Department: Electronic Technologies

Subject: DC Circuits

Lecture: Basic of Electrical Concepts

Instructor: Asst-Lect :Zahraa Hassan Hadi

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[Introduction to Electrical Concepts]

Electrical engineering is a fundamental field of science and technology that deals with the study and application of electricity, electronics, and electromagnetism. To understand how complex electrical systems work, one must first grasp the core concepts that govern the behavior of electric circuits. The most essential parameters in any electrical system are **Voltage (V)**, **Current (I)**, and **Resistance (R)**, which are inextricably linked through physical laws.

Electric Current is defined as the organized flow of electric charge, typically carried by electrons moving through a conductor like a copper wire. It is measured in Amperes (A). For this charge to flow, there must be a driving force, which we call **Voltage** or Potential Difference. Voltage, measured in Volts (V), represents the energy per unit charge that pushes the current through the circuit. Without a voltage source, such as a battery or a generator, current cannot exist in a passive circuit.

However, no material is a perfect conductor at room temperature; every component offers some degree of opposition to the flow of current. This property is known as **Resistance**, measured in Ohms (\Omega). The relationship between these three quantities is defined by the most famous law in electrical engineering: **Ohm's Law**. It states that the current passing through a conductor between two points is directly proportional to the voltage across the two points and inversely proportional to the resistance. Mathematically, this is expressed as $V = I \ R$.

Beyond these basics, electrical circuits are classified into **Linear** and **Non-linear** systems. A linear circuit is one where the parameters (like resistance) remain constant regardless of the voltage or current applied, resulting in a straight-line characteristic graph. In contrast, non-linear elements, such as diodes or light bulbs, change their behavior as the electrical conditions vary. Understanding these concepts is the first step toward analyzing more complex networks using Kirchhoff's Laws and Power theorems.

Electricity is not just about moving charges; it is about the **Transfer of Energy**. The rate at which this energy is transferred or consumed is called **Electric Power**, measured in Watts (W). In every electrical design, engineers must balance these variables to ensure efficiency, safety, and functionality, providing the power that drives our modern world.

[1.1 Electrical Units]

To ensure precision in electrical engineering calculations, it is essential to understand the standardized electrical units and their respective symbols. The following tables provide a comprehensive overview of these fundamental units along with the common metric prefixes used for multiples and submultiples.

[Table 1: Electrical Units]

Quantity	Symbol	Unit	Symbol
Current	I	Ampere	A
Voltage	V	Volt	V
Resistance	R	Ohm	Ω
Capacitance	C	Farad	F
Inductance	L	Henry	H
Power	P	Watt	W
Frequency	f	Hertz	Hz
Conductance	G	Siemens	S
Electric charge	Q	Coulomb	C
Energy	E	Joule	J

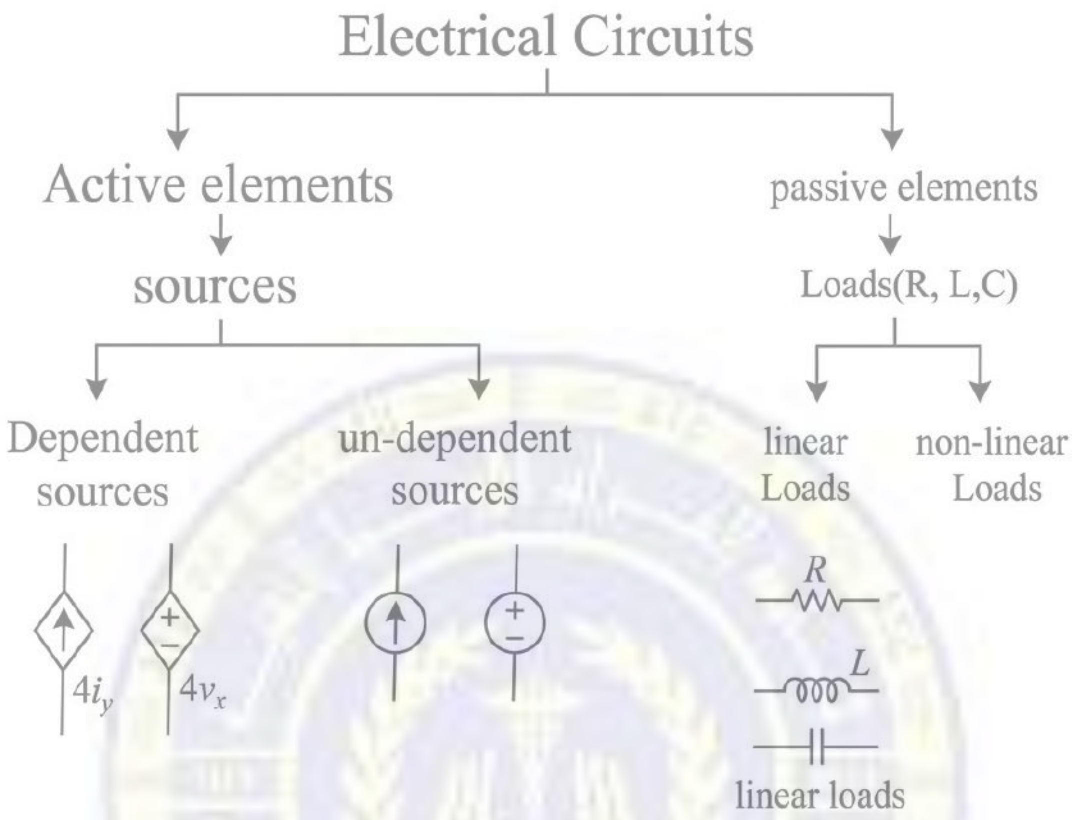
[1.2 Muliples And Submulitiples]

In electrical engineering, quantities vary across a vast range of magnitudes, from very small to extremely large. Therefore, metric prefixes are utilized as multiples and submultiples to simplify numerical notation and express values more efficiently. These standardized prefixes, such as 'Kilo' for thousands or 'Milli' for thousandths, allow engineers to communicate measurements clearly without using excessively long strings of zeros.

[Table 2: Muliples And Submulitiples]

Prefix	Symbol	Exponential	Multiplier
Milli	m	10^{-3}	0.001
Micro	μ	10^{-6}	0.000001
Nano	n	10^{-9}	0.000000001
Pico	p	10^{-12}	0.000000000001
Kilo	k	10^{3}	1000
Mega	M	10^{6}	1000000
Giga	G	10^{9}	1000000000
Tera	T	10^{12}	1000000000000

[1.3 Electrical Circuits]



Electric Current: The number of charged particles that passing a point in a conductor every second. Expressed in Amperes.

$$1\,Amp = 1\,coulomb/second$$

Voltage: The difference in electrical charge between two points in a circuit. Expressed in Volts

$$1\,Volt = 1\,Joule/coulomb$$

Electrical Power: is the rate at which electrical energy is converted to another form, such as motion, heat, light or an electromagnetic field.

$$P = V \times I \quad \left(\frac{J}{C} \times \frac{C}{s} = \frac{J}{s} = Watt\right)$$

One Watt: is the power resulting from an energy dissipation, conversion, or storage process equivalent to one joule per second.

In the resistance, the energy absorbed is dissipated by the resistor in the form of heat.

Power Equations Summary

$P = V \times I$ } Power supplied by the sources

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

$P = I^2 \times R$

} Power dissipated by the resistor

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[Introduction to ohms law]

Ohm's law is named for the German physicist Georg Simon Ohm, who is credited with establishing the Voltage-current relationship for resistance. As a result of his pioneering work, the unit of resistance bears his name.

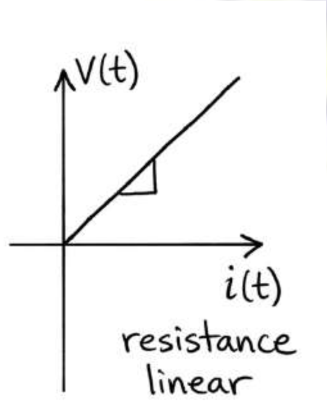
Ohm's law states that the voltage across a resistance is directly proportional to the current flowing through it.

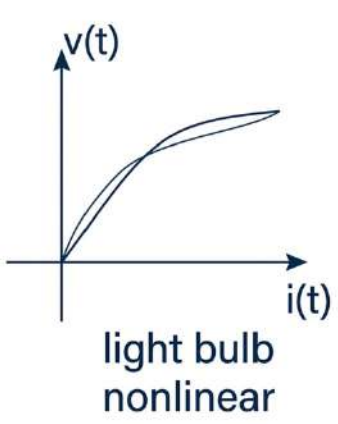
The resistance, measured in ohms, is the constant of proportionality between the voltage and current.

