• Basic Electrical Circuits

EEE-1241
13.08.17
2A.SKG

Syllabus: DC Circuit
A.C Circuit
Electronics
Machine (DC)
Electrical wiring

Circuit:

An electric circuit is an interconnection of electrical elements. There are two types of elements:

i. Active elements: Active elements produce energy or electricity.

Example: Battery, Generator, OP-Amp

Independent source   Dependent source

ii. Passive elements: Passive elements consumed ~~or~~ dissipation or store energy.

Example: Resistance, Inductors, capacitors.

Every elements has two terminals.

Charge and current:

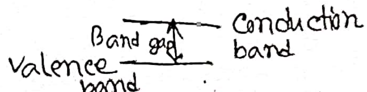
Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

* Properties of electric charge:

1. The coulomb is a large unit for charges. In 1C of charge, there are $(1/1.6023 \times 10^{-19}) = 6.24 \times 10^{18}$ electrons.

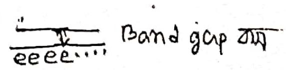
2. According to experimental observations, the only charge occur in nature are integral multiples of the electronic charge ($e = -1.602 \times 10^{-19}$ C).

3. The law of conservation of charge states that charge can neither be created nor destroyed, only transferred. Thus the algebraic sum of the electric charges in a system does not change.



Conductor: Charge can move freely. There has no band gab between Conduction band and valence band.

Semiconductor: It is intermediated between



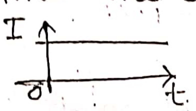
Insulator: Huge band gap and charge can not move freely.

Electric current is the time rate of change of charge, measured in amperes (A).

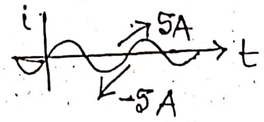
Mathematically relation: $I = \frac{dQ}{dt}$ $\quad$ 1 ampere $= \frac{1 \text{ coulomb}}{1 \text{ second}}$

There are two types of current.

i. DC: A direct current is a current that remains constant with time. The current does not change with time.



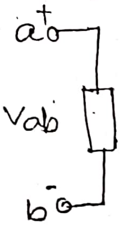
ii. AC: An alternating current is a current that varies with respect to time.



Voltage:

Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).

The V_{ab} can be interpreted in two ways:



1. Point a is at a potential of V_{ab} volts higher than point b.
2. The potential at point a with respect to point b is V_{ab}. It ~~flow~~ follows logically that in general: $V_{ab} = -V_{ba}$

$$V_{ab} = \frac{dw}{dQ}$$

DC voltage source (V, E, ±) Current source (↑)

AC voltage source (v, e, ~) Current ↑

Ideal: There are no internal resistance in ideal current (↑) source and ideal voltage (±) source. The given current and voltage can get back fully in ideal current and voltage source.

Practical: There is some internal resistance in practical current 5A (↑) 2Ω source and in practical voltage source.

I.C.S: Internal resistance is (∞) infinity.

P.C.S: Internal resistance is parallal to the source.

Power:

Power is the time rate of expending or absorbing energy, measured in watts (W).

$$P = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = vi$$

$$dw = Pdt$$

$$\Rightarrow \int_0^W dw = \int P dt$$

$$P = v(t)\, i(t)$$

current time varing

voltage time varing

$\Rightarrow P(t) =$ instantaneous power

$P = VI$.

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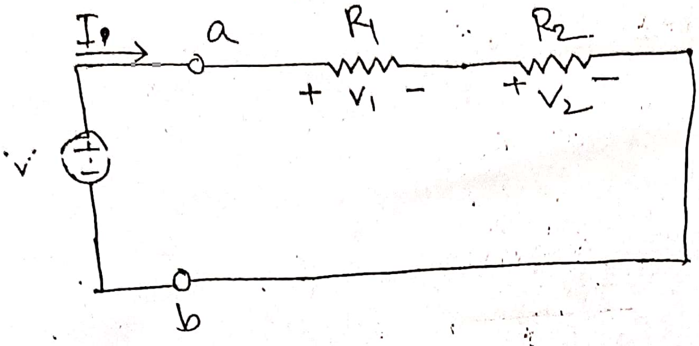
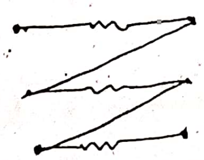
Series resistance of voltage division:



If one point be common between two element, then they are connected by series.



Ohm's law:

$V_1 = IR_1$ —(i)

$V_2 = IR_2$ —(ii)

Clock wise direction KVL:

$-V + V_1 + V_2 = 0$

$\Rightarrow V = V_1 + V_2$

$= I(R_1 + R_2)$

$= I R_{eq}$

$R_{eq} = R_1 + R_2$

$\Rightarrow I = \frac{V}{R_{eq}}$ —(iii)

If $R_1, R_2, R_3 --- R_n$ be stay in series connection, then

$R_{eq} = R_1 + R_2 + R_3 + R_4 + --- + R_n$

$V_1 = \frac{R_1}{R_1+R_2} \times V$

$V_2 = \frac{R_2}{R_1+R_2} \times V.$

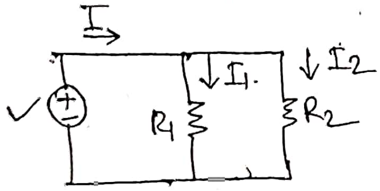
} voltage division rule.

$\therefore V_n = \frac{R_n}{R_1+R_2+--+R_n} \times V$

Calculate conductance.

$$G_1 = \frac{1}{R_1}, \quad G_2 = \frac{1}{R_2}$$

* Parallel resistance of current division:



By appling KCL:

$$I = I_1 + I_2$$

$$= \frac{V}{R_1} + \frac{V}{R_2}$$

$$= V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$= V/R_{eq}$$

$$\therefore V = \cancel{\frac{I}{R_{eq}}}\; IR_{eq}$$

$$V = I_1 R_1 \Rightarrow I_1 = \frac{V}{R_1}$$

$$V = I_2 R_2 \Rightarrow I_2 = \frac{V}{R_2}$$

$$\therefore \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\Rightarrow R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

$$\boxed{\frac{1}{R_{eq}} = \frac{R_1 R_2 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1}}$$

$$\therefore \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

$$I_1 = \frac{V}{R_1} = \frac{I R_{eq}}{R_1}$$

$$= I \times \frac{R_1 R_2}{R_1 + R_2} \times \frac{1}{R_1}$$

$$= \frac{R_2}{R_1 + R_2} \times I$$

$$I_2 = \frac{V}{R_2} = \frac{I R_{eq}}{R_2}$$

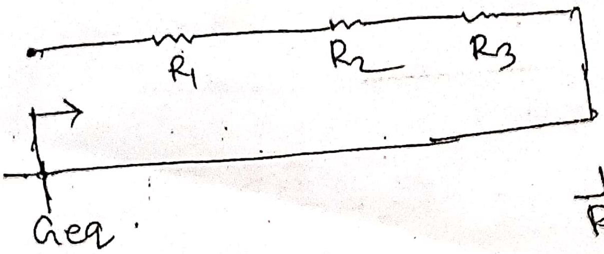
$$= I \times \frac{R_1 R_2}{R_1 + R_2} \times \frac{1}{R_2}$$

$$= \frac{R_1}{R_1 + R_2} \times I.$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}$$

Conductance: $G_{eq} = G_1 + G_2 + G_3 + \cdots + G_n$.

** Calculate the conductance in series :



$$\frac{1}{R_1} = G_1$$

$$\frac{1}{R_2} = G_2$$

$$\frac{1}{R_3} = G_3$$

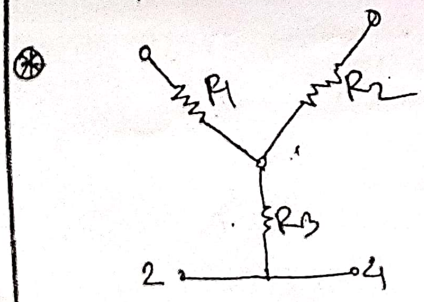
$$R_{eq} = R_1 + R_2 + R_3$$

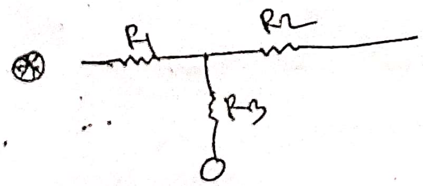
$$\Rightarrow \frac{1}{G_{eq}} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3}$$

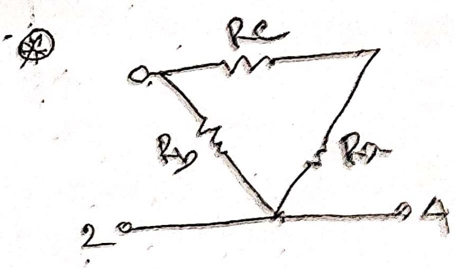
$$\Rightarrow G_{eq} = \frac{G_1 G_2 G_3}{G_1G_2 + G_2G_3 + G_3G_1}$$

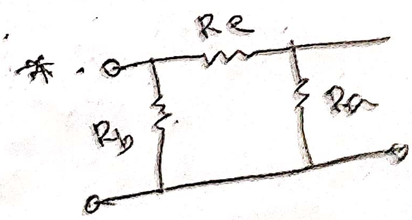
Y connection ওয়াই

Δ - connection ডেল্টা



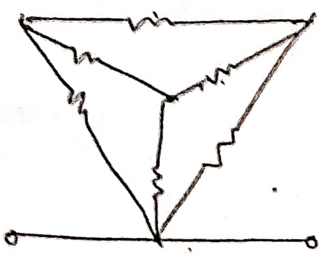






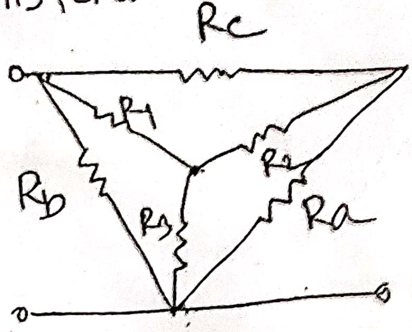
Y connection

Transfer:



Δ Connection

Transfer:



$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c}$$

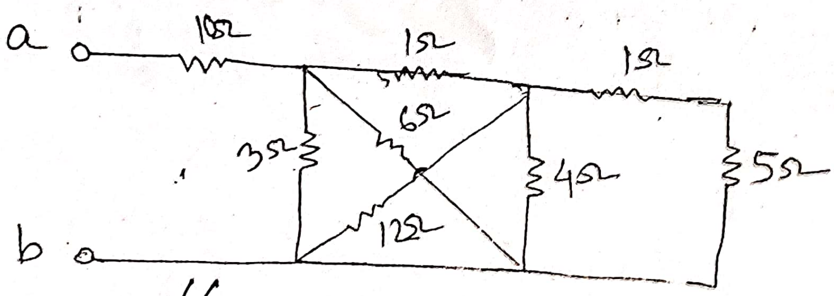
$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

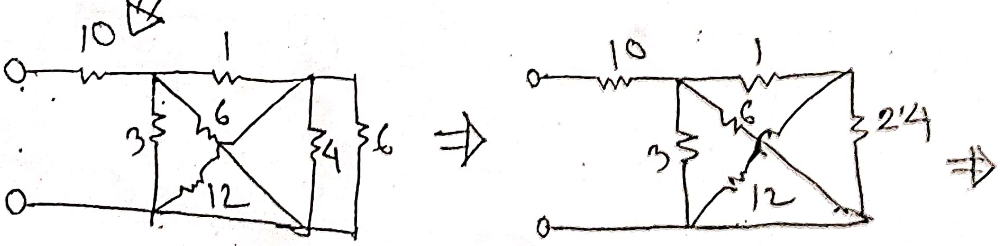
$$R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$$

