 e^{-t/CR}} \quad \text{—— (5)}$$

where $\tau = CR$

Eq^n (5) gives the value of the charge on the capacitor at any time during discharging

Assignment - 6

Three Phase System

DATE :

(1) Derive the voltage and current relationship in star connected load and Draw complete phasor diagram of voltage and current.

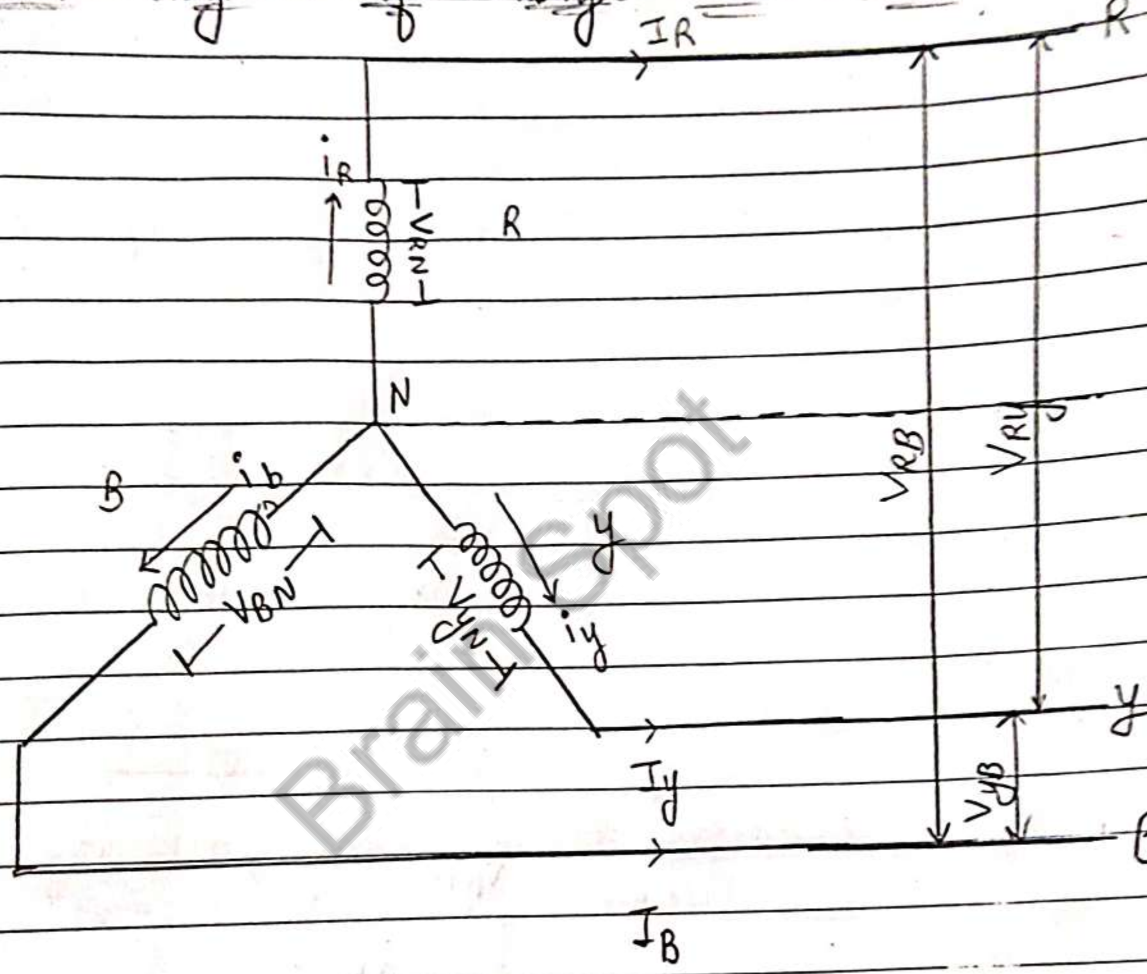


figure - 1

→ figure 1 shows a 3-phase, 4 fire blanced system

→ Here, as discussed,

V_{RN}, V_{YN} and V_{BN} are phase voltages.
V_{RY}, V_{YB} & V_{BR} are line voltages.
i_R, i_y & i_B are phase currents.
I_R, I_Y & I_B are line currents