Equation:

$R = V / I \ (\Omega)$

In our analysis we will always assume that the resistor are linear and are thus described by a straight-line characteristic that passes through the origin. It is important that readers realize that some very useful and practical elements do exist that exhibit a nonlinear resistance characteristic; that is, the Voltage-Current relationship is not a straight line.





[1.1 Electrical Power and Conductance]

Since a resistor is a passive element, the power supply to the terminals is absorbed by the resistor. The energy absorbed is dissipated by the resistor in the form of heat

Instantaneous Power formulas

$$P(t) = V(t) \times I(t) \quad \text{(Watt)}$$

And can be written as :

$$P(t) = R \times I^2(t) = \frac{V^2(t)}{R}$$

Conductance (G):

Represented by the symbol **G**, it is the reciprocal of resistance. Measured in Siemens (S).

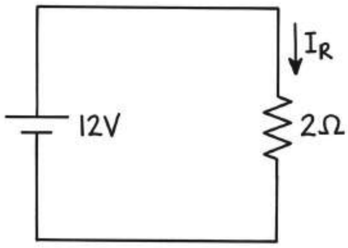
$$G = \frac{1}{R}$$

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

$$P(t) = \frac{I^2(t)}{G} = G \times V^2(t)$$

[1.2 Solved Examples]

Ex (1): For the circuit as shown in fig., find the current in the resistance (2Ω).



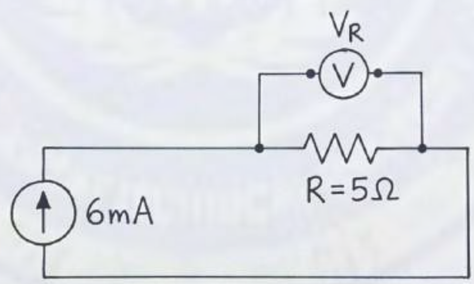
Single Loop circuit

Sol:

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

$$I_R = \frac{12V}{2\Omega} = 6A$$

Ex (2): For the circuit as shown in fig., find the voltage across the resistance (5Ω).

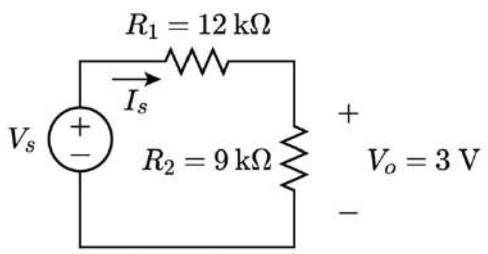


$$V_R = I \times R$$

$$V_R = (6 \times 10^{-3} A) \times 5\Omega = 30\,mV$$

$$V_R = 0.0030\ V$$

Ex (3): If $V_o = 5\,V$ in the circuit in fig., find V_s



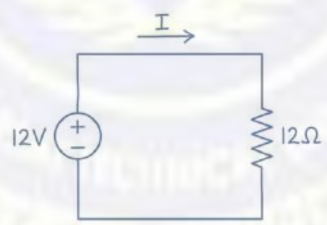
Sol:

$$I = \frac{V_O}{R} = \frac{3V}{9k\Omega} = \frac{1}{3}\,mA$$

$$V_S = I \times (12k\Omega + 9k\Omega)$$

$$V_S = (\frac{1}{3} \times 10^{-3}) \times (21 \times 10^3) = 7\,Volt$$

Ex (4): For the circuit as shown in fig., find the power absorbed in the resistance



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

$$I = \frac{V}{R} = \frac{12}{12} = 1\,(A)$$

$$P = V * I = 12 * 1 = 12\,\text{watt}$$

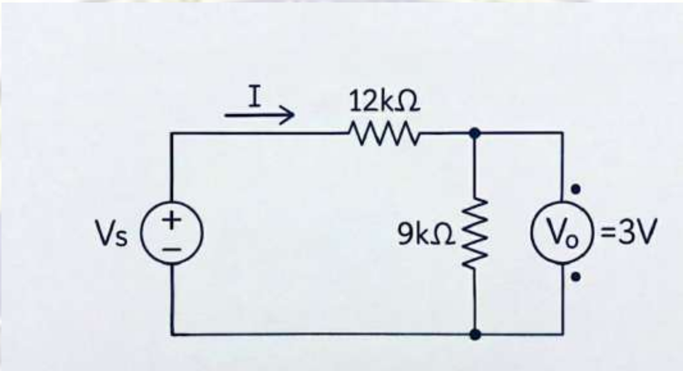
<u>OR</u> $P = I^2 * R = (1)^2 * 12 = 12\,\text{watt}$

$$\underline{\text{OR}}\, P = \frac{V^2}{R} = \frac{(12)^2}{12} = 12\,\text{watt}$$

$$P = V * I = (I * R) * I = I^2 R$$

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

Ex (5): If $V_o = 3\,V$ in the circuit in fig., find V_s



$$I = \frac{3}{9k\Omega} = \frac{1}{3}\,mA$$

$$I = \frac{V_s}{12k\Omega + 9k\Omega} = \frac{1}{3}\,mA$$

$$V_s = \frac{21\,k\Omega}{3}\,mA = 7\,\text{Volt}$$

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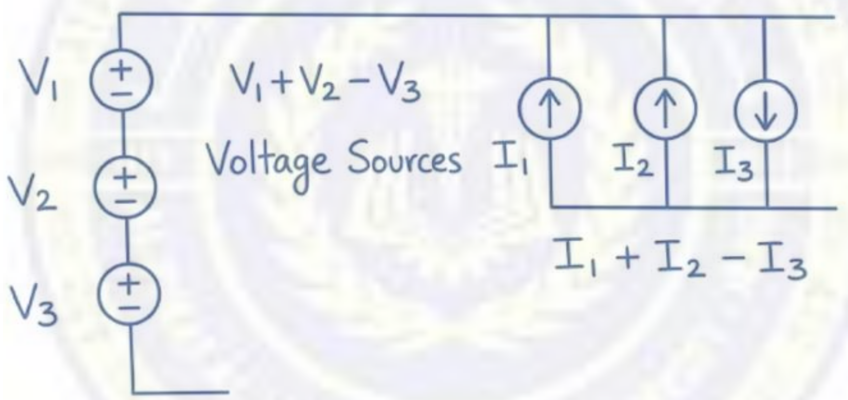
[3. Combination of Sources]

is a fundamental technique used to simplify complex electrical circuits by replacing multiple sources with a single equivalent one. Voltage sources connected in series are added algebraically by considering their polarities, while current sources in parallel are combined based on their flow directions. This process reduces the total number of components in a network, making it much easier to apply Ohm's Law and Kirchhoff's Laws for analysis. Ultimately, it streamlines the calculation of unknown currents and voltages across the remaining circuit elements.

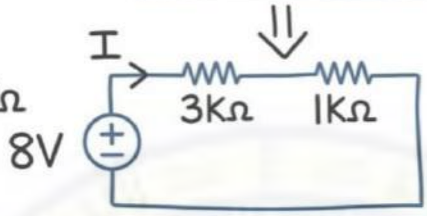


[3.1 Voltage Source]

Ex:- Find the current in the network in Fig., and the power supplied.

$V = 12 - 4$

$V = 8$ Volt



$$R_{eq} = 3K\Omega + 1K\Omega = 4K\Omega$$

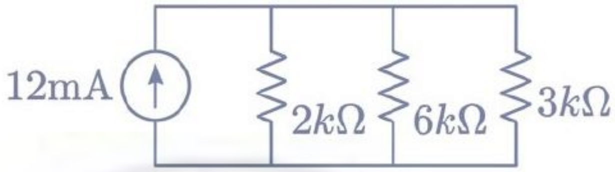
$$I = \frac{8}{4K\Omega} = 2\,mA$$

$$P = V \times I = 2\times10^{-3} \times 8 = 16\ mwatt$$

[3.2 Current Source]

((Current Source))

Ex:-- For the circuit as shown in Fig., find the power supplied from the Current Source.



$$\frac{1}{R_{eq}} = \frac{1}{2k\Omega} + \frac{1}{3k\Omega} + \frac{1}{6k\Omega} = \frac{3+2+1+1}{6k\Omega}$$

$$\frac{1}{R_{eq}} = \frac{3+2+1}{6k\Omega} = \frac{6}{6k\Omega} \quad \Rightarrow R_{eq} = 1k\Omega$$

Then the Voltage is $V = 12 * 10^{-3} * 1k\Omega$

$V = 12$ (volt)

$P = I * V = 12 * 10^{-3} * 12$

$P = 144$ mwatt

The dependent source, may be current or voltage and is depend on the current or voltage.

dependent Current Source   dependent Voltage Source

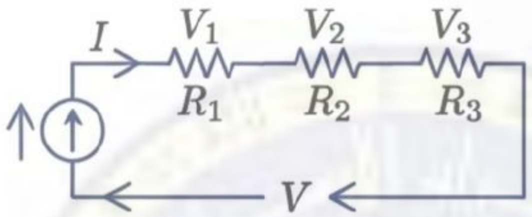
[3.3 Resistance Combination Parallel and Series]