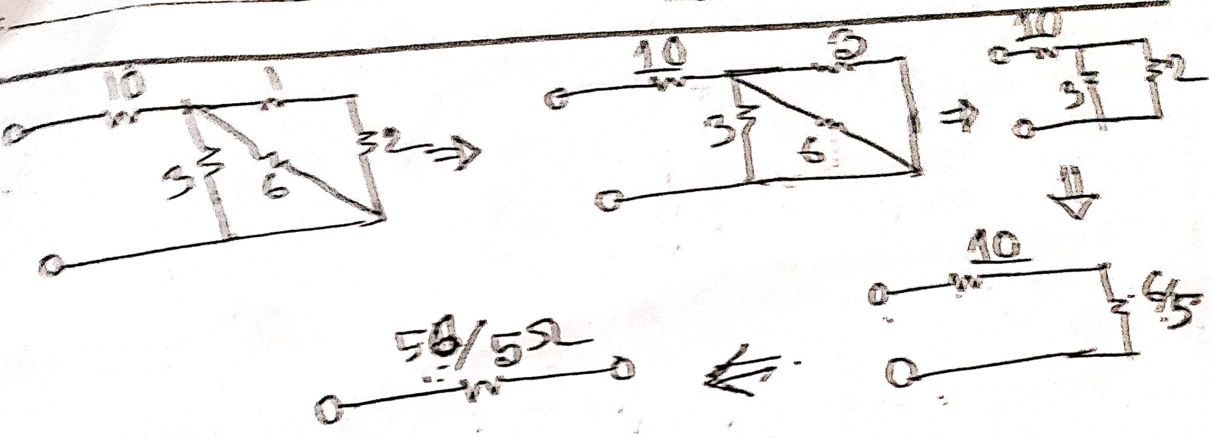
$$R_b = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$$

$$R_c = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$$

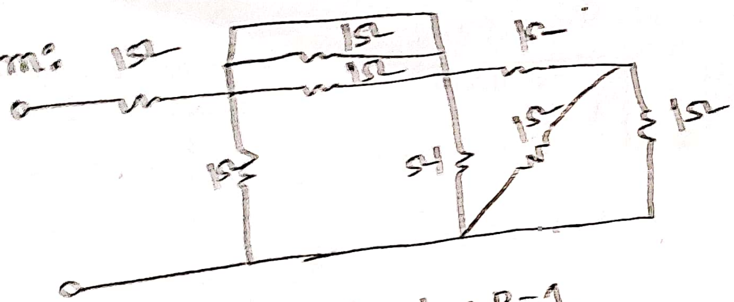
* Problem:



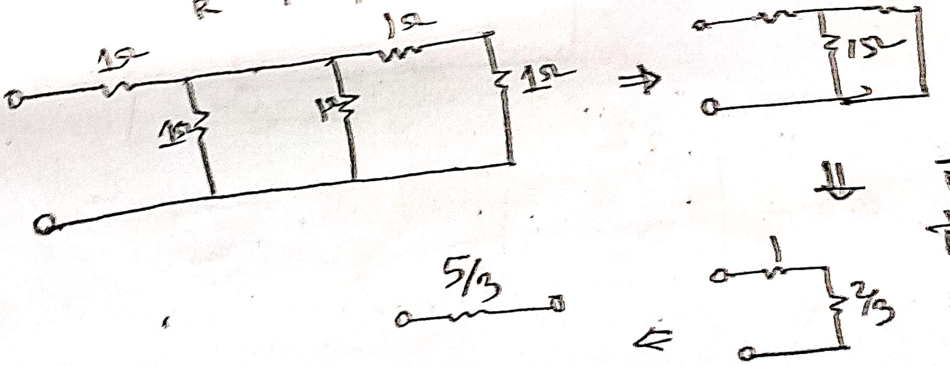




Problem:



$$\frac{1}{R} = \frac{1}{1} + \frac{1}{1} \Rightarrow R = 1$$



$$\frac{1}{R} = \frac{1}{2} + \frac{1}{1}$$

$$\frac{1}{R} = \frac{1+2}{2}$$

$$R = \frac{2}{3}$$

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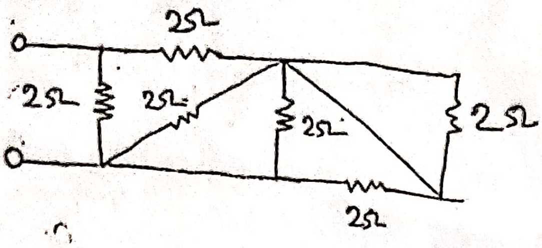
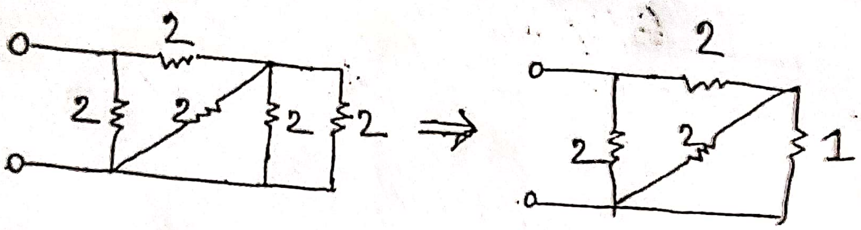
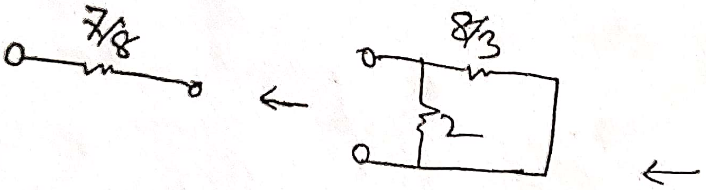
**Equivalent circuit:





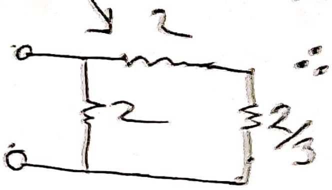
$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{2} = 1$

$\therefore R_{eq} = 1$



$\frac{1}{R_{eq}} = \frac{1}{1} + \frac{1}{2} = \frac{3}{2}$

$\therefore R_{eq} = \frac{2}{3}$



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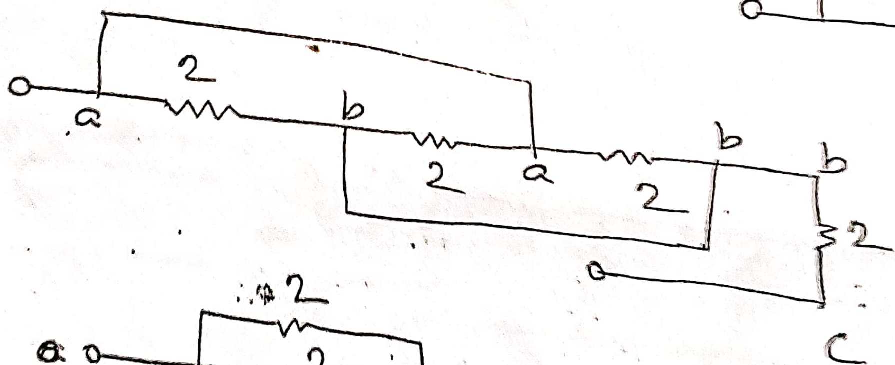

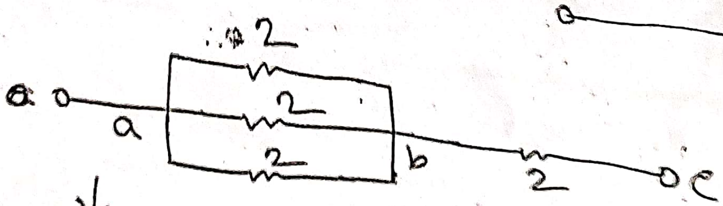

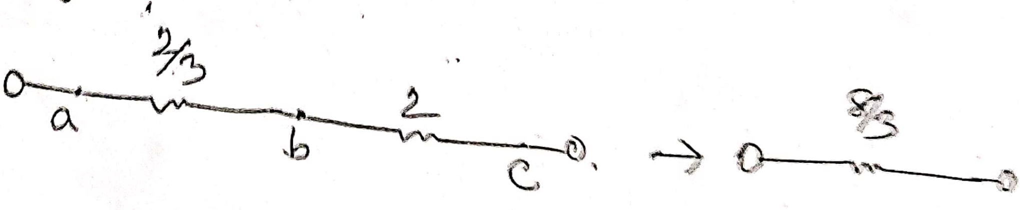

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4C - SKG

Sub:

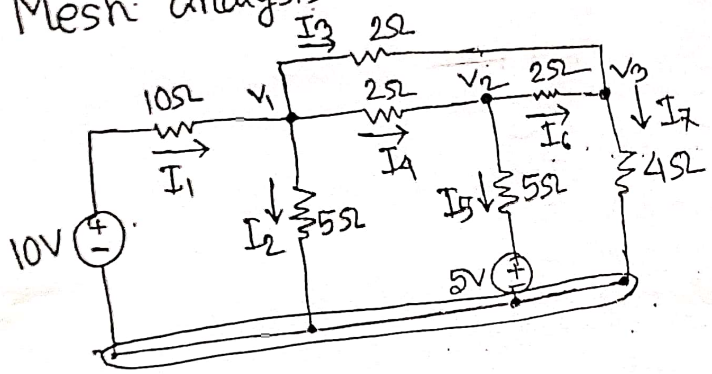
** Method of analysis:

1. Nodal analysis : @. Find effective node

b. Apply KCL

c. The effective nodes are equal to the number of system equation.

ii. Mesh analysis.



Apply KCL at node-1,

$$I_1 = I_2 + I_3 + I_4$$

$$\Rightarrow \frac{10-V_1}{10} = \frac{V_1-0}{5} + \frac{V_1-V_3}{2} + \frac{V_1-V_2}{2}$$

$$\Rightarrow \frac{10-V_1}{10} = \frac{2V_1+5V_1-5V_3+5V_1-5V_2}{10}$$

$$\Rightarrow 10 = 13V_1 - 5V_2 - 5V_3$$

$$\Rightarrow 13V_1 - 5V_2 - 5V_3 = 10 \quad \text{——— (1)}$$

Apply KCL at node 2,

$$I_4 = I_5 + I_6$$

$$\Rightarrow \frac{V_1-V_2}{2} = \frac{V_2-5}{5} + \frac{V_2-V_3}{2}$$

$$\Rightarrow 5V_1 - 5V_2 = 2V_2 - 10 + 5V_2 - 5V_3$$

$$\Rightarrow 5V_1 - 12V_2 + 5V_3 = -10 \quad \text{——— (ii)}$$

Apply KCL at node 3,

$$I_3 + I_6 = I_7$$

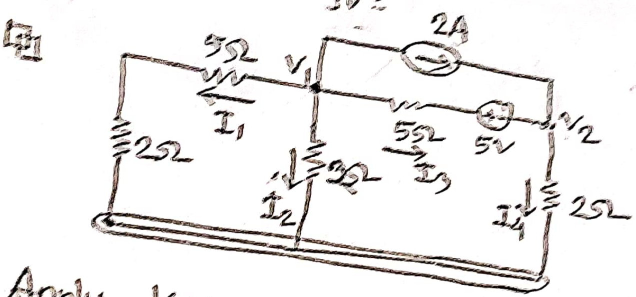
$$\Rightarrow \frac{V_1 - V_3}{2} + \frac{V_2 - V_3}{2} = \frac{V_3 - 0}{4}$$

$$\Rightarrow 2V_1 - 2V_3 + 2V_2 - 2V_3 = V_3$$

$$\Rightarrow 2V_1 + 2V_2 - 5V_3 = 0 \quad \text{——— (iii)}$$

From equation (i), (ii) and (iii),

$$\left.\begin{aligned} V_1 &= 2.79\,\text{V} \\ V_2 &= 2.95\,\text{V} \\ V_3 &= 2.295\,\text{V} \end{aligned}\right\} \text{(Ans:)}$$



Apply KCL at node-1,

$$I_1 + I_2 + I_3 + 2 = 0$$

$$\Rightarrow \frac{V_1 - 0}{7} + \frac{V_1 - 0}{2} + \frac{V_1 - (5 + V_2)}{5} + 2 = 0$$

$\Rightarrow 10V_1 + 35V_1 + 14V_1 - 70 - 14V_2 + 140 = 0$

$\Rightarrow 59V_1 - 14V_2 = -70$ ———— (i)

Apply KCL at node-2,

$$I_5 + 2 = I_4$$

$$\Rightarrow \frac{V_1 - (5+V_2)}{5} + 2 = \frac{V_2 - 0}{2}$$

$$\Rightarrow \frac{V_1 - 5 - V_2 + 10}{5} = \frac{V_2}{2}$$

$$\Rightarrow 2V_1 - 10 - 2V_2 + 20 = 5V_2$$

$$\Rightarrow 2V_1 - 7V_2 = -10 \text{ ———— (ii)}$$

From equation (i) and (ii),

$$\left.\begin{aligned} V_1 &= -0.9\,V \\ V_2 &= 1.16\,V \end{aligned}\right\} \text{(Ans)}$$

* Super node: If a voltage source exist between two nodes then it is called super node.