Teacher's Sign. :

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Since the system is balanced,

$$V_{RN} = V_{YN} = V_{BN} = V_{ph}$$
$$i_R = i_y = i_B = I_{ph}$$
$$V_{Ry} = V_{yB} = V_{BR} = V_L$$
$$I_R = I_y = I_B = I_L$$

from figure 1, it is clear that

$$i_R = I_R$$
$$i_y = I_y$$
$$i_B = I_B$$

Thus in star connection,

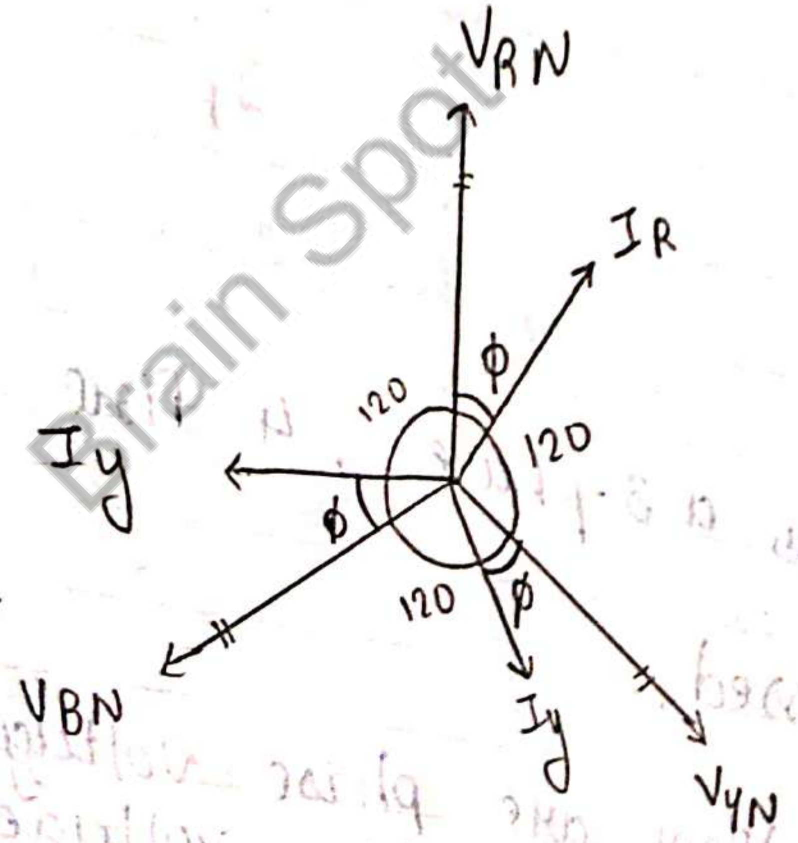
$$\boxed{I_{ph} = I_L}$$

Thus, for star connection no discrimination bt^n line current & phase current.

In figure, there are two phase winding bt^n each pair of line terminals

The phasor diagram of the phase emfs and currents in a star connected system is shown here.

Teacher's Sign. :



VRN
IR
ϕ
120
120
Iy
ϕ
120
ϕ
VBN
Iy
VYN

DATE :

→ Line voltage btn terminals R & Y.