((Resistance Combinations))

((Series and Parallel))

We have shown the equivalent resistance in series for N resistor:-

$$R_{eq} = R_1 + R_2 + R_3 + \cdots + R_N$$



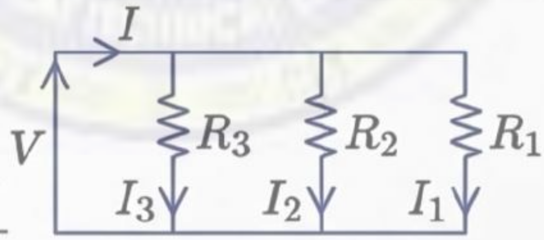
$$V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$$

$$\boxed{\frac{V}{I} = (R_1 + R_2 + R_3) = R_{eq}}$$

The equivalent resistance for N parallel resistor is found from

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

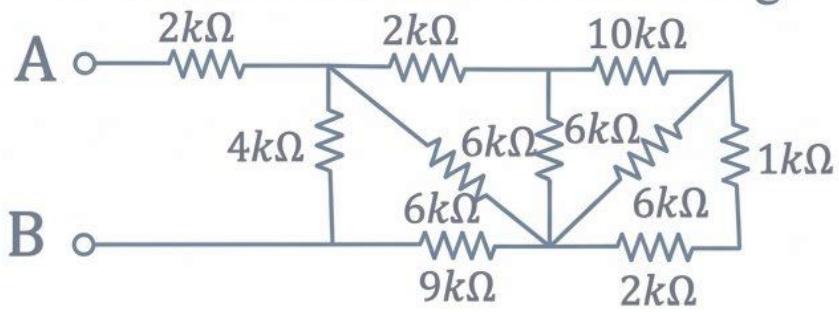
$$I = I_1 + I_2 + I_3$$



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

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

Ex:-- Find the equivalent resistance between A and B for the circuit as shown in Fig.



$$Req_1 = 1k\Omega + 2k\Omega = 3k\Omega$$

$$Req_2 = \frac{3k\Omega * 6k\Omega}{3k\Omega + 6k\Omega} = \frac{18*10^3/k\Omega}{9k\Omega} = 2k\Omega$$

$$Req_3 = 2k\Omega + 10k\Omega = 12k\Omega$$

$$Req_4 = \frac{12k\Omega * 6k\Omega}{12k\Omega + 6k\Omega} = \frac{72*10^3/k\Omega}{18k\Omega} = 4k\Omega$$

$$Req_5 = 4k\Omega + 2k\Omega = 6k\Omega$$

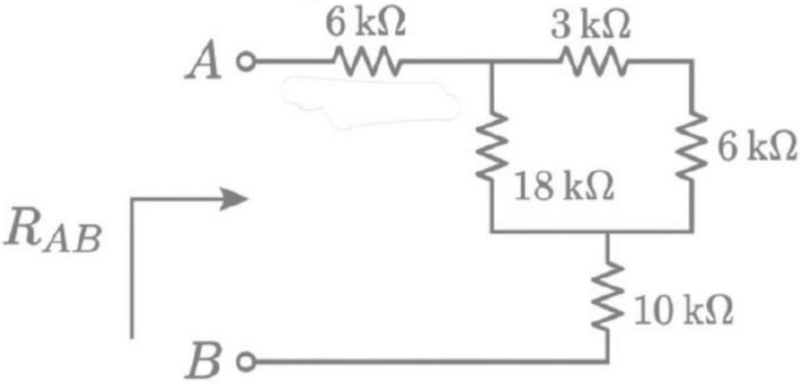
$$Req_6 = \frac{6k\Omega * 6k\Omega}{6k\Omega + 6k\Omega} = \frac{36*10^3/k\Omega}{12k\Omega} = 3k\Omega$$

$$Req_7 = 3k\Omega + 9k\Omega = 12k\Omega$$

$$Req_8 = \frac{12k\Omega * 4k\Omega}{12k\Omega + 4k\Omega} = \frac{48*10^3/k\Omega}{16k\Omega} = 3k\Omega$$

$$\therefore R_{AB} = 3k\Omega + 2k\Omega = \boxed{5k\Omega.}$$

Example 1: Find R_{eq} for the circuit as shown in Fig.

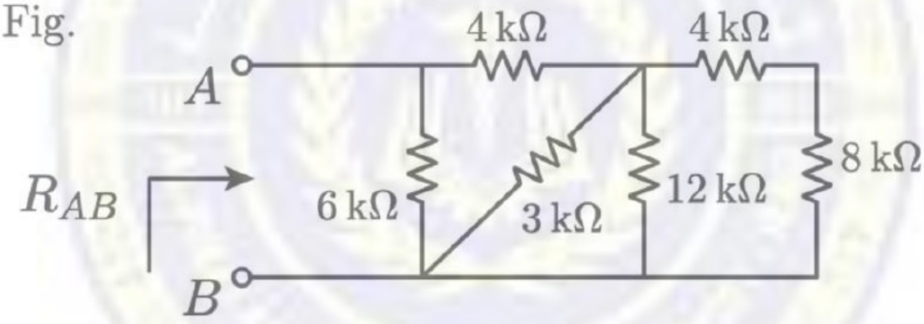


$$R_{eq1} = 6\text{ k}\Omega + 3\text{ k}\Omega = 9\text{ k}\Omega$$

$$R_{eq2} = \frac{9\text{ k}\Omega \times 18\text{ k}\Omega}{9\text{ k}\Omega + 18\text{ k}\Omega} = \frac{162 \times 10^3\text{ k}\Omega}{27\text{ k}\Omega} = 6\text{ k}\Omega$$

$$R_{AB} = 6\text{ k}\Omega + 6\text{ k}\Omega + 10\text{ k}\Omega = \boxed{22\text{ k}\Omega}$$

Example 2: Find R_{eq} for the circuit as shown in Fig.



$$R_{eq1} = 8\text{ k}\Omega + 4\text{ k}\Omega = 12\text{ k}\Omega$$

$$R_{eq2} = \frac{12\text{ k}\Omega \times 12\text{ k}\Omega}{12\text{ k}\Omega + 12\text{ k}\Omega} = \frac{144 \times 10^3\text{k}\Omega}{24\text{ k}\Omega} = 6\text{ k}\Omega$$

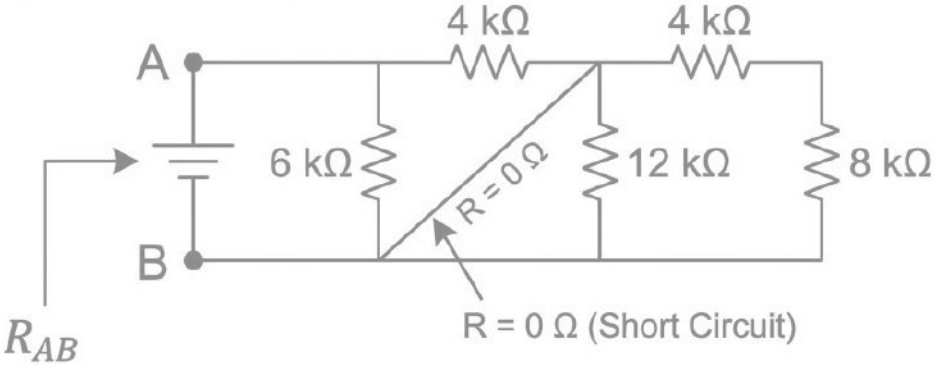
$$R_{eq3} = \frac{6\text{ k}\Omega \times 3\text{ k}\Omega}{6\text{ k}\Omega + 3\text{ k}\Omega} = \frac{18 \times 10^3\text{k}\Omega}{9\text{ k}\Omega} = 2\text{ k}\Omega$$

$$Req_4 = 2k\Omega + 4k\Omega = 6k\Omega$$

$$Req = R_{AB} = \frac{6k\Omega \times 6k\Omega}{6k\Omega + 6k\Omega} = \frac{36 \times 10^3 k\Omega}{12k\Omega}$$

$$R_{AB} = \mathbf{3k\Omega}$$

Example: Circuit Analysis.



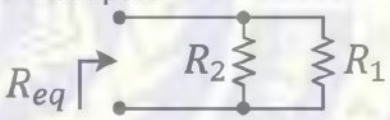
$$R_{AB} = \frac{4\ \mathrm{k}\Omega * 6\ \mathrm{k}\Omega}{4\ \mathrm{k}\Omega + 6\ \mathrm{k}\Omega} = \frac{24 * 10^3\ \Omega}{10\ \Omega}$$

$$\boxed{R_{AB} = 2.4\ \mathrm{k}\Omega = 2400\ \Omega}$$

Explain Why: The short circuit resistance is zero.
and why the open circuit resistance is ∞.