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Nodal analysis with voltage source:

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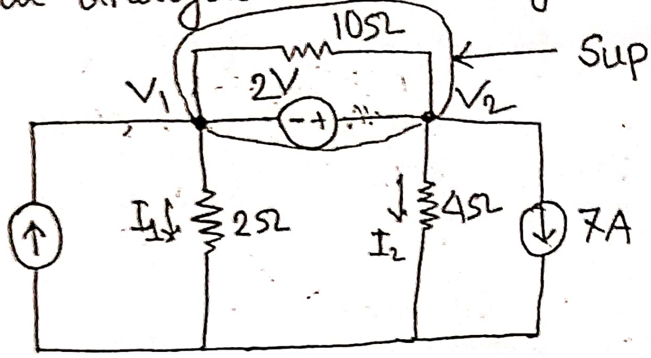


Solve:

Apply KCL at super node,

$$2 = I_1 + I_2 + 7$$

$$\Rightarrow 2 = \frac{V_1 - 0}{2} + \frac{V_2 - 0}{4} + 7$$

$$\Rightarrow 8 = 2V_1 + V_2 + 28$$

$$\Rightarrow 2V_1 + V_2 = -20 \quad \text{——— (i)}$$

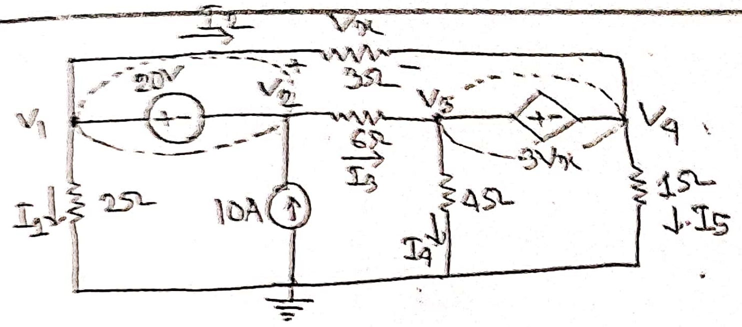
Apply KVL for super node,

$$V_1 - V_2 = -2 \quad \text{——— (ii)}$$

from equation (i) & (ii),

$$V_1 = -7.33\,V$$

$$V_2 = -5.33\,V.$$



Solve:

Apply KCL at super node ①:

$I_1 + I_2 + I_3 = 10$

$\Rightarrow \frac{V_1}{2} + \frac{V_1 - V_4}{3} + \frac{V_2 - V_3}{6} = 10$

$\Rightarrow 5V_1 + V_2 - V_3 - 2V_4 = 60$ —— (I)

Apply KCL at super node ②

$I_3 + I_2 = I_4 + I_5$

$\Rightarrow \frac{V_1 - V_4}{3} + \frac{V_2 - V_3}{6} = \frac{V_3}{4} + \frac{V_4}{1}$

$\Rightarrow 8V_1 + 4V_2 - 4V_3 - 8V_4 = 6V_3 + 24V_4$

$\Rightarrow 4V_1 + 2V_2 - 5V_3 - 16V_4 = 0$ —— (II)

From super node ①

$V_1 - V_2 = 20$ —— (III)

$V_1 - V_4 = V_x$

From Super node (II)

$V_3 - V_4 = 3V_x$

$\Rightarrow V_3 - V_4 = 3(V_1 - V_4)$

$\Rightarrow 3V_1 - V_3 - 2V_4 = 0$ —— (IV)

From equation (III) $\Rightarrow$ $V_1 = V_2 + 20$

(I) $\Rightarrow$ $6V_2 - V_3 - 2V_4 = -40$ —— (V)

(II) $\Rightarrow$ $6V_2 - 5V_3 - 16V_4 = -80$ —— (VI)

(IV) $\Rightarrow$ $3V_2 - V_3 - 2V_4 = -60$ —— (VII)

From equation (V), (VI), (VII);

$V_2 = 6.67V$, $V_3 = 173.33V$; $V_4 = -46.67V$.

$\therefore V_1 = 6.67 + 20 = 26.67V$

(Ans:)

Mesh analysis: Loop current $\neq$ Branch current

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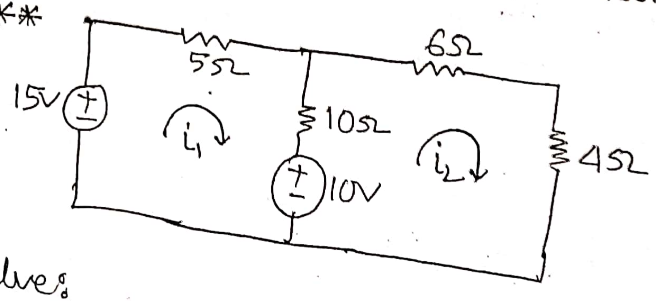


Solve:

Apply KVL at loop-(I)

$-15 + 5i_1 + 10(i_1 - i_2) + 10 = 0$

$\Rightarrow 15i_1 - 10i_2 = 5$

$\Rightarrow 3i_1 - 2i_2 = 1$ ——— (I)

Apply KVL at Loop-(II)

$6i_2 + 4i_2 - 10 + 10(i_2 - i_1) = 0$

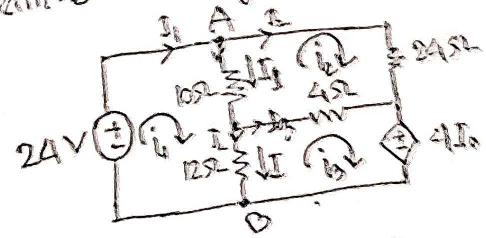
$\Rightarrow 20i_2 - 10i_1 = 10$

$\Rightarrow 2i_2 - i_1 = 1$ ——— (II)

from equation (I) & (II).

$i_1 = 1A$, $i_2 = 1$ Ans

Sub: Exam-56: Using mesh analysis find out i_1, i_2, i_3, I_0 | 16.02.17 5th EEE



loop current = i
Branch " = I

Apply KVL at loop-①

$-24 + 10(i_1 - i_2) + 12(i_1 - i_3) = 0$

$\Rightarrow 22i_1 + 10i_2 - 12i_3 = 24$ ——— ①

Apply KVL at loop-②

$24i_2 + 4(i_2 - i_3) + 10(i_2 - i_1) = 0$

$\Rightarrow -10i_1 + 38i_2 - 4i_3 = 0$

$\Rightarrow 10i_1 - 38i_2 + 4i_3 = 0$ ——— ⑪

Apply KVL at loop ③

$4I_0 + 12(i_3 - i_1) + 4(i_3 - i_2) = 0$

$\Rightarrow 4(i_1 - i_2) + 12(i_3 - i_1) + 4(i_3 - i_2) = 0$

$\Rightarrow -8i_1 - 8i_2 + 16i_3 = 0$ ——— ⑪⑪

$\Rightarrow i_1 + i_2 - 2i_3 = 0$

from ①, ⑪ & ⑪⑪.

$i_1 = 0.77A$, $i_2 = 0.15A$, $i_3 = -0.46A$.

Apply KCL at node A.

$i_1 = I_0 + i_2$

$\Rightarrow I_0 = i_1 - i_2$

$\Rightarrow I_0 = 0.77 - 0.15$

$= 0.62A$.

$P = I^2R$
$= \frac{V^2}{R}$

Apply KCL at node B

$I + i_3 = i_1$

$I = 1.23A$.

$P_{12} = I \cdot \times 12^2$

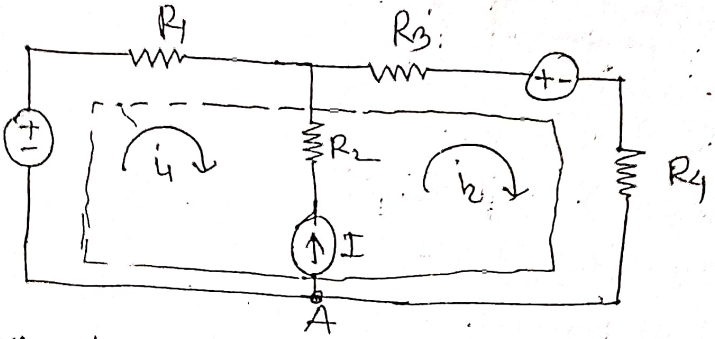
$= 1.23 \times 12^2$

$= 177.12$ Watt.

** Super mesh:

If a current source and a resistor in serise exist between two loop then: that is called super mesh.

**



Apply KVL at super mesh

$$-V_1 + i_1 R_1 + i_2 R_3 + V_2 + i_2 R_4 = 0 \quad \text{—— (i)}$$

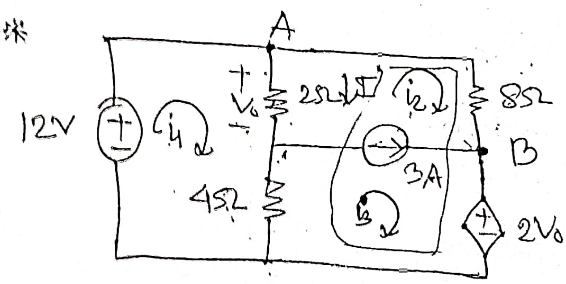
KCL at node A,

$i_1, i_2 = ?$

$$I + i_1 = i_2$$

$$\Rightarrow I = i_2 - i_1 \quad \text{—— (ii)}$$

**



Apply KVL at ~~super mesh (1)~~ loop (1)

$$-12 + 2(i_1 - i_2) + 4(i_1 - i_3) = 0$$

$$\Rightarrow 6i_1 - 2i_2 - 4i_3 = 12 \quad \text{—— (1)}$$

Apply KVL at super mesh

$8i_2+2(i_2-i_1)+2V_0+4(i_3-i_1)=0$ ——— (I)

Apply KCL at node A

$i_1 = I+i_2$

$\Rightarrow I = i_1-i_2$

$V_0 = 2I = 2(i_1-i_2)$

From (I) $\Rightarrow 8i_2+2i_2-2i_1+4i_1-4i_2+4i_3-4i_1=0$

$\Rightarrow -2i_1+6i_2+4i_3=0$

$\Rightarrow i_1-3i_2-2i_3=0$ ——— (III)

Apply KCL at node B.

$i_2+3=i_1$

(III) $\Rightarrow i_2+3-3i_2-2i_3=0$

$\Rightarrow 2i_2+2i_3=3$ ——— (IV)

(I) $\Rightarrow 6(i_2+3)-2i_2-4i_3=12$

$\Rightarrow 4i_2-4i_3=-6$ ——— (V)

from equation (IV) and (V).

$i_2=0A,\ i_3=1.5A$

$i_1=0+3=3A$ (Ans:)

Chapter 4.

17.09.17
5C-EEE

Theorem for circuit:

130 page

i. Superposition theorem ✓
ii. Source transformation theorem
iii. Norton's theorem
iv. Thevenin's theorem
v. Maximum power transfer theorem.

*A linear circuit is one whose output is linearly related (or directly proportional) to its input.

⊞ Superposition:

The superposition principle states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or currents through) that element due to each independent source acting alone.

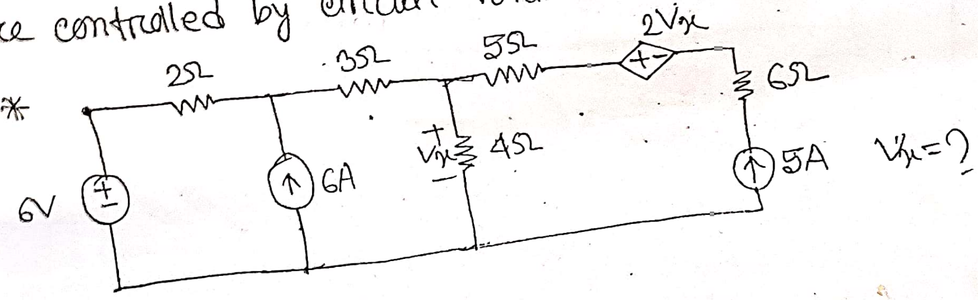
See example from book.

To apply the superposition principle, we must keep two things in mind:

1. We consider one independent source at a time while all other independent source are turned off. This implies that we replace every voltage source by 0V (or a short circuit), and every current source by 0A (or an open circuit). This way we obtain a simpler and more manageable circuit.

2. Dependent sources are left intact because they are controlled by circuit variables.

***



$V_x = ?$

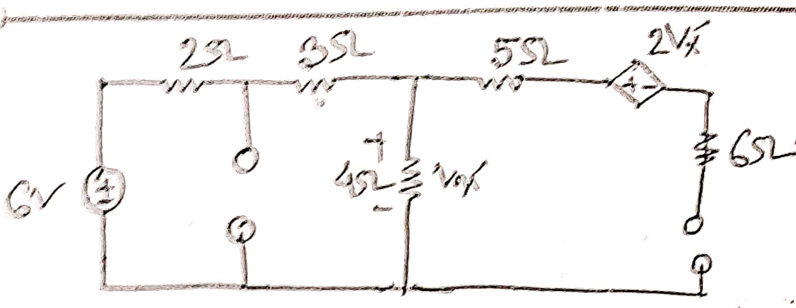
$V_x = V_{x_1} + V_{x_2} + V_{x_3}$

Where, V_{x_1}, V_{x_2}, V_{x_3} are due to the 6V, 6A, 5A source respectively.