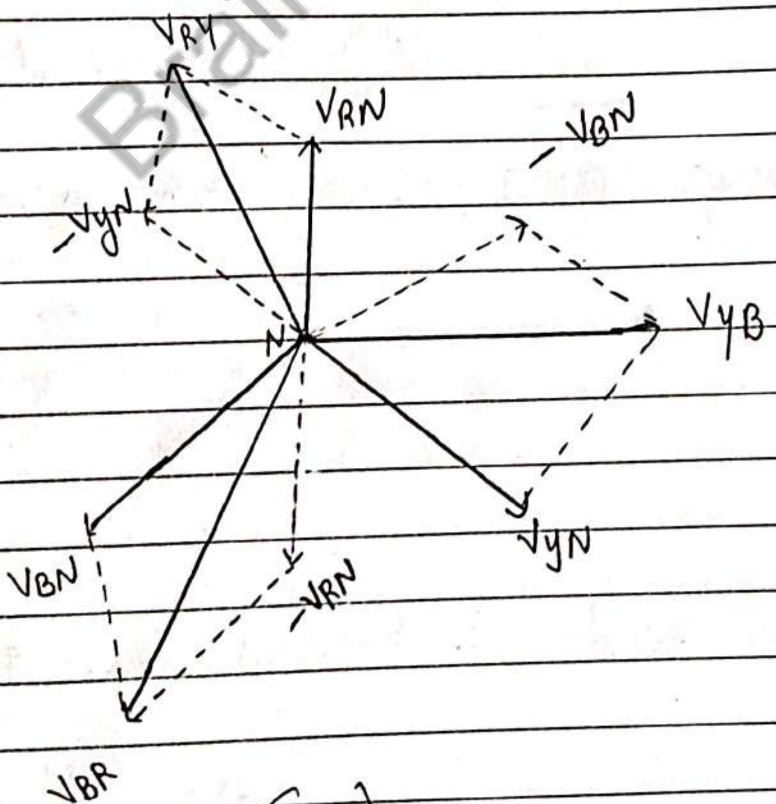
$$V_{RY} = V_{RN} + V_{NY}$$

$$\boxed{\vec{V}_{RY} = \vec{V}_{RN} - \vec{V}_{YN}}$$

Similarly,

$$\boxed{\vec{V}_{YB} = \vec{V}_{YN} - \vec{V}_{BN}} \quad \& \quad \boxed{\vec{V}_{BR} = \vec{V}_{BN} - \vec{V}_{RN}}$$

→ Hence, it is clear that in a star connected system, the line voltage is obtained as the vector difference of the two corresponding phase voltages.



Teacher's Sign. :

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From figure (2),

The resultant or line voltage is given by

$$|V_{RY}| = V_{RN} - V_{YN}$$

$$= 2V_{ph}\cos\left(\frac{60}{2}\right)$$

$$= 2V_{ph}\cos 30^\circ$$

$$= \cancel{2}V_{ph}\frac{\sqrt{3}}{\cancel{2}}$$

$$\boxed{|V_{RY}| = \sqrt{3}\,V_{ph}}$$

Similarly, $\boxed{V_{YB} = V_{BR} = \sqrt{3}\,V_{ph} = V_L}$

Thus in balanced star connected system,

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

Thus,

Relation btn line current & phase current

$$\boxed{I_L = I_{ph}}$$

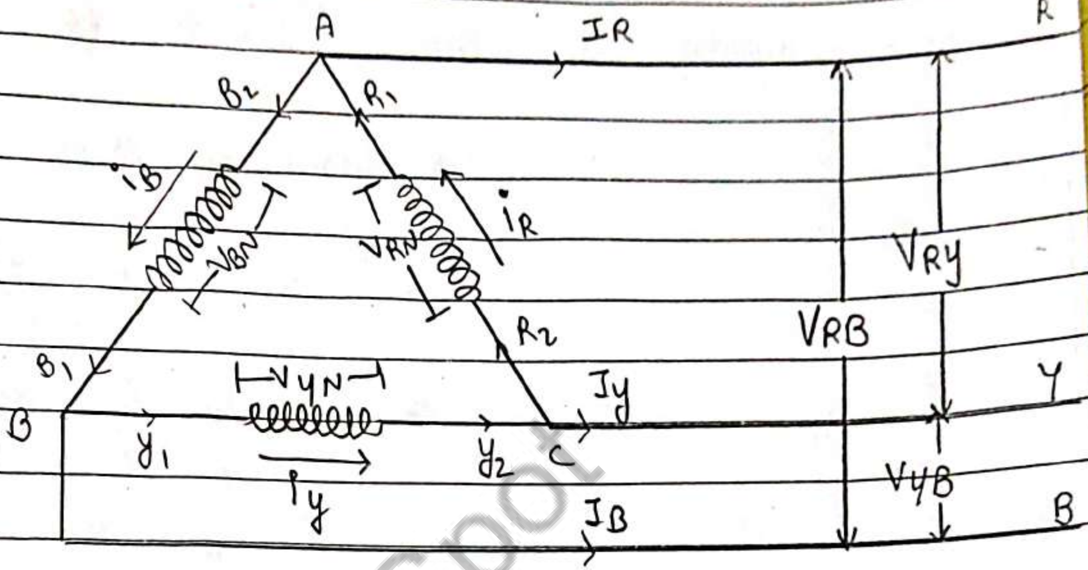
Relation btn line voltage & phase voltage

