UNIT - I

Circuit Concepts

Network :- Network is a system with interconnected electrical elements. Network and circuit are the same. The only difference is circuit contain at least one closed path.

Circuit :- A circuit is a closed conducting path through which an electric current flows.

Electric Network :- A combination of various electric elements connected in any manner is called an electric network.

Electric circuits consists of two basic types of elements. They are active elements and passive elements.

Active elements :- It is capable of generating or supplying an electrical energy.

Ex :- voltage sources such as battery or generator and current sources.

passive elements :- A passive element is one which does not generate electricity but either consumes it or store it.

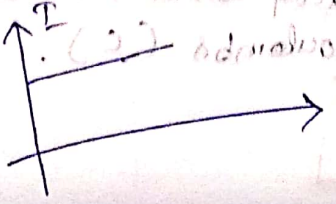
Ex : Resistors, Inductors and Capacitors.

DC circuit :- The closed path in which the direct current flows is called DC circuit. The current flows in only one direction. It is used in low voltage applications.

AC circuit :- The closed path in which the alternating current flows is called AC circuit. It is used in high voltage applications.

Direct current : A current does not change with time.

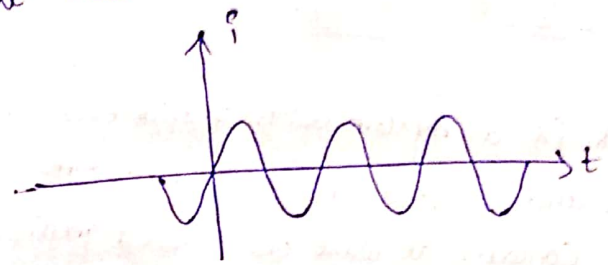
(or) A current that remains constant with time.



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Alternating Current :-

A current that varies sinusoidally with time.



Electrical Devices :- (AC current)

The electrical devices convert the electrical energy into the other form of energy like heat, light, sound etc.
Ex:- generators, motors

Electronic devices :- (DC current)

Electronic devices control the flow of electrons.
Ex Transistors, microprocessors, flipflop, amplifier etc.

Electromotive force :- It is the force which causes to flow the electrons in any closed ckt. The units of emf is volts.

potential Difference :- The potential difference b/w the two points in a ckt is electrical pressure or voltage required to drive the current between them. The units of potential difference is volts.

Voltage :- potential difference is the energy required to move a unit charge through an element measured in volts.

$$V = \frac{dw}{dq}$$

Current :-

⇒ flow of electrons in a circuit is any conductor is called current. It is represented by I. The units of current is Ampere.

⇒ Time rate of change of charge is called current.

$$I = \frac{dq}{dt}$$

Charge :- Charge is an electrical property of the atomic particles of which matter consists is called charge. It is measured in coulombs (C).

$$Q = i \times t$$

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Power :- power is the time rate of expending or absorbing energy. It is measured in watts.

$$p = \frac{dw}{dt}$$

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

$$\boxed{p = vi}$$

Resistance :- Resistance may be defined as the property of a substance which opposes the flow of electricity. It is represented by R. It is measured in Ω.

The resistance depends upon the following factors.

⟹ The resistance of the conductor varies directly as its length i.e conductor length increases, resistance increases.

$$R \propto L$$

⟹ The resistance of the conductor varies inversely as its cross sectional area i.e cross section area increases, resistance decreases.

$$R \propto \frac{1}{A}$$

⟹ The resistance of a conductor depends on the nature of the material

⟹ The resistance of a conductor depends on its temperature.

formula for calculating the resistance from one point to another point is

$$R \propto L \quad \& \quad R \propto \frac{1}{A}$$

$$R \propto \frac{L}{A}$$

$$R = \rho \frac{L}{A}$$

ρ is constant for the material called its specific resistance

ρ is the resistivity.

Energy :- Energy is the capacity to do work. It is measured in Joules.

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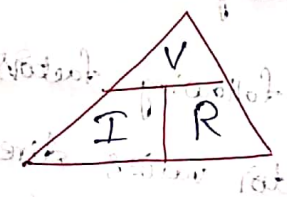
ohm's Law :-

ohm's law states that the voltage across a resistor is directly proportional to the current flowing through the resistor.

$$V \propto I$$

$$V = IR$$

R is the proportionality constant that is resistance.



What ever you want to find out place your thumb on it - the other two will tell the result.

Limitations of ohm's Law

→ ohm's law not applicable for some materials & devices.

Ex: diode

→ Non-linear elements do not support ohm's law

Ex: Thyristor.

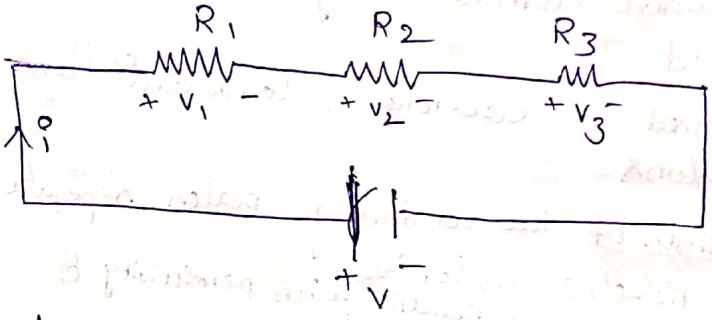
→ Conductors which does not obey ohm's law. It is called non-ohmic conductors.

→ Semiconductors like Ge, Si do not obey ohm's law.

→ It is not applicable for unilateral networks.

→ It is not applied for LED.

Resistance in series ckt :-



→ current will be same in each resistance.

→ voltage drops according to the branch resistance and the voltage will be equal to the applied voltage.

$$V = V_1 + V_2 + V_3$$

$$V = IR_1 + IR_2 + IR_3$$

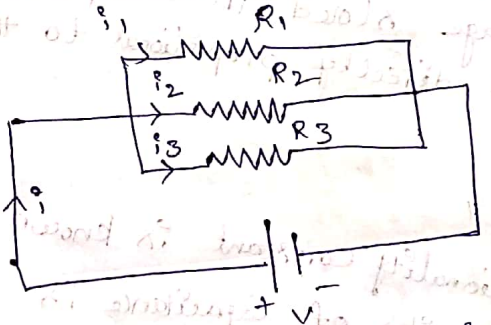
$$V = I(R_1 + R_2 + R_3)$$

$$\frac{V}{I} = R_1 + R_2 + R_3$$

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

The total resistance in series ckt will be equal to the sum of all the resistance connected in series.

Resistance in parallel ckt :-



In parallel ckt the voltage is same in each branch.
Total current I divides in seperate branches.

$$I = I_1 + I_2 + I_3$$

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{I}{V} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$R = \frac{V}{I}$$

The total resistance in parallel ckt is equal to the sum of the reciprocal of individual resistances.

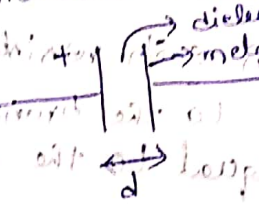
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Capacitor :-

Capacitor is a passive element designed to store energy in its electric field.

Capacitors are used in electronics, communications, computers and power systems.

A capacitor consists of two conducting plates separated by a insulating or dielectric material.



The metal plates may be aluminium foil while the dielectric may be air, paper or mica.

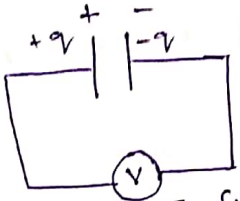


fig: Capacitor with applied voltage.

When a voltage source V is connected to the capacitor, the source deposits a positive charge q on one plate and a negative charge −q on the other plate.

The amount of charge stored in a capacitor, represented by q is directly proportional to the applied voltage

$$q \propto V$$

$$q = CV$$

where C is the proportionality constant is known as the capacitance of the capacitor. The units of capacitance is farad (F).

The capacitance of a capacitor is the ratio of the charge q per plate to the applied voltage V. It does not depends on q or V. It depends on the physical dimensions of the capacitor.

for a parallel plate capacitor the capacitance is

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

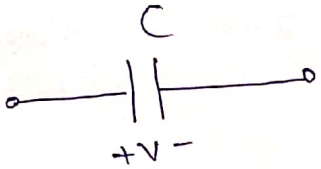
A → surface area

d → distance b/w two plates.

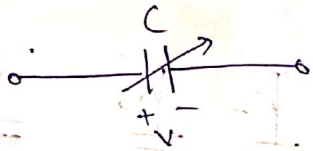
ε → permittivity of the dielectric material b/w the plates.

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Symbolic representation of capacitors



fixed Capacitor



variable capacitor.

Current - voltage relationship of the capacitor :

The current - voltage relationship of the capacitor is

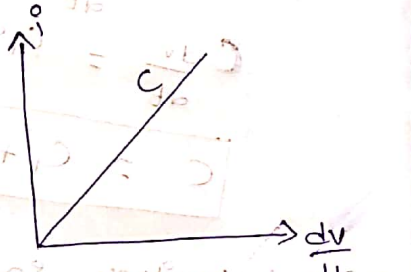
$$q = CV$$

Differentiating on both sides with respect to t

$$\frac{dq}{dt} = C\frac{dv}{dt}$$

$$i = \frac{dq}{dt}$$

$$i = C\frac{dv}{dt}$$



Current - voltage relationship of the capacitor.

The current - voltage relationship of the capacitor can be obtained by integrating the both sides of the equation $i = C\frac{dv}{dt}$

$$\int_{to}^{t} i(t)\,dt = \int_{to}^{t} C\frac{dv}{dt}\,dt$$

$$\frac{1}{C}\int_{to}^{t} i(t)\,dt = \int_{to}^{t} dV$$

$$\boxed{v(t) = \frac{1}{C}\int_{to}^{t} i(t)\,dt}$$

The power delivered to the capacitor is

$$\boxed{P = vi = v \cdot C\frac{dv}{dt}}$$

The Energy stored in the capacitor is

$$P = \frac{dw}{dt}$$

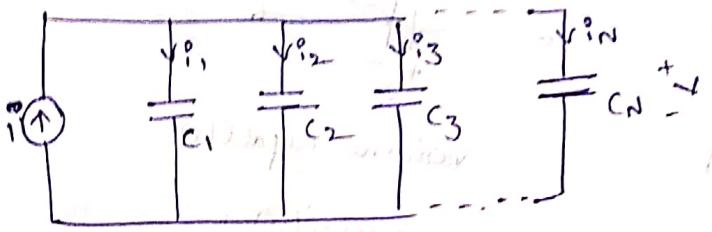
$$\int_{to}^{t} P(t)\,dt = w$$

$$w = \int_{to}^{t} v \cdot C\frac{dv}{dt}\,dt = C\int_{to}^{t} v\,dv$$

$$\boxed{w = \frac{1}{2}Cv^2}$$

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Capacitance in parallel Ckt :-



The capacitors have the same voltage

$$i = i_1 + i_2 + i_3 + \cdots + i_N$$

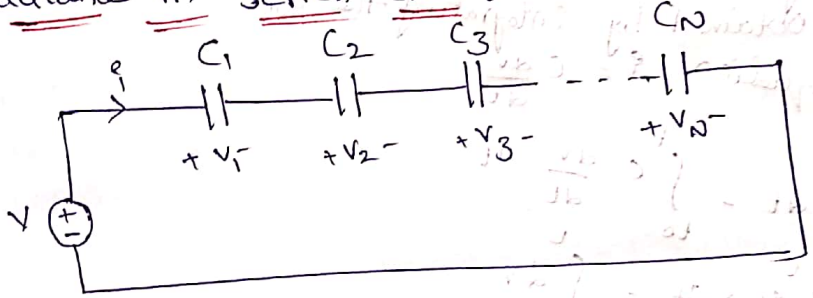
$$i = C\frac{dv}{dt}$$

$$C\frac{dv}{dt} = C_1\frac{dv}{dt} + C_2\frac{dv}{dt} + C_3\frac{dv}{dt} + \cdots + C_N\frac{dv}{dt}$$

$$\boxed{C = C_1 + C_2 + C_3 + \cdots + C_N}$$

Total capacitance in parallel Ckt is the sum of the individual capacitances.

Capacitance in series Ckt :-



$$v = v_1 + v_2 + v_3 + \cdots + v_N$$

$$v = \frac{1}{C}\int_{t_0}^{t} i(t)\,dt$$

$$\frac{1}{C}\int_{t_0}^{t} i(t)\,dt = \frac{1}{C_1}\int_{t_0}^{t} i(t)\,dt + \frac{1}{C_2}\int_{t_0}^{t} i(t)\,dt + \frac{1}{C_3}\int_{t_0}^{t} i(t)\,dt + \cdots + \frac{1}{C_N}\int_{t_0}^{t} i(t)\,dt$$

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

Total capacitance in the series connected capacitor is the reciprocal of the sum of the reciprocals of the individual capacitance.

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Inductor :- Inductor is a passive element designed to store the energy in its magnetic field.

Inductors are used in electronics, power systems, power suppliers, transformers, radios, TV's, electric motors etc.

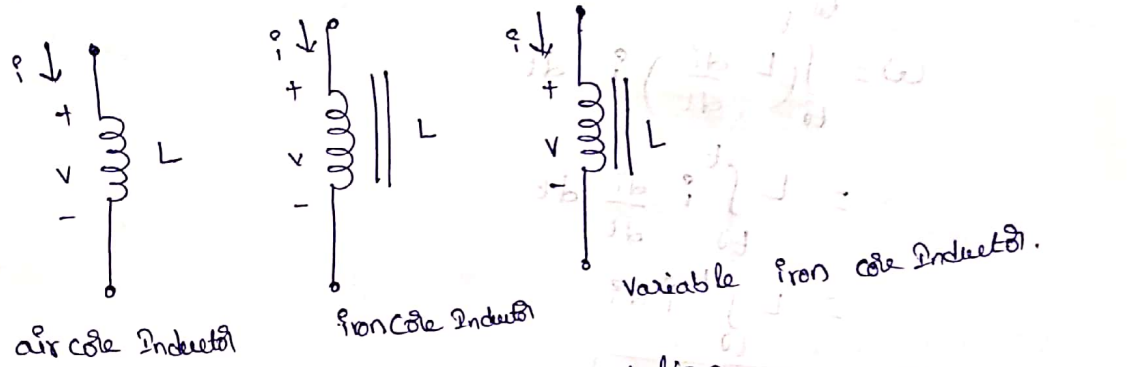


fig: Symbolic Representation.

If current is allowed to pass through an inductor is find that the voltage across the inductor is directly propotional to the time rate of change of the current :-

$$V \propto \frac{di}{dt}$$

$$\boxed{V = L \frac{di}{dt}}$$

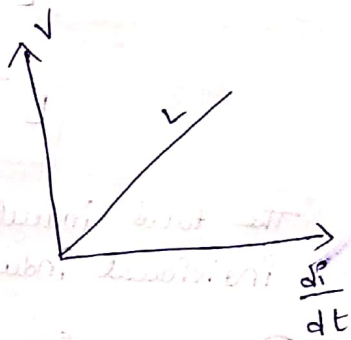
where L is the propotionality constant, it is called Inductance.

The units of Inductance is henrys (H).

Current - voltage relationship of an inductor :-

$$V = L \frac{di}{dt}$$

$$\frac{1}{L} V = \frac{di}{dt}$$



Integrating both sides w.r.t t

$$\int_{t0}^{t} \frac{1}{L} V \, dt = \int_{t0}^{t} \frac{di}{dt} \cdot dt$$

$$\boxed{i(t) = \frac{1}{L} \int_{t0}^{t} V(t) \, dt}$$

power delivered to the inductor is

$$\boxed{P = Vi = \left(L \frac{di}{dt}\right) i}$$

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The energy stored in a inductor is

$$P = \frac{dw}{dt}$$

$$w = \int_{t_0}^{t} P(t)\,dt$$

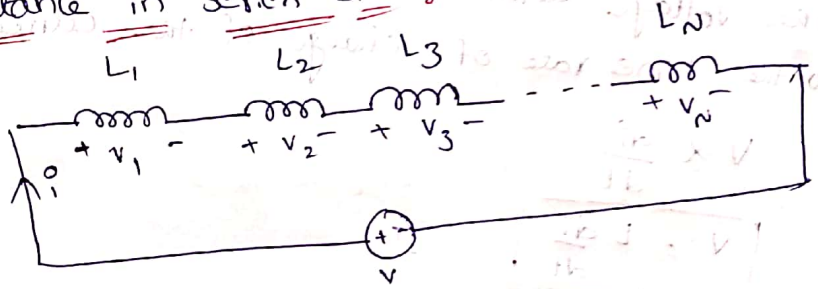
$$w = \int_{t_0}^{t} \left(L \frac{di}{dt}\right) i \, dt$$

$$= L \int_{t_0}^{t} i \frac{di}{dt} dt$$

$$= L \int_{t_0}^{t} i \, di$$

$$\boxed{w = \frac{1}{2} L i^2}$$

Inductance in series ckt :-



$$V = V_1 + V_2 + V_3 + \cdots + V_N$$

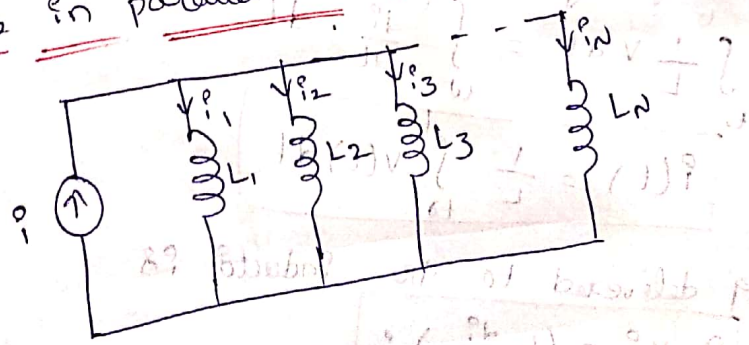
$$V = L \frac{di}{dt}$$

$$L \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + L_3 \frac{di}{dt} + \cdots + L_N \frac{di}{dt}$$

$$\boxed{L = L_1 + L_2 + L_3 + \cdots + L_N}$$

The total inductance in series ckt is the sum of the individual inductances.

Inductance in parallel ckt :-



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$$i = i_1 + i_2 + i_3 + \cdots + i_N$$

$$i = \frac{1}{L}\int_{t_0}^{t} v\,dt$$

$$\frac{1}{L}\int_{t_0}^{t} v\,dt = \frac{1}{L_1}\int_{t_0}^{t} v\,dt + \frac{1}{L_2}\int_{t_0}^{t} v\,dt + \frac{1}{L_3}\int_{t_0}^{t} v\,dt + \cdots + \frac{1}{L_N}\int_{t_0}^{t} v\,dt$$

$$\boxed{\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_N}}$$

The equivalent inductance of parallel connected inductors is the reciprocal of the sum of the reciprocals of the individual inductance.

Problems :-

① The total charge entering a terminal is given by $q = 5t \sin 4\pi t$ mC. Calculate the current at $t = 0.5$ sec.

Sol

$$\boxed{i = \frac{dq}{dt}} = \frac{d}{dt}(5t \sin 4\pi t)$$

$$= 5\sin 4\pi t + 5t \cos 4\pi t \times 4\pi$$

$$= 5\sin 4\pi t + 20\pi t \cos 4\pi t$$

At $t = 0.5$ sec

$$i = 5\sin 4\pi \times 0.5 + 20\pi (0.5)\cos 4\pi \times 0.5$$

$$= 5\sin 2\pi + 10\pi \cos 2\pi$$

$$= 5 \times 0 + 10\pi \times 1$$

$$i = 10\pi$$

$$\boxed{i = 10 \times 3.14 = 31.4 \text{ mA}}$$

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(2) Determine the total charge entering a terminal between $t = 1\,sec$ and $t = 2\,sec$. If the current passing the terminal is $i = (3t^2 - t)\,A$

Sol

$$Q = \int_{t_0}^{t} i\,dt$$

$$Q = \int_{1}^{2} (3t^2 - t)\,dt$$

$$= \left[\frac{3t^3}{3} - \frac{t^2}{2} \right]_1^2$$

$$= \left[t^3 - \frac{t^2}{2} \right]_1^2$$

$$= \left[2^3 - 1^3 \right] - \frac{1}{2}\left[2^2 - 1^2 \right]$$

$$= [8 - 1] - \frac{1}{2}[4 - 1]$$

$$= 7 - \frac{1}{2}[3]$$

$$= 7 - \frac{3}{2}$$

$$= 7 - 1.5$$

$$Q = 5.5\,C$$

(3) An electric blanket that is connected to 120V outlet consumes 0.140kW. what is the resistance of blanket?

Sol

$V = 120V$

$P = 0.140kW = 140W$

$P = VI$

$P = V \cdot \frac{V}{R}$

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

$140 = \frac{120 \times 120}{R}$

$R = \frac{120 \times 120}{140} = 102.8\,\Omega$

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(5) A 12V automobile light is rated at 30W. The total charge that flows through the filament in one minute.

Sol

$V = 12V$ $\quad t = 1 min$

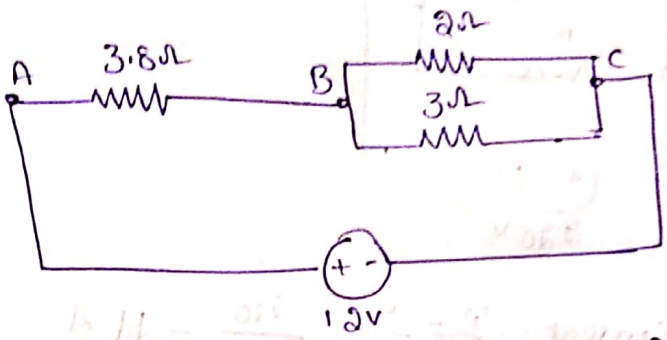
$P = 30 W$ $\quad t = 60 sec$

$P = VI$

$I = \frac{P}{V} = \frac{30}{12} = 2.5 A$

Charge $Q = I \times t = 2.5 \times 60 = 150 C$

(6)



a) Calculate resistance between A & C

b) Calculate potential difference b/w A & B

c) Calculate current in 3Ω branch.

Sol

a) find Resistance b/w A & C

Resistance b/w B & C

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{2} + \frac{1}{3} = \frac{3+2}{6} = 5/6$

$R = 6/5 = 1.2 \Omega$

Resistance b/w A & C

$R = \frac{6}{5}$ (+) $R = 3.8 + 1.2 = 5 \Omega$

b) Calculate potential difference b/w A & B.

The total current in ckt $I = \frac{V}{R} = \frac{12}{5} = 2.4 A$

potential difference b/w A & B $V = IR$

$V = 2.4 \times 3.8$

$V = 9.2V$

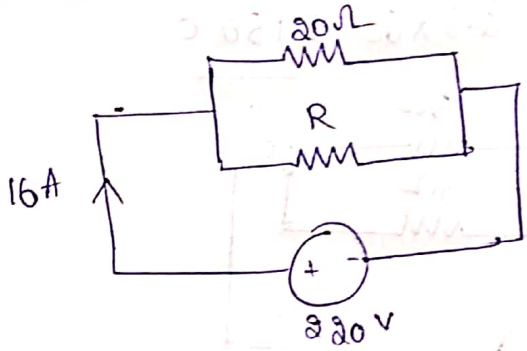
voltage across B & C $V = IR = 2.4 \times 1.2 = 2.88 V$

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c) Current in 3Ω branch resistance

$$I = \frac{V}{R} = \frac{2.88}{3} = 0.96\ A$$

(7) A current of 16 A is distributed in a ckt having two branches connected on 220V supply. If the resistance of one branch is 80Ω. find out the resistance of the other branch and power taken by both branches.