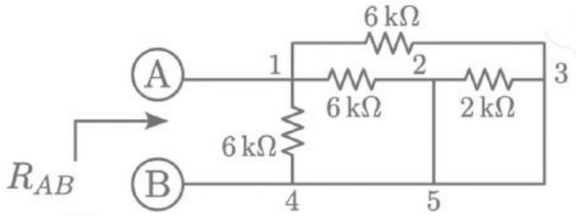
In this circuit, the diagonal branch with $R = 0\ \Omega$ effectively creates a direct, zero-resistance path from one part of the circuit to the other. Since current follows the path of least resistance, almost all the current bypasses the parllel resistance combination. This makes the effective resistance of the main part of the circuit effectively zero, which in turn leads to the simple calculation of the first parallel combination being the main part.

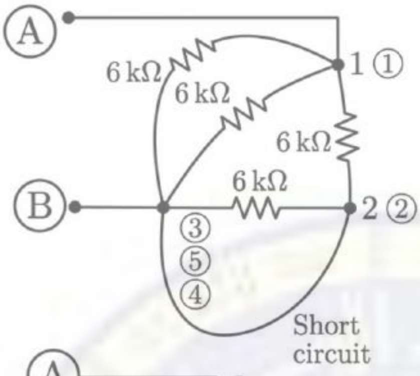
$$R_{eq} = \frac{R_1 * R_2}{R_1 + R_2}$$

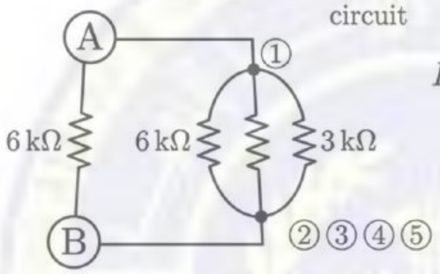


For two Combination resistance only.

Ex: Find R_{AB} in the network in Fig.







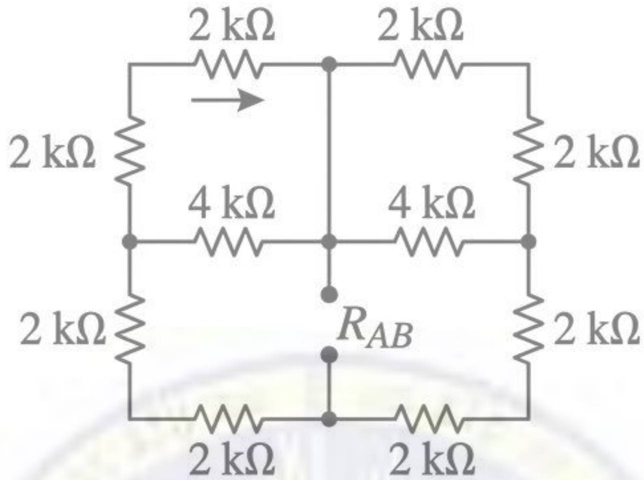
$$R_{eq_1} = \frac{6\,\text{k}\Omega \times 6\,\text{k}\Omega}{6\,\text{k}\Omega + 6\,\text{k}\Omega}$$

$$R_{eq_1} = 3\,\text{k}\Omega$$

$$R_{AB} = \frac{6\,\text{k}\Omega \times 3\,\text{k}\Omega}{6\,\text{k}\Omega + 3\,\text{k}\Omega}$$

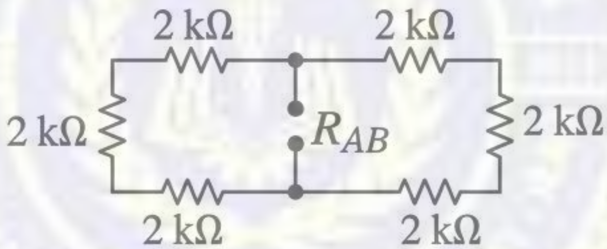
$$\boldsymbol{R_{AB} = 2\,\text{k}\Omega}$$

Ex: Find R_{AB} in the circuit as shown in Fig. (Q 2.54)



$R_{eq_1} = 2\text{ k}\Omega + 2\text{ k}\Omega = 4\text{ k}\Omega$; $R_{eq_2} = 2\text{ k}\Omega + 2\text{ k}\Omega = 4\text{ k}\Omega$

$R_{eq_3} = \frac{4\text{ k}\Omega \times 4\text{ k}\Omega}{4\text{ k}\Omega + 4\text{ k}\Omega} = 2\text{ k}\Omega$; $R_{eq_4} = \frac{4\text{ k}\Omega \times 4\text{ k}\Omega}{4\text{ k}\Omega + 4\text{ k}\Omega} = 2\text{ k}\Omega$



$R_{eq_5} = 2\text{ k}\Omega + 2\text{ k}\Omega + 2\text{ k}\Omega = 6\text{ k}\Omega$

$R_{eq_6} = 2\text{ k}\Omega + 2\text{ k}\Omega + 2\text{ k}\Omega = 6\text{ k}\Omega$

$$R_{AB} = \frac{6\text{ k}\Omega \times 6\text{ k}\Omega}{6\text{ k}\Omega + 6\text{ k}\Omega} = \frac{36 \times 10^3\text{ k}\Omega}{12\text{ k}\Omega}$$

$$\boxed{R_{AB} = 3\text{ k}\Omega}$$

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Lecture: Wye -Delta Transformation

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[4. Wye -Delta Transformation]

Delta–Star transformation is a fundamental technique in electrical engineering used to simplify complex three-phase circuits and analyze power systems efficiently

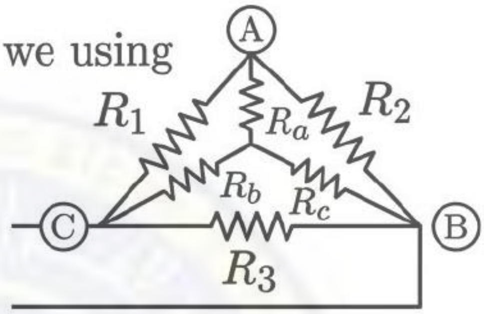
We find that nowhere is a resistor in series or parallel with another.

To Transform from Y to Δ, we using

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

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

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



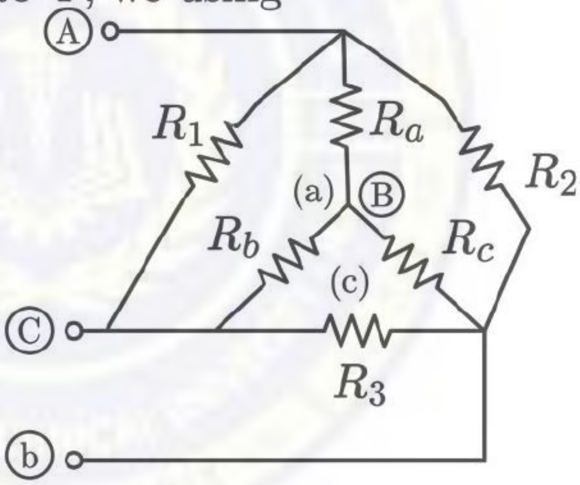
Delta-Connection

To Transform from Δ to Y, we using

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

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

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



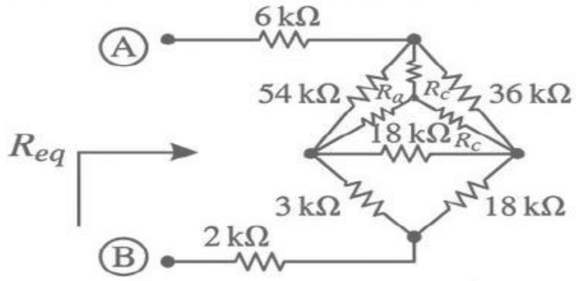
The above equations are general relationships and apply to any set of resistances connected in a Y or Δ.