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

Teacher's Sign. :

DATE :

(2) Derive the voltages & current relationship in delta connected load and Draw complete phasor diagram of voltages & currents



→ The circuit diagram resembles the greek letter delta Δ, so this connection is called delta conection. The line conductors are joined at the junctions of the winding of 3 phase system.

→ In delta connection, the three coil windings are connected together such that the finishing end of one coil is connected to the starting end of the other coil and so on as shown

→ In this method, there is no natural wire and so it is called as 3-phase, 3-wire system.

Teacher's Sign. :

DATE :

→ Here,

* V_{RN}, V_{YN} & V_{BN} are the phase voltages
* V_{RY}, V_{YB} & V_{BR} are the line voltages
* I_R, I_y & I_B are the line currents.
* i_R, i_y & i_B are the phase currents

→ Since the system is balanced,

$$I_R = I_y = I_B = \cancel{I_{ph}}\ I_L$$
$$i_R = i_y = i_B = I_{ph}$$
$$V_{RN} = V_{YN} = V_{BN} = V_{ph}$$
$$V_{RY} = V_{YB} = V_{BR} = V_L$$

→ It is clear that

$$V_{RN} = V_{RY}$$
$$V_{YN} = V_{YB}$$
$$V_{BN} = V_{BR}$$

$$\therefore \boxed{V_L = V_{ph}}$$

Hence, for Delta connection no descrimination bt^n line voltage & phase voltage.

→ Current flowing in each line is the vector difference of the two phase currents

current in line R, $\vec{I_R} = \vec{i_R} - \vec{i_B}$
current in line y, $\vec{I_y} = \vec{i_y} - \vec{i_R}$
current in line B, $\vec{I_B} = \vec{i_B} - \vec{i_y}$

Teacher's Sign. :

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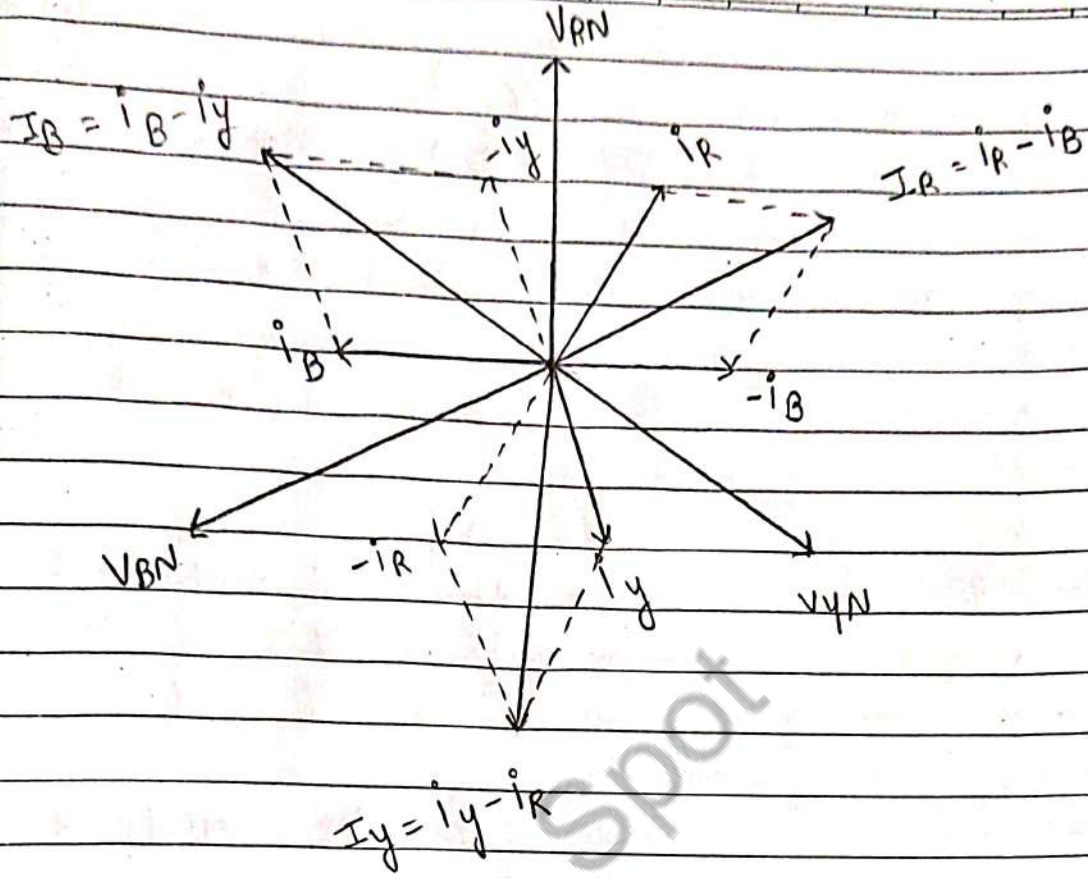