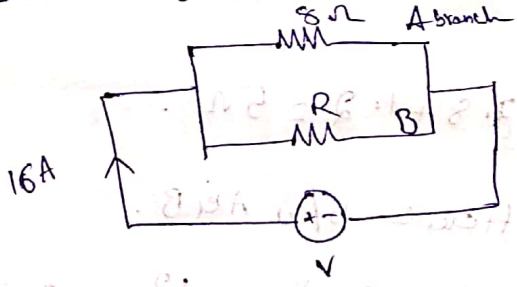
Sol) 20Ω branch current $I = \frac{V}{R} = \frac{220}{20} = 11\ A$

Current in other branch $I = 16 - 11 = 5\ A$.

resistance of other branch $R = \frac{V}{I} = \frac{220}{5} = 44\Omega$

power of the ckt $P = VI = 220 \times 16 = 3520\ W$.

(8) A current of 16 A divides in two branches of circuits in parallel, one branch having a resistance of 8Ω. Determine the current in each branch and power in each branch if the total power wasted in 1280 Watts.



Sol) power $P = 1280\ W$

$$P = V I$$

$$1280 = V \times 16$$

$$V = \frac{1280}{16} = 80 \text{ Volts}.$$

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Current in A branch $I = \frac{V}{R} = \frac{80}{8} = 10A$

Current in B branch $I = 16 - 10 = 6A$

power in A branch $P = VI$

$P = 80 \times 10 = 800W$

power in B branch $P = 80 \times 6 = 480W$

9) find the power delivered to an element at $t = 3msec$ if the current entering its positive terminal is $i = 5\cos 60\pi t$ A and the voltage is a) $v = 3i$ b) $v = 3\frac{di}{dt}$

Sol

a) The voltage is $v = 3i$

$v = 3(5\cos 60\pi t)$

$v = 15\cos 60\pi t$

$p = vi$

$p = 15\cos 60\pi t \times 5\cos 60\pi t$

$p = 75\cos^2 60\pi t$

At $t = 3msec$

$p = 75\cos^2(60\pi \times 3 \times 10^{-3})$

$p = 75\cos^2(0.18\pi)$

$\boxed{p = 53.48W}$

b) $v = 3\frac{di}{dt}$.

$v = 3\frac{d}{dt}(5\cos 60\pi t) = 3(5\sin 60\pi t) \times 60\pi$

$v = 900\pi \sin 60\pi t$

$p = vi$

$p = 900\pi \sin 60\pi t \times 5\cos 60\pi t$

$p = 4500\pi \sin 60\pi t \cos 60\pi t$

At $t = 3msec$

$p = 4500\pi \sin 60\pi \times 3 \times 10^{-3} \cos 60\pi \times 3 \times 10^{-3}$

$\boxed{p = 6.396kW}$

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Circuit elements :-

An element is the basic building block of a ckt

There are two types of elements.

→ Active elements

→ passive elements.

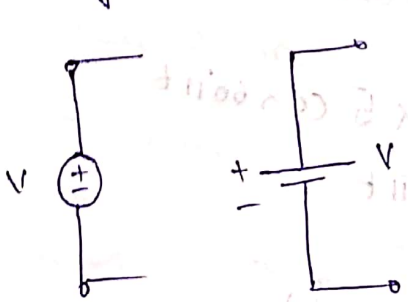
The most important active elements are voltage source and current source.

There are two kinds of sources.

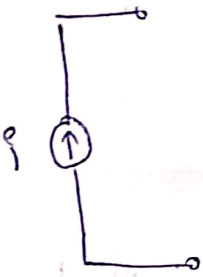
→ Independent sources

→ Dependent sources.

Symbols for Independent sources

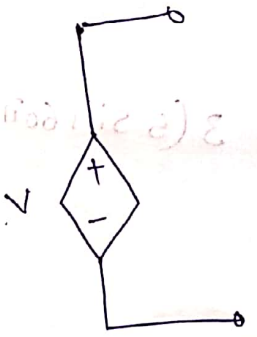


Independent voltage source.

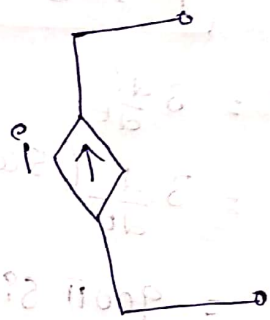


Independent current source.

Symbols for dependent sources.



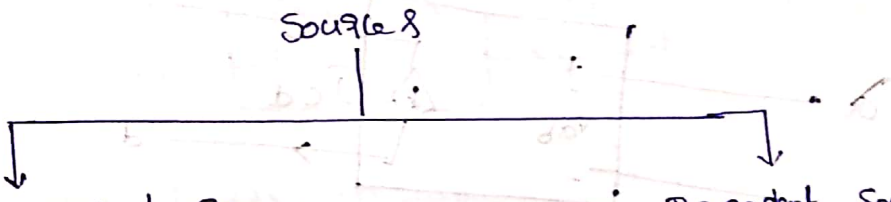
Dependent voltage source.



Dependent current source.

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Sources :-



(The value of independent sources does not depend upon any other voltage & current)

(The value of dependent sources depends upon some voltage or current)

There are two types of Independent Sources

Voltage source:- It will provide a constant voltage irrespective of any amount of current.

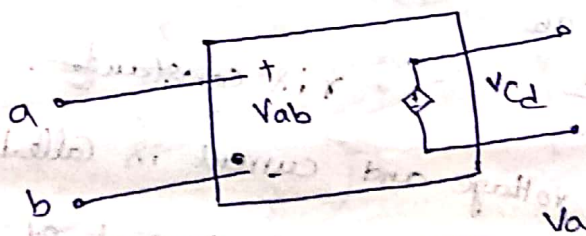
It will maintain a constant voltage across two terminals.

Current Source:- It will always maintain a constant current in the ckt.

There are four types of Dependent Sources.

It depends which voltage and current is being controlled by which voltage & current.

Voltage controlled voltage source (VCVS):-

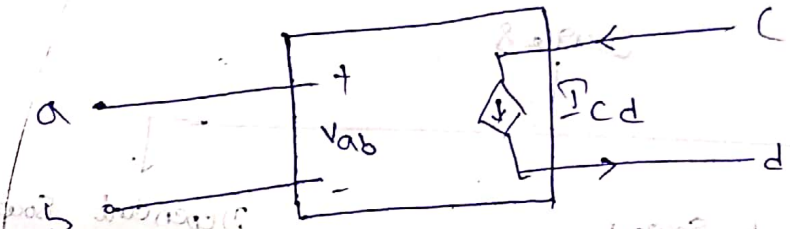


the V_{cd} is depends upon V_{ab} that dependent factor is μ

$V_{cd} = \mu V_{ab} \Rightarrow \mu = \frac{V_{cd}}{V_{ab}}$ (i.e voltage gain).

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Voltage controlled current source (VCCS):-



I_{cd} is depends on V_{ab}.

$$I_{cd} = g_m \cdot V_{ab}$$

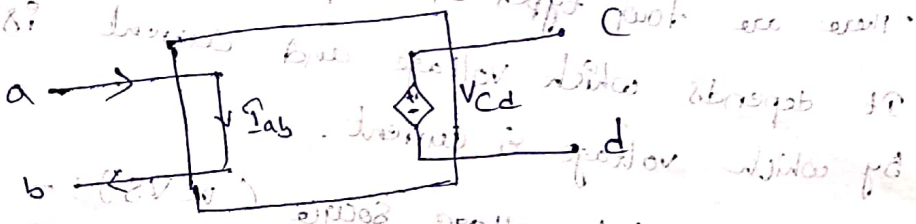
g_m is constant.

$$g_m = \frac{I_{cd}}{V_{ab}} \rightarrow \text{o/p current}, \quad \rightarrow \text{i/p voltage}$$

Ratio of current and voltage is a conductance.

The ratio of o/p current to the i/p voltage is called transconductance.

Current controlled voltage source (CCVS):-



V_{cd} depends of I_{ab}

$$V_{cd} = r \cdot I_{ab}$$

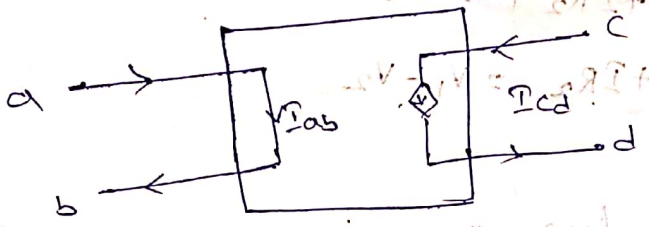
$$r = \frac{V_{cd}}{I_{ab}}$$

r is constant.

The ratio of voltage and current is called resistance.

But the ratio of voltage and current of a different current ports is called transresistance.

Current controlled current source (CCCS) :→



I_{cd} is depends on I_{ab}.

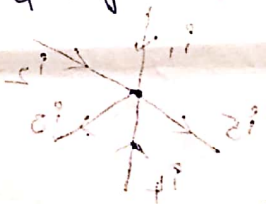
$I_{cd} = \beta I_{ab}$ → β is controlled factor.

$\beta = \frac{I_{cd}}{I_{ab}}$ (i.e current gain)

Significance of dependent sources :-

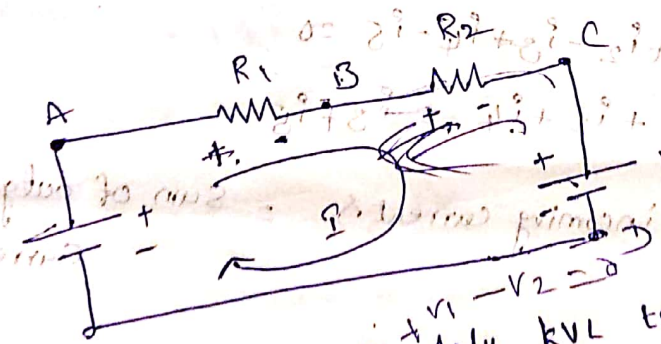
* In practice dependent sources do not exist.
* Dependent sources/Gain are used in the analyse the Ckt.

Ex ; Small signal & large signal amplifier analysis of BJT



KVL

The algebric sum of voltages across all the elements in a closed loop is zero.



$-V_1 - V_2 + V_2 = 0$

$-V_1 + V_2 = V_1 + V_2$

$-V + V_1 + V_2 + V_2 = 0$

$-V_1 + V_1 - V_2 = 0$

Apply KVL to loop ABCDEA

$-V_2 - IR_1 + V_1 - V_2 = 0$

Anti clock $+IR_1 + IR_2 + V_2 - V_1 = 0$

$\therefore -V_1 + V_2 = IR_1 + IR_2$

$V_1 - V_2 = IR_1 + IR_2$

Σ algebric sum of voltage sources = Σ voltage drops across resistors.

Anti clockwise

Sign convension

+ to − ⇒ −ve

− to + ⇒ +ve

clockwise

+ to − ⇒ +ve

− to + ⇒ −ve

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Clock wise

$$-V_1 + IR_1 + IR_2 + V_2 = 0$$

$$IR_1 + IR_2 = V_1 - V_2$$

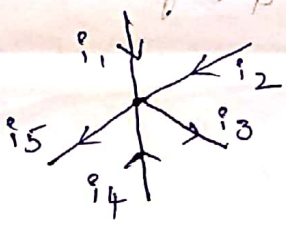
Kirchoff's current law :-

Kirchoff's current law states that the algebric sum of the currents entering a node is zero.

The total current leaving a junction is equal to the current entering that junction.

$$\sum_{m=1}^{m} i_m = 0$$

m — no. of current in loop



The incoming currents to be positive and the outgoing currents to be negative.

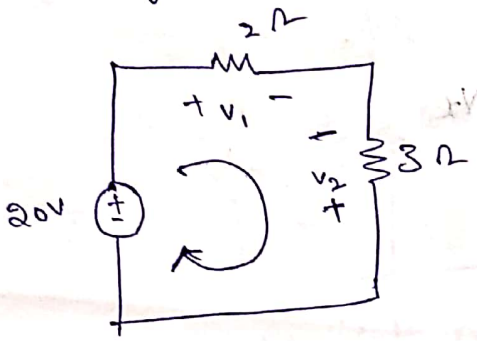
$$i_1 + i_2 - i_3 + i_4 - i_5 = 0$$

$$i_1 + i_2 + i_4 = i_3 + i_5$$

Sum of incoming currents = Sum of outgoing currents.

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(1) for the ckt as shown in below fig. find voltages v_1 & v_2



Sol

$v_1 = 2i$

$-v_2 = 3i$

$v_2 = -3i$

$-20 + v_1 - v_2 = 0$

$-20 + 2i + 3i = 0$

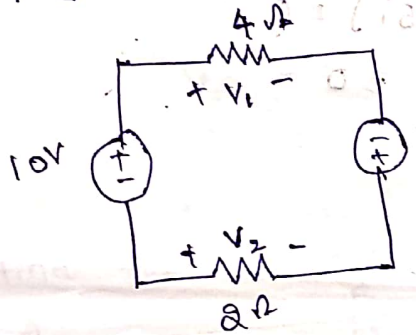
$5i = 20$

$i = 4A$

$v_1 = 2 \times 4 = 8V$

$v_2 = -3 \times 4 = -12V$

(2) find v_1 & v_2 in the ckt



Sol $v_1 = 4i$ $v_2 = -2i$

Apply KVL

$-10 + v_1 - 8 - v_2 = 0$

$-10 + 4i - 8 - (-2i) = 0$

$4i + 2i = 18$

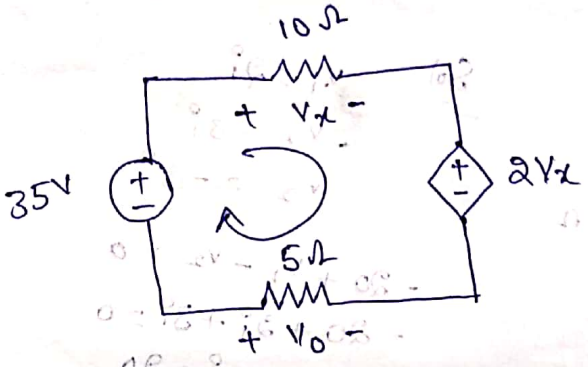
$6i = 18 \Rightarrow i = 3A$

$v_1 = 4 \times 3 = 12V$

$v_2 = -2 \times 3 = -6V$

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3) Find V_x and V_o in the Ckt



Sol

$V_x = 10i$, $V_o = -5i$

Apply KVL

$$-35 + V_x + 2V_x - V_o = 0$$

$$-35 + 10i + 2 \times 10i - (-5i) = 0$$

$$-35 + 10i + 20i + 5i = 0$$

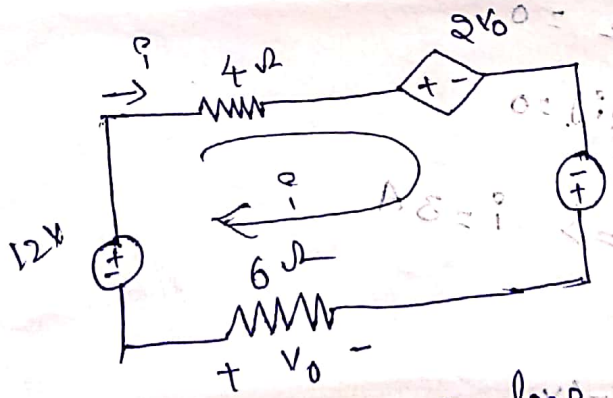
$$35i = 35$$

$$i = 1\ A$$

$$V_x = 10 \times 1 = 10V$$

$$V_o = -5 \times 1 = -5V$$

4) Determine V_o & i in the Ckt



Sol Apply KVL to the loop

$$-12 + 4i + 2V_o - 4 - V_o = 0$$

$$-12 + 4i + 2(-6i) - 4 - (-6i) = 0$$

$$-12 + 4i - 12i - 4 + 6i = 0$$

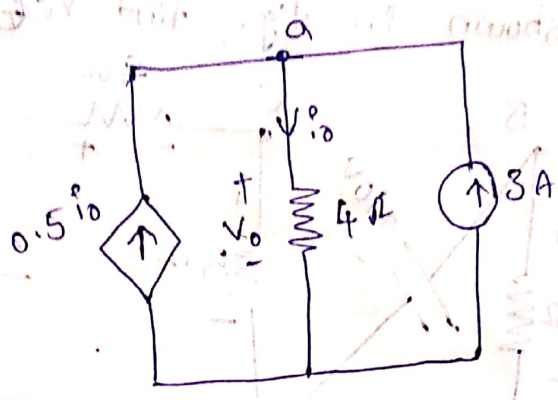
$$-2i = +16$$

$$i = -8\ A$$

$$V_o = -6 \times -8 = 48V$$

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5) find current i_o & voltage v_o in the ckt

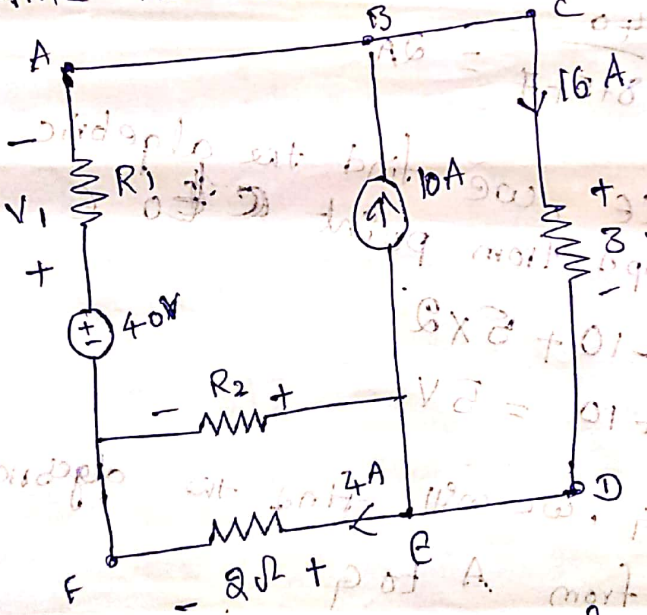


Sol Apply KCL at node a

$$0.5 i_o + 3 = i_o$$
$$3 = i_o - 0.5 i_o$$
$$3 = 0.5 i_o$$
$$i_o = 3/0.5 = 6\,A$$

$$v_o = 4 i_o$$
$$v_o = 4 \times 6 = 24\,V$$

6) find the unknown voltage V_1 in the ckt

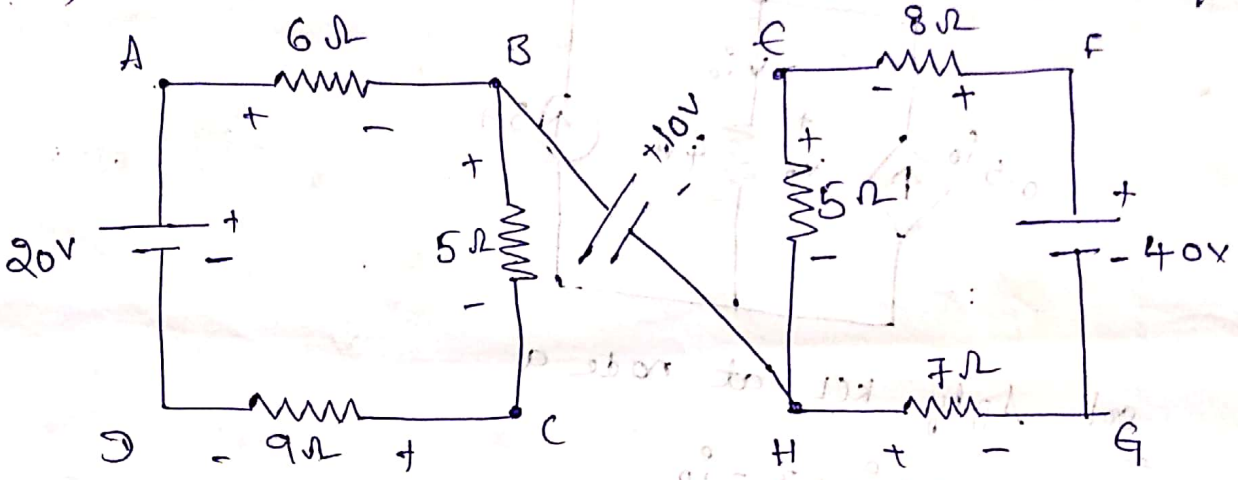


Sol Taking the outer closed loop ABCDEFA and applying KVL to it.

$$16 \times 3 + 4 \times 2 - 40 + V_1 = 0$$
$$48 + 8 - 40 + V_1 = 0$$
$$16 + V_1 = 0$$
$$V_1 = -16\,V$$

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7) for the ckt shown in fig. find V_{CE} & V_{AG}



Sol

Consider the two battery ckts seperately.

Current in the 20V battery ckt ABCD is

$$I = \frac{V}{R} = \frac{20}{6+5+9} = \frac{20}{20} = 1\,A$$

current in the 40V battery ckt EFGH

$$I = \frac{V}{R} = \frac{40}{8+5+7} = 2A$$

for finding V_{CE}, we find the algebric sum of the voltage drops from point C to E,

$$V_{CE} = +5\times1 - 10 + 5\times2$$

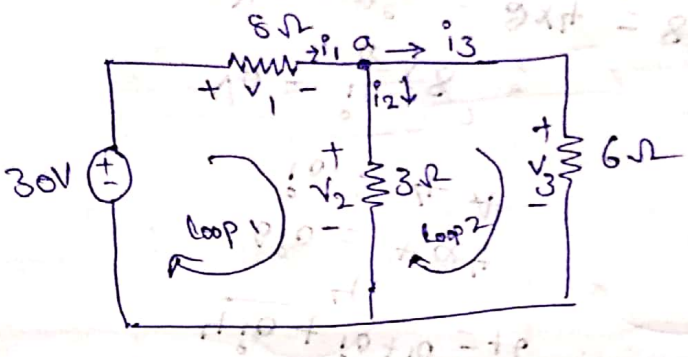
$$V_{CE} = 5 - 10 + 10 = 5\,V$$

for finding V_{AG}, we will find the algebric sum of voltage drops from A to G

$$V_{AG} = 6\times1 + 10 + 7\times2 = 6 + 10 + 14 = 30\,V$$

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* find currents and voltages in the ckt