To obtain V_{x_1}, we turn off the 6A and 5A source.

On the other hand, Dependent source এর short/open এর কোনোটিই হবে না।

NOTE: Independent source এর Voltage source হবে short হবে, Current source হবে open.

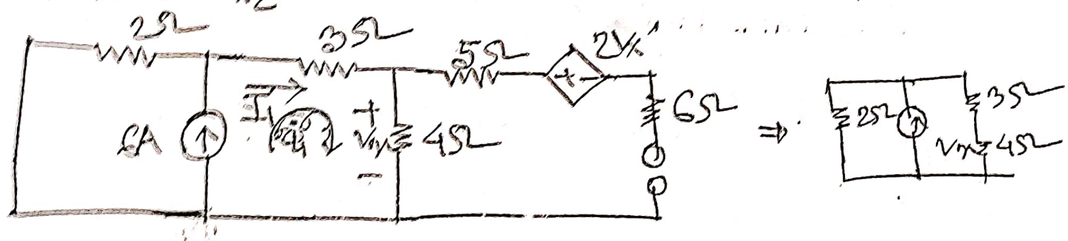


$V = \dfrac{\text{resistance of passage current}}{\text{total resistance}} \times \text{source}$

$I = \dfrac{\text{Parallel resistance}}{\text{flowing and parallel resistance}} \times \text{source.}$

$$V_{x_1} = \frac{4}{2+3+4} \times 6 = \frac{4}{9} \times 6 = \frac{8}{3}$$

To obtain V_{x_2} turn off 6V and 5A source.

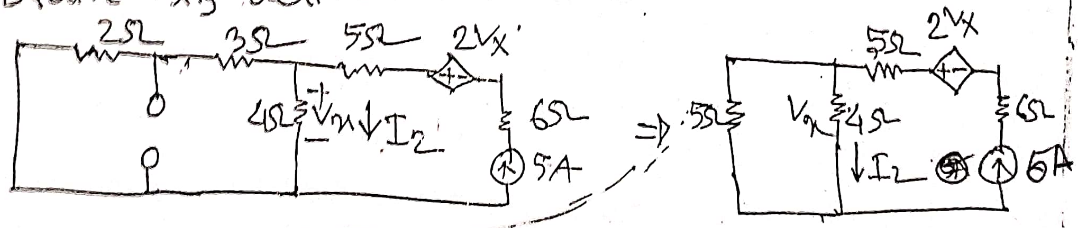


$$I = \frac{2}{2+3+4} \times 6 = \frac{4}{3}$$

$$V_{x_2} = 4 \times \frac{4}{3} = \frac{16}{3} \text{ V.}$$

DC [illegible] frequency zero

To obtain V_{x_3} active 5A source



$$I_2 = \frac{5}{5+4} \times 5 = \frac{25}{9}$$

$$V_{x_3} = 4 \times \frac{25}{9} = 100/9$$

$$V_x = V_{x_1} + V_{x_2} + V_{x_3} = \frac{8}{3} + \frac{16}{3} + \frac{100}{9} = 19.11 \text{ V.}$$

Sub:

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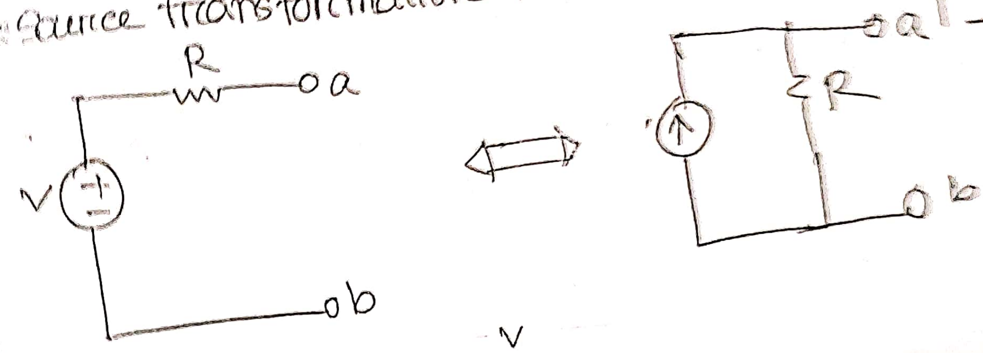
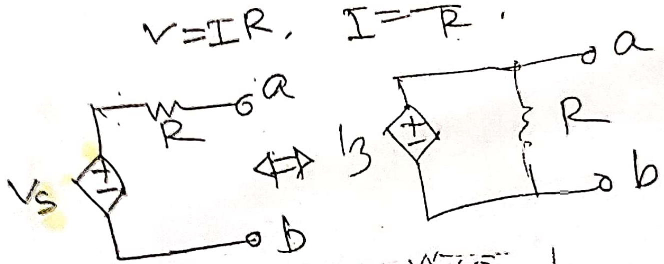
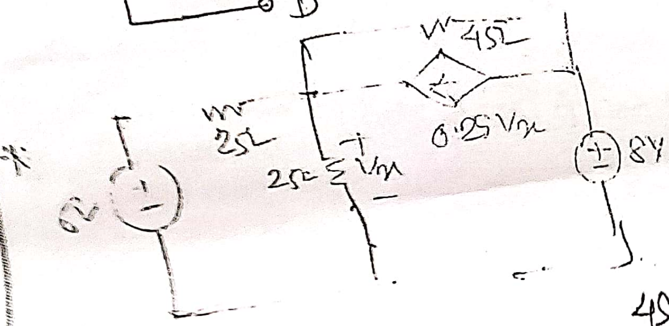
6A-EEE

* Source transformation method:



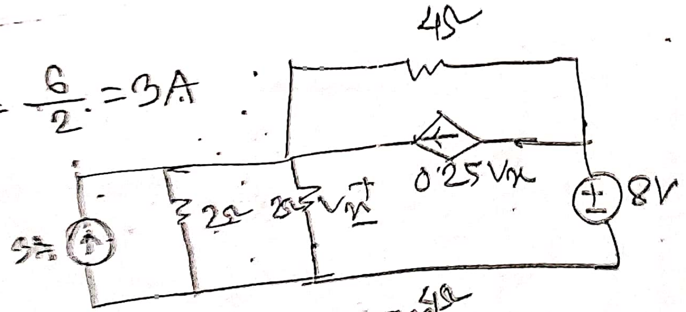
$V = IR, \quad I = \frac{V}{R}.$

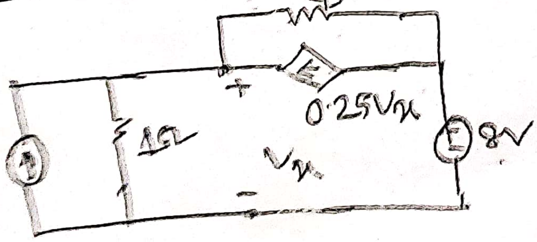


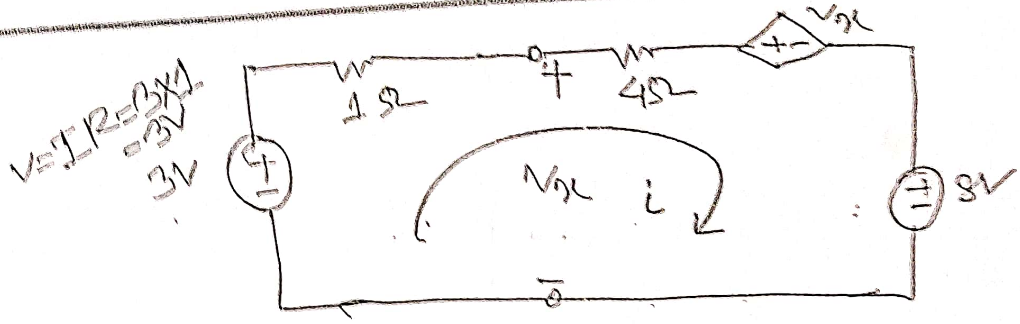


Find V_x using source transfer technique.

$i = \frac{6}{2} = 3A$





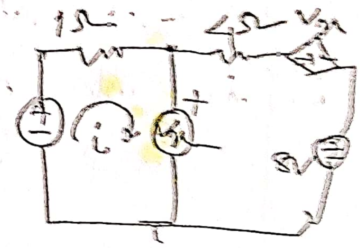


Apply KVL

$-3 + i\times1 + 4\times i + V_x + 8 = 0$ —— (i)

$\Rightarrow -3 + i + V_x = 0$

$\Rightarrow V_x = 3 - i$ —— (ii)



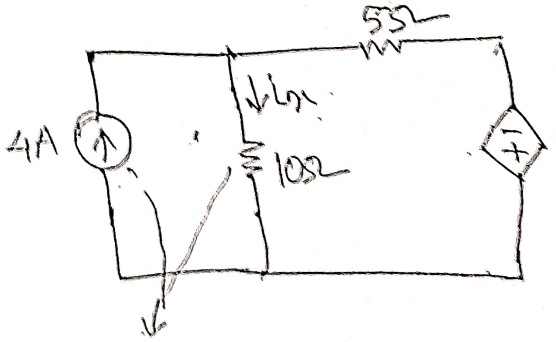
from (i)

$-3 + i + 4i + 3 - i + 8 = 0$

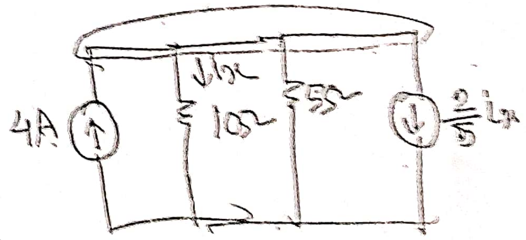
$\Rightarrow 4i = -8$

$i = -2$ (Ans:)

***



$i_x = ?$



Change করা যাবে না।
কারণ resistence আগে current transfer হতে পারতো না।

Apply KCL at node :

$$4 = i_x + i + \frac{2}{5} i_x \qquad i_x = \frac{V_1}{10}$$

$$\Rightarrow 4 = \frac{V_1}{10} + \frac{V_1}{5} + \frac{2}{5} i_x$$

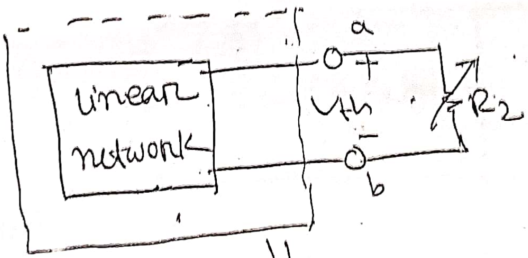
$$\Rightarrow 4 = \frac{3V_1}{10} + \frac{2}{5} \cdot \frac{V_1}{10} = \frac{3V_1}{10} + \frac{2V_1}{50}$$

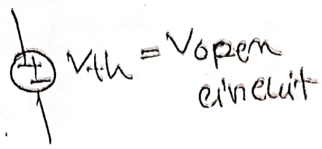
$$\Rightarrow 4 = \frac{17V_1}{50}$$

$$\Rightarrow V_1 = \frac{4 \times 50}{17}$$

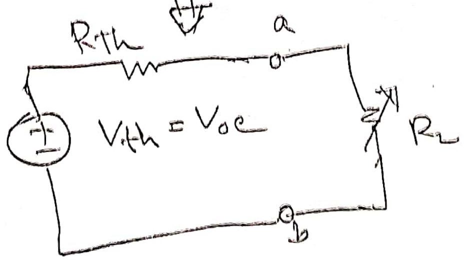
$$= 11.76 \text{ V.}$$

Thevenin's theorem:





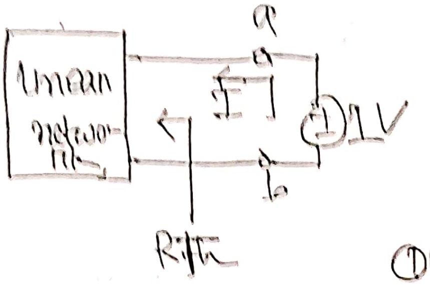
$\Downarrow$



$$R_{Th} = \frac{V_{oc}}{I_{sc}} = \frac{1V}{I} = R_{Th}$$

Voltage short V=0
Current open I=0

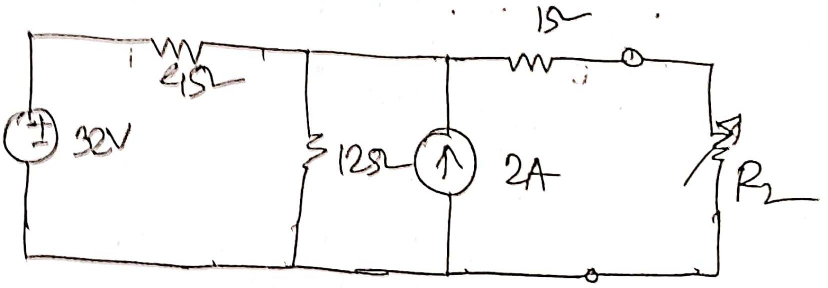
dependent source থাকলে →

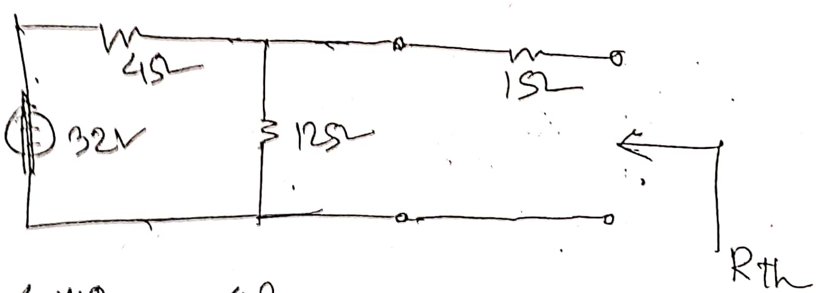


Application of thevenin's theorem:
① Maximum power transfer.