For the balanced case where $R_a = R_b = R_c$ and $R_1 = R_2 = R_3$, the equations reduce to:

$$R_Y = \frac{1}{3} R_\Delta \qquad \text{and} \qquad R_\Delta = 3R_Y$$

[4.1 Delta to Transformation]

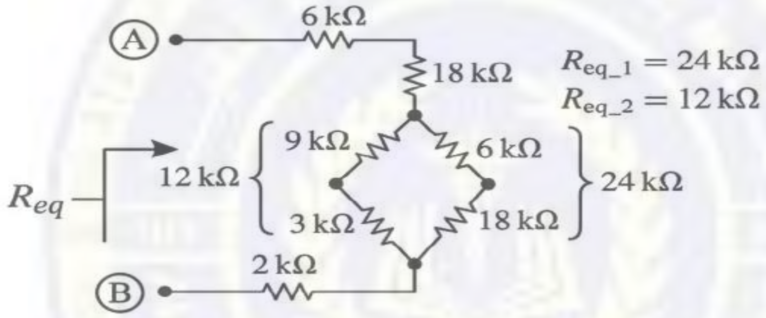
Determine the total resistance R_T in the circuit in Fig. (Q 10)



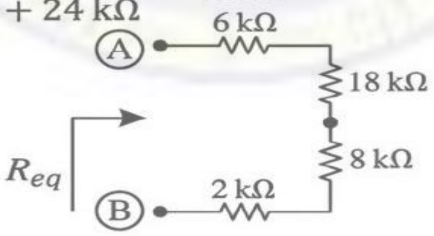
$$R_a = \frac{54\,\text{k}\Omega \times 36\,\text{k}\Omega}{54\,\text{k}\Omega + 36\,\text{k}\Omega + 18\,\text{k}\Omega} = \frac{1944 \times 10^3\,\text{k}\Omega}{108\,\text{k}\Omega} = 18\,\text{k}\Omega$$

$$R_b = \frac{18\,\text{k}\Omega \times 36\,\text{k}\Omega}{54\,\text{k}\Omega + 36\,\text{k}\Omega + 18\,\text{k}\Omega} = \frac{648 \times 10^3\,\text{k}\Omega}{108\,\text{k}\Omega} = 6\,\text{k}\Omega$$

$$R_c = \frac{54\,\text{k}\Omega \times 18\,\text{k}\Omega}{54\,\text{k}\Omega + 36\,\text{k}\Omega + 18\,\text{k}\Omega} = \frac{972 \times 10^3\,\text{k}\Omega}{108\,\text{k}\Omega} = 9\,\text{k}\Omega$$



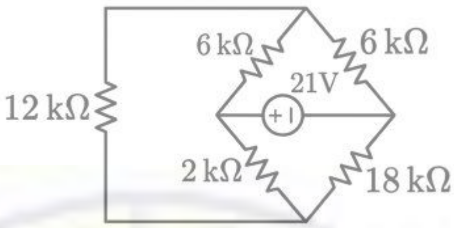
$$R_{eq_3} = \frac{12\,\text{k}\Omega \times 24\,\text{k}\Omega}{12\,\text{k}\Omega + 24\,\text{k}\Omega} = 8\,\text{k}\Omega$$



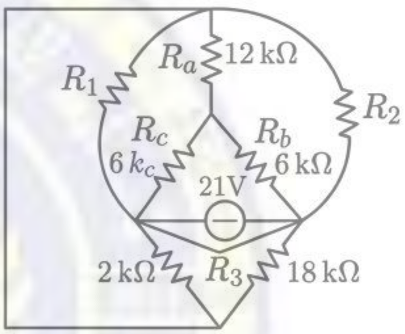
$$R_{AB} = 6\,\text{k}\Omega + 18\,\text{k}\Omega + 8\,\text{k}\Omega + 2\,\text{k}\Omega = 34\,\text{k}\Omega$$

$$\boxed{R_{AB} = 34\,\text{k}\Omega}$$

EX / Find the power absorbed by the network in fig below.



SOL



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

$$= 12k + 6k + \frac{12k \cdot 6k}{6k}$$

$$\underline{\underline{R_1 = 30\ k\Omega}}$$

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

$$= 12k + 6k + \frac{12k \cdot 6k}{6k}$$

$$\underline{\underline{R_2 = 30\ k\Omega}}$$

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

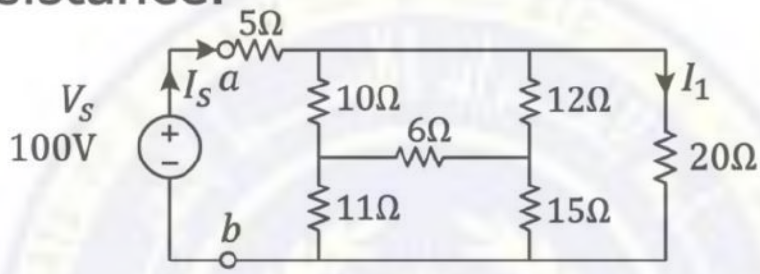
$$= 6k + 6k + \frac{6k \cdot 6k}{12k}$$

$$\underline{\underline{R_3 = 15\ k\Omega}}$$

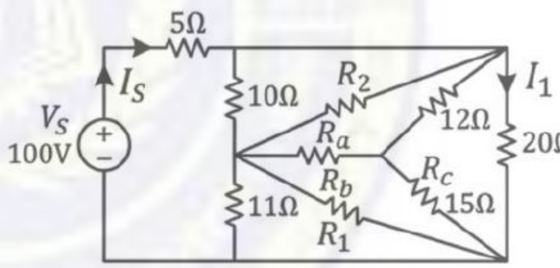
[4.2 wye to Delta Transformation]

EX/ In the circuit shown in fig. below.

1. calculate the equivalent resistance at terminal a-b, R_{ab}.
2. calculate the current (I_s) .
3. calculate the current I_1 in the 20Ω resistance.



<u>SOL.</u>



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

$$= 6 + 15 + \frac{6 \cdot 15}{12}$$

$$= 28.5\Omega$$

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

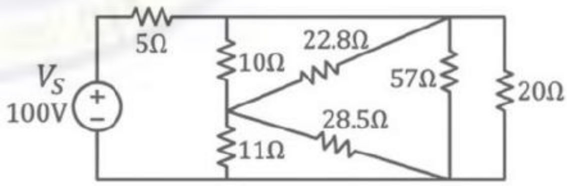
$$= 6 + 12 + \frac{6 \cdot 12}{15}$$

$$R_2 = 22.8\Omega$$

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

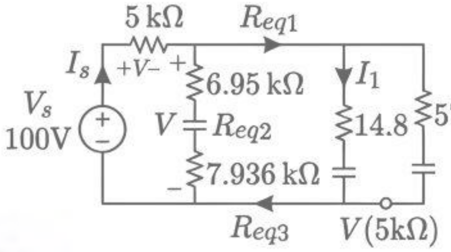
$$= 12 + 15 + \frac{12 \cdot 15}{6}$$

$$= 57\Omega$$



$$Req_1 = 20 \parallel 57 = \frac{20 \times 57}{20 + 57} = 14.8\,\text{k}\Omega$$

$$Req_2 = 28.5 \,//\, 11 = \frac{28.5 \times 11}{28.5 + 11} = 7.936\,\text{k}\Omega$$



$$Req_3 = 10 \,//\, 22.8 = \frac{10 \times 22.8}{10 + 22.8} = 6.95\,\text{k}\Omega$$

$$((Req_3 + Req_2) \parallel Req_1) + (Req_T + 5k\Omega) = R_{AB}$$

1.
$$(5k + Req) = Req_{ab} = \left[\frac{(7.936+6.95)\times 14.8}{(7.936+6.95)+14.8} + 5\right] = 12.42\,\text{k}\Omega$$

2. $$I_s = \frac{V_s}{Req_{ab}} \Rightarrow I_s = \frac{100}{12.42} = \underline{\underline{8\text{A}}}$$

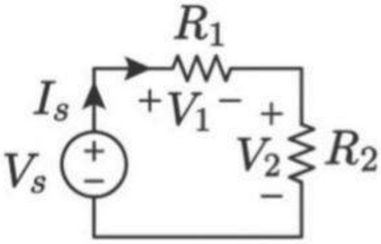
3. $$V(5k\Omega) = I_s \times 5 = 8 \times 5 = 40\,\text{Volt}$$

$$V(20k\Omega) = 100 - 40 = 60\,\text{Volt}$$

$$I_1 = \frac{60}{20} = \underline{\underline{3\text{A}}}$$

[4.3 voltage divider $ current divider]

Voltage divider



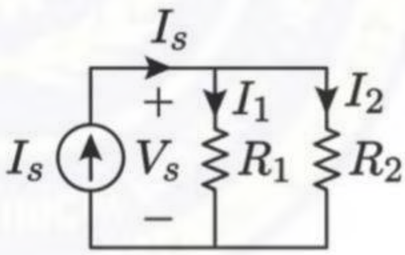
$$\therefore I_s = \frac{V_s}{R_1 + R_2} \qquad V_1 = I_s \cdot R_1$$

$$V_2 = I_s \cdot R_2$$

$$\therefore \quad V_1 = \frac{V_s}{R_1 + R_2} \cdot R_1$$

$$\therefore \quad V_2 = V_s \cdot \frac{R_2}{R_1 + R_2}$$

Current divider



$$I_1 = \frac{V_s}{R_1}$$

$$I_2 = \frac{V_s}{R_2}$$

$$\therefore \quad V_s = I_s \cdot \frac{R_1 R_2}{R_1 + R_2}$$

$$\therefore \quad I_1 = I_s \cdot \frac{R_1 R_2}{R_1 + R_2} \cdot \frac{1}{R_1} = I_s \cdot \frac{R_2}{R_1 + R_2} \checkmark$$

$$\therefore \quad I_2 = I_s \cdot \frac{R_1 R_2}{R_1 + R_2} \cdot \frac{1}{R_2} = I_s \cdot \frac{R_1}{R_1 + R_2} \checkmark$$

Department: Electronic Technologies

Subject: DC circuits

Lecture: Kirchhoff's laws

Instructor: Asst-Lect :Zahraa Hassan Hadi

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[5. Kirchhoff's laws]

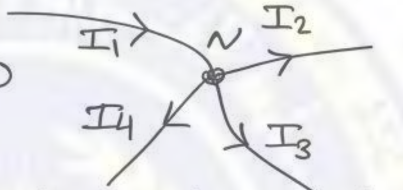
"Kirchhoff's Laws" قوانين كرشوف

Kirchhoff Current Law (KCL)

The algebraic sum of the currents entering any closed surface is zero. or at any node is zero.