Sol

we apply ohm's law

$V_1 = 8i_1 \quad V_2 = 3i_2 \quad V_3 = 6i_3$

Apply KCL to the ckt

$$i_1 - i_2 - i_3 = 0 \longrightarrow (1)$$

Applying KVL to loop 1

$$30 + 8i_1 + 3i_2 = 0$$

$$8i_1 = -3i_2 + 30$$

$$i_1 = \frac{30 - 3i_2}{8} \longrightarrow (2)$$

Apply KVL to loop 2

$$-V_2 + V_3 = 0 \longrightarrow (3)$$

$$V_3 = V_2$$

$$6i_3 = 3i_2 \Rightarrow i_3 = \frac{3i_2}{6} = \frac{i_2}{2}$$

substituting the values in eq (1)

$$\frac{30 - 3i_2}{8} - i_2 - \frac{i_2}{2} = 0$$

$$30 - 3i_2 - 8i_2 - 4i_2 = 0$$

$$30 - 15i_2 = 0$$

$$-15i_2 = -30$$

$$i_2 = 30/15 = 2A$$

$$i_1 = \frac{30 - 3\times 2}{8} = \frac{30-6}{8} = \frac{24}{8} = 3A$$

$$i_3 = i_2/2 = \frac{2}{2} = 1A$$

$V_1 = 8i_1$

$= 8 \times 3 = 24V$

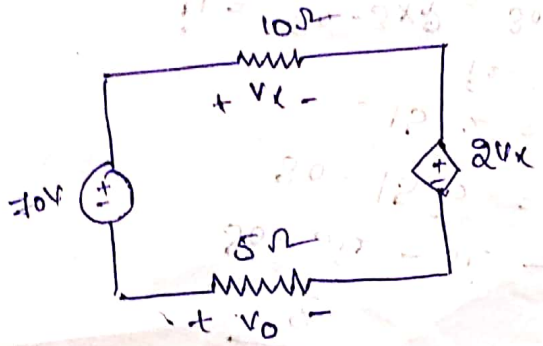
$V_2 = 3i_2$

$= 3 \times 2 = 6V$

$V_3 = 6 \times 1 = 6V$

Scanned with CamScanner

* find V_x & V_o in the ckt



Sol $V_o = -5i$ $\quad V_x = 10i$ $\quad i = \frac{V_x}{10}$

Apply KVL

$V_x + 2V_x - V_o - 70 = 0$

$3V_x + 5i = 70$

$3V_x + 5\left(\frac{V_x}{10}\right) = 70$

$3V_x + \frac{V_x}{2} = 70$

$\frac{7V_x}{2} = 70$

$7V_x = 140$

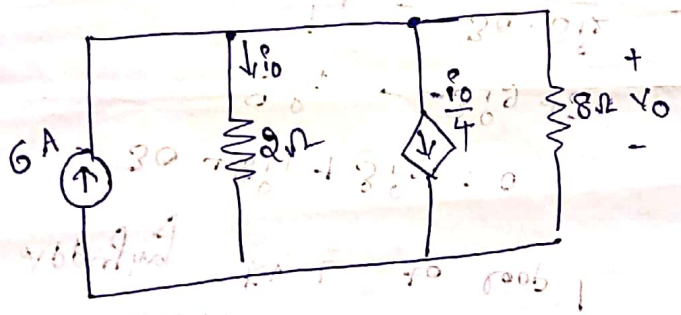
$V_x = \frac{140}{7} = 20V$

$V_x = 10i$

$20 = 10 \times i \Rightarrow i = 2A$

$V_o = -5 \times 2 = -10V$

* find current i_o and voltage V_o in the ckt



Sol Apply KCL

$6 - i_o - \frac{i_o}{4} - \frac{i_o}{4} = 0$

$-i_o - \frac{i_o}{4} - \frac{i_o}{4} = -6$

$-\left(i_o + \frac{i_o}{4} + \frac{i_o}{4}\right) = -6$

$\frac{4i_o + i_o + i_o}{4} = +6$

$6i_o = +24$

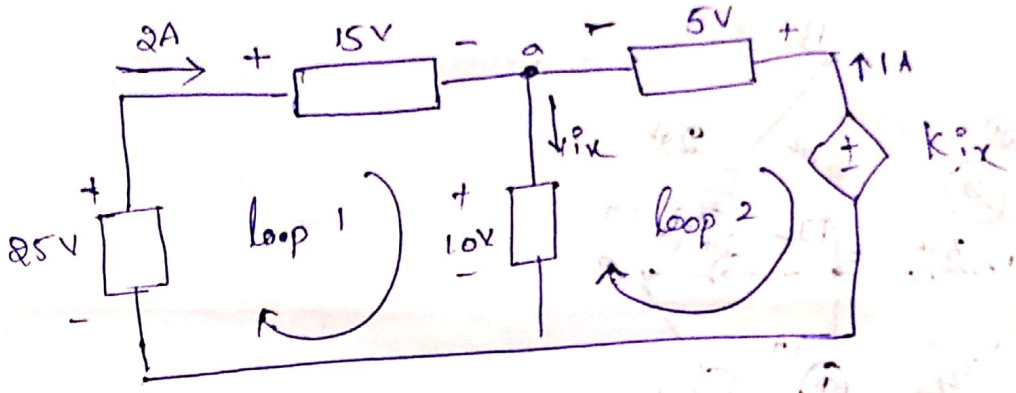
$i_o = 4A$

$V_o = \frac{i_o}{4} \times 8^2$

$V_o = 2i_o = 2 \times 4 = 8V$

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* find the value of k in the ckt



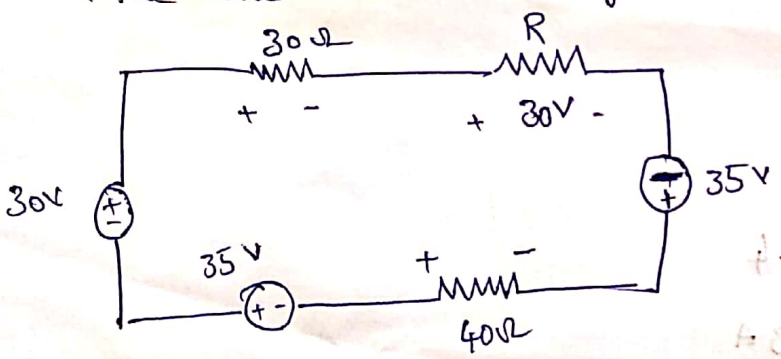
Sol Apply KVL to loop 2

$$-5 + kix - 10 = 0$$
$$kix = 15$$

Applying KCL at node a

$$2 + 1 = ix$$
$$ix = 3$$
$$k(3) = 15$$
$$k = 15/3 = 5$$

For the ckt shown in fig find the value of R



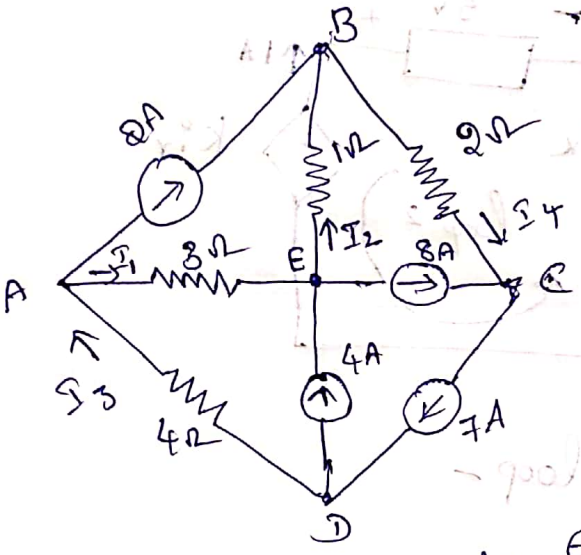
Sol Apply KVL

$$-30 + 30i + 30 - 35 - 40i - 35 = 0$$
$$-10i - 70 = 0$$
$$10i = -70$$
$$i = -7$$

$$V = IR$$
$$30 = -7(R)$$
$$R = -30/7 = -4.2\ \Omega$$

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(4) In the given ckt find I_1 & I_2



Sol Apply KCL at node E

$$I_1 - I_2 - 8 + 4 = 0$$

$$I_1 + 4 = I_2 + 8$$

$$I_2 = I_1 + 4 - 8$$

$$I_2 = I_1 - 4 \longrightarrow (1)$$

Apply KCL at node D

$$4 + I_3 = 7$$

$$I_3 = 3A \longrightarrow (2)$$

At node A

$$I_1 + 2 = I_3$$

$$I_1 = 1\ A$$

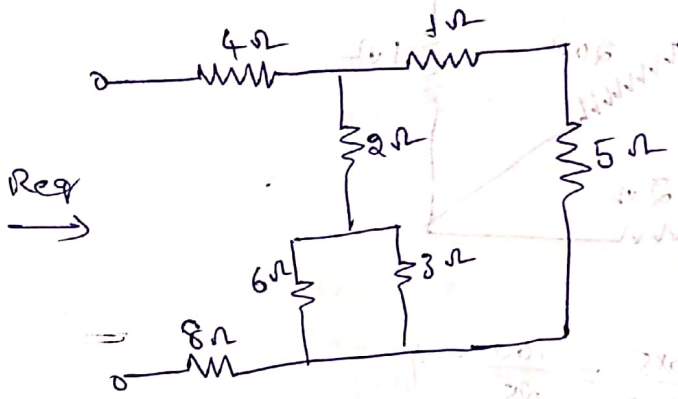
eq (1) $\Rightarrow$ $I_2 = 1 - 4$

$$I_2 = -3\ A$$

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Circuit Reduction techniques

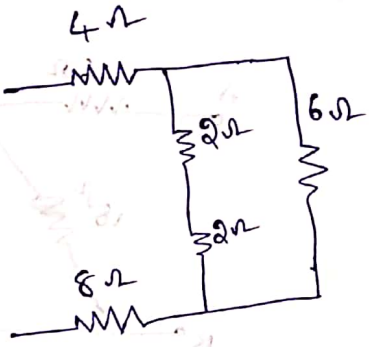
① find equivalent resistance of ckt.



Sol:

6Ω & 3Ω are in parallel

$$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{6 \times 3}{6+3} = \frac{18}{9} = 2\Omega$$

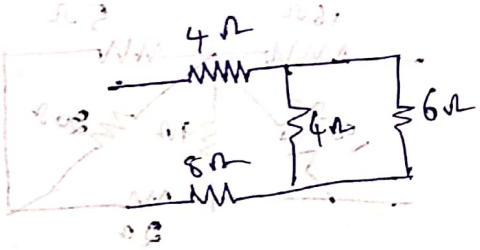


1Ω & 5Ω are in series

$R = 1+5 = 6\Omega$

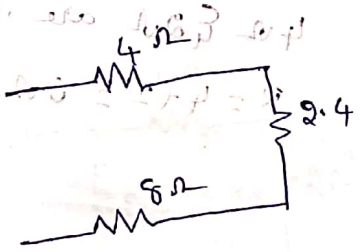
2Ω & 2Ω are in series

$R = 2+2 = 4\Omega$



$4\Omega \,//\, 6\Omega$

$$R = \frac{4 \times 6}{4+6} = \frac{24}{10} = 2.4$$

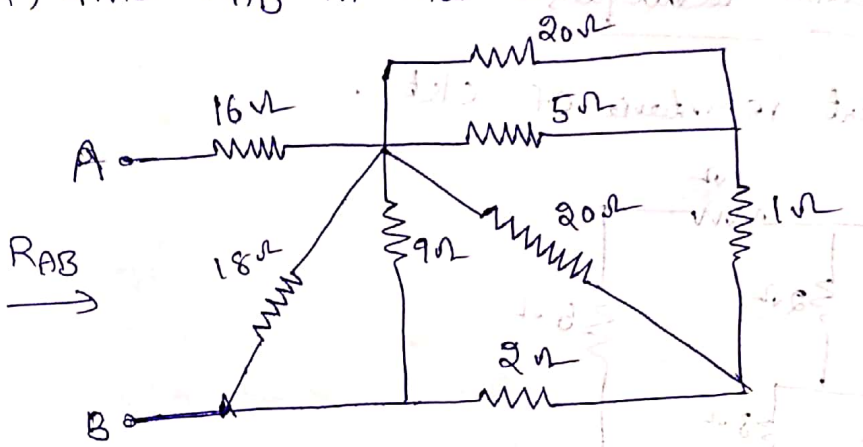


4Ω & 5Ω & 2.4Ω are in series

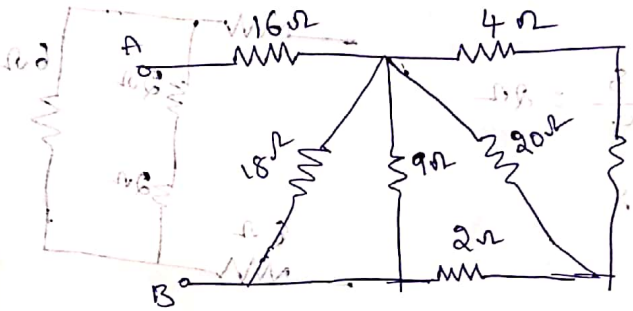
$R = 4 + 2.4 + 8 = 14.4\Omega$

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2) find R_{AB} in the Ckt.

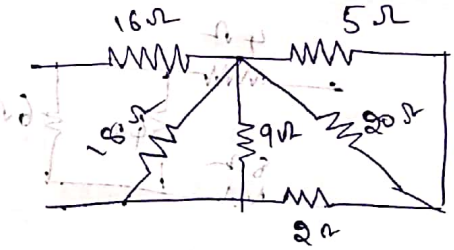


Sol $20\Omega // 5\Omega = \frac{20\times5}{20+5} = \frac{100}{25} = 4$



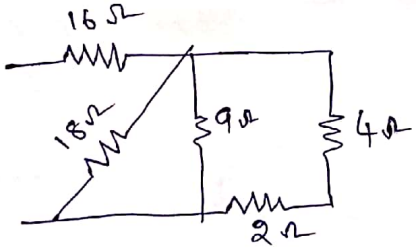
$\therefore 4\Omega$ & 1Ω are in series

$R = 4+1 = 5\Omega$



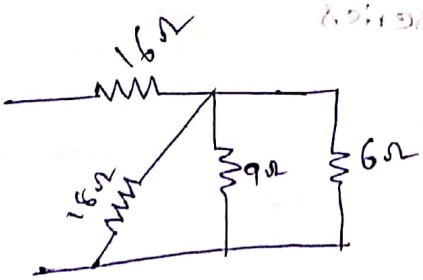
$5\Omega // 20\Omega$

$R = \frac{5\times20}{5+20} = \frac{100}{25} = 4$



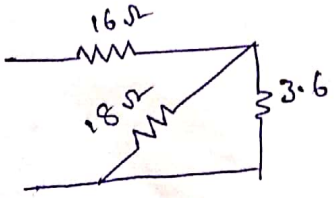
4Ω & 2Ω are in series

$R = 4+2 = 6\Omega$



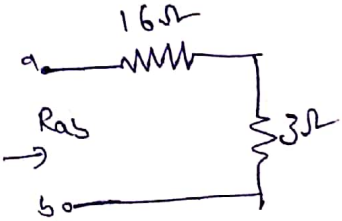
$9\Omega // 6\Omega$

$R = \frac{9\times6}{9+6} = \frac{54}{15} = 3.6$



$18\Omega // 3.6\Omega$

$R = \frac{18\times3.6}{18+3.6} = 3\Omega$

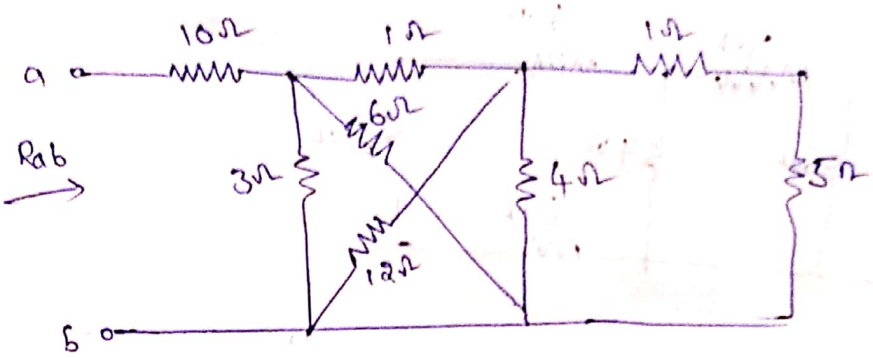


16Ω & 3Ω are in series

$R_{ab} = 16+3 = 19\Omega$

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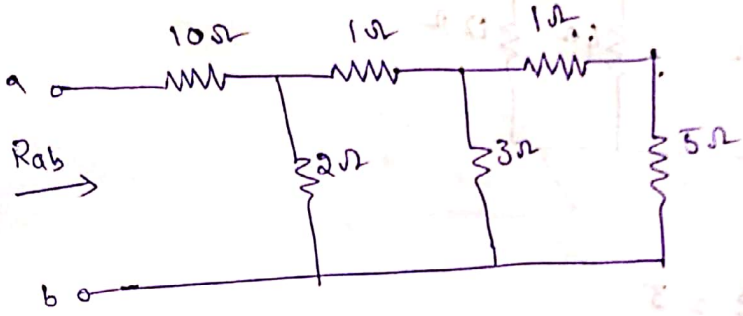
3) Calculate the resistance Rab in the ckt



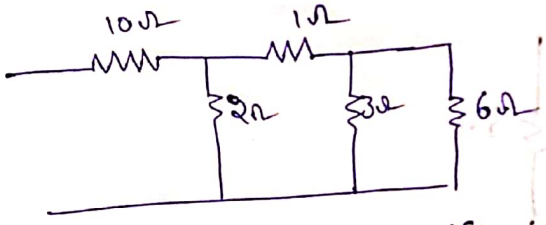
Sol

$3\Omega \,//\, 6\Omega = \frac{3\times 6}{3+6} = \frac{18}{9} = 2$

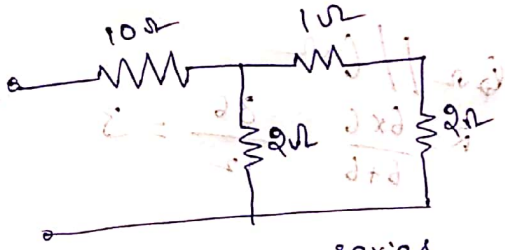
$12\Omega \,//\, 4\Omega = \frac{12\times 4}{12+4} = \frac{48}{16} = 3$



1Ω & 5Ω are in series $R = 1+5 = 6\Omega$

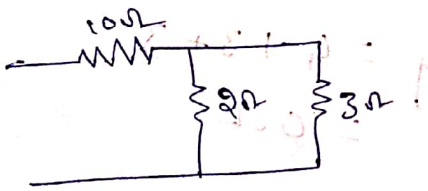


$6\Omega \,//\, 3\Omega = \frac{6\times 3}{6+3} = \frac{18}{9} = 2\Omega$

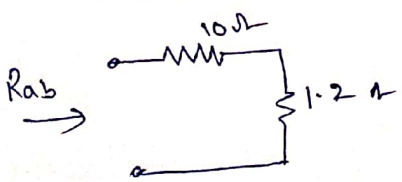


1Ω & 2Ω are in series

$R = 1+2 = 3\Omega$



$2\Omega \,//\, 3\Omega = \frac{2\times 3}{2+3} = \frac{6}{5} = 1.2$



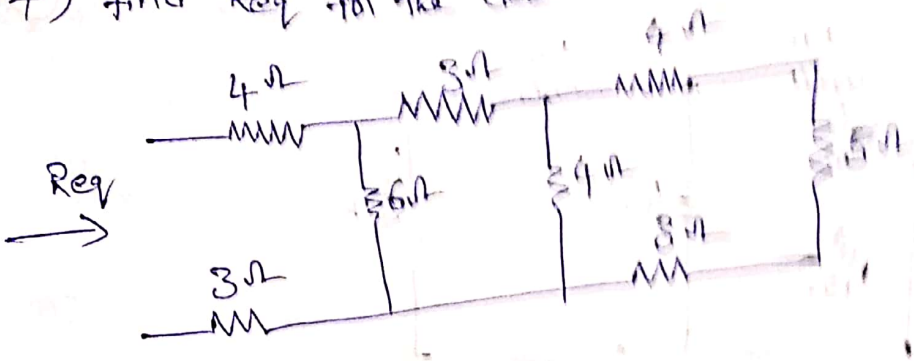
10Ω & 1.2Ω are in series

$R_{ab} = 10 + 1.2$

$R_{ab} = 11.2\Omega$

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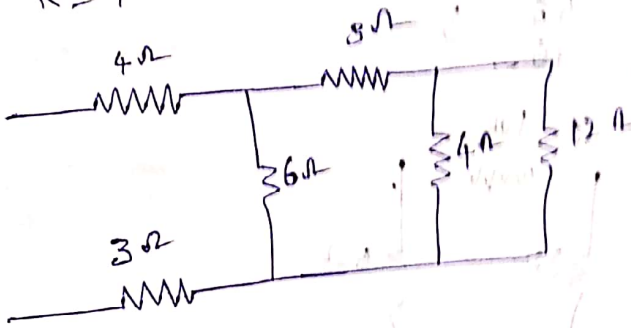
4) find Req for the ckt



Sol

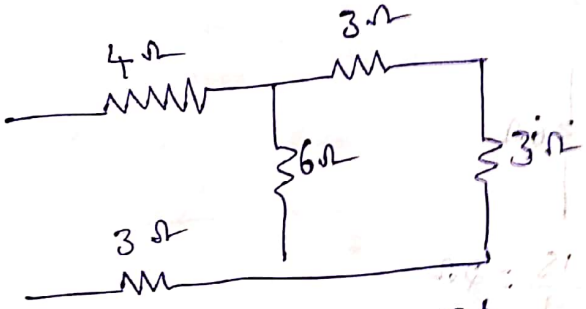
4Ω & 5Ω & 3Ω are in series

$R = 4+5+3 = 12\,\Omega$



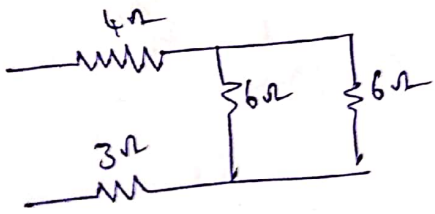
$4\Omega \,//\, 12\Omega$

$R = \frac{4\times12}{4+12} = \frac{48}{16} = 3$



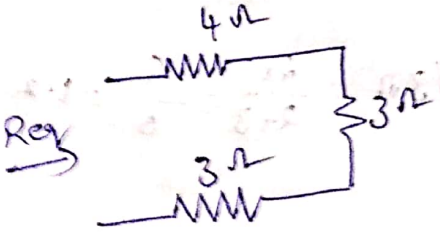
3Ω & 3Ω are in series

$R = 3+3 = 6$



$6\Omega \,//\, 6\Omega$

$R = \frac{6\times6}{6+6} = \frac{36}{12} = 3$



4Ω, 3Ω, 3Ω are in series

$Req = 4+3+3$

$= 10\,\Omega$

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Wye - Delta transformations :-

Star - delta transformations and delta - Star transformations allow us to convert one type of circuit connection into another type of circuit connection inorder to easily analyze the Ckt.

These transformation techniques can be used to good effect for either Star or delta Ckts containing resistances or impedances.

In Ckt analysis when the resistors are neither in parallel nor in series.

Ex: Bridge Ckt

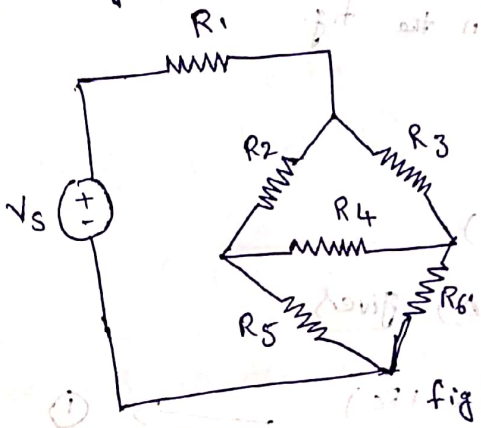


fig: Bridge circuit

Many Ckts are bridge type networks, it can be simplified by using three terminal equivalent networks. These are the Y or T network and Δ or Π network.

These networks are used in the three phase networks, electrical filters and matching networks.

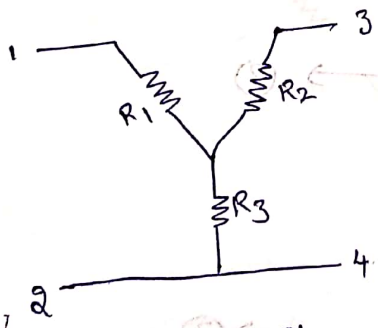


fig: Y - network

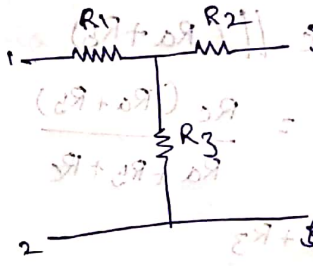


fig: T - network.

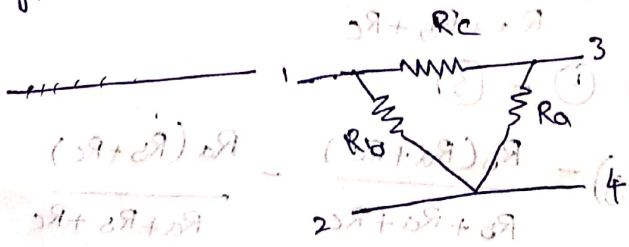


fig: Δ - network

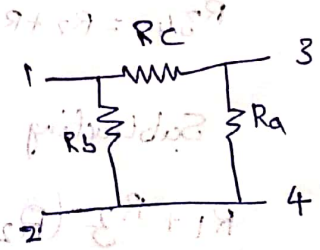


fig: Π - network.