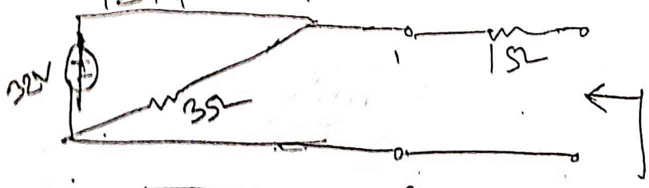
Example 4.8:

H.W. 4.9

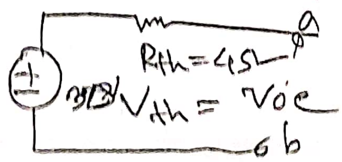


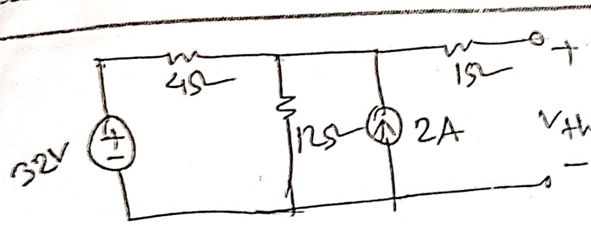


$$R_p = \frac{4 \times 12}{12+4} = \frac{48}{16} = 3\Omega$$



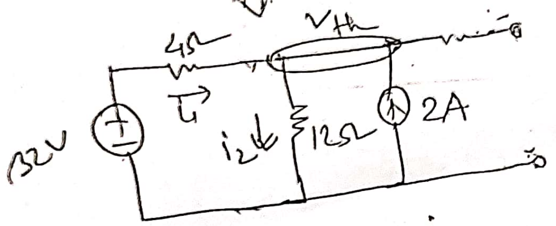
$R_{Th} = 3+1 = 4\Omega$





$V_{th} = V_{oc}$

$\Downarrow$



$\cancel{i_1 + i_2 =}$ $\; i_1 + 2 = i_2$

$\Rightarrow \dfrac{32 - V_{th}}{4} + 2 = \dfrac{V_{th}}{12}$

$\Rightarrow \dfrac{40 - V_{th}}{4} = \dfrac{V_{th}}{12}$

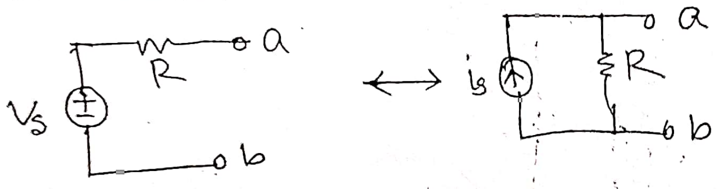
$\Rightarrow 480 - 12V_{th} = 4V_{th}$

$\Rightarrow 16V_{th} = 480$

$\Rightarrow V_{Th} = 30V.$

* Source transformation theorem:

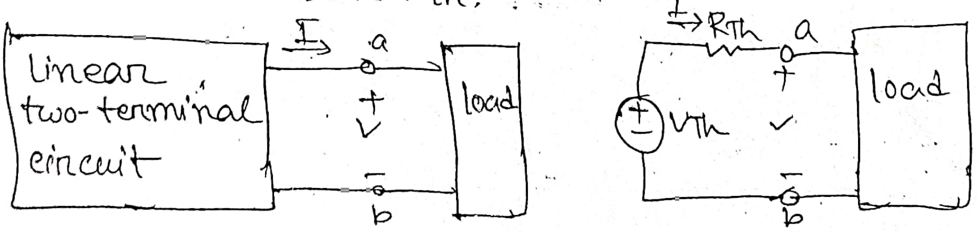
A source transformation is the process of replacing a voltage source V_s in series with a resistance R by a current source, i_s in parallel with a resistor R, or vice versa.



$$V_s = i_s R \text{ , or } i_s = \frac{V_s}{R}$$

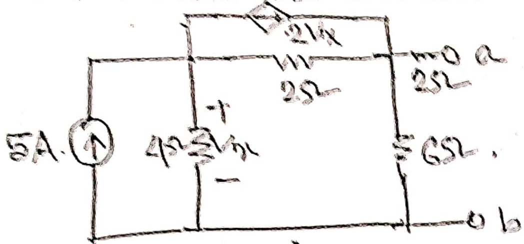
*Thevenin's theorem:

A linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} ~~in terminals and R_{Th} is the input or equivalent resistance~~ series with a resistor R_{Th}.

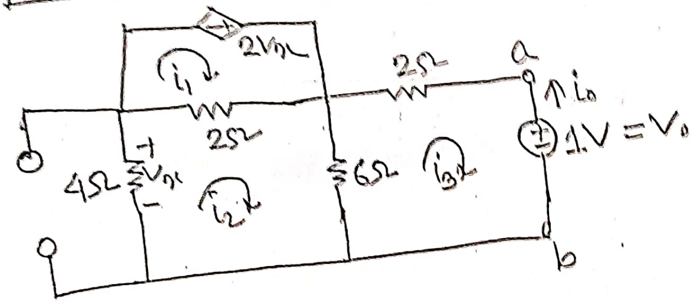


Exm 4.9: Find the thevenin circuit:

23.09.17
6B-EEE



Solve:



$R_{Th} = ?$

$V_{Th} = ?$

Applying mesh analysis to loop 1 $\Rightarrow$

$-2V_x + 2(i_1 - i_2) = 0$ | $V_x = -4i_2$

$\Rightarrow V_x = i_1 - i_2$

$\Rightarrow -4i_2 = i_1 - i_2$

$\Rightarrow i_1 = -3i_2$ —— (I)

Apply KVL at loop 2 $\Rightarrow$ $4i_2 + 2(i_2 - i_1) + 6(i_2 - i_3) = 0$ —— (II)

Apply KVL at loop 3 $\Rightarrow$ $6(i_3 - i_2) + 2i_3 + 1 = 0$ —— (III)

from (II), $4i_2 + 2(i_2 + 3i_2) + 6(i_2 - i_3) = 0$

$\Rightarrow 4i_2 + 8i_2 + 6i_2 - 6i_3 = 0$

$\Rightarrow 18i_2 - 6i_3 = 0.$ —— (IV)

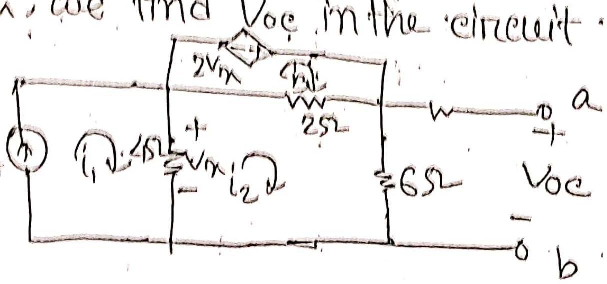
From (iii) ⇒ $-6i_2 + 8i_3 = -1$ —— (v)

(iv) and (v) ⇒ $i_2 = -\frac{1}{18}A$ $\quad i_3 = -\frac{1}{6}A$

$i_0 = -i_3 = \frac{1}{6}A$.

∴ $R_{Th} = \frac{1V}{i_0} = 6\Omega$.

To get V_{Th}, we find V_{oc} in the circuit.



Loop 1

$i_1 = 5A$.

Loop 3

$-2V_x + 2(i_3 - i_2) = 0$

⇒ $V_x = i_3 - i_2$ —— (i)

Loop 2

$4(i_2 - i_1) + 2(i_2 - i_3) + 6i_2 = 0$

⇒ $12i_2 - 4i_1 - 2i_3 = 0$.

⇒ $12i_2 - 2i_3 = 20$ [∵ $i_1 = 5A$] —— (ii)

again, $V_x = 4(i_1 - i_2)$

⇒ $i_3 - i_2 = 4(5 - i_2)$

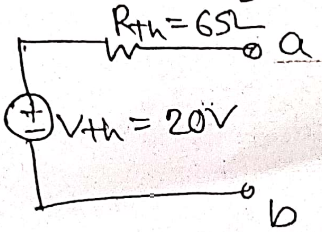
⇒ $i_3 - i_2 = 20 - 4i_2$

⇒ $3i_2 + i_3 = 20$ —— (iii)

From (ii) and (iii) $i_2 = \frac{10}{3} A$, $i_3 = 10 A$.

$$V_{oc} = V_{Th} = 6 i_2$$
$$= 20 V.$$

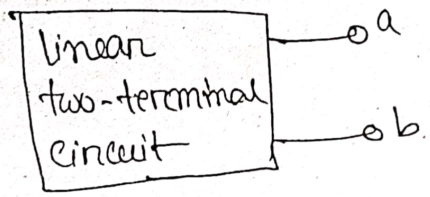
∴ The thevenin equivalent is shown :



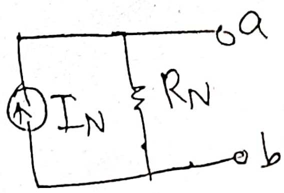
$$R_{th} = \frac{V_{th}}{I_N} = R_N$$

Northon's theorem:

Northon's theorem states that a linear two terminal circuit can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N.



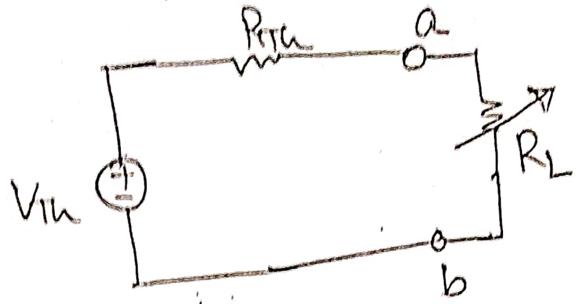
Where,
I_N = short circuit current.
R_N = input or equivalent resistance when independent source are turned off.



$$R_{th} = \frac{V_{oc}}{I_{sc}} = R_N \cdot$$

$R_N = R_{Th}$ $I_N = I_{sc}$.

** Maximum power transfer theorem:



The thevenin equivalent is useful in finding the maximum power a linear circuit can deliver to a load. We assume that we can adjust the load resistance R_L. If the entire circuit is replaced by its thevenin equivalent except for the load, as shown in the figure, the power delivered to the load is.

$$i = \frac{V_{TH}}{R_{TH}+R_L}$$

$$P = i^2 R_L$$

$$\Rightarrow P = \left(\frac{V_{TH}}{R_{TH}+R_L}\right)^2 \cdot R_L \text{ ——— } (1)$$

$$\frac{dP}{dR_L} = 0$$

$$\Rightarrow V_{TH}^2 \left[\frac{(R_{TH}+R_L)^2 - 2R_L(R_{TH}+R_L)}{(R_{TH}+R_L)^4}\right] = 0$$

$$\Rightarrow V_{TH}^2 \left[\frac{R_{TH}+R_L - 2R_L}{(R_{TH}+R_L)^3}\right] = 0$$

Sub:

$\Rightarrow R_{TH} + R_L - 2R_L = 0$

$\Rightarrow R_{TH} - R_L = 0.$

$\Rightarrow R_{TH} = R_L.$

$\therefore$ Maximum power is transfer to the load when the load resistance equals the thevenin resistance as seen from the load ($R_L = R_{TH}$).