Kirchhoff Voltage Law (KVL)

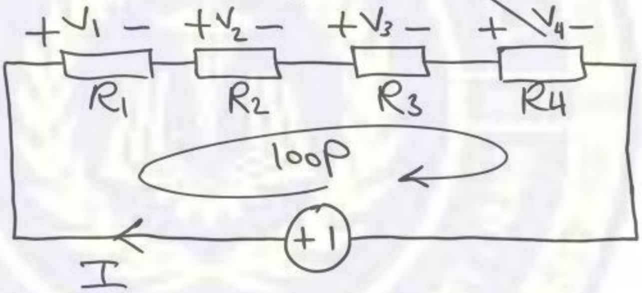
The algebraic sum of the voltages around any loop is zero.



$$I_1 - I_2 - I_3 - I_4 = 0$$

OR

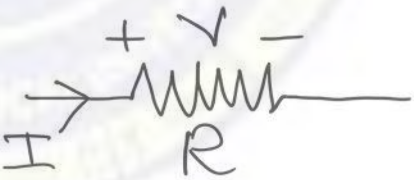
$$I_1 = I_2 + I_3 + I_4$$



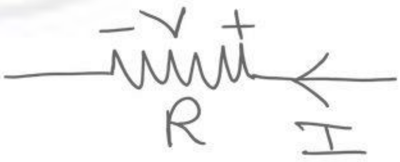
$$V - V_1 - V_2 - V_3 - V_4 = 0$$

OR

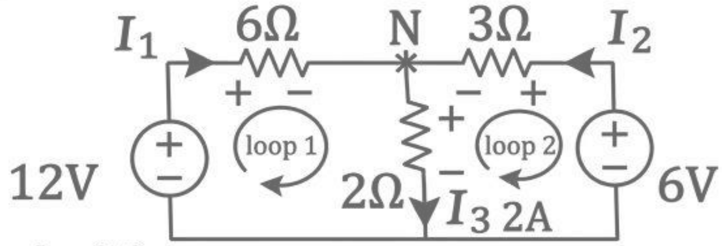
$$V = V_1 + V_2 + V_3 + V_4$$



* The Current and Voltage direction in resistance



Ex:- Using KCL and KVL to find the currents and voltages of the circuit.



KCL at Node (N)

$I_1 + I_2 = I_3$ -----①

loop 1 / KVL

$12 - V_1 - V_3 = 0$ $\qquad V_1 = I_1 * 6$, $V_2 = I_2 * 3$

$V_3 = I_3 * 2$

$12 - 6I_1 - 2I_3 = 0$---②′

loop 2 /KVL

$6 - V_2 - V_3 = 0$

$6 - 3I_2 - 2I_3 = 0$ ----- ③

$I_1 = I_3 - I_2$ ------①′

$6I_1 + 2I_3 = 12$ ----②′

$3I_2 + 2I_3 = 6$ ----- ③′

Sub. ①′ in ②′

$6(I_3 - I_2) + 2I_3 = 12$

$6I_3 - 6I_2 + 2I_3 = 12$

$8I_3 - 6I_2 = 12$ ------ ④

by solving ③′and ④

$3I_2 + 2I_3 = 6$

$-6I_2 + 8I_3 = 12$ (÷2)

$-3I_2 + 4I_3 = 6$ (+)

$-3I_2 + 4I_3 = 6$ (−)

$6I_3 = 12$

$I_3 = \frac{12}{6} = 2$ (A)

$I_2 = 0.666$ (A)

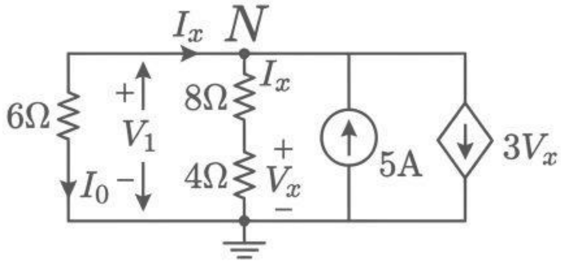
$I_1 = 1.333$ (A)

$V_1 = 8$ (Volt)

$V_2 = 2$ (Volt)

$V_3 = 4$ (Volt)

EX: Find I_0 in the network in fig.



Sol

at node N (KCL)

$$V_x = 4I_x$$

$$I_0 + I_x + 3V_x = 5 \qquad \therefore I_x = \frac{V_1}{12}$$

$$\left[\frac{V_1}{6} + \frac{V_1}{12} + \frac{3V_1}{3} = 5\right] \times 12 \qquad \therefore V_x = \frac{4V_1}{12} = \frac{V_1}{3}$$

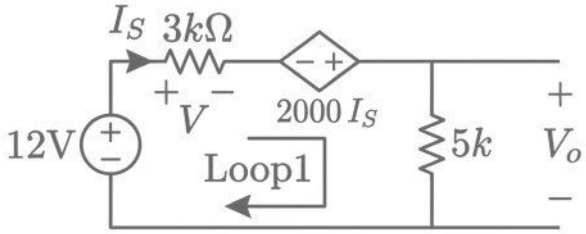
$$2V_1 + V_1 + 12V_1 = 60$$

$$15V_1 = \frac{60}{15} = 4 \text{ Volt}$$

$$\therefore I_0 = \frac{V_1}{6} \quad \Rightarrow \quad I_0 = \frac{4}{6} = \frac{2}{3} \text{ A}$$

Ex: Find V_o in the circuit in fig.

sol



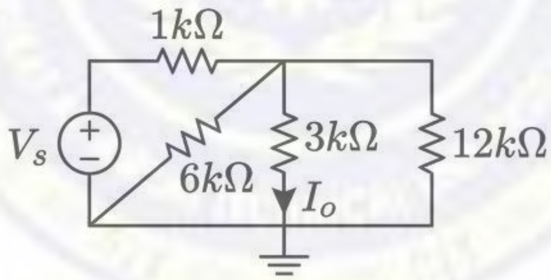
at Loop1 (KVL)

$$-12 + 3k\,I_S - 2000\,I_S + 5k\,I_S = 0$$

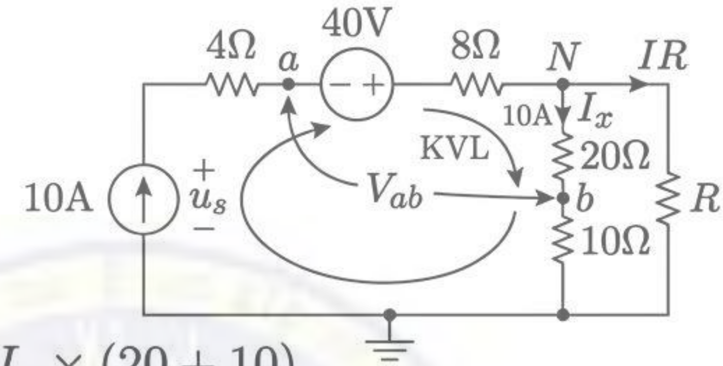
$$I_S = \frac{12}{6k} = 2mA$$

$$\therefore V_o = I_S * 5k \Rightarrow V_o = 2*10^{-3}*5*10^{3} = \underline{\underline{10V}}$$

H.w: IF $I_o = 2mA$ in the circuit in fig. find V_s.



EX: Given that $I_x = 4\text{A}$, find R, V_{ab}, and the power supplied by the 10A current source in the network in fig.