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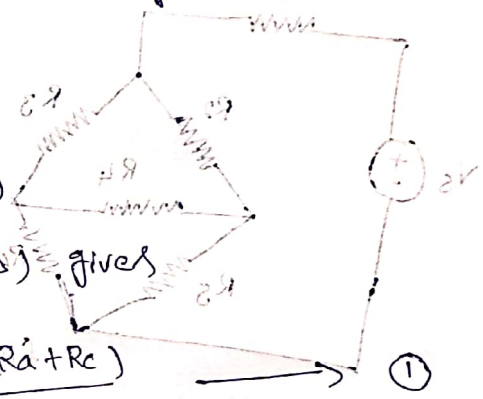
Delta to wye Conversion :-

It is more convinient to work with a wye n/w, in a place where the ckt contains a delta configuration.

we have to superimpose a wye n/w on the existing delta n/w and find the equivalent resistances in the wye n/w.

The resistance b/w each pair of nodes in the Δ or π n/w is the same as the resistance b/w the same pair of nodes in the Y or T n/w.

for the terminals 1 & 2 in the fig.



$$R_{12}(Y) = R_1 + R_3$$

$$R_{12}(\Delta) = R_b \,||\, (R_a + R_c)$$

Equating $R_{12}(Y) = R_{12}(\Delta)$ gives

$$R_{12} = R_1 + R_3 = \frac{R_b(R_a + R_c)}{R_b + (R_a + R_c)} \longrightarrow (1)$$

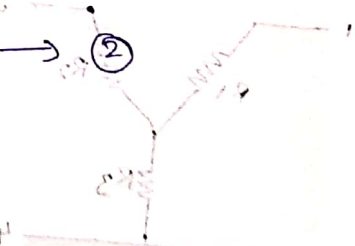
Similarly

$$R_{13}(T) = R_{13}(\pi)$$

$$R_{13}(T) = R_1 + R_2$$

$$R_{13}(\pi) = R_c \,||\, (R_a + R_b)$$

$$R_{13} = R_1 + R_2 = \frac{R_c(R_a + R_b)}{R_a + R_b + R_c} \longrightarrow (2)$$



$$R_{34}(T) = R_2 + R_3$$

$$R_{34}(\pi) = R_a \,||\, (R_b + R_c)$$

$$R_{34} = R_2 + R_3 = \frac{R_a(R_b + R_c)}{R_a + R_b + R_c} \longrightarrow (3)$$

Subtracting eq (1) - (3)

$$R_1 + R_3 - (R_2 + R_3) = \frac{R_b(R_a + R_c)}{R_b + R_a + R_c} - \frac{R_a(R_b + R_c)}{R_a + R_b + R_c}$$

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$$R_1 + R_3 - R_2 - R_3 = \frac{R_a R_b + R_b R_c - R_a R_b - R_a R_c}{R_a + R_b + R_c}$$

$$R_1 - R_2 = \frac{R_c (R_b - R_a)}{R_a + R_b + R_c} \longrightarrow (4)$$

Adding eq (2) + (4)

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} \longrightarrow (5)$$

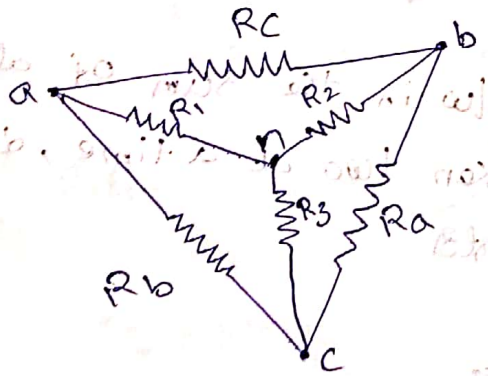
Subtracting eq (4) - (2)

$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c} \longrightarrow (6)$$

Subtracting equations (5) - (1)

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c} \longrightarrow (7)$$

Each resistor in the Y network is the product of the resistor in the two adjacent Δ branches devided by the sum of the three Δ resistors.





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Y to Δ Conversion :-

To obtain the conversion formulas for transforming a Y-n/w to an equivalent delta n/w.

from equations ⑤, ⑥, ⑦

⑤×⑥ + ⑥×⑦ + ⑦×⑤

$$R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_a R_b R_c (R_a + R_b + R_c)}{(R_a + R_b + R_c)^2} \longrightarrow ⑧$$

Dividing eq ⑧ by eq ⑤

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_aR_bR_c}{R_a + R_b + R_c} \longrightarrow ⑧$$

Dividing eq ⑧ by eq ⑤

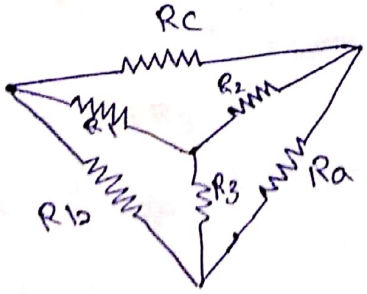
$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} \longrightarrow ⑨$$

eq ⑧/⑥ ⇒ $R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} \longrightarrow ⑩$

eq ⑧/⑦ ⇒ $R_C = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} \longrightarrow ⑪$

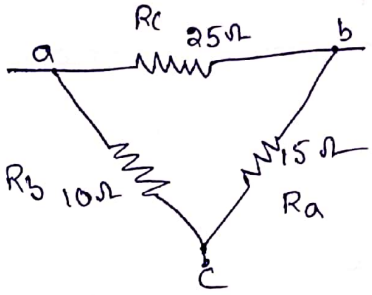
from eq ⑨, ⑩, ⑪ are the conversion rule for Y to Δ network.

Each resistor in the Δ n/w is the sum of all possible products of Y resistors taken two at a time, divided by the opposite Y-resistor.



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(1). Convert the Δ n/w to an equivalent Y n/w

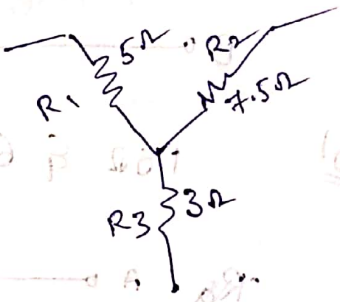


Sol

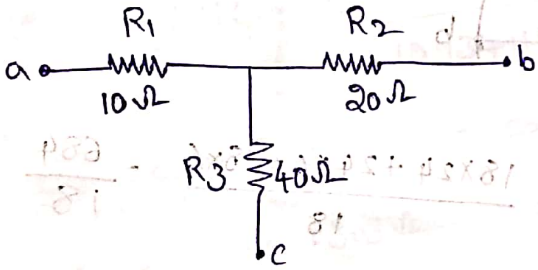
$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} = \frac{10 \times 25}{25+10+15} = 5\Omega$$

$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c} = \frac{25 \times 15}{25+10+15} = 7.5\Omega$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c} = \frac{15 \times 10}{50} = 3\Omega$$



(2) Transform the Y n/w to delta n/w

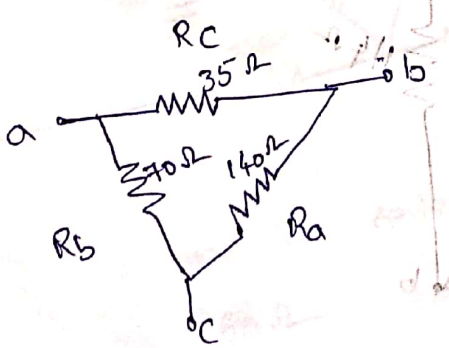


Sol

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} = \frac{10\times20 + 20\times40 + 10\times40}{10} = \frac{1400}{10} = 140$$

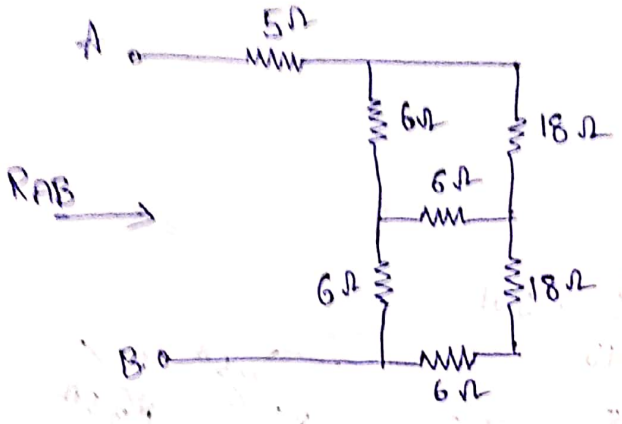
$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} = \frac{1400}{20} = 70\Omega$$

$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = \frac{1400}{40} = 35\Omega$$

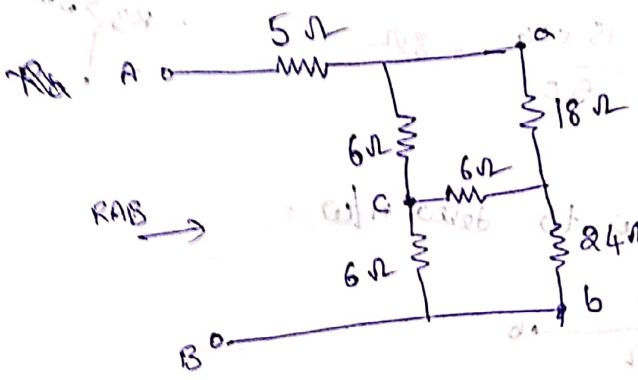


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(9) find equivalent R_{AB} using Y − Δ transformation.



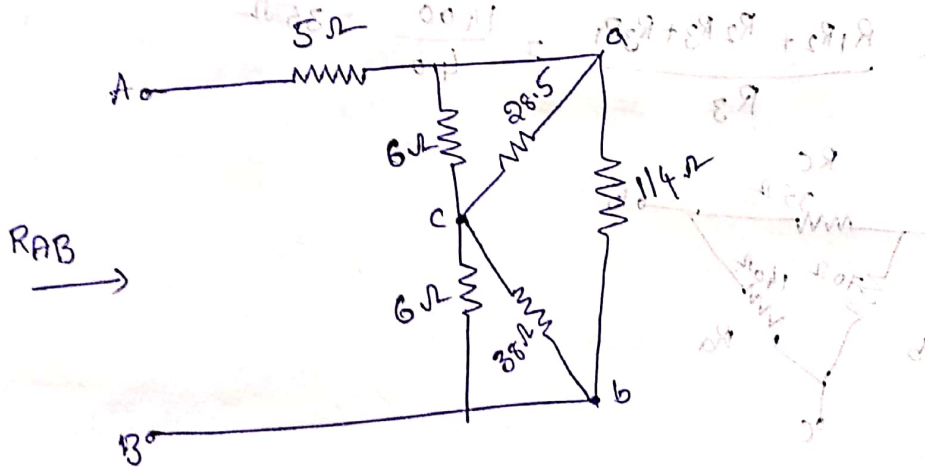
Sol 18Ω & 6Ω are in series.



$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} = \frac{18\times24 + 24\times6 + 18\times6}{18} = \frac{684}{18} = 38\Omega$$

$$R_b = \frac{684}{24} = 28.5\Omega$$

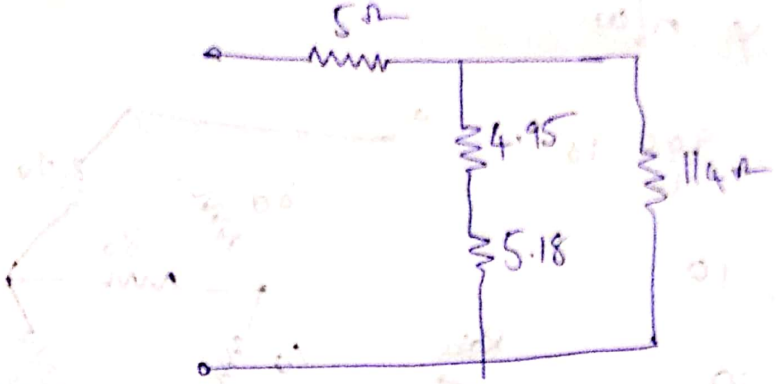
$$R_c = \frac{684}{6} = 114$$



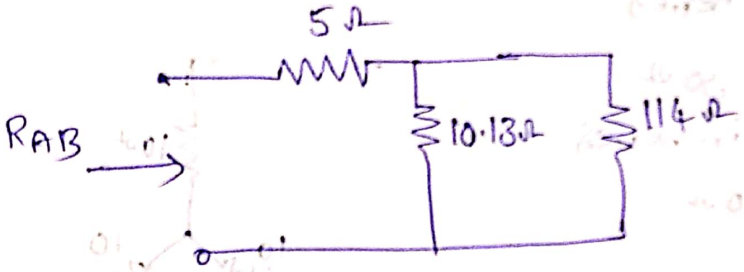
$$6\Omega \,//\, 28.5 \Rightarrow \frac{6\times28.5}{6+28.5} = \frac{171}{34.5} = 4.956$$

$$6\Omega \,//\, 38\Omega \Rightarrow \frac{6\times38}{6+38} = \frac{228}{44} = 5.18$$

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4.95Ω & 5.18 are in series

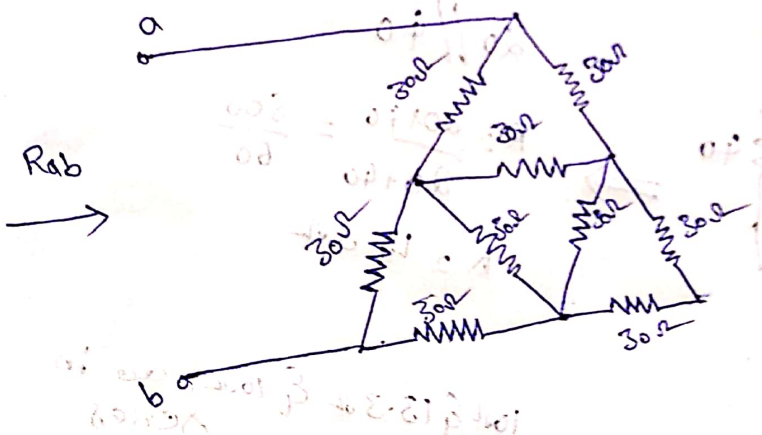


$$10.13\Omega \,||\, 11.4\Omega = \frac{10.13 \times 11.4}{10.13 + 11.4} = \frac{1154.8}{124.13} = 9.303$$

5Ω & 9.303 are in series

$R_{AB} = 14.303\Omega$

(2) find equivalent R_{ab} using wye-delta transformation.



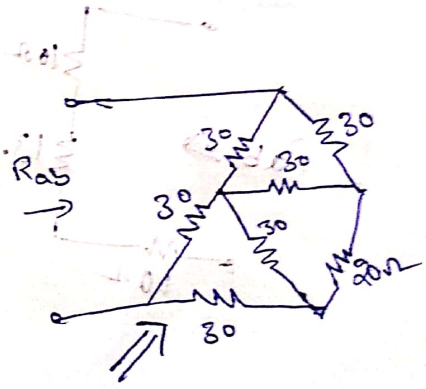
Sol

30Ω & 30Ω are in series

$R = 30 + 30 = 60\Omega$

$60\Omega \,||\, 30\Omega$

$$R = \frac{60 \times 30}{60 + 30} = \frac{1800}{90} = 20\Omega$$



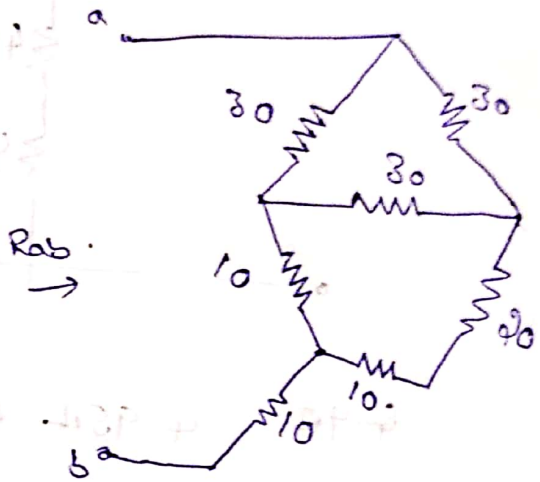
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Convert Δ to Y n/w

$$R_1 = \frac{30 \times 30}{30+30+30} = \frac{900}{90} = 10$$

$$R_2 = \frac{30 \times 30}{30+30+30} = 10$$

$$R_3 = \frac{30 \times 30}{30+30+30} = 10$$



10Ω & 20Ω are in series

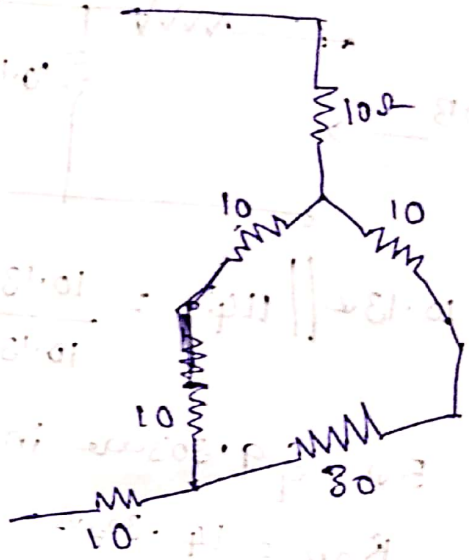
$R = 10 + 20 = 30\Omega$

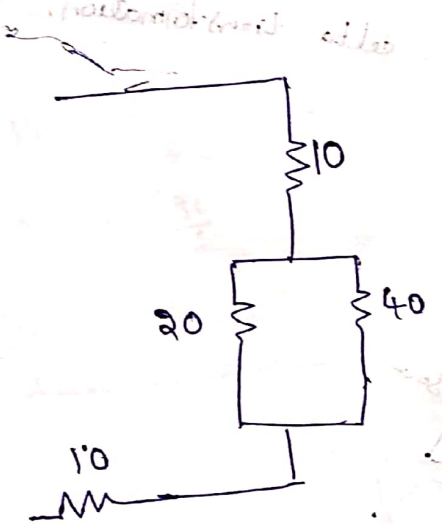
10Ω & 10Ω are in series

$R = 10 + 10 = 20\Omega$

10 & 30 are in series

$R = 10 + 30 = 40$

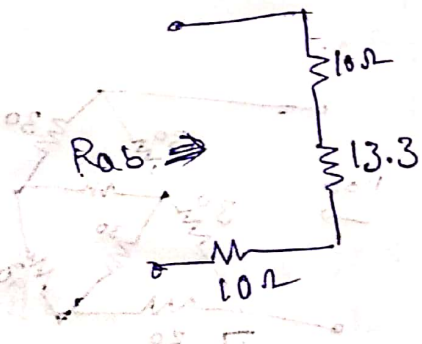




$20 // 40$

$$R = \frac{20 \times 40}{20+40} = \frac{800}{60}$$

$R = 13.3\Omega$



10Ω & 13.3Ω & 10Ω are in series

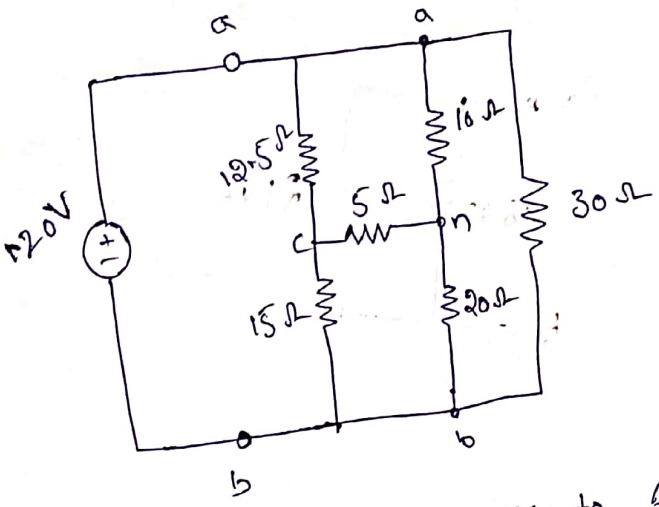
$R = 10 + 13.3 + 10$

$R = 33.3\Omega$

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(*) Obtain the equivalent resistance R_{ab} for the ckt and use it to find current i.

(4.1)



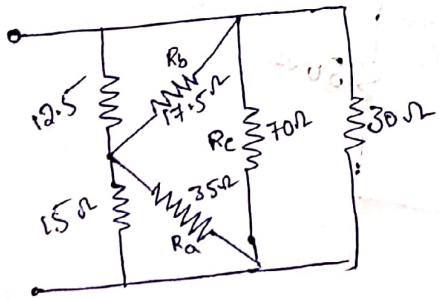
Sol Convert the Y network to Δ n/w.