↳ Since the sides of parallelogram are equal in magnitude and the angle btn them is 60°, the resultant current or the line current is given as,

$$\vec{I_R} = \vec{i_R} - \vec{i_B}$$

$$|I_R| = 2 I_{ph} \cos\left(\frac{60^\circ}{2}\right)$$

$$= 2 I_{ph} \cos 30^\circ$$

$$= 2 I_{ph} \frac{\sqrt{3}}{2}$$

$$\boxed{|I_R| = \sqrt{3}\, I_{ph}}$$

Teacher's Sign. :

DATE :

Similarly $I_B = I_y = \sqrt{3}\, I_{ph} = I_L$

Thus in delta connection,

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

Thus,

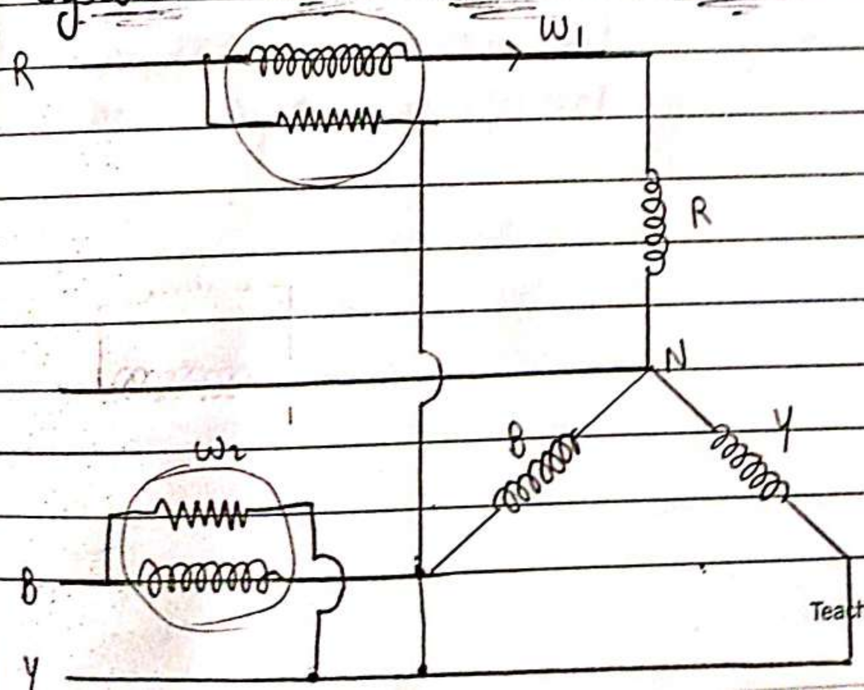
Relationship bt^n line voltage & phase voltage

$$\boxed{V_L = V_{ph}}$$

& Relation bt^n line current & phase current

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

(3) How can we measure the power with the help of two watt meter method in three phase system with Star connected load?



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- This is the most common method for the measurement of power in 3-phase system.

- In this method two wattmeters are connected.

- The current coils of two wattmeters are connected in series in any two lines & the potential coils are connected btⁿ these lines and the third line in which the current coil is not connected.