$\therefore$ from ① $\Rightarrow$

$$\therefore P_{max} = \frac{V_{TH}^2}{4R_{TH}}$$

Chapter- 9

Sinusoids and phasors

24.09.17
6C-EEE

A sinusoid is a signal that has the form of the sine or cosine function.

Consider the sinusoidal voltage

$$v(t) = V_m \sin \omega t$$

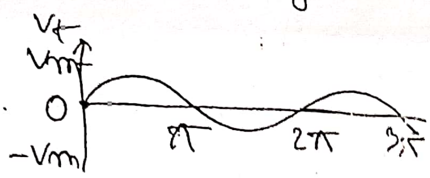
Where, V_m = the amplitude of the sinusoid

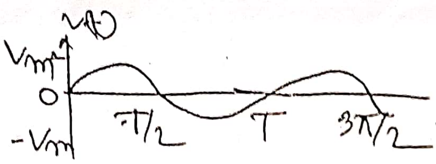
ω = the angular frequency in radians/s

ωt = the argument of the sinusoid.

$T = \frac{2\pi}{\omega}$

$f = \frac{1}{T}$





50 Hz; $T = \frac{1}{50} = 20ms$.

Phasors:

A phasor is a complex number that represents the amplitude and phase of a sainusoid.

A complex number z can be written in rectangular form as, $z = x + jy$; $j = \sqrt{-1}$

Where, x = real part. y = imaginary part.

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The complex number z can ~~be~~ also be written in polar or exponential form as.

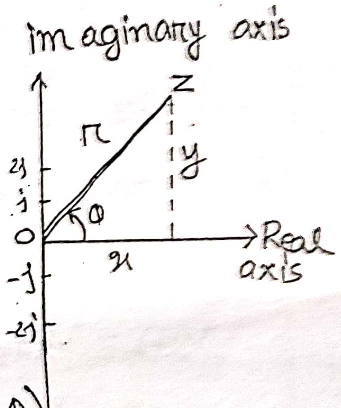
$$z = r\angle\phi = re^{j\phi}$$

Where r is the magnitude of z, and ϕ is the phase of z. We notice that z can be represented in three ways.

$z = x + jy$ Rectangular form

$z = r\angle\phi$ Polar form

$z = re^{j\phi}$ Exponential form



$r = \sqrt{x^2 + y^2}$, $\phi = \tan^{-1}\frac{y}{x}$

and, $x = r\cos\phi$. $y = r\sin\phi$

z may be written as,

$$z = x + jy = r\angle\phi = r(\cos\phi + j\sin\phi)$$

Kirchhoff's Laws in the frequency domain:

For KVL, let $v_1, v_2, \ldots, v_n$ be the voltages around a closed loop. Then,

$$v_1 + v_2 + \cdots + v_n = 0.$$

In the sinusoidal steady state, each voltage may be written ~~a closed loop~~ in cosine form, so that Equation becomes.

$$V_{m_1}\cos(\omega t+\theta_1) + V_{m_2}\cos(\omega t+\theta_2) + \cdots + V_{mn}\cos(\omega t+\theta_n) = 0 \quad (1)$$

Time domain	Phasor
$v_1(t) = V_{m_1}\cos(\omega t+\theta_1)$	$V_1 = V_{m_1}\angle\phi_1$
$v_2(t) = V_{m_2}\cos(\omega t+\theta_2)$	$V_2 = V_{m_2}\angle\theta_2$
$v_n(t) = V_{mn}\cos(\omega t+\theta_n)$	$V_n = V_{mn}\angle\theta_n$.

class lecture

From equation (1)

$$V_{m_1}\angle\phi_1 + V_{m_2}\angle\phi_2 + \cdots + V_{mn}\angle\theta_n = 0$$

This can be written as.

$$\mathrm{Re}\left(V_{m_1}e^{j\theta_1}\cdot e^{j\omega t}\right) + \mathrm{Re}\left(V_{m_2}e^{j\theta_2}e^{j\omega t}\right) + \cdots + \mathrm{Re}\left(V_{mn}e^{j\theta_n}\cdot e^{j\omega t}\right) = 0$$

or, $\mathrm{Re}\left[\left(V_{m_1}e^{j\theta_1} + V_{m_2}e^{j\theta_2} + \cdots + V_{mn}e^{j\theta_n}\right)e^{j\omega t}\right] = 0$

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If we let, $V_k = V_{mk} e^{j\theta_k}$, then

$$Re\left[(V_1+V_2+\cdots+V_n)\,e^{j\omega t}\right]=0$$

Since $e^{j\omega t} \neq 0$,

$$V_1+V_2+\cdots+V_n=0.$$

indicating that Kirchhoff's voltage law holds for phasors.

By following a similar procedure, we can show that Kirchhoff's current law holds for phasors. If we let $i_1, i_2 \ldots i_n$ be the current leaving or entering a closed surface in a network at time t, then

$$i_1+i_2+\cdots+i_n=0$$

If $I_1, I_2, \ldots I_n$ are the phasor forms of the sinusoids $i_1, i_2, \ldots i_n$ then

$$I_1+I_2+\cdots+I_n=0.$$

which is Kirchhoff's current ~~forms of the sinusoids~~ law in the frequency domain.

Time domain	Phasor
$i_1 = I_{m_1}\cos(\omega t+\theta_1)$	$I_1 = I_{m_1}\angle\phi_1$
$i_2 = I_{m_2}\cos(\omega t+\theta_2)$	$I_2 = I_{m_2}\angle\phi_2$
$i_3 = I_{m_3}\cos(\omega t+\theta_3)$	$I_3 = I_{m_3}\angle\phi_3$

$\therefore i_1(t)+i_2(t)+\cdots+i_n(t)=0$

$I_1+I_2+\cdots+I_n=0$

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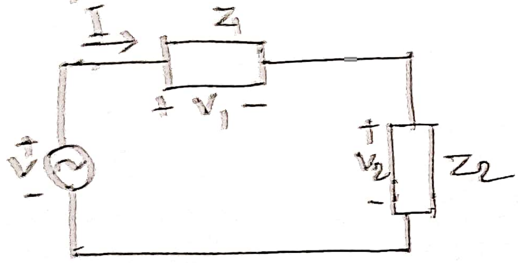
* Impedance combinations:

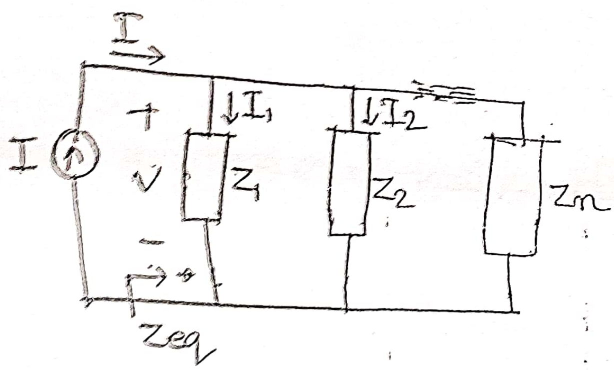


$$I = \frac{V}{Z_1 + Z_2}$$

$V_1 = Z_1 I$ and $V_2 = Z_2 I$

$$V_1 = \frac{Z_1}{Z_1 + Z_2} \times V, \quad V_2 = \frac{Z_2}{Z_1 + Z_2} \times V.$$

$$\therefore V_n = \frac{Z_n}{Z_1 + Z_2 + \cdots + Z_n} \times V$$



$$I_1 = \frac{Z_2}{Z_1 + Z_2} \times I \qquad I_2 = \frac{Z_1}{Z_1 + Z_2} \times I$$

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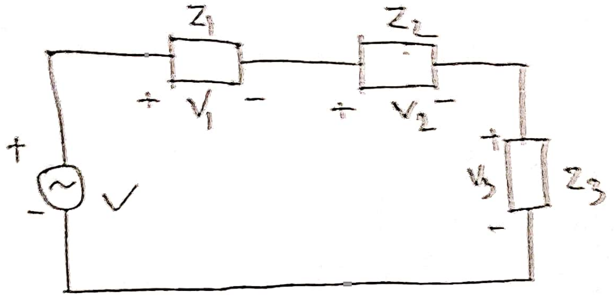
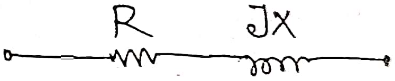


$$V = V_m \sin(\omega t + \theta) V$$

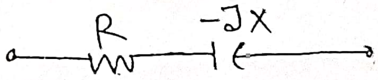
$$= V_m \angle \theta$$

Voltage divider rule:

$$V_3 = \frac{Z_3}{Z_1 + Z_2 + Z_3} \times V.$$



$Z = R + JX$



$Z = R - JX$.

$Z = R$

It can be,

$Z = R \pm JX$

$= R$

$= -JX$

$= +JX$

$Z = R + JX_L$

$Z = R - JX_C$

Current divider rule:

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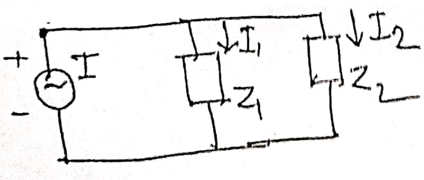
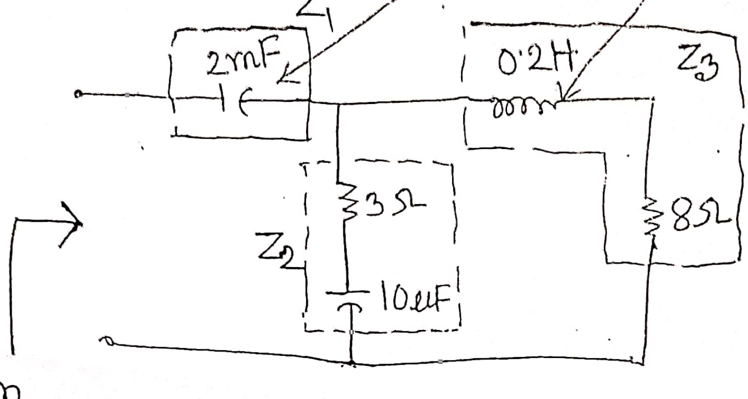


$V = IZ$.

Example 9.10:



$X_L = \omega L$

$X_C = \frac{1}{\omega C}$

$\omega = 50$ rad/s. $Z_{in} = ?$

$$X_{C_1} = \frac{1}{\omega C} = \frac{1}{50 \times 2 \times 10^{-3}} = 10\,\Omega$$

$$X_L = \omega L = 50 \times 0.2 = 10\,\Omega$$

$$Z_1 = -jX_{C_1} = -j10\,\Omega$$

$$Z_2 = R - jX_{C_2}$$

$$= 3 - j \cdot \frac{1}{50 \times 10 \times 10^{-3}}$$

$$= (3 - j2)\,\Omega$$

$$Z_3 = R + jX_L = (8 + j10)\,\Omega$$

$$Z_{in} = Z_1 + Z_2 \parallel Z_3$$

$$= Z_1 + \frac{Z_2 Z_3}{Z_2 + Z_3}$$

$$= -j10 + \frac{(3-j2)(8+j10)}{3 - j2 + 8 + j10} = 11.52\angle -73.774$$

Ans

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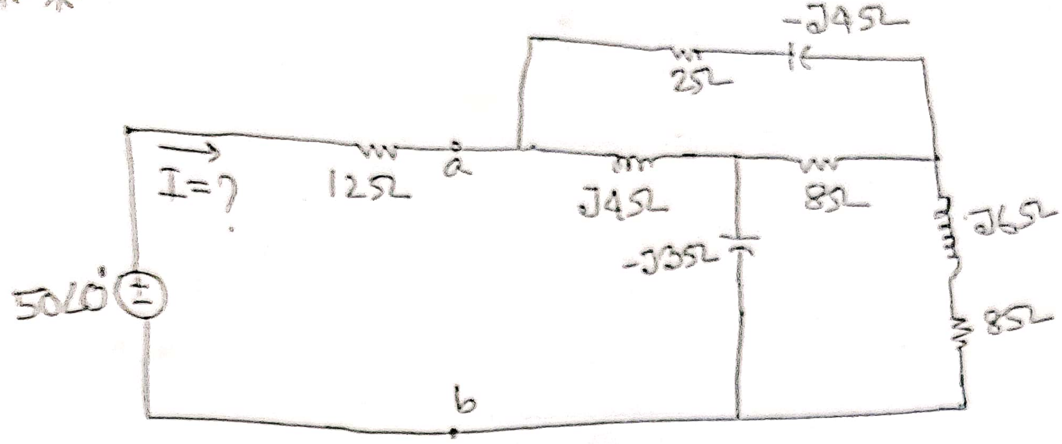