$R_1 = 10\Omega \quad R_2 = 20\Omega \quad R_3 = 5\Omega$

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} = \frac{10\times20 + 20\times5 + 10\times5}{10} = 35\Omega$$

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} = \frac{350}{20} = 17.5\Omega$$

$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = \frac{350}{5} = 70\Omega$$



$70\Omega \,//\, 30\Omega$

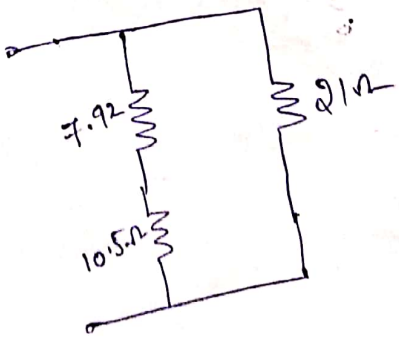
$$R = \frac{70\times30}{70+30} = 21\Omega$$

$12.5\Omega \,//\, 17.5\Omega$

$$R = \frac{12.5\times17.5}{12.5+17.5} = 7.292\Omega$$

$15\Omega \,//\, 35\Omega$

$$R = \frac{15\times35}{15+35} = 10.5\Omega$$

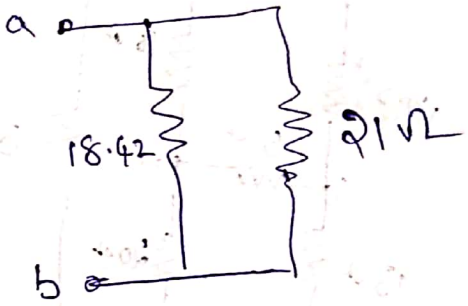


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7.92 Ω & 10.5 Ω is in series

$R = 7.92 + 10.5$

$R = 18.42\Omega$



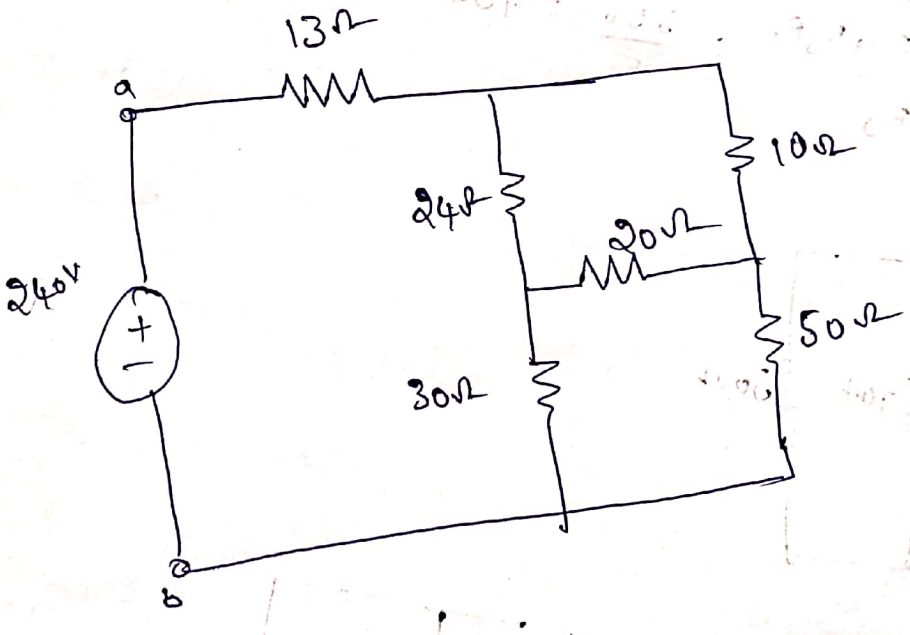
$18.42\Omega \,//\, 21\Omega$

$$R_{ab} = \frac{18.42 \times 21}{18.42 + 21}$$

$$= 9.632$$

$$i = \frac{V_s}{R_{ab}} = \frac{120}{9.632} = 12.458\,A$$

find R_{ab} & i in the ckt



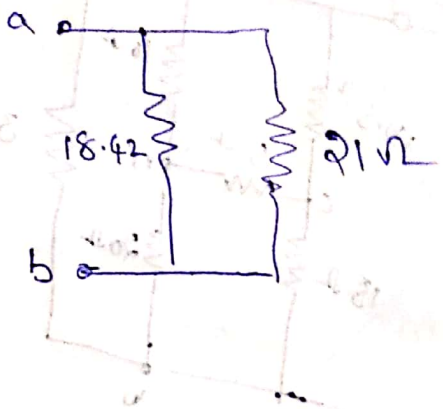
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7.92 Ω & 10.5 Ω is in series

$R = 7.92 + 10.5$

$R = 18.42\Omega$

$18.42\Omega // 21\Omega$

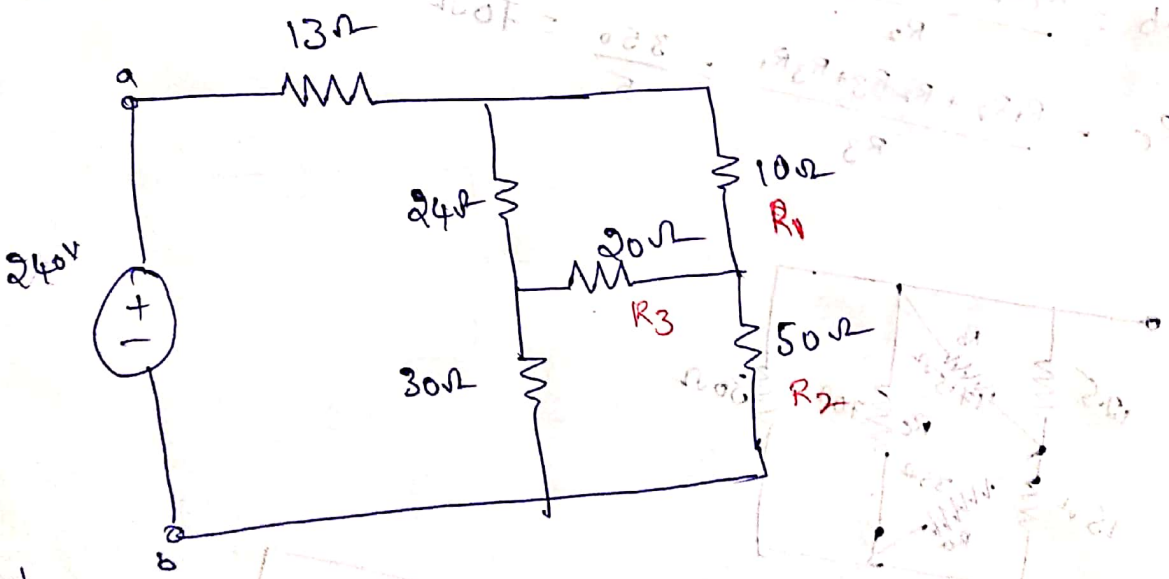


$$R_{ab} = \frac{18.42 \times 21}{18.42 + 21}$$

$$= 9.632$$

$$i = \frac{V_s}{R_{ab}} = \frac{120}{9.632} = 12.458\,A$$

* find R_{ab} & i in the ckt



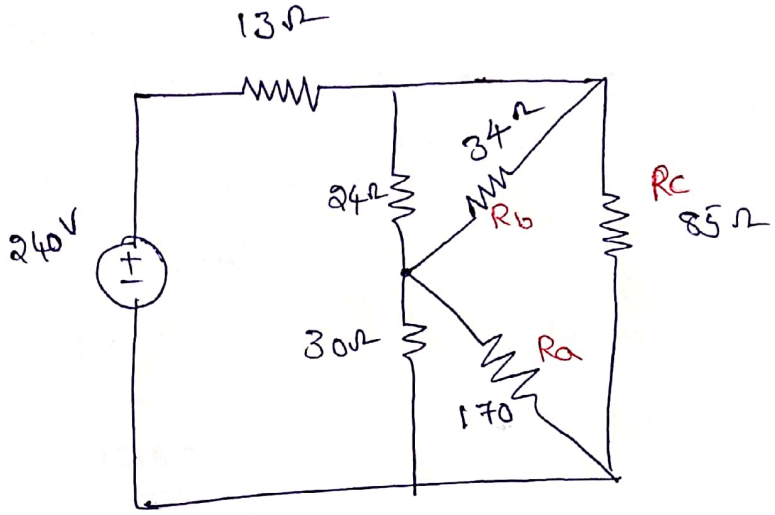
Sol

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} = \frac{10\times50 + 50\times20 + 10\times20}{10} = \frac{1700}{10} = 170$$

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} = \frac{1700}{50} = 34$$

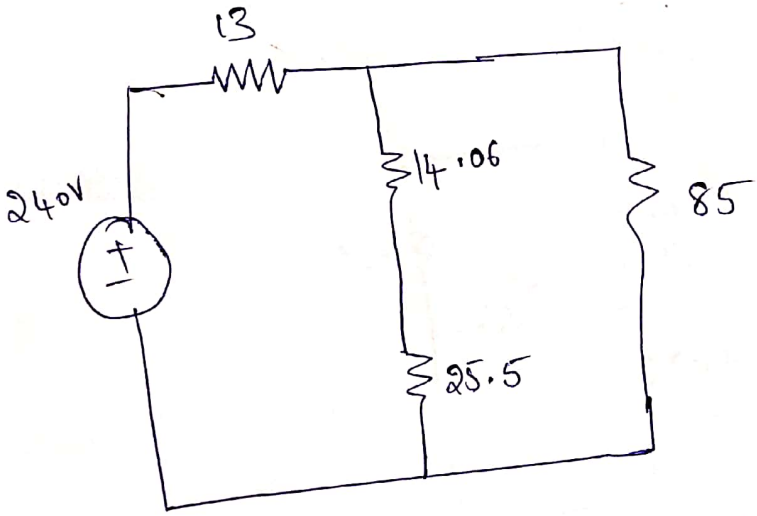
$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = \frac{1700}{20} = 85$$

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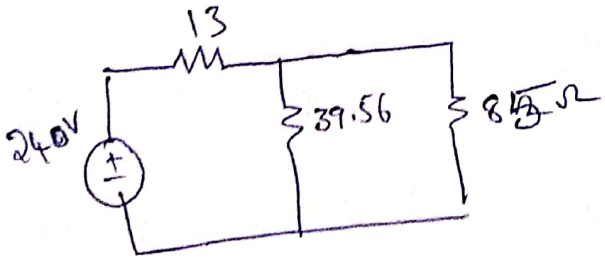
$24\Omega \,//\, 34\Omega = \frac{24 \times 34}{24+34} = \frac{816}{58} = 14.06$

$30\Omega \,//\, 170 = \frac{30 \times 170}{30+170} = \frac{5100}{200} = 25.5$



14.06 & 25.5 is in Series

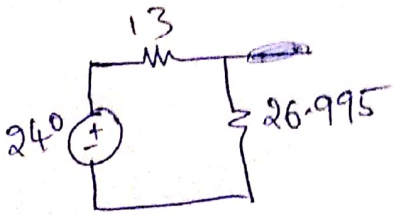
$R = 39.56$



$39.56 \,//\, 85 = \frac{39.56 \times 85}{}$

$= \frac{3362.6}{124.56}$

$= 26.995$



$R_{ab} = 13 + 26.995 = 40\ \Omega$

$I = \frac{240}{40} = 6A$

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Nodal Analysis :- (Branch current method).

A method of determining the voltage between nodes in an electric circuit interms of the branch currents.

Node :- A node is the point of connection between two or more branches. A node is usually indicated by a dot in a circuit.

Nodal analysis provides a general procedure for analysing circuits using node voltages as the ckt variable. Choosing node voltages instead of element voltages as a ckt variable.

The nodal analysis of the ckt involves taking the following three steps.

→ select a node as the reference node. Assign voltages $V_1, V_2 \cdots V_{n-1}$ to the remaining $n-1$ nodes. The voltages are referenced with respect to the reference node.

→ Apply KCL to each of the $n-1$ non reference nodes. Use ohm's law to express the branch currents interms of node voltages.

→ Solve the resulting simultaneous equations to obtain the unknown node voltages by using standard analysis methods such as elimination method or Cramer's rule or matrix inversion method.

The first step in nodal analysis is selecting a node as the reference node. The reference node is commonly called the ground. It is assumed to have zero potential.

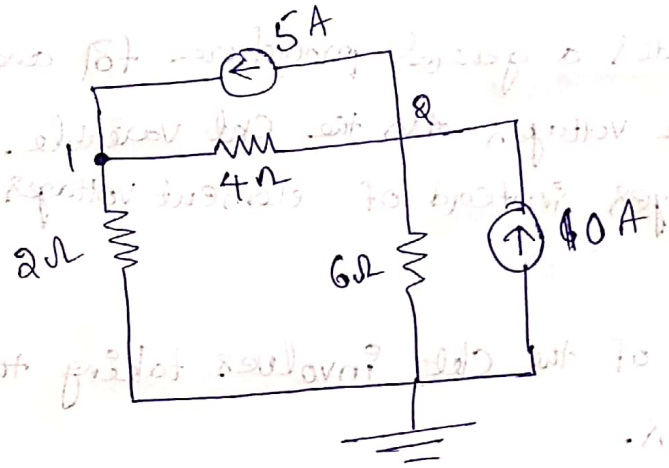
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A reference node is indicated by any of the three symbols.



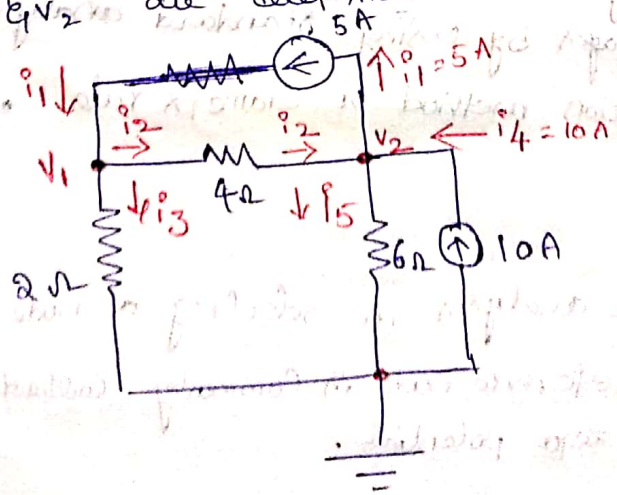
Common symbols for indicating a reference node.

① ~~calculate~~ Calculate the node voltages in the ckt.



Sol The currents are selected for the application of KCL. Except for the branches with current sources, the labeling of the currents is arbitary but consistent. (By consistent, we mean that for example we assume i_2 enters the 4Ω resistor from the left hand side, i_2 must leave the resistor from the right hand side.

The reference node is selected and the node voltages V_1 & V_2 are determined.



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At node 1 Applying KCL & ohm's law

KCL $\Rightarrow i_1 - i_2 - i_3 = 0$

$i_1 = i_2 + i_3$

$i_1 = 5\,A, \; i_2 = \frac{V_1 - V_2}{4}, \; i_3 = \frac{V_1}{2}, \; i_4 = 10\,A, \; i_5 = \frac{V_2}{6}$

$5 = \frac{V_1 - V_2}{4} + \frac{V_1 - 0}{2} \Rightarrow 5 = \frac{V_1 - V_2 + 2V_1}{4}$

$20 = V_1 - V_2 + 2V_1$

$3V_1 - V_2 = 20 \longrightarrow (1)$

At node 2

$i_2 + i_4 = i_1 + i_5$

$\frac{V_1 - V_2}{4} + 10 = 5 + \frac{V_2 - 0}{6}$

$\frac{V_1 - V_2 + 40}{4} = \frac{30 + V_2}{6}$

$\frac{V_1 - V_2 + 40}{4} - \frac{30 - V_2}{6} = 0$

$\frac{3V_1 - 3V_2 + 120 - 60 - 2V_2}{12} = 0$

$3V_1 - 3V_2 + 60 - 2V_2 = 0$

$3V_1 - 5V_2 = -60$

$(-3V_1 + 5V_2) = 60$

$-3V_1 + 5V_2 = 60 \longrightarrow (2)$

we can solve the equations by using Cramer's rule and obtain the values of V_1 & V_2.

(1) $\Rightarrow 3V_1 - V_2 = 20$

(2) $\Rightarrow -3V_1 + 5V_2 = 60$

$$\begin{bmatrix} 3 & -1 \\ -3 & 5 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 60 \end{bmatrix}$$

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The determinant of matrix is

$$\Delta = \begin{vmatrix} 3 & -1 \\ -3 & 5 \end{vmatrix} = 15 - 3 = 12$$

To obtain V_1 & V_2 as

$$V_1 = \frac{\Delta_1}{\Delta} = \frac{\begin{vmatrix} 20 & -1 \\ 60 & 5 \end{vmatrix}}{\Delta} = \frac{100+60}{12} = \frac{160}{12} = 13.333\,V$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{\begin{vmatrix} 3 & 20 \\ -3 & 60 \end{vmatrix}}{\Delta} = \frac{180+60}{12} = \frac{240}{12} = 20\,V$$

$i_1 = 5\,A$

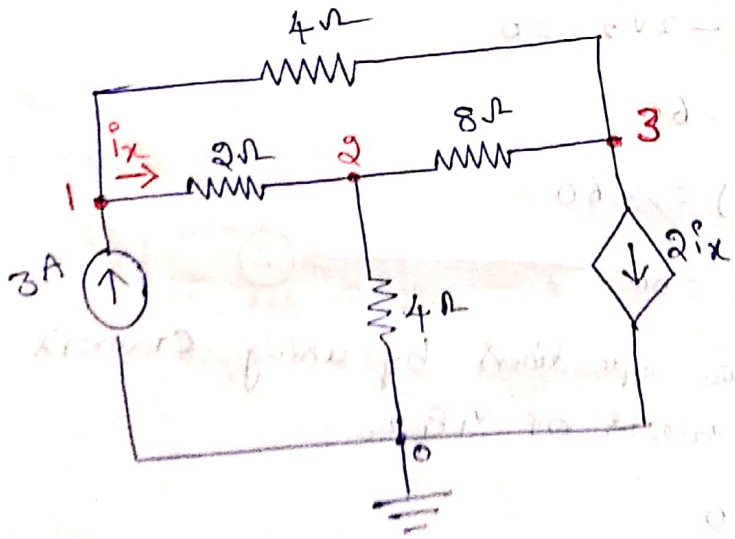
$$i_2 = \frac{V_1 - V_2}{4} = \frac{13.33 - 20}{4} = -1.6668\,A$$

$$i_3 = \frac{V_1}{2} = \frac{13.333}{2} = 6.666\,A$$

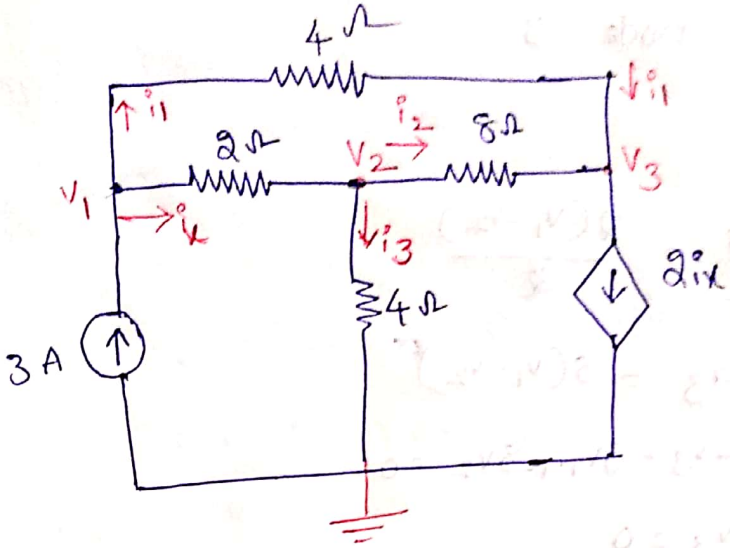
$i_4 = 10\,A$

$$i_5 = \frac{V_2}{6} = \frac{20}{6} = 3.333\,A$$

(2) Determine the voltages at the nodes shown in fig:



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Apply KCL at node 1

$$3 = i_1 + i_x$$

$$i_1 = \frac{v_1 - v_3}{4} \qquad i_x = \frac{v_1 - v_2}{2}$$

$$3 = \frac{v_1 - v_3}{4} + \frac{v_1 - v_2}{2}$$

$$3 = \frac{v_1 - v_3 + 2v_1 - 2v_2}{4}$$

$$12 = 3v_1 - 2v_2 - v_3 \longrightarrow (1)$$

Apply KCL at node 2

$$i_x = i_2 + i_3$$

$$\frac{v_1 - v_2}{2} = \frac{v_2 - v_3}{8} + \frac{v_2 - 0}{4}$$

$$\frac{v_1 - v_2}{2} = \frac{v_2 - v_3 + 2v_2}{8}$$

$$\frac{v_1 - v_2}{2} = \frac{3v_2 - v_3}{8}$$

$$\frac{v_1 - v_2}{2} - \frac{3v_2 + v_3}{8} = 0$$

$$4v_1 - 4v_2 - 3v_2 + v_3 = 0$$

$$4v_1 - 7v_2 + v_3 = 0$$

$$-(-4v_1 + 7v_2 - v_3) = 0 \longrightarrow (2)$$

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Apply KCL at node 3

$$i_1 + i_2 = 2i_x$$

$$\frac{v_1 - v_3}{4} + \frac{v_2 - v_3}{8} = \frac{2(v_1 - v_2)}{2}$$

$$2v_1 - 2v_3 + v_2 - v_3 = 8(v_1 - v_2)$$

$$2v_1 - 2v_3 + v_2 - v_3 - 8v_1 + 8v_2 = 0$$

$$-6v_1 + 9v_2 - 3v_3 = 0$$

$$-3(2v_1 - 3v_2 + v_3) = 0$$

$$2v_1 - 3v_2 + v_3 = 0 \longrightarrow (3)$$

(1) $\Rightarrow$ $3v_1 - 2v_2 - v_3 = 12$

(2) $\Rightarrow$ $-4v_1 + 7v_2 - v_3 = 0$

(3) $\Rightarrow$ $2v_1 - 3v_2 + v_3 = 0$

$$\begin{bmatrix} 3 & -2 & -1 \\ -4 & 7 & -1 \\ 2 & -3 & 1 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} 12 \\ 0 \\ 0 \end{bmatrix}$$

$$\Delta = 3(7-3) - (-2)(-4+2) - 1(12-14)$$

$$= 3(4) + 2(-2) - (-2)$$

$$= 12 - 4 + 2 = 12 - 2$$

$$\Delta = 10$$

$$v_1 = \frac{\Delta_1}{\Delta}$$

$$\Delta_1 = \begin{vmatrix} 12 & -2 & -1 \\ 0 & 7 & -1 \\ 0 & -3 & 1 \end{vmatrix}$$

$$= 12(7-3) - (-2)(0-0) - 1(0-0)$$

$$= 12 \times 4 = 48$$

$$v_1 = \frac{48}{10} = 4.8$$

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$$V_2 = \frac{\Delta 2}{\Delta}$$

$$\Delta_2 = \begin{vmatrix} 3 & 12 & -1 \\ -4 & 0 & -1 \\ 2 & 0 & 1 \end{vmatrix}$$

$$= 3(0-0) - 12(-4+2) + (-1)(0-0)$$

$$= 0 - 12(-2) \times 0$$

$$\Delta_2 = 24$$

$$V_2 = \frac{24}{10} = 2.4$$

$$V_3 = \frac{\Delta 3}{\Delta}$$

$$\Delta_3 = \begin{vmatrix} 3 & -2 & 12 \\ -4 & 7 & 0 \\ 2 & -3 & 0 \end{vmatrix}$$

$$= 3(0-0) - (-2)(0-0) + 12(12-14)$$

$$= 0 - 0 + 12(-2)$$

$$= -24$$

$$V_3 = \frac{-24}{10} = -2.4$$

$$i_1 = \frac{V_1 - V_3}{4} =$$

$$i_x = i_2 + i_3$$

$$i_1 = \frac{V_1 - V_3}{4} = \frac{4.8 - (-2.4)}{4} = \frac{4.8 + 2.4}{4} = 1.8$$

$$i_x = \frac{V_1 - V_2}{2} = \frac{4.8 - 2.4}{2} = \frac{2.4}{2} = 1.2$$

$$i_1 + i_2 = 2 i_x$$

$$1.8 + i_2 = 2 \times 1.2$$

$$i_2 = 2.4 - 1.8$$

$$i_2 = 0.6 \text{ A}$$

$$i_x = i_2 + i_3$$

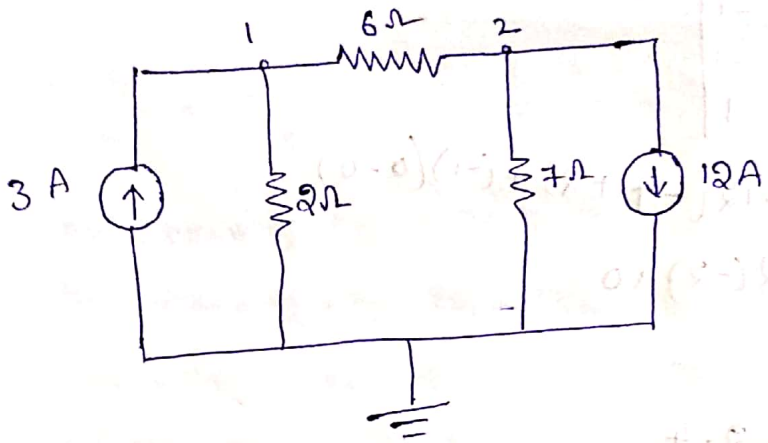
$$1.2 = 0.6 + i_3$$

$$i_3 = 1.2 - 0.6$$

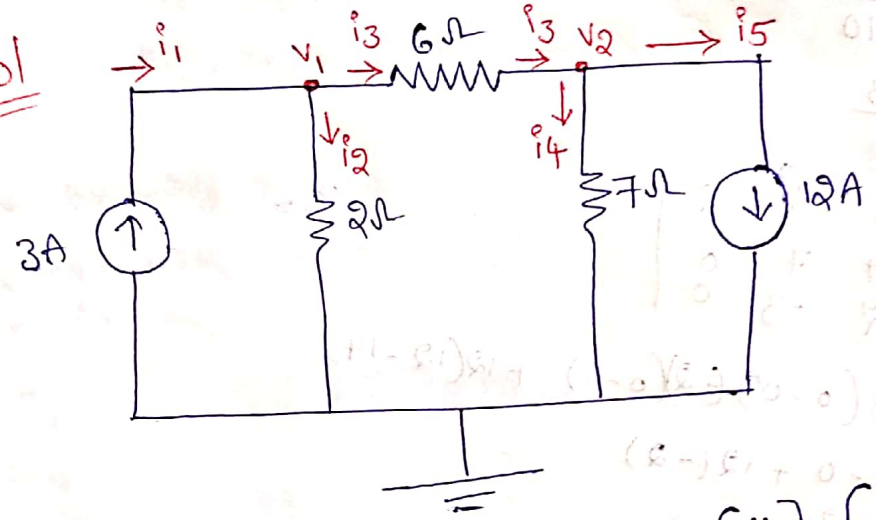
$$i_3 = 0.6 \text{ A}$$

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(*) Obtain the node voltages in the ckt :



Sol



Apply KCL at node ①

$$i_1 = i_2 + i_3$$

$$3 = \frac{v_1 - 0}{2} + \frac{v_1 - v_2}{6}$$

$$3 = \frac{3v_1 + v_1 - v_2}{6}$$

$$18 = 4v_1 - v_2 \longrightarrow ①$$

Apply KCL at node ②

$$i_3 = i_4 + i_5$$

$$\frac{v_1 - v_2}{6} = \frac{v_2}{7} + 12$$

$$\frac{v_1 - v_2}{6} - \frac{v_2}{7} = 12$$

$$\frac{7v_1 - 7v_2 - 6v_2}{42} = 12$$

$$7v_1 - 13v_2 = 504 \longrightarrow ②$$

$$\begin{pmatrix} 4 & -1 \\ 7 & -13 \end{pmatrix} \begin{pmatrix} v_1 \\ v_2 \end{pmatrix} = \begin{pmatrix} 18 \\ 504 \end{pmatrix}$$

$$\Delta = ad - bc$$

$$= 4 \times -13 - (-7)$$

$$= -52 + 7 = -45$$

$$v_1 = \frac{\Delta_1}{\Delta}$$

$$\Delta_1 = \begin{vmatrix} 18 & -1 \\ 504 & -13 \end{vmatrix} = -234 + 504$$

$$= 270$$

$$v_1 = \frac{270}{-45} = -6\,V$$

$$v_2 = \frac{\Delta_2}{\Delta}$$

$$\Delta_2 = \begin{vmatrix} 4 & 18 \\ 7 & 504 \end{vmatrix} = 2016 - 126$$

$$= 1890$$

$$v_2 = \frac{1890}{-45} = -42\,V$$

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mesh analysis :-

A mesh is a loop that does not contain any other loop within it.
mesh analysis provides another general procedure for analysing circuits using mesh currents as the circuit variables.