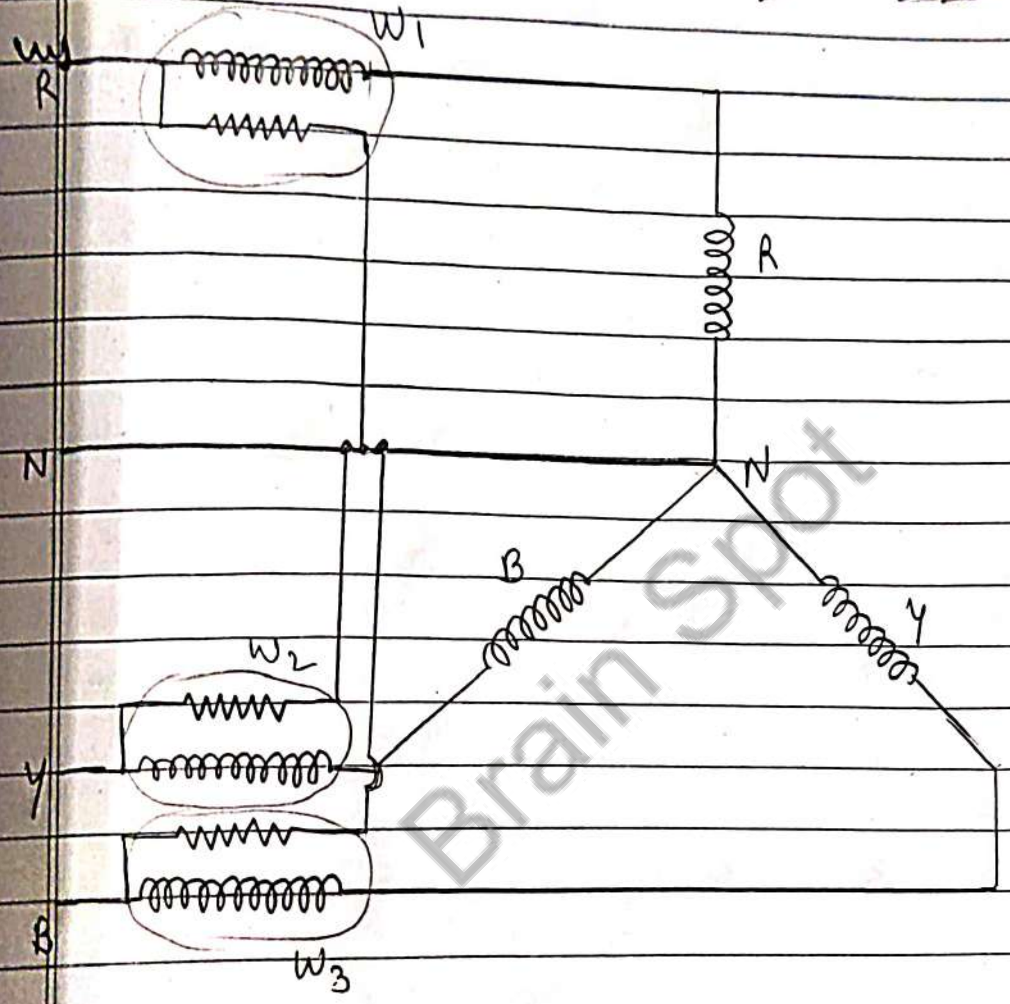
- It can be proved that the sum of instantaneous values of power indicated by these wattmeters equals the total power absorbed by the 3-phase load.

- The former method is used for 3-phase star connected balanced & unbalanced load.

- Hence, two wattmeter method is invariably used for measurement of power in 3-phase supply system in practice.

DATE :

4) How can we measure the power with the help of theree watt meter method in three phase system with star connected load.?



- In this method three watt meters are connected to measure to measure the power of each phase separately as shown in figure.

- The algebric sum of three watt meter readings given the total power

$\therefore$ Total 3-ϕ power = $W_1 + W_2 + W_3$

Teacher's Sign. :

DATE :

→ The difficulty with this method is that sometimes it is not possible to have acess to the neutral point in the star connection. Also it is not easy to make connections into the phases of a delta connection.