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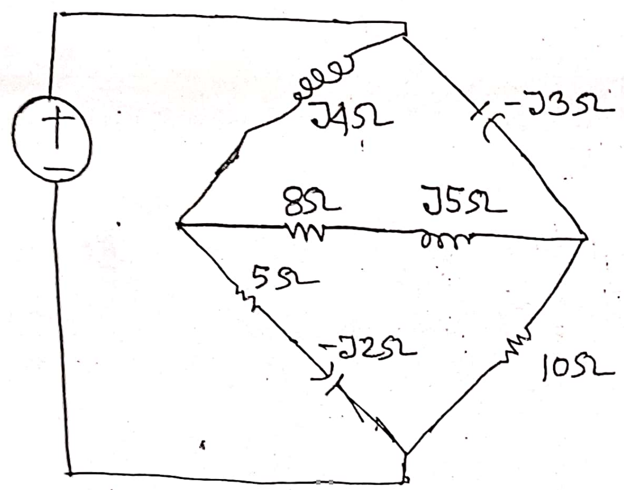
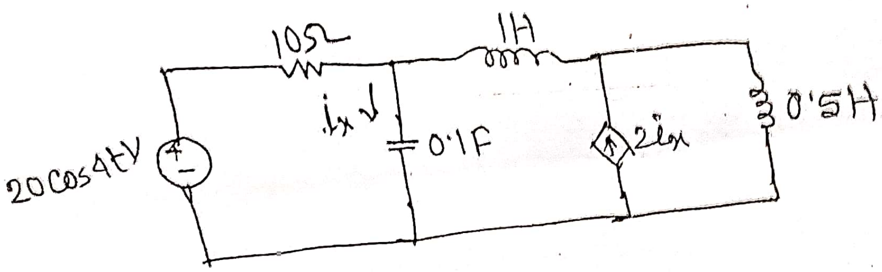


Chapter 10

Sinusoidal steady-state Analysis

Exmple 10.2: Find i_x from the figure.



Solve:

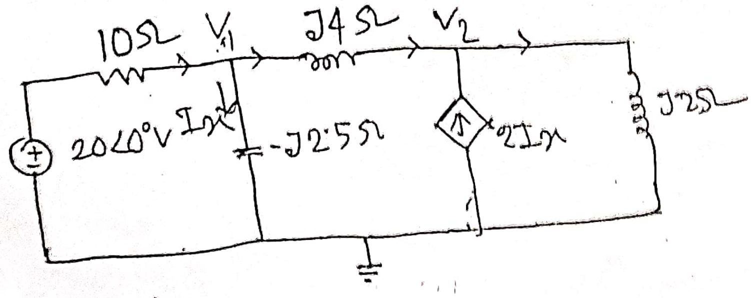
We first convert the circuit to the frequency domain:

$20 \cos 4t \Rightarrow 20\angle 0^\circ$, $\omega = 4$ rad/s

$1H \Rightarrow j\omega L = j4$

$0.5H \Rightarrow j\omega L = j2$

$0.1F \Rightarrow \frac{1}{j\omega C} = -j2.5$



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Apply KCL at node 1.

$$\frac{20-V_1}{10} = \frac{V_1}{-j2.5} + \frac{V_1-V_2}{j4}$$

or, $(1+j1.5)V_1 + j2.5\,V_2 = 20$ ——— ①

Apply KCL at node 2

$$2I_x + \frac{V_1-V_2}{j4} = \frac{V_2}{j2}$$

But. $I_x = V_1/-j2.5$. substituting this gives

$$\frac{2V_1}{-j2.5} + \frac{V_1-V_2}{j4} = \frac{V_2}{j2}$$

By simplifying we get

$$11V_1 + 15V_2 = 0 \quad \text{——— ②}$$

Equation ① and ② can be put in matrix from as

$$\begin{bmatrix} 1+j1.5 & j2.5 \\ 11 & 15 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 0 \end{bmatrix}$$

We obtain the determinats as.

$$\Delta = \begin{vmatrix} 1+j1.5 & j2.5 \\ 11 & 15 \end{vmatrix} = 15-j5 \qquad \Delta_2 = \begin{vmatrix} 1+j1.5 & 20 \\ 11 & 0 \end{vmatrix} = -220$$

$$\Delta_1 = \begin{vmatrix} 20 & j2.5 \\ 0 & 15 \end{vmatrix} = 300$$

$$V_1 = \frac{\Delta_1}{\Delta} = \frac{300}{15-j5} = 18.97\angle 18.43^\circ \text{ V}.$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{-220}{15-j5} = 13.91\angle 198.3^\circ \text{ V}$$

The current I_x is given by,

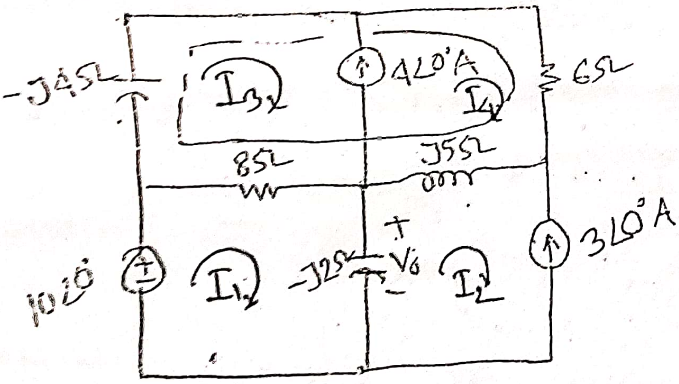
$$I_x = \frac{V_1}{-j2.5} = \frac{18.97\angle 18.43^\circ}{2.5\angle -90^\circ} = 7.59\angle 108.4^\circ \text{ A}.$$

Transforming this to the time domain.

$$i_x = 7.959\cos(4t + 108.4^\circ) \text{ A}$$

(Ans)

*** Example 10.4:



$V_o = ?$

Solve:

Apply KVL at supermesh.

$$-10 + \cancel{(8-j2)}\, 8(I_1 - I_2) - j2(I_4 - I_4) = 0$$

$$\Rightarrow (8-j2)I_1 + j2I_4$$

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As shown in fig meshes 3 and 4 from a supermesh due to the current source between the meshes. For mesh 1.

$$-10+(8-J2)I_1-(-J2)I_2-8I_3=0$$

$$\Rightarrow (8-J2)I_1+J2I_2-8I_3=10 \quad \text{—— (i)}$$

For mesh 2, $I_2=-3$ —— (ii)

For the supermesh,

$$(8-J4)I_3-8I_1+(6+J5)I_4-J5I_2=0 \quad \text{—— (iii)}$$

Due to the current source between meshes 3 and 4 at node A.

$$I_4=I_3+4 \quad \text{—— (iv)}$$

from equation (1) and (2).

$$(8-J2)I_1-8I_3=10+J6 \quad \text{—— (v)}$$

from (iii) and (iv).

$$-8I_1+(14+j)I_3=-24-J35 \quad \text{—— (vi)}$$

From (v) and (vi)

$$\begin{bmatrix} 8-J2 & -8 \\ -8 & 14+J \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10+J6 \\ -24-J35 \end{bmatrix}$$

We obtain the following determinants,

$$\Delta = \begin{vmatrix} 8-J2 & -8 \\ -8 & 14+J \end{vmatrix} = 112+J8-J28+2-64 = 50-J20$$

$$\Delta_1 = \begin{vmatrix} 10+J6 & -8 \\ -24-J35 & 14+J \end{vmatrix} = 140+J10+J84-6-192-J280$$

$$= -58-J186.$$

Current I is obtained as

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{-58-J186}{50-J20} = 3.618\angle 274.5^\circ A$$

The required voltage V_o is,

$$V_o = -J2(I_1 - I_2) = -J2(3.618\angle 274.5 + 3)$$

$$= -7.2134 - J6.568 = 9.756\angle 222.32\ V$$

Alternating current (AC) and voltage

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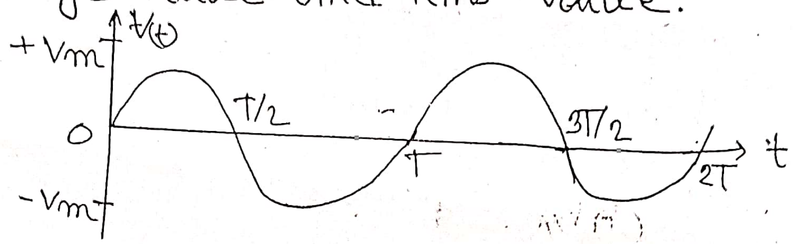
⇒ Average value and rms value.



We know, $V(t) = V_m \sin \omega t$

$$V_{average} = \frac{1}{T}\int_0^T V(t)\,dt$$

$$= \frac{1}{T}\left[\int_0^{T/2} V_m \sin\omega t\,dt + \int_{T/2}^{T} V_m \sin\omega t\,dt\right]$$

$$= \frac{V_m}{T}\left[\frac{-\cos\omega t}{\omega}\right]_0^{T/2} + \frac{V_m}{T}\left[\frac{-\cos\omega t}{\omega}\right]_{T/2}^{T}$$

$$= \frac{V_m}{T}\left[-\cos\omega T/2 + \cos 0^\circ - \cos\omega T + \cos\omega T/2\right]$$

$$= \frac{V_m}{T}\left[1 - \cos\omega T\right]$$

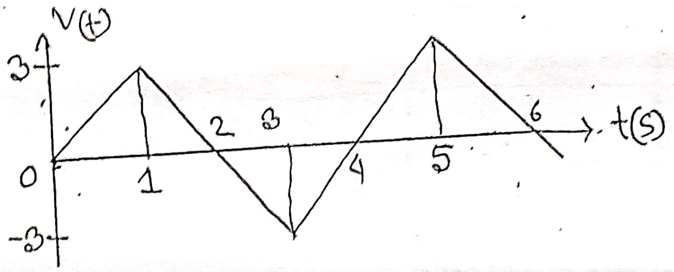
$$= \frac{V_m}{T}(1 - \cos 2\pi)$$

$$= 0$$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v(t)^2\,dt}$$

$$= \sqrt{\frac{1}{T}\int_0^T V_m^2 \sin^2 \omega t\,dt}$$

**



$$\frac{y-y_1}{y_1-y_2} = \frac{x-x_1}{x_1-x_2}$$

$$\Rightarrow \frac{V_t-3}{3-(-3)} = \frac{t-1}{1-3}$$

$$\Rightarrow V_t = \left(6\times\frac{t-1}{-2}\right)+3$$

$$= -3t+3+3$$

$$= -3t+6$$

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$$V_{rms} = \sqrt{\frac{2}{4}\int_0^{T/2} v(t)^2\, dt}$$

$$= \sqrt{\frac{1}{2}\int_0^{3} (-3t+6)^2\, dt}$$

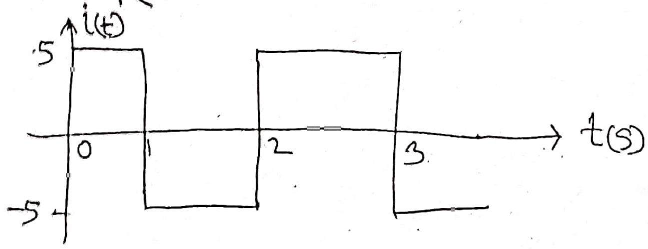
$$= \sqrt{\frac{1}{2}\int_0^{3} (9t^2-36t+36)\, dt}$$

$$= \frac{1}{\sqrt{2}}\left[\frac{9t^3}{3} - \frac{36t^2}{2} + \frac{36t}{2}\right]_0^3$$

$$=$$

$$P_R = \frac{V_{rms}^2}{R}$$

**



$i(t) = 5 \quad ; 0 < t < 1$

$i(t) = -5 \quad ; 1 < t < 2$

$$I_{rms} = \sqrt{\frac{2}{2}\int_0^1 25t}$$

$$= \sqrt{25} = 5.$$

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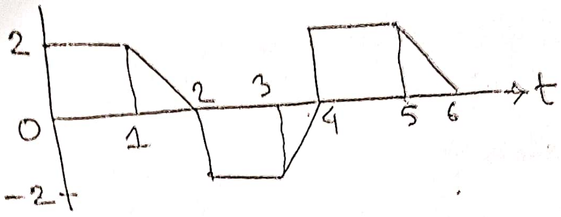