Nodal analysis applies KCL to find unknown voltages in a given ckt, while mesh analysis applies KVL to find unknown currents.

The current through a mesh is known as mesh current.

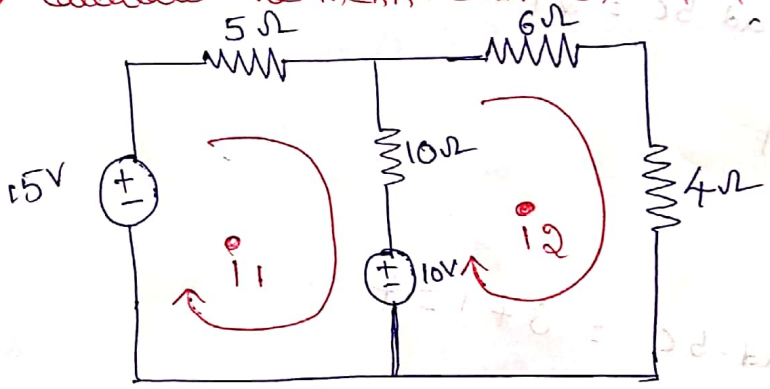
Steps to determine the mesh currents.

→ Assign mesh currents $i_1, i_2 \cdots i_n$ to the n meshes.

→ Apply KVL to each of the n meshes. Use ohm's law to express the voltages interms of the mesh currents.

→ Solve the resulting n simultaneous equations to get the mesh currents.

① Calculate the mesh currents i_1 & i_2



Sol Apply KVL to the mesh 1

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

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

$$15i_1 - 10i_2 - 5 = 0$$

$$5(3i_1 - 2i_2 - 1) = 0$$

$$3i_1 - 2i_2 = 1 \longrightarrow (1)$$

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Apply KVL to mesh (2)

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

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

$$20i_2 - 10i_1 - 10 = 0$$

$$10(-i_1 + 2i_2 - 1) = 0$$

$$-i_1 + 2i_2 = 1 \longrightarrow (2)$$

Use Cramer's rule method

$$\begin{bmatrix} 3 & -2 \\ -1 & 2 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 3 & -2 \\ -1 & 2 \end{vmatrix} = ad - bc = 6 - 2 = 4$$

$$i_1 = \frac{\Delta_1}{\Delta}$$

$$\Delta_1 = \begin{vmatrix} 1 & -2 \\ 1 & 2 \end{vmatrix} = ad - bc = 2 + 2 = 4$$

$$i_1 = \frac{4}{4} = 1\,A$$

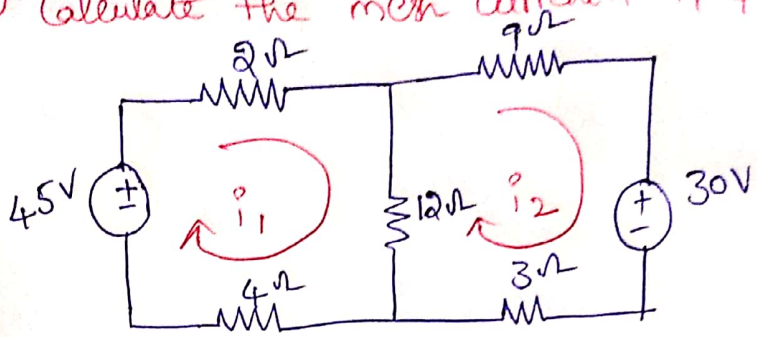
$$i_2 = \frac{\Delta_2}{\Delta}$$

$$\Delta_2 = \begin{vmatrix} 3 & 1 \\ -1 & 1 \end{vmatrix} = ad - bc = 3 + 1 = 4$$

$$i_2 = \frac{4}{4} = 1\,A$$

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② Calculate the mesh currents i_1 & i_2



Sol Apply KVL to mesh ①

$$-45+2i_1+12(i_1-i_2)+4i_1=0$$
$$-45+2i_1+12i_1-12i_2+4i_1=0$$
$$18i_1-12i_2-45=0$$
$$3(6i_1-4i_2-15)=0$$
$$6i_1-4i_2=15 \longrightarrow ①$$

Apply KVL to mesh ②

$$9i_2+30+3i_2+12(i_2-i_1)=0$$
$$9i_2+30+3i_2+12i_2-12i_1=0$$
$$24i_2-12i_1+30=0$$
$$3(8i_2-4i_1+10)=0$$
$$8i_2-4i_1=-10 \longrightarrow ②$$

using cramer's rule

$$\begin{bmatrix} 6 & -4 \\ -4 & 8 \end{bmatrix}\begin{bmatrix} i_1 \\ i_2 \end{bmatrix}=\begin{bmatrix} 15 \\ -10 \end{bmatrix}$$

$$\Delta = ad-bc = 48-16 = 32$$

$$i_1=\frac{\Delta_1}{\Delta} \Rightarrow \Delta_1=\begin{vmatrix} 15 & -4 \\ -10 & 8 \end{vmatrix} = ad-bc = 120-40 = 80$$

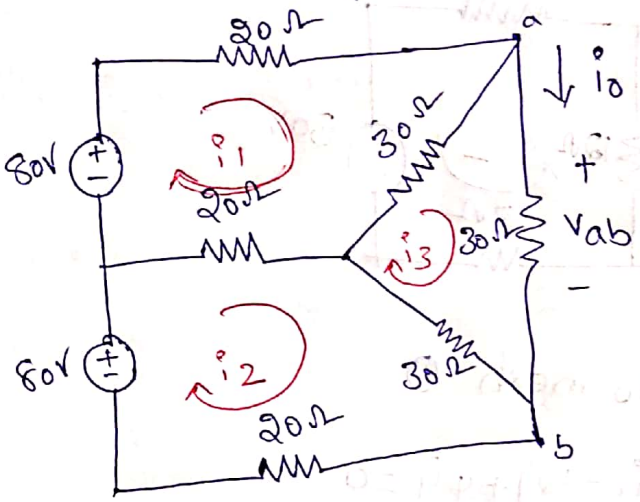
$$i_1=\frac{80}{32}=2.5\,A$$

$$i_2=\frac{\Delta_2}{\Delta} \Rightarrow \Delta_2=\begin{vmatrix} 6 & 15 \\ -4 & -10 \end{vmatrix} = ad-bc = -60+60 = 0$$

$$i_2=\frac{0}{32}=0$$

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3) use mesh analysis to find V_{ab} and i_o in the ckt



Sol

Apply KVL to loop ①

$$-80 + 20i_1 + 30(i_1 - i_3) + 20(i_1 - i_2) = 0$$

$$-80 + 20i_1 + 30i_1 - 30i_3 + 20i_1 - 20i_2 = 0$$

$$-80 + 70i_1 - 20i_2 - 30i_3 = 0$$

$$70i_1 - 20i_2 - 30i_3 = 8 \longrightarrow ①$$

Apply KVL to loop ②

$$-80 + 20(i_2 - i_1) + 30(i_2 - i_3) + 20i_2 = 0$$

$$-80 + 20i_2 - 20i_1 + 30i_2 - 30i_3 + 20i_2 = 0$$

$$-80 - 20i_1 + 70i_2 - 30i_3 = 0$$

$$-20i_1 + 70i_2 - 30i_3 = 80 \longrightarrow ②$$

Apply KVL to loop ③

$$30(i_3 - i_1) + 30i_3 + 30(i_3 - i_2) = 0$$

$$30i_3 - 30i_1 + 30i_3 + 30i_3 - 30i_2 = 0$$

$$-30i_1 - 30i_2 + 90i_3 = 0 \longrightarrow ③$$

Apply Cramer's rule

$$\begin{bmatrix} 70 & -20 & -30 \\ -20 & 70 & -30 \\ -30 & -30 & 90 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 80 \\ 80 \\ 0 \end{bmatrix}$$

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$$\Delta = 70(6300 - 900) - (-20)(-1800 - 900) - 30(600 + 9100)$$

$$= 5400 \times 70 + 20 \times (-2700) - 30(9700)$$

$$\Delta = 243000$$

$$\Delta_3 = \begin{vmatrix} 70 & -20 & 80 \\ -20 & 70 & 80 \\ -30 & -30 & 0 \end{vmatrix}$$

$$= 70(70 \times 0 - (-30 \times 80)) - (-20)(-20 \times 0 - (-30 \times 80)) + 80(-20 \times -30 - (-30 \times 70))$$

$$= 70(30 \times 80) + 20(30 \times 80) + 80(30 \times 70)$$

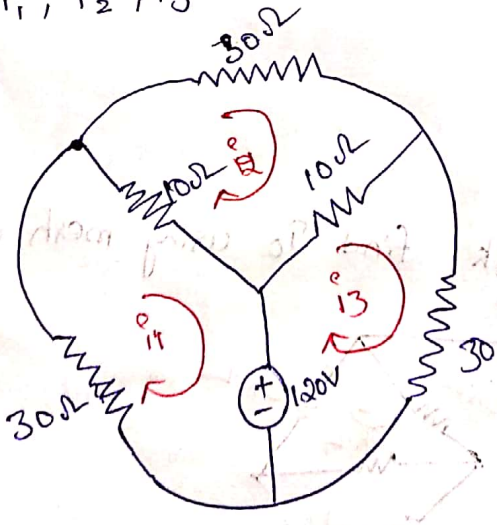
$$= 168000 + 48000 + 216000$$

$$\Delta_3 = 432000$$

$$i_0 = i_3 = \frac{\Delta_3}{\Delta} = \frac{432000}{243000} = 1.777\ A$$

$$V_{ab} = 30 i_3 = 1.777 \times 30 = 53.33\ V$$

* find i_1, i_2, i_3 in the Ckt



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Apply KVL to loop (1)

$$120 + 40i_1 - 10i_2 = 0$$

$40i_1 - i_2$

$$10(12 + 4i_1 - i_2) = 0$$

$$4i_1 - i_2 = -12 \longrightarrow (1)$$

Apply KVL to loop (2).

$$50i_2 - 10i_1 - 10i_3 = 0 \longrightarrow (2)$$

$$-i_1 + 5i_2 - i_3 = 0$$

Apply KVL to loop (3)

$$-120 - 10i_2 + 40i_3 = 0$$

$$-i_2 + 4i_3 = 12 \longrightarrow (3)$$

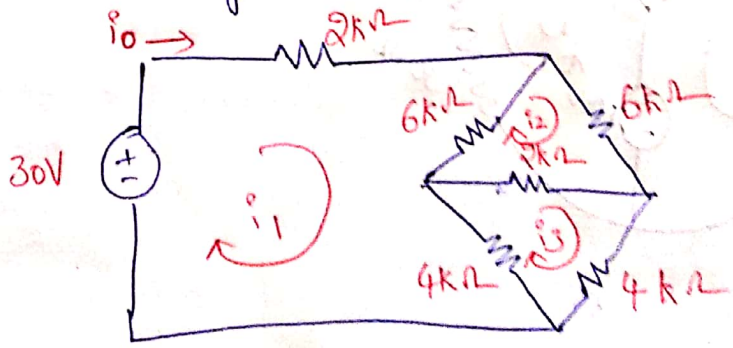
$$\begin{bmatrix} 4 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 4 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} -12 \\ 0 \\ 12 \end{bmatrix}$$

$$i_1 = \frac{\Delta_1}{\Delta} = -3A$$

$$i_2 = \frac{\Delta_2}{\Delta} = 0$$

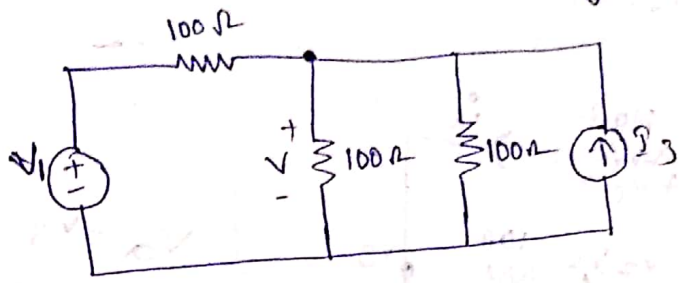
$$i_3 = \frac{\Delta_3}{\Delta} = 3A$$

for the bridge network find i_0 using mesh analysis



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b) If $V = AV_1 + BI_3$ in the following ckt, the value of A+B is



Sol $\frac{V - V_1}{100} + \frac{V}{100} + \frac{V}{100} = I_3$

$3V - V_1 = 100 I_3$

$3V = V_1 + 100 I_3$

$V = \frac{1}{3}V + \frac{100}{3} I_3$

$A = \frac{1}{3}$, $B = \frac{100}{3}$

$A+B = \frac{1}{3} + \frac{100}{3} = \frac{101}{3}$

C) A 12V automobile light is rated at 30W. The total charge that flows through the filament in one minute.

$t = 1 min = 60 sec$

Sol $V = 12V$

$P = 30$

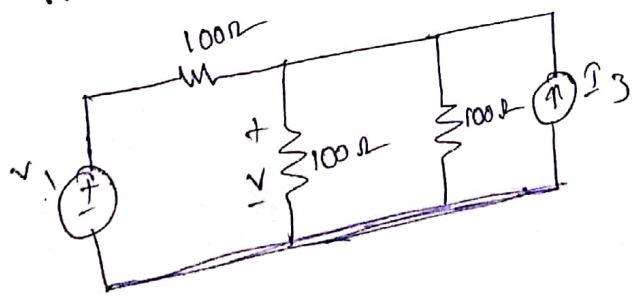
$P = VI$

$I = \frac{P}{V} = \frac{30}{12} = 2.5A$

Charge $Q = I \times t = 2.5 \times 60 = 150 C$

d) If $V_1 = AV + BI_3$ in the following ckt the value of A+B is

Sol



Sol $\frac{V - V_1}{100} + \frac{V}{100} + \frac{V}{100} = I_3$

$3V - V_1 = 100 I_3$

$-V_1 = 100 I_3 - 3V$

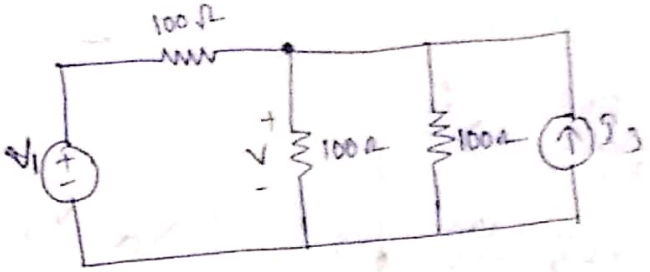
$V_1 = +3V + 100 I_3$

$A = 3 \quad B = -100$

$A+B = 3 - 100 = -97$

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b) If $V = AV_1 + BI_3$ in the following ckt, the value of A+B is



Sol

$$\frac{V - V_1}{100} + \frac{V}{100} + \frac{V}{100} = I_3$$

$$3V - V_1 = 100 I_3$$

$$3V = V_1 + 100 I_3$$

$$V = \frac{1}{3}V + \frac{100}{3} I_3$$

$$A = \frac{1}{3}, \quad B = \frac{100}{3}$$

$$A+B = \frac{1}{3} + \frac{100}{3} = \frac{101}{3}$$

C) A 12V automobile light is rated at 30W. The total charge that flows through the filament in one minute.

$t = 1 \text{ min} = 60 \text{ sec}$

Sol

$V = 12V$

$P = 30$

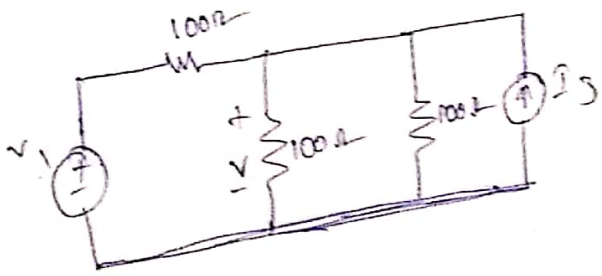
$P = VI$

$I = \frac{P}{V} = \frac{30}{12} = 2.5A$

Charge $Q = It = 2.5 \times 60 = 150\,C$

d) If $V_1 = AV + BI_3$ in the following ckt the value of A+B is

Sol



Sol

$$\frac{V - V_1}{100} + \frac{V}{100} + \frac{V}{100} = I_3$$

$$3V - V_1 = 100 I_3$$

$$-V_1 = 100 I_3 - 3V$$

$$V_1 = +3V - 100 I_3$$

$A = 3 \quad B = -100$

$A + B = 3 - 100 = -97$

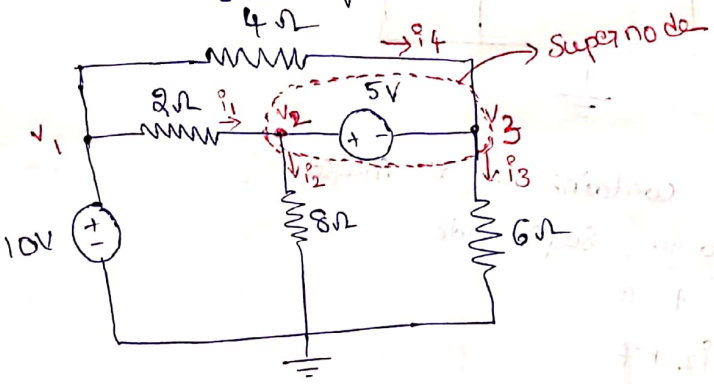
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Nodal Analysis with voltage Sources :-

How the voltage sources affect the nodal analysis. Consider the following two possibilities.

Case I :-

If a voltage source is connected b/w the reference node and a non reference node, we simply set the voltage at the non-reference node equal to the voltage of the voltage source. In the fig $V_1 = 10V$ i.e



Case II :-

If the voltage source (dependent & Independent) is connected b/w two non-reference nodes, the two non reference nodes form a generalised node & supernode, we apply both KCL and KVL to determine the node voltages.

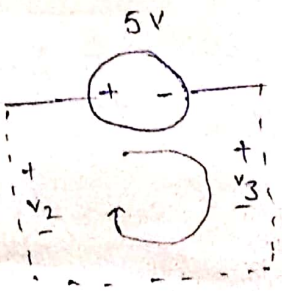
> A Super node is formed by enclosing a (dependent or Independent) voltage source connected b/w two non-reference nodes and any elements connected in parallel with it.

In the above figure node 2 & 3 form a super node. Hence at the super node apply KCL

$$i_1 + i_4 = i_2 + i_3$$

$$\frac{V_1 - V_2}{2} + \frac{V_1 - V_3}{4} = \frac{V_2}{8} + \frac{V_3}{6}$$

Apply KVL to the super node

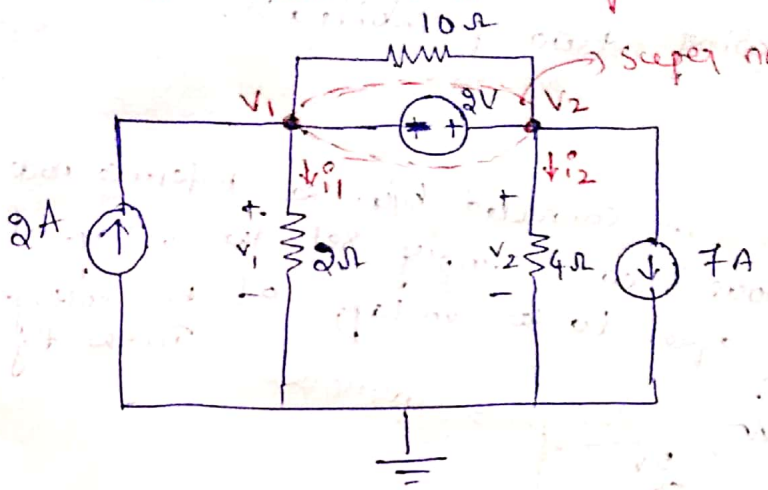


$$-V_2 + 5 + V_3 = 0$$

$$V_2 - V_3 = 5V$$

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For the ckt shown in below fig. find the node voltages.



Sol The super node contains the 2V source.