Sol

$$V(20\Omega + 10\Omega) = I_x \times (20 + 10)$$
$$= 4 \times 30 = 120\text{V}$$

at node N (KCL)

$$10 = I_x + I_R$$
$$10 = 4 + I_R \quad \Rightarrow \quad I_R = 6\text{A}$$

$\because V(20\Omega + 10\Omega) = V_R$ (The two resistances are parallel)

$$\therefore V_R = 120\text{V}$$
$$R = \frac{V_R}{I_R} \quad \Rightarrow \quad \therefore R = \frac{120}{6} = 20\Omega$$

at inner loop (KVL)

$$-40 + 8 \times 10 + 20 \times 4 = V_{ab}$$
$$V_{ab} = 120\text{V}$$

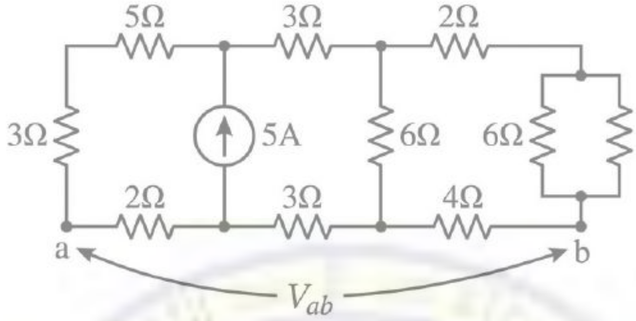
at outer Loop (KVL)

$-V_S + 40 - 40 + 80 + 120 = 0 \qquad \therefore V_S = 200V$

$p(10A) = V_S \times I_S$

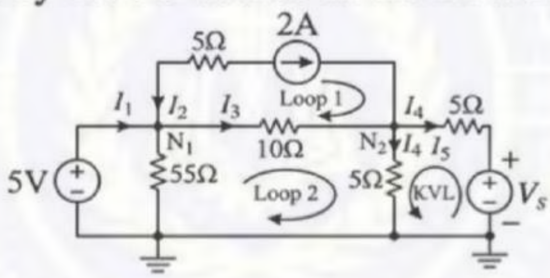
$= 200 \times 10 = 2kW$

H.w : Find V_{ab} in the network in fig.



ans : $V_{ab} = -5.83V$

EX: If the power supplied by the 2A current source is 40w, find Vs and the power absorbed by the 5U source in the network in fig.



Sol

$$p(2A) = V_{(2A)} \times I_{(2A)}$$

$$40 = V_{(2A)} \times 2 \quad \Rightarrow \quad V_{(2A)} = 20V$$

$$I_3 = \frac{V_{(5\Omega)}}{5\Omega} \quad \Rightarrow \quad I_3 = \frac{5}{5} = 1A \qquad (V_{(5\Omega)} = 5V)$$

at Loop 1 (KVL)

$$5 \times 2 - 20 - 10I_2 = 0$$

$$10 - 20 = 10I_2$$

$$I_2 = \frac{-10}{10} = -1A$$

at node N_1 (KCL)

$$I_1 = 2 + I_3 + I_2$$

$$I_1 = 2 + (1) + (-1) \qquad \therefore \; I_1 = 2A$$

at Loop 2 (KVL)

$$-5 \times I_3 + 10 \times I_2 + 5 \times I_4 = 0$$

$$-5 \times 1 + 10 \times -1 + 5I_4 = 0$$

$$5I_4 = \frac{15}{5} = 3A$$

at node N_2 (KCL)

$$2 + I_5 + I_2 = I_4 \quad \Rightarrow \quad 2 + I_5 + (-1) = 3$$

$$1 + I_5 = 3 \quad \Rightarrow \quad I_5 = 2A$$

at Loop 3 (KVL)

$$V_S - 5 \times I_4 - 5 \times I_5 = 0$$

$$V_S - 5 \times 3 - 5 \times 2 = 0 \quad \therefore V_S = 25 \text{ Volt}$$

$$p(5U) = I_1 \times 5$$

$$= 2 \times 5 = 10 \text{ watt}$$

Department: Electronic Technologies

Subject: DC circuits

Lecture: Maxwell Currents (Mesh Loop Analysis)

Instructor: Asst-Lect :Zahraa Hassan Hadi

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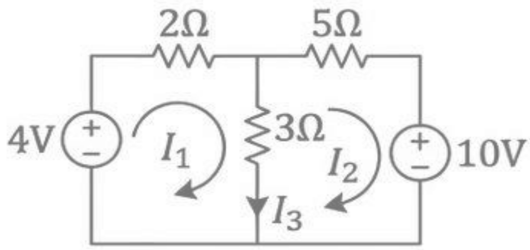
[6. Maxwell Currents (Mesh Loop Analysis)]

Maxwell's Mesh Analysis, often called the Loop Current Method, is a powerful technique used to solve complex electrical circuits by assigning a unique clockwise current to each "mesh" or window. Instead of dealing with numerous individual branch currents, you apply Kirchhoff's Voltage Law (KVL) around each closed loop to create a system of linear equations. The total voltage drops across the resistors in a loop, calculated using V = I \cdot R, must equal the sum of the voltage sources in that path. This method significantly reduces the mathematical workload by minimizing the number of variables needed to find unknown values. Once the mesh currents are found, the actual current in any shared branch is simply the algebraic difference between the adjacent loop currents.

Find the current I_3 in the 3Ω resistance using loop analysis method.



Sol.

Loop 1

$$-4 + 2I_1 + 3(I_1 - I_2) = 0$$

$$-4 + 5I_1 - 3I_2 = 0 \text{ ------ } (1)$$

Loop 2

$$10 + 3(I_2 - I_1) + 5I_2 = 0$$

$$10 + 8I_2 - 3I_1 = 0 \text{ ----- } (2)$$

$$-4 + 5I_1 - 3I_2 = 0 \quad * 8$$
$$10 - 3I_1 + 8I_2 = 0 \quad * 3$$

$$-32 + 40I_1 - 24I_2 = 0$$
$$30 - 9I_1 + 24I_2 = 0$$
$$-2 + 31I_1 = 0 \quad \rightarrow I_1 = \frac{2}{31} = 0.064 \text{ A}$$

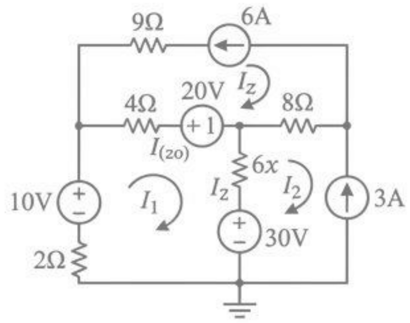
نعوض I_1 في المعادلة (1) لإيجاد I_2

$$-4 + 5 \times \frac{2}{31} - 3I_2 = 0 \quad \therefore I_2 = -1.225 \text{ A}$$

$$\therefore I_3 = I_1 - I_2$$

$$= 0.064 - (-1.225) = \mathbf{1.289A}$$

EX: Find the power supplied from sources (20) and (30)



Sol.

Loop 1

$$2I_1 - 10 + 4(I_1 - I_3) + 20 + 6(I_1 - I_2) + 30 = 0$$

$$12I_1 - 4I_3 - 6I_2 + 40 = 0 \text{ ------------------- } (1)$$

Loop 2

$$I_2 = -3A$$

Loop 3

$$I_3 = -6A$$

لإيجاد I_1 نعوض I_2 & I_3 في المعادلة (1)

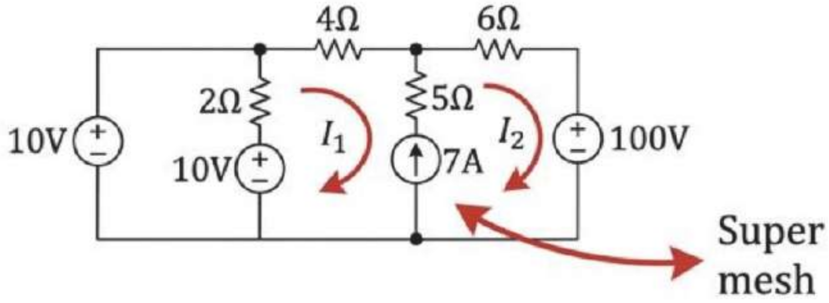
$$12I_1 + 4 \times -6 - 6 \times -3 + 40 = 0$$

$$\therefore \quad I_1 = \frac{-82}{12} \quad \Rightarrow \quad I_1 = -6.83A$$

$$p(20V) = I(20) \times 20$$
$$= (I_3 - I_1) \times 20$$
$$= (-6 - (-6.83)) \times 20 \Rightarrow p(20V) = 16.6\, watt$$

$$p(30V) = I(30V) \times 30$$
$$= (I_2 - I_1) \times 30$$
$$= (-3 - (-6.83)) \times 30$$
$$= \mathbf{114.9}\, \boldsymbol{watt}$$

Ex: Find the power supplied from source (10V)



Sol.