$0 < t < 1$; $V_1(t) = 2$

$1 < t < 2$; $\frac{V_2(t) - 2}{2 - 0} = \frac{t-1}{1-2}$

$\Rightarrow V_2(t) = \left(\frac{t-1}{-1}\right) \times 2 + 2$

$= -2t + 2 + 2$

$= -2t + 4$

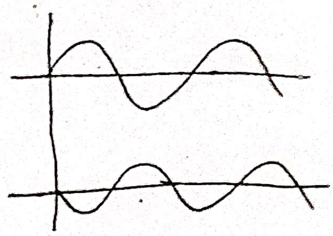
$V_t = V_1(t) + V_2(t) = 2 - 2t + 4 = -2t + 6$

$V_t = \sqrt{\frac{2}{4} \int_0^1 4\,dt + \int_1^2 (-2t+6)^2\,dt}$

AC power / instantaneous power

$$v(t) = V_m \cos(\omega t + \theta_v)$$

$$i(t) = I_m \cos(\omega t + \theta_i)$$



$$P(t) = v(t)\, i(t)$$

$$= V_m I_m \cos(\omega t + \theta_v) \cos(\omega t + \theta_i)$$

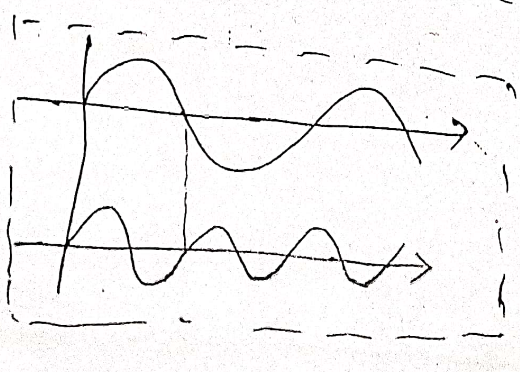
$$= \frac{V_m I_m}{2} \cdot 2\cos(\omega t + \theta_v) \cos(\omega t + \theta_i)$$

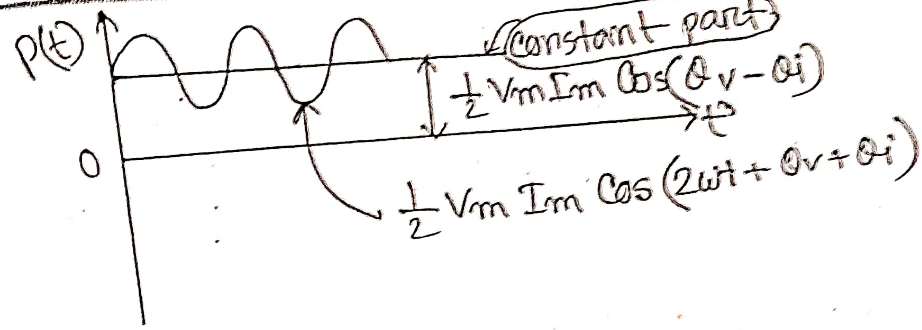
$$= \frac{V_m I_m}{2} \left[\cos(\omega t + \theta_v + \omega t + \theta_i) + \cos(\omega t + \theta_v - \omega t - \theta_i) \right]$$

$$= \frac{1}{2} V_m I_m \left[\cos(2\omega t + \theta_v + \theta_i) + \cos(\theta_v - \theta_i) \right]$$

Time independent part $= \cos(\theta_v - \theta_i)$

Time dependent part $= \cos(2\omega t + \theta_v + \theta_i)$.





Average power

$$P_{average} = \frac{1}{T} \int_0^T p(t)\, dt$$

$$= \frac{1}{T} \int_0^T \frac{1}{2} V_m I_m \begin{bmatrix} \cos(2\omega t + \theta_v + \theta_i) + \\ \cos(\theta_v - \theta_i) \end{bmatrix}$$

$$= \frac{V_m I_m}{2T} \int_0^T \cos(\theta_v - \theta_i)\, dt + \frac{V_m I_m}{2T} \int_0^T \cos(2\omega t + \theta_v + \theta_i)\, dt$$

$$= \frac{V_m I_m}{2} \cos(\theta_v - \theta_i) + 0$$

$$= \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$$

Power factor $= \cos(\theta_v - \theta_i)$

Chapter 11

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Power for ac circuit:

$P = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$ [real power/ average power]

$= V_{rms} \cdot I_{rms} \cos(\theta_v - \theta_i)$

$V_{rms} = \frac{V_m}{\sqrt{2}}$ $I_{rms} = \frac{I_m}{\sqrt{2}}$

V.V.I Complex power:

$S = \frac{1}{2} V I^*$ $* =$ conjugate.

$= \frac{1}{2} V_m \angle\theta_v \cdot I_m \angle -\theta_i$

$= \frac{1}{2} V_m I_m \angle\theta_v - \theta_i$

$= \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i) + j \frac{1}{2} V_m I_m \sin(\theta_v - \theta_i)$

$$\boxed{\begin{aligned} V(t) &= V_m \sin(\omega t + \theta_v) \\ V &= V_m \angle\theta_v . \end{aligned}}$$

$\therefore S = V_{rms} I_{rms} \cos(\theta_v - \theta_i) + j V_m I_m \sin(\theta_v - \theta_i)$

$S = P \pm JQ$

P = real power/ average power

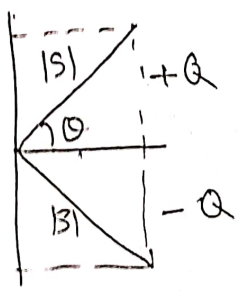
Q = reactive power.

For pure ~~restive~~ resistive, $S = P$.

If it will pure inductive or capacitive
$S = Q$ or $-Q$.

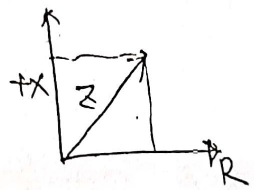
magnatude of ~~capacitor~~ complex power is equal to apparent power $= \frac{1}{2} V_m I_m$.

$S = P \pm JQ$

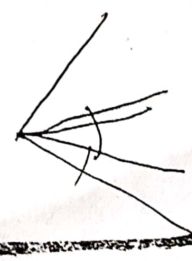


power triangle

$Z = R \pm JX$

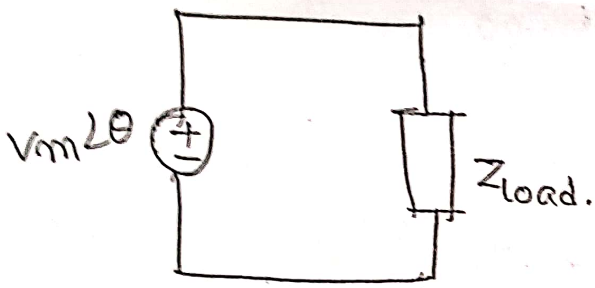


Impedance power triangle.

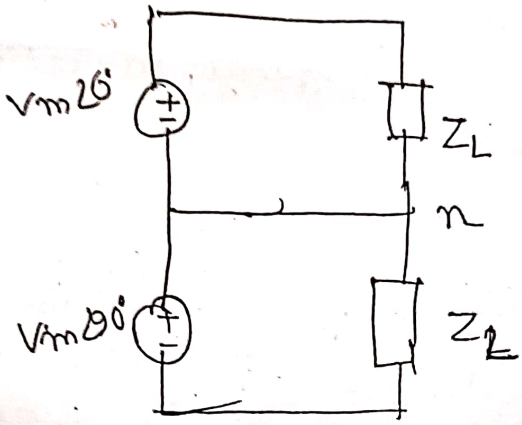


Three phase / Poly phase system

If two or more than two voltage source operate at the same frequency are ~~cause~~ called polyphase system.



Single phase two wire system.

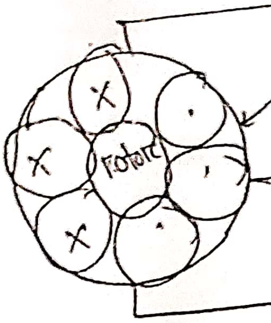


two phase three wire system.

Three phase system are two types:

① Y - connection.

⑪ Δ - connection.



$V_a \,/\, V_{an} = V_p \angle 0^\circ$

$V \begin{cases} \text{(i) conductor} \\ \text{(ii) flux} \\ \text{(iii) motion.} \end{cases}$

$V_b \,/\, V_{bn} = V_p \angle -120^\circ$

$V_c \,/\, V_{cn} = V_p \angle -240 = V_p \angle +120^\circ.$

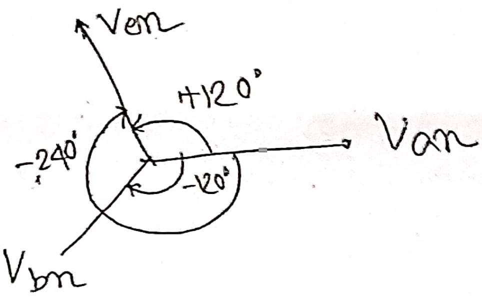
$V_{an} = V_p \angle 0^\circ$

$V_{bn} = V_p \angle -120^\circ$

$V_{cn} = V_p \angle +120^\circ = V_p \angle -240^\circ.$

$|V_{an}| = |V_{bn}| = |V_{cn}|$

120° out of phase.



The condition of three phase system:

Every phase is differ from 120° angle.

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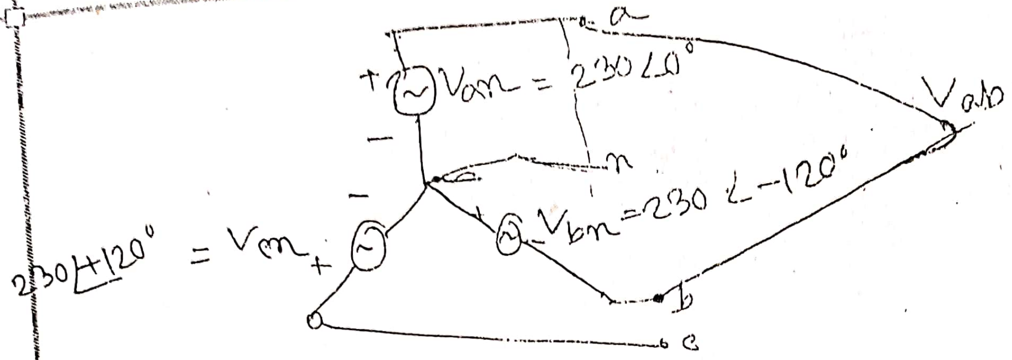
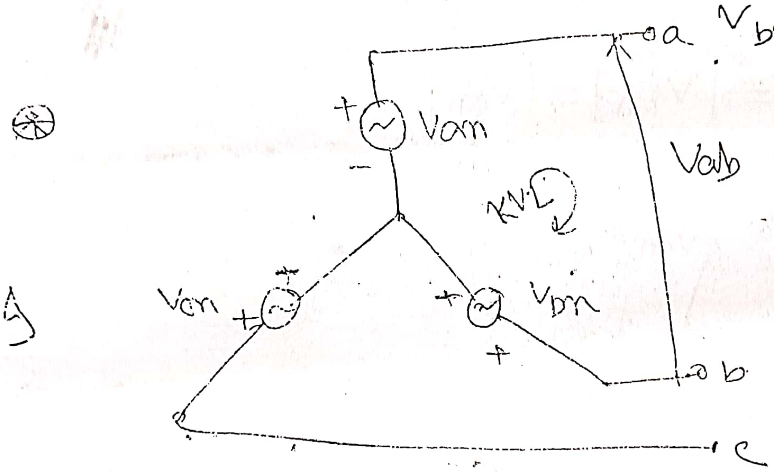


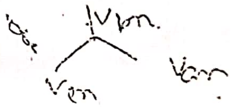
a-b-c sequence (positive) V_{an}, V_{bn}, V_{cn}

a-c-b-sequence (negative) $V_{an} = V_p\angle 0^\circ$

$V_{cn} = V_p\angle -120^\circ$

$V_{bn} = V_p\angle -240 = V_p\angle 120$





$\therefore V_{an} + V_{ab} + V_{bn} = 0$

$\Rightarrow V_{ab} = V_{an} - V_{bn}$

$= V_p\angle 0^\circ - V_p\angle -120^\circ$

$= V_p(1\angle 0^\circ - 1\angle -120^\circ)$

$= \sqrt{3}\, V_p\angle 30^\circ$