Apply KCL to the super node

$$2 - i_1 - i_2 - 7 = 0$$

$$2 = i_1 + i_2 + 7$$

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

$$2 = \frac{2V_1 + V_2 + 28}{4}$$

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

$$V_2 = -20 - 2V_1 \longrightarrow (1)$$

Apply KVL to the ckt

$$-V_1 - 2 + V_2 = 0$$

$$V_2 = V_1 + 2 \longrightarrow (2)$$

from eq (1) & (2)

$$V_1 + 2 = -20 - 2V_1$$

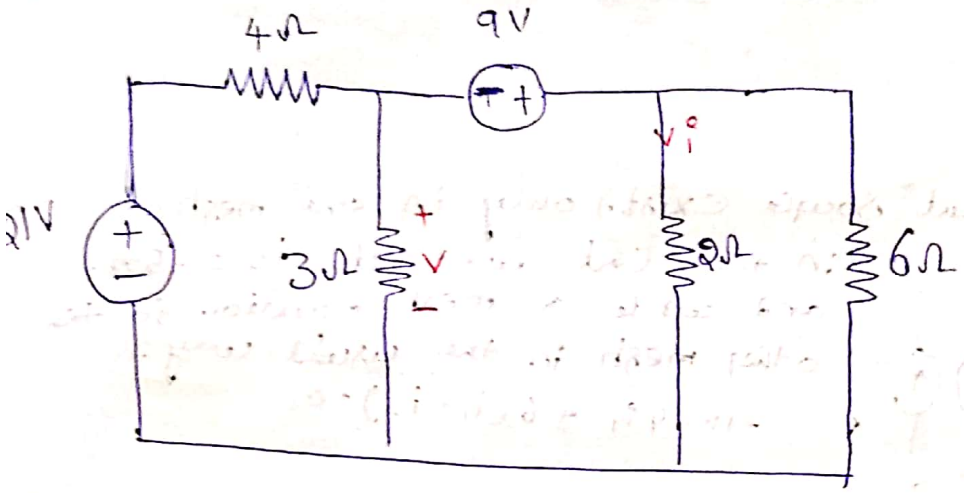
$$3V_1 = -22$$

$$V_1 = -22/3 = -7.333V$$

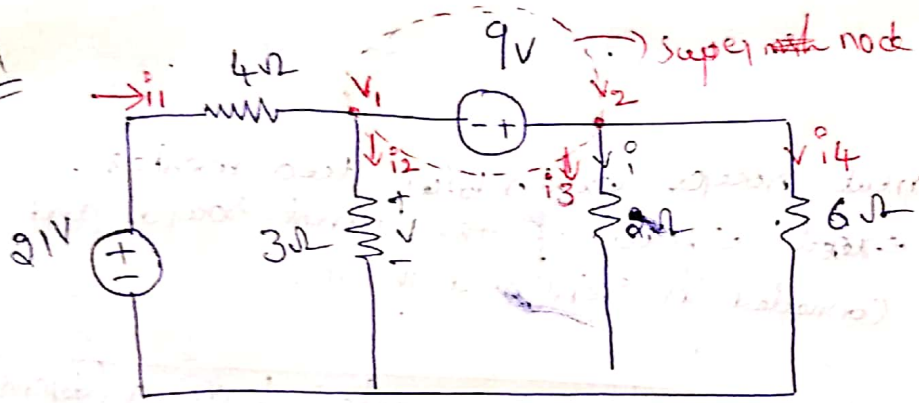
$$V_2 = V_1 + 2 \Rightarrow V_2 = -7.33 + 2 = -5.33$$

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* find v and i in the ckt



Sol



Apply KCL to super node

$$i_1 = i_2 + i_3 + i_4$$

$$\frac{21}{4} = \frac{V_1}{3} + \frac{V_2}{2} + \frac{V_2}{6}$$

$$\frac{21}{4} = \frac{2V_1 + 3V_2 + V_2}{6}$$

$$31.5 = 2V_1 + 4V_2$$

$$31.5 = 2(V_1 + 2V_2)$$

$$\frac{31.5}{2} = V_1 + 2V_2$$

$$15.75 = V_1 + 2V_2 \rightarrow (1)$$

$$V_1 = 15.75 - 2V_2$$

Apply KVL to super node

$$-V_1 - 9 + V_2 = 0$$

$$-V_1 = -V_2 + 9$$

$$V_1 = V_2 - 9 \rightarrow (2)$$

equating (1) & (2)

$$15.75 - 2V_2 = V_2 - 9$$

$$3V_2 = 15.75 + 9$$

$$3V_2 = 24.75$$

$$V_2 = \frac{24.75}{3} = 8.25$$

$$V_1 = V_2 - 9$$

$$V_1 = 8.25 - 9$$

$$V_1 = -0.75$$

$$\boxed{V_1 = V = -0.75}$$

$$i = \frac{V_2}{R} = \frac{8.25}{2}$$

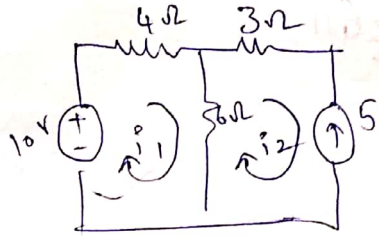
$$\boxed{i = 4.12\ A}$$

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mesh analysis with current sources :-

Case I :-

when a current source exists only in one mesh.



in this ckt we set $i_2 = -5A$.
and write a mesh equation for the other mesh in the usual way.

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

Case II :-

when a current source exists b/w two meshes.
A supermesh ~~exists~~ excluding the current source and any elements connected in series with it.

> A supermesh results when two meshes have a (dependent or independent) current source in common.

Ex :-

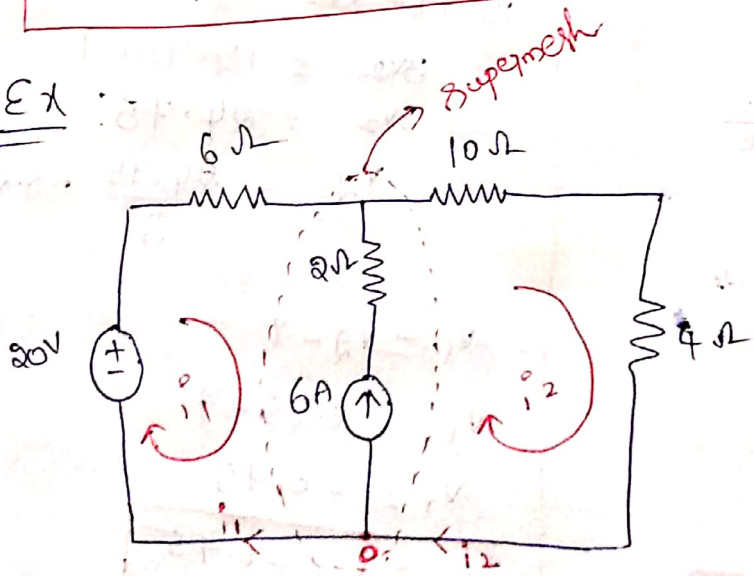


fig: Two meshes having a current source in common.

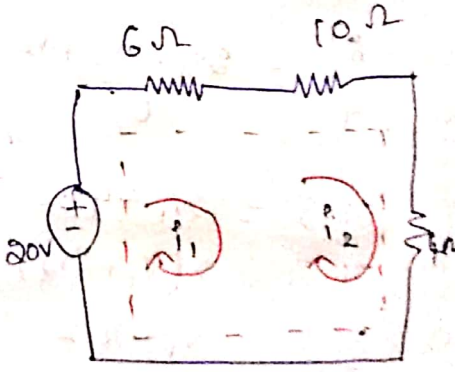


fig: A supermesh created by excluding the current.

Sol

Apply KVL to super mesh

$$-20 + 6i_1 + 10i_2 + 4i_2 = 0$$

$$6i_1 + 14i_2 = 20 \longrightarrow (1)$$

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Apply KCL to a node in the branch where the two meshes intersect.

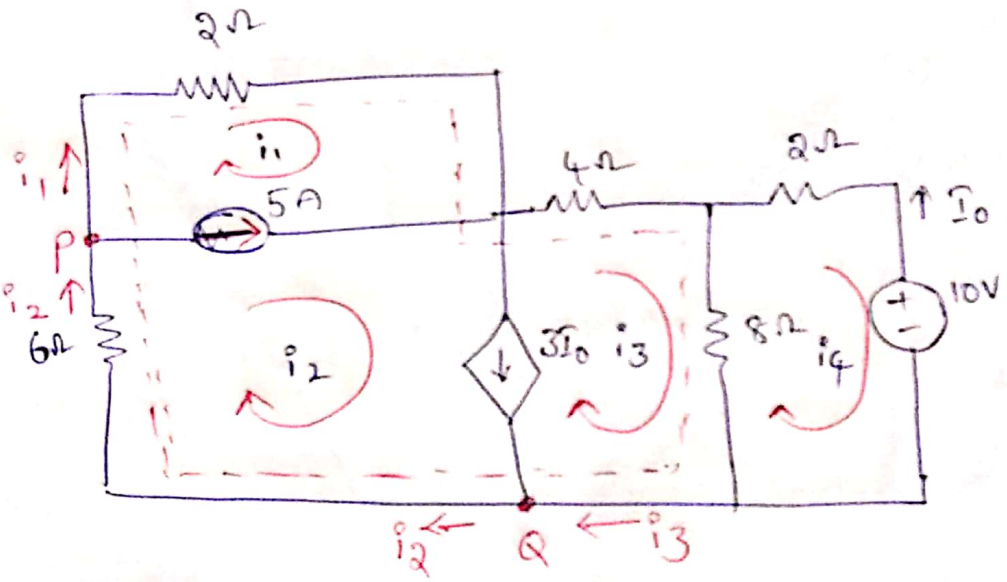
Apply KCL to node O

$$i_2 = i_1 + 6 \longrightarrow (2)$$

Solving the equations (1) & (2)

$$i_1 = -3.2\ A \qquad i_2 = 2.8\ A$$

* For the ckt find i_1 & i_4 using mesh analysis.



Sol

Apply KVL to super mesh

$$2i_1 + 4i_3 + 8(i_3 - i_4) + 6i_2 = 0$$

$$i_1 + 3i_2 + 6i_3 - 4i_4 = 0 \longrightarrow (1)$$

For the independent current source, we apply KCL to node P,

$$i_2 = i_1 + 5 \Rightarrow -i_1 + i_2 = 5 \longrightarrow (2)$$

For the dependent current source, we apply KCL to node Q.

$$i_2 = i_3 + 3I_0$$

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But $I_0 = -I_4$

$i_2 = i_3 - 3i_4 \Rightarrow -i_2 + i_3 - 3i_4 = 0 \longrightarrow (3)$

Apply KVL in mesh (4)

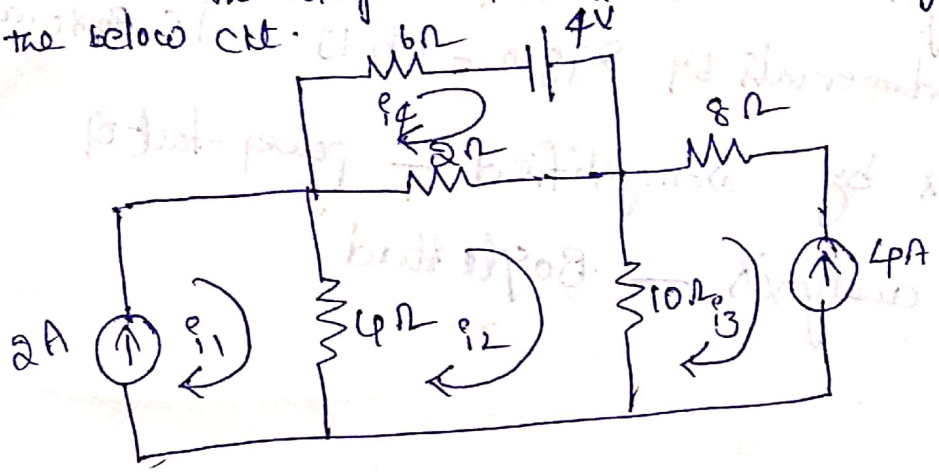
$2i_4 + 8(i_4 - i_3) + 10 = 0$

$5i_4 - 4i_3 = -5 \longrightarrow (4)$

$i_1 = -7.5A \quad i_2 = -2.5A \quad i_3 = 3.93A \quad i_4 = 2.143A$

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(2) b) find the voltage across 8Ω resistor by using MESH analysis for the below ckt.



Sol

from the ckt $i_1 = 2\,A$ $\quad i_3 = -4\,A$

KVL at loop (2) $\Rightarrow$ $2(i_2 - i_4) + 10(i_2 - i_3) + 4(i_2 - i_1) = 0$

$2i_2 - 2i_4 + 10(i_2 + 4) + 4(i_2 - 2) = 0$

$2i_2 - 2i_4 + 10i_2 + 40 + 4i_2 - 8 = 0$

$16i_2 - 2i_4 = -32 \longrightarrow (1)$

KVL at loop (4) $\Rightarrow$ $6i_4 - 4 + 2(i_4 - i_2) = 0$

$6i_4 - 4 + 2i_4 - 2i_2 = 0$

$8i_4 - 2i_2 = 4 \longrightarrow (2)$

from eq (1) & (2)

(1) $\Rightarrow$ $16i_2 - 2i_4 = -32$

(2) $\times 8$ $\Rightarrow$ $-16i_2 + 64i_4 = 32$

$-66i_4 = 0$

$i_4 = 0$

Substitute $i_4 = 0$ in (2)

$-2i_2 = 4$

$i_2 = -2\,A$

The voltage across 8Ω resistor $V = 2(i_2 - i_4)$ or $V = 2(i_4 - i_2)$

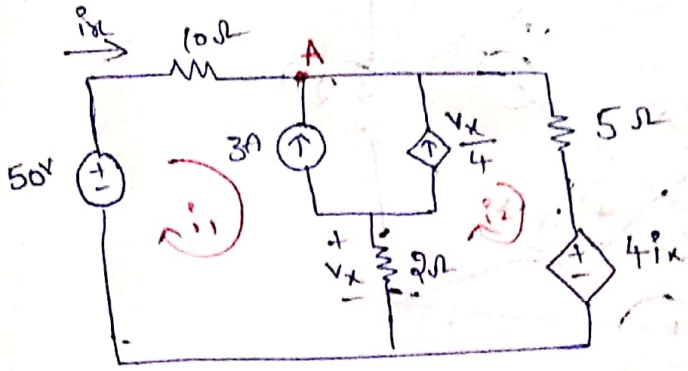
$V = 2(-2)$ (or) $V = 2(0 + 2)$

$V = -4\,A$ $\qquad V = 4\,A$

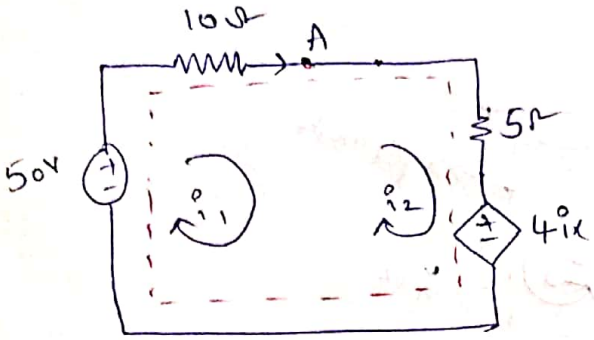
(3) a)

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1) Find v_x and i_x in the ckt.



Sol



For the supermesh Apply KVL

$$-50 + 10i_1 + 5i_2 + 4i_x = 0$$

But $i_x = i_1$

Hence $$+50 = 14i_1 + 5i_2 \longrightarrow (1)$$

At node 'A' Apply KCL

$$i_1 + 3 + \frac{v_x}{4} = i_2$$

But $v_x = 2(i_1 - i_2)$

$$i_1 + 3 + \frac{2(i_1 - i_2)}{4} = i_2$$

$$i_1 + 3 + \frac{i_1 - i_2}{2} = i_2$$

$$2i_1 + 6 + i_1 - i_2 = 2i_2$$

$$3i_1 - 3i_2 + 6 = 0$$

$$3(i_1 - i_2 + 2) = 0$$

$$i_1 + 2 = i_2 \longrightarrow (2)$$

Solving (1) & (2)

$$14i_1 + 5(i_1 + 2) = 50$$

$$14i_1 + 5i_1 + 10 = 50$$

$$19i_1 = 40$$

$$i_1 = \frac{40}{19} = 2.105\ A$$

$$i_2 = 4.105\ A$$

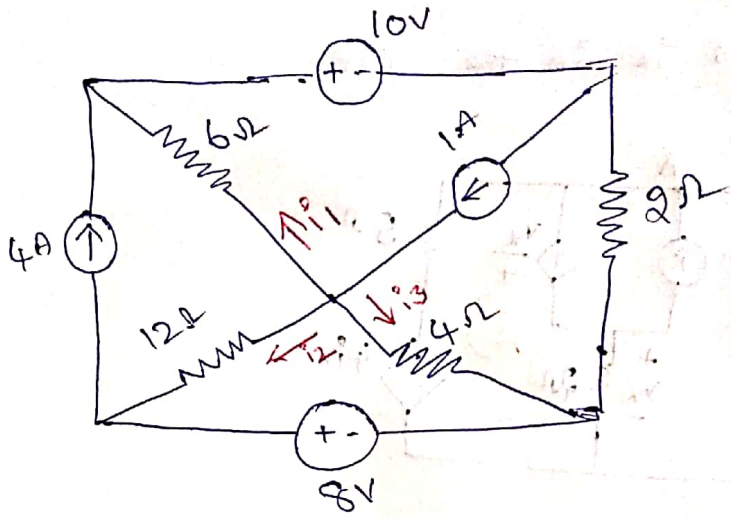
$$v_x = 2(i_1 - i_2)$$

$$v_x = -4\ \text{Volts}$$

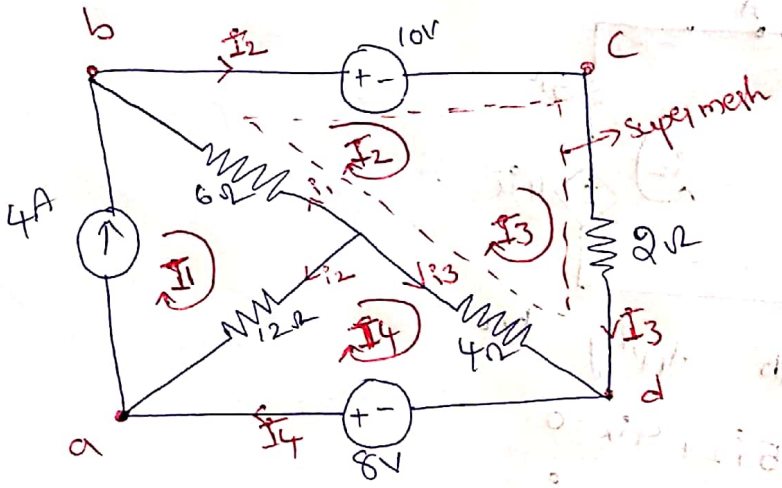
$$i_x = i_1 = 2.105\ A$$

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* In the ckt of fig: Solve i_1, i_2, i_3



Sol



from the fig $I_1 = 4A$ ⟶ (1)

Apply KVL to mesh (4)

$12(I_4 - I_1) + 4(I_4 - I_3) - 8 = 0$

$12I_4 - 12I_1 + 4I_4 - 4I_3 - 8 = 0$

$-12I_1 + 4I_3 + 16I_4 - 8 = 0$

$-3I_1 - I_3 + 4I_4 = 2$ ⟶ (2)

for the supermesh

$6(I_2 - I_1) + 10 + 2I_3 + 4(I_3 - I_4) = 0$

$-3I_1 + 3I_2 + 3I_3 - 2I_4 = -5$ ⟶ (3)

At node C

$I_2 = I_3 + 1$ ⟶ (4)

At node b $\Rightarrow$ $i_1 = I_2 - I_1$

At node a $\Rightarrow i_2 = 4 - I_4$

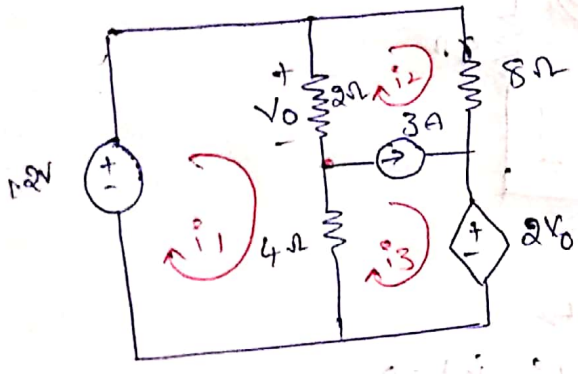
At node d $\Rightarrow i_3 = I_4 - I_3$

Solving equations (1), (2), (3), (4)

$I_1 = 4A$, $I_2 = 3A$, $I_3 = 2A$, $I_4 = 4A$

$$i_1 = I_2 - I_1 = -1\,A$$
$$i_2 = 4 - I_4 = 0\,A$$
$$i_3 = I_4 - I_3 = 2\,A$$

* use mesh analysis to find i_1, i_2, i_3 in the ckt.



Sol Apply KVL to mesh (1)

$$2(i_1 - i_2) + 4(i_1 - i_3) - 12 = 0 \longrightarrow (1)$$
$$3i_1 - i_2 - 2i_3 = 6$$

Apply KVL to super mesh

$$2(i_2 - i_1) + 8i_2 + 2V_o + 4(i_3 - i_1) = 0$$

But $V_o = 2(i_1 - i_2)$

$$2(i_2 - i_1) + 8i_2 + 2\times 2(i_1 - i_2) + 4(i_3 - i_1) = 0$$
$$-i_1 + 3i_2 + 2i_3 = 0 \longrightarrow (2)$$

for the independent current source

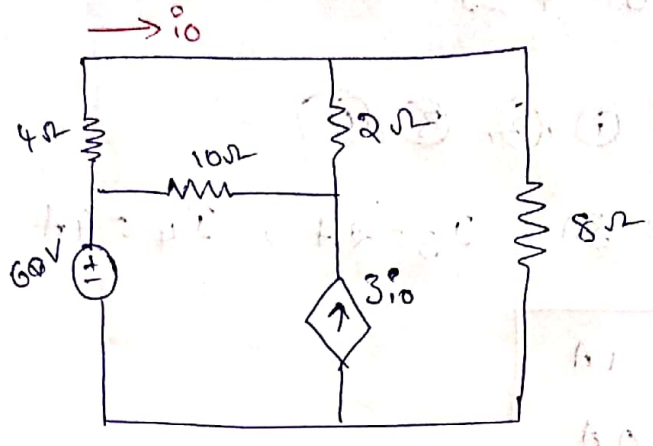
$$i_3 = 3 + i_2 \longrightarrow (3)$$

Solving (1) & (2), (3)

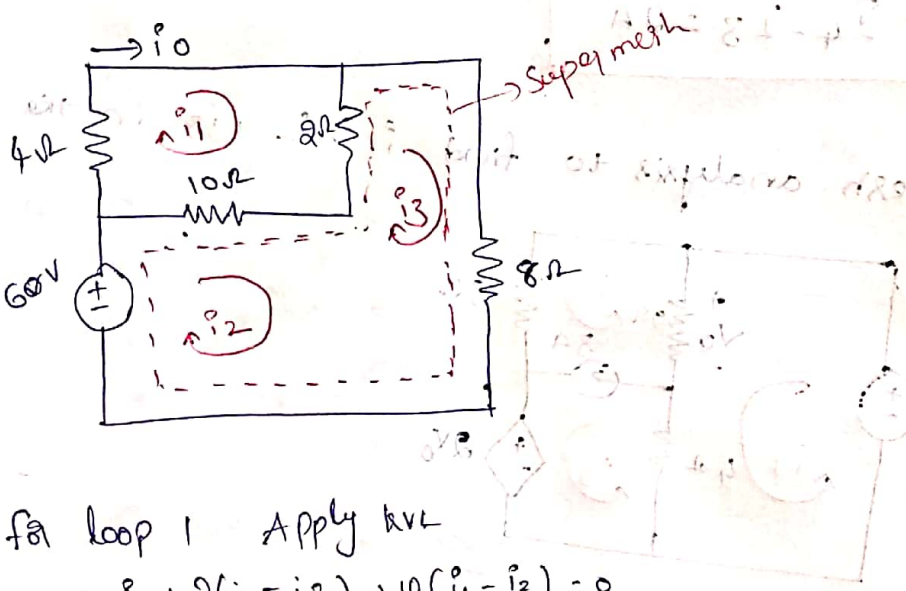
$i_1 = 3.5\,A$ $i_2 = -0.5\,A$, $i_3 = 2.5\,A$

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* use mesh analysis to find the current i_o in the ckt



Sol



Sol for loop 1 Apply KVL

$$4i_1 + 2(i_1 - i_3) + 10(i_1 - i_2) = 0$$
$$4i_1 + 2i_1 - 2i_3 + 10i_1 - 10i_2 = 0$$
$$16i_1 - 10i_2 - 2i_3 = 0$$
$$2(8i_1 - 5i_2 - i_3) = 0$$
$$8i_1 - 5i_2 - i_3 = 0 \longrightarrow (1)$$

for supermesh apply KVL

$$-60 + 10(i_2 - i_1) + 2(i_3 - i_1) + 8i_3 = 0$$
$$-60 + 10i_2 - 10i_1 + 2i_3 - 2i_1 + 8i_3 = 0$$
$$-12i_1 + 10i_2 + 10i_3 - 60 = 0$$
$$2(-6i_1 + 5i_2 + 5i_3 - 30) = 0$$
$$-6i_1 + 5i_2 + 5i_3 = 30 \longrightarrow (2)$$

$$3i_o = i_3 - i_2 \quad \& \quad i_o = i_1$$
$$3i_1 = i_3 - i_2$$

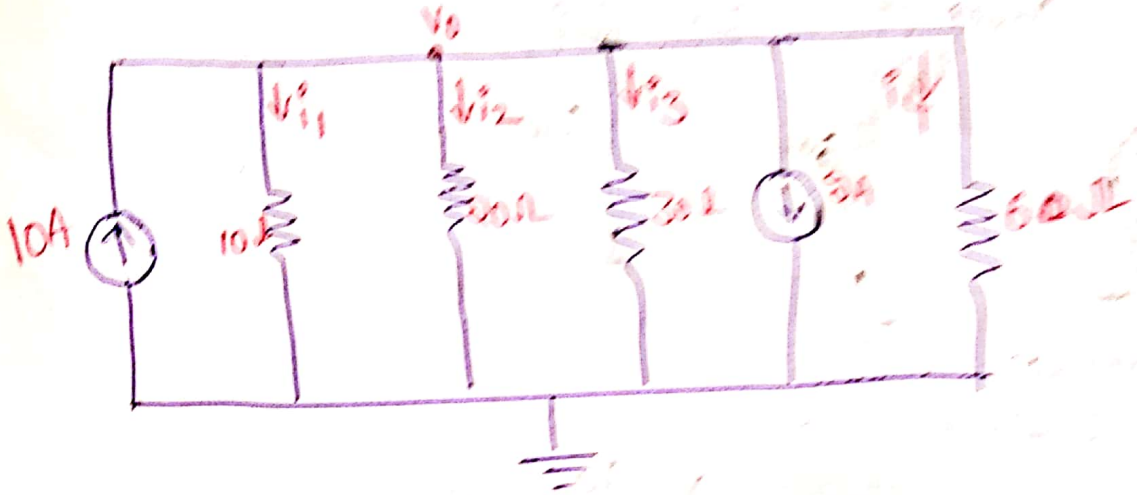
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Solving ①, ②, ③

$i_1 = 1.731$ & $i_0 = i_1 = 1.731\,A$

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* Find the currents i_1, through i_4 and the voltage v_0 in the ckt



Sol

Applying KCL to the upper node.

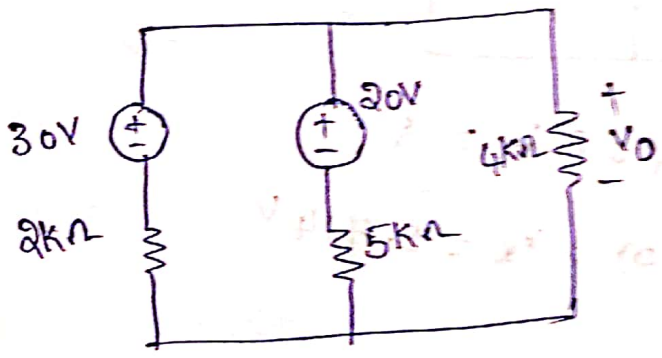
$$10 = \frac{v_0}{10} + \frac{v_0}{20} + \frac{v_0}{30} + 2 + \frac{v_0}{60}$$

$$v_0 = 40V$$

$$i_1 = \frac{v_0}{10} = 4A, \quad i_2 = \frac{v_0}{20}, \quad i_3 = \frac{v_0}{30} = 1.333A$$

$$i_4 = \frac{v_0}{60} = 666.7mA$$

* obtain v_0 in the ckt.



Sol

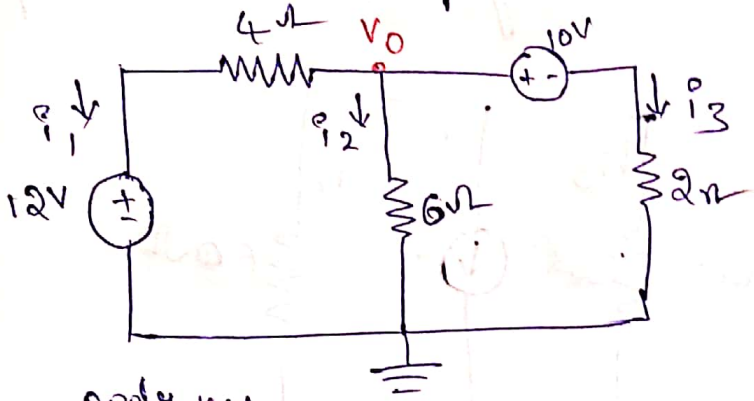
Apply KCL to the top node

$$\frac{30 - v_0}{2k} + \frac{20 - v_0}{5k} = \frac{v_0}{4k}$$

$$v_0 = 20V$$

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* Use nodal analysis to obtain V_o in the ckt.



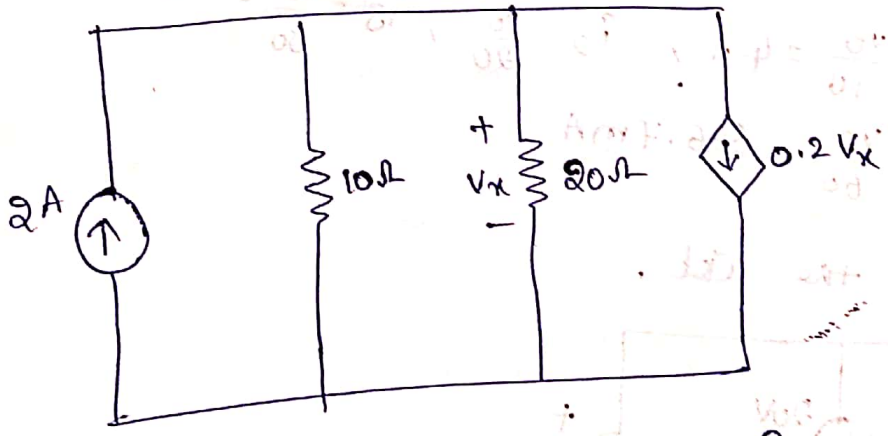
Sol Apply KCL

$$i_1 + i_2 + i_3 = 0$$

$$\frac{V_o - 12}{4} + \frac{V_o}{6} + \frac{V_o - 10}{2} = 0$$

$$V_o = 8.727V$$

* Apply nodal analysis to solve for V_x in the ckt.



Sol

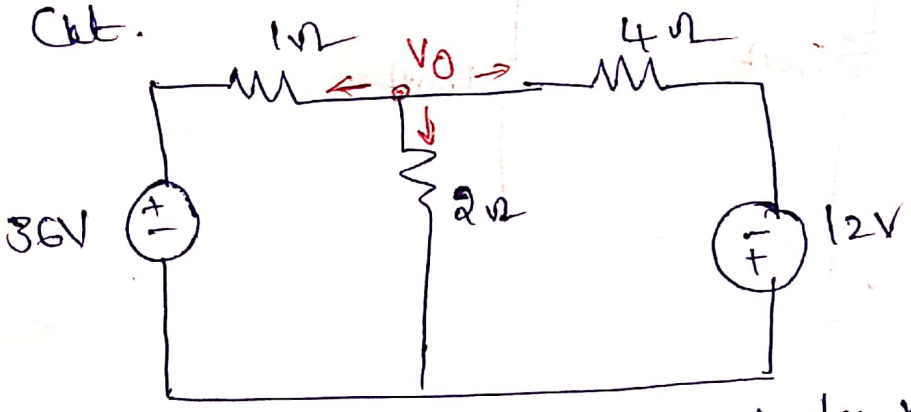
$$\frac{V_x - 0}{10} + \frac{V_x - 0}{20} + 0.2V_x = 2$$

$$0.35V_x = 2 \quad \text{or} \quad V_x = 5.714V$$

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find v_o and power dissipated in all resistors in the Ckt.



Sol: At the top node Apply KCL at node V_o

$$\frac{V_o - 36}{1} + \frac{V_o}{2} + \frac{V_o - (-12)}{4} = 0$$

$$1.75 V_o = 33$$

$$V_o = 18.857 V$$

$$P_{1\Omega} = \frac{(V_o - 36)^2}{1} = \frac{(18.857 - 36)^2}{1} = (-17.143)^2 = 293.882 W$$

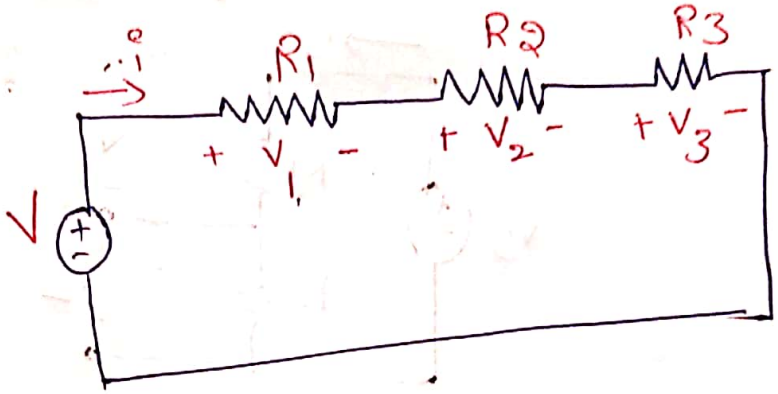
$$P_{2\Omega} = \frac{(V_o)^2}{2} = 177.79 W$$

$$P_{4\Omega} = \frac{(V_o + 12)^2}{4} = 238 W$$

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Voltage and current Division Rule

Voltage Division :



We know

$$i = \frac{V}{R}$$

$$i = \frac{V_{Total}}{R_1+R_2+R_3}$$

So the voltage over the first resistor is

$$V_1 = iR_1$$

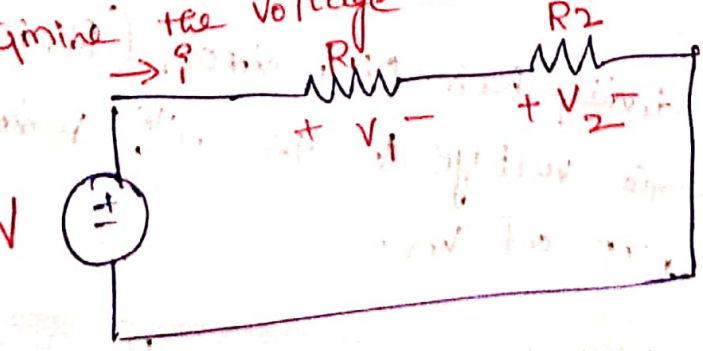
$$V_1 = R_1 \frac{V_{Total}}{R_1+R_2+R_3} \qquad V_{Total} = V$$

$$\boxed{V_1 = V \frac{R_1}{R_1+R_2+R_3}}$$

To find the voltage over an individual resistance in series, take the total series voltage and multiplying by the individual resistance over the total resistance.

Ex

Determine the voltage across each resistor.



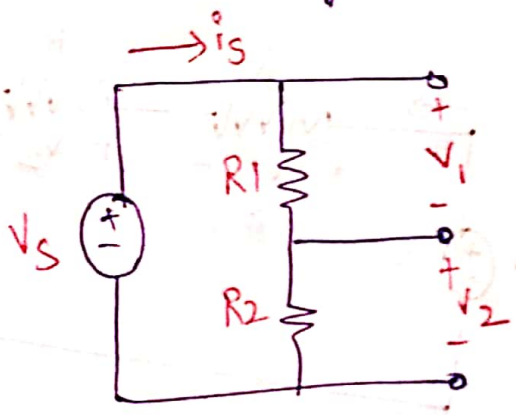
$$V_1 = V \frac{R_1}{R_1+R_2} \qquad V_2 = V \frac{R_2}{R_1+R_2}$$

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

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Example :-

Determine the voltage across each resistor.



$$i_S = \frac{V_S}{R_1+R_2}$$

$$V_1 = \frac{R_1}{R_1+R_2} V_S \implies i_S = \frac{V_S}{R_1+R_2} \implies V_1 = i_S R_1$$

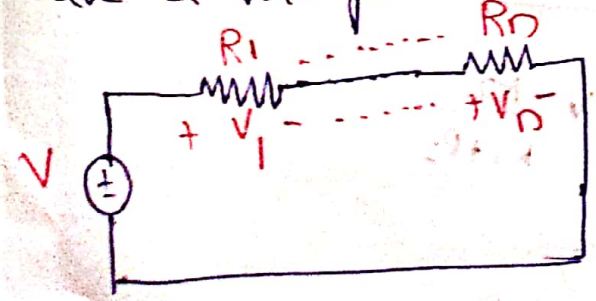
$$V_2 = \frac{R_2}{R_1+R_2} V_S \implies i_S = \frac{V_S}{R_1+R_2} \implies V_2 = i_S R_2$$

→ The source voltage v is divided among the resistors in direct propation to their resistances.

→ The larger the resistance, the larger the voltage drop.

This is called the principle of voltage division.

In a voltage divider has N resistors $(R_1, R_2 \cdots R_N)$ in series with the source voltage V, the n^{th} resistor (R_n) will have a voltage drop of V_n.

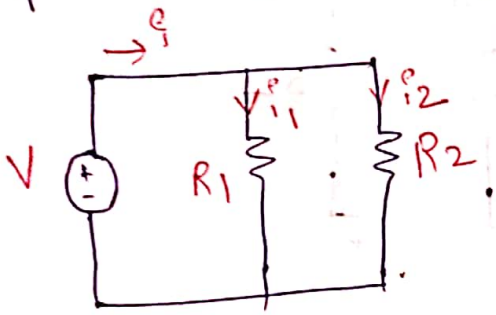


$$V_n = \frac{R_n}{R_1+R_2+\cdots+R_N} \cdot V$$

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Current division :-

If we know the current flowing into two parallel resistors, we can find out how the current will divide up in one step.



$$V = i R_{eq}$$

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

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

$$i_1 = \frac{V}{R_1}$$

$$i_1 = \frac{1}{R_1}\left[i \frac{R_1 R_2}{R_1 + R_2} \right] \Rightarrow \boxed{i_1 = i \frac{R_2}{R_1 + R_2}}$$

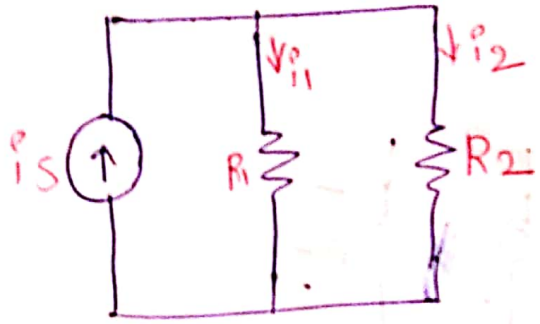
$$i_2 = \frac{V}{R_2}$$

$$i_2 = \frac{1}{R_2}\left[i \frac{R_1 R_2}{R_1 + R_2} \right] \Rightarrow \boxed{i_2 = \frac{R_1 i}{R_1 + R_2}}$$

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Example

find i_1 & i_2 in terms of i_s



$$i_s = i_1 + i_2$$

$$V_1 = V_2$$

$$i_1 R_1 = i_2 R_2$$

$$i_2 = \frac{i_1 R_1}{R_2} \Rightarrow i_s = i_1 + \frac{i_1 R_1}{R_2}$$

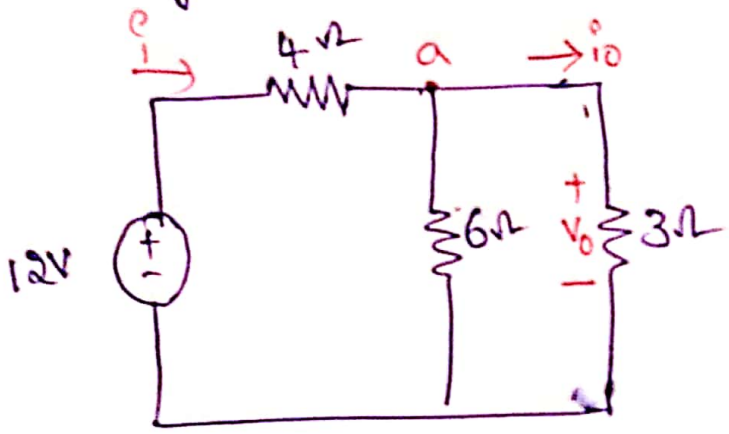
$$i_s = i_1 \left(\frac{R_2 + R_1}{R_2} \right)$$

$$\boxed{i_1 = i_s \left(\frac{R_2}{R_1 + R_2} \right)}$$

$$\boxed{i_2 = i_s \left(\frac{R_1}{R_1 + R_2} \right)}$$

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* use voltage and current division rules to find V_o & i_o

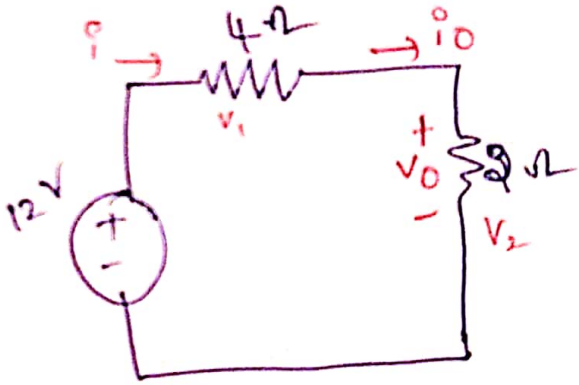


$6 \| 3 = \frac{6 \times 3}{6+3} = \frac{18}{9} = 2\Omega$

Sol

$$i = \frac{V}{R} = \frac{12}{4+2} = 2\ A$$

$$v_2 = V_o = (12)\frac{2}{4+2} = 4V$$



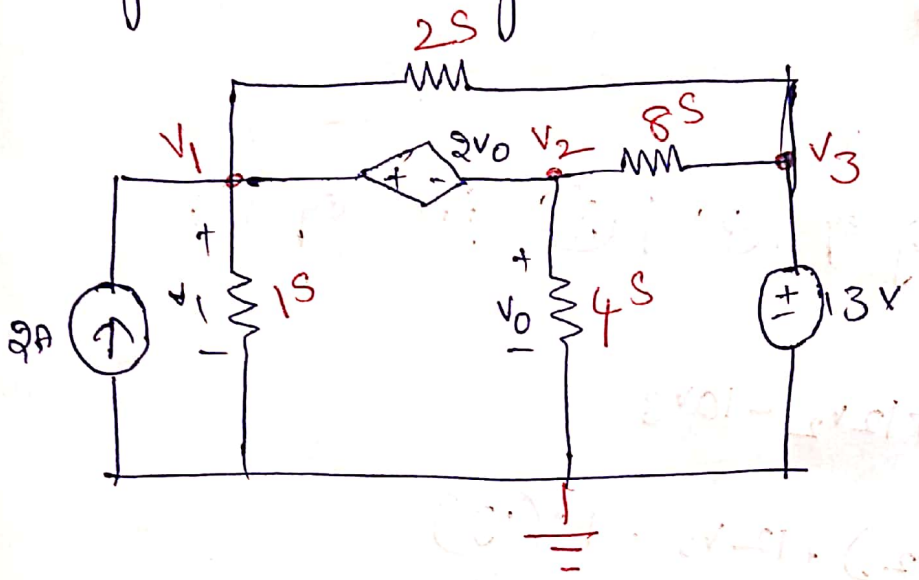
$$V_2 = V\frac{R_2}{R_1+R_2}$$

$$i_2 = i\frac{R_1}{R_1+R_2}$$

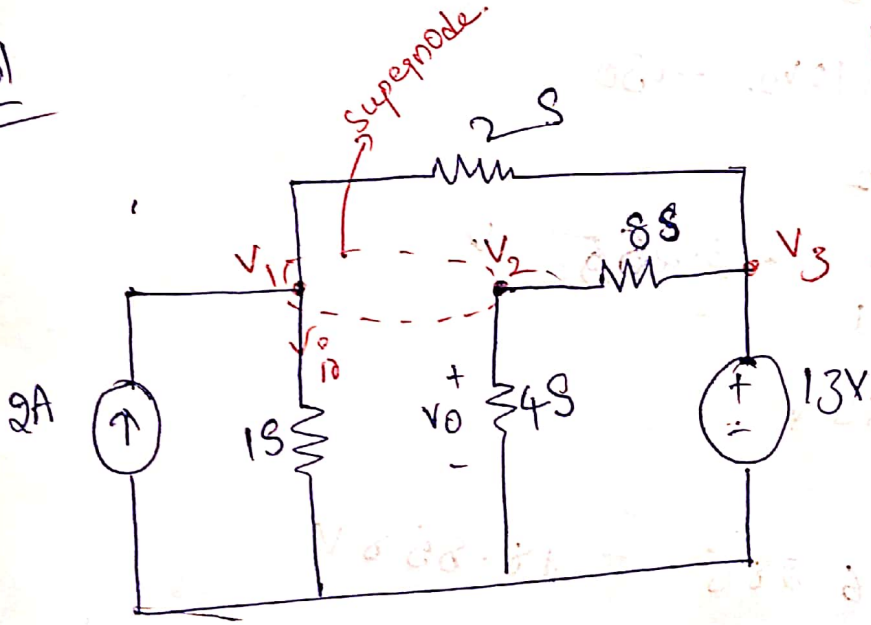
$$i_o = 2 \cdot \frac{6}{6+3} = \frac{4}{3}\ A$$

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Determine the voltages v_1 through v_3 in the ckt using nodal analysis.



Sol



Conductance $G = \frac{1}{R}$

Units of Conductance is Siemen's or $\mho$

Conductance is an expression of the ease with which electric current flows through a substance.

At the supernode Apply KCL

$$2 = v_1 + 2(v_1 - v_3) + 8(v_2 - v_3) + 4v_2$$

$$2 = 3v_1 + 12v_2 - 10v_3 \longrightarrow (1)$$

Apply KVL to the super node loop.

$$-v_1 + 2v_o + v_2 = 0$$

$$v_1 = v_2 + 2v_o$$

$v_o = v_2$

$v_1 = v_2 + 2v_2$

$v_1 = 3v_2 \longrightarrow (2)$

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$V_1 = 3V_2$

$V_3 = 13V$ ⟶ (3)

~~$V_1 = V_2 + 2V_0$~~

~~$3V_2 =$~~

Substituting eq (2) & (3) in eq (1)

(1) $\Rightarrow 2 = 3V_1 + 12V_2 - 10V_3$

$2 = 3(3V_2) + 12V_2 - 10(13)$

$2 = 9V_2 + 12V_2 - 130$

$132 = 21V_2$

$V_2 = \frac{132}{21} = 6.285$ V

$V_2 = 6.285$ V

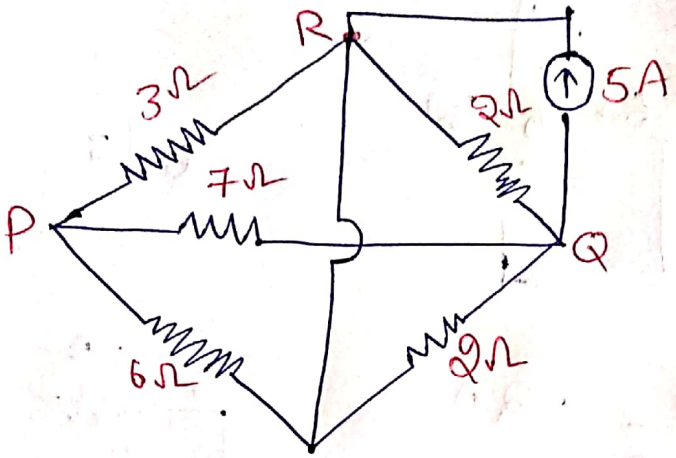
$V_1 = 3V_2$

$V_1 = 3 \times 6.285 = 18.858$ V

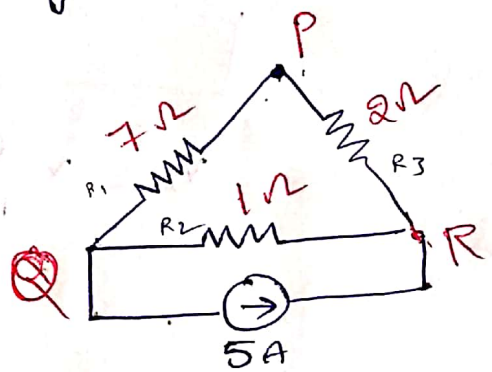
$V_3 = 13$ V

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* Find the current I_{PQ}



Sol Rearrange the Ckt



$3\Omega \,//\, 6\Omega = \frac{3\times 6}{3+6} = \frac{18}{9} = 2\Omega$

$2\Omega \,//\, 2\Omega = \frac{2\times 2}{2+2} = \frac{4}{4} = 1\Omega$

Current division rule

$$I_{PQ} = i \cdot \frac{R_2}{R_1+R_2+R_3} = 5\,\frac{1}{7+2+1} = 0.5A$$

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