$I_2 - I_1 = 7$ --- (1) (Super mesh)

at the outer Loop

$-10 + 2I_1 + 4I_1 + 6I_2 + 100 = 0$ --- (2)

$6I_1 + 6I_2 + 90 = 0$

from eq(1) $I_2 = 7 + I_1$ --- (3)

(تعوض المعادلة (3) في المعادلة (2))

$6I_1 + 6(7 + I_1) + 90 = 0$

$12I_1 = -132 \quad \Rightarrow \quad I_1 = \frac{-132}{12} = -11\text{A}$

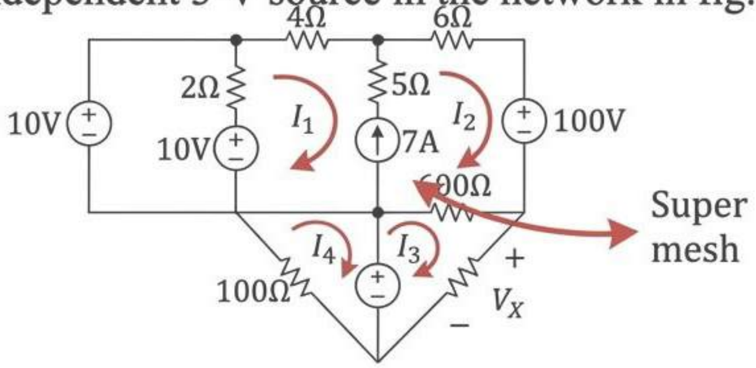
(نعوض I_1 في المعادلة (3) لإيجاد I_2)

$\therefore I_2 = 7 + 11 = 18\text{A}$

$p(10V) = I_1 \times 10$

$= 11 \times 10 = \underline{110 watt}$

Ex: use mesh analysis to determine the power delivered by the independent 3-V source in the network in fig.



Sol.

Loop 1

$$I_1 = 40mA$$

Loop 3

$$300I_3 - 300I_1 + 600I_3 - 3 = 0$$
$$900I_3 - 300 \times 40 \times 10^{-3} - 3 = 0$$
$$I_3 = \frac{15}{900} = 16.67mA$$

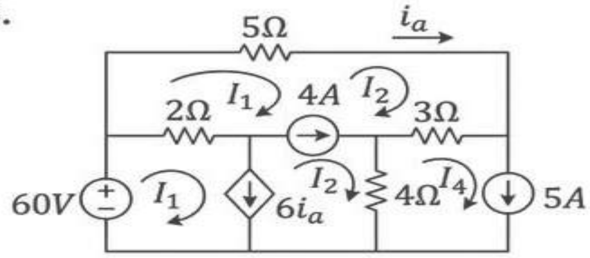
Loop 4

$$100I_4 + 3 = 0 \quad \Rightarrow \quad I_4 = \frac{-3}{100} = -30mA$$

Final Power Calculation

$$p(3V) = 3 \times (I_3 - I_4)$$
$$= 3 \times (16.67m - (-30m)) = \boxed{140.0mwatt}$$

Calculate the power being dissipated in the 2Ω resistor for the circuit of fig. using loop analysis.



Sol.

Loop 1

$$-60 + 2I_1 - 2I_4 + 6i_a = 0 \quad \text{--- (1)} \quad (i_a = I_4)$$

Loop 2 & Loop 4 (super mesh)

$$I_2 - I_4 = 4 \quad \Rightarrow \quad I_2 = 4 + I_4 \quad \text{--- (2)}$$

$$5I_4 + 3I_4 - 3I_3 + 4I_2 - 4I_3 + 2I_4 - 2I_1 = 0$$

$$4I_4 - 7I_3 + 4I_2 - 2I_1 = 0 \quad \text{--- (3)}$$

Loop 3

$$I_3 = 5A$$

(نبسط المعادلة (1) ونجعل I_1 بدلالة I_4)

$$-60 + 2I_1 - 2I_4 + 6I_4 = 0$$

$$2I_1 = 60 - 4I_4 \div 2 \quad \therefore \quad I_1 = 30 - 2I_4 \text{ --- (4)}$$

نعوض المعادلة (2) و (4) في المعادلة (3))

$$4I_4 - 7(5) + 4(4 + I_4) - 2(30 - 2I_4) = 0$$

$$4I_4 - 35 + 16 + 4I_4 - 60 + 4I_4 = 0$$

$$I_4 = \frac{79}{12} = 6.583A$$

نعوض I_4 في المعادلة (4))

$$\therefore \quad I_1 = 30 - 2(6.583) = 16.834A$$

$$p(2\Omega) = (I_1 - I_4)^2 \times 2$$

$$= (16.834 - 6.583)^2 \times 2$$

$$= 210.166 \text{ watt}$$

Department: Electronic Technologies

Subject: DC circuits

Lecture: Nodal Analysis

Instructor: Asst-Lect :Zahraa Hassan Hadi

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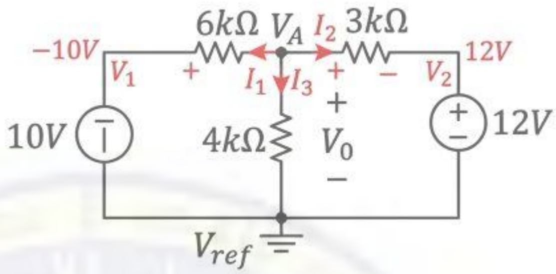
[7. Nodal Analysis Method]

Nodal Analysis is a systematic method used to determine the voltage at each node relative to a reference point in an electrical circuit. It is fundamentally based on **Kirchhoff's Current Law (KCL)**, which states that the algebraic sum of currents entering or leaving a node must equal zero. The process begins by selecting one node as the **Reference Node** (Ground), where the potential is defined as 0V.

For all other non-reference nodes, equations are formulated by expressing branch currents in terms of node voltages using **Ohm's Law** (I = V / R). This results in a set of simultaneous linear equations that can be solved using matrix algebra or substitution. Nodal analysis is particularly efficient for circuits with many parallel branches, as it typically requires fewer equations than Mesh Analysis. It serves as the mathematical backbone for most modern circuit simulation software (like SPICE) due to its structured and algorithmic nature.

Nodal analysis

Ex: use nodal analysis to find V_0 in the circuit in fig.



<u>Sol</u>

at node N

note:

$V_{ref} - V_1 = 10 \quad \therefore V_1 = -10V$

$V_2 - V_{ref} = 12 \quad \therefore V_2 = 12V$

$$I_1 + I_2 + I_3 = 0$$

$$\left[\frac{V_A - (-10)}{6K} + \frac{V_A - 12}{3K} + \frac{V_A}{4K} = 0\right] \times 12k$$

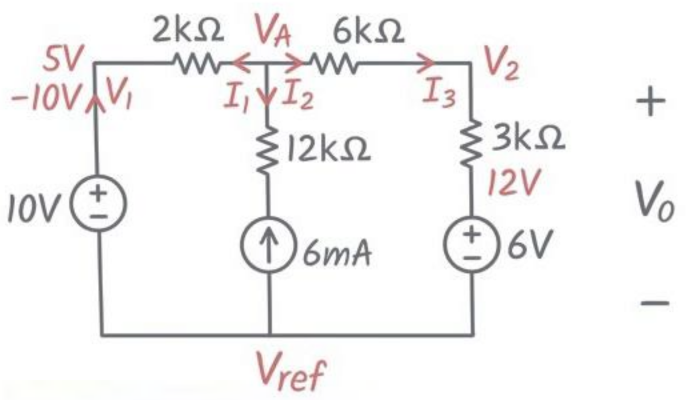
$$2V_A + 20 + 4V_A - 48 + 3V_A = 0$$

$$V_A = \frac{28}{9} = 3.11 \text{ Volt}$$

$$\therefore V_0 = V_A - V_{ref}$$

$$\Rightarrow 3.11 - 0 = 3.11 \text{ Volt}$$

Ex: Use nodal analysis to find V_0 in the circuit in fig.



sol.

at node N

$$I_1 + I_2 = 6mA$$

$$\left[\frac{V_A - 5}{2K} + \frac{V_A - (-6)}{(6k+3k)} = 6mA\right] * 18K$$

$$9V_A - 45 + 2V_A + 12 = 108$$

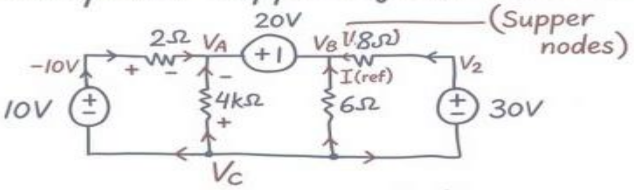
$$\therefore V_A = \frac{141}{11} = 12.82 \text{ Volt}$$

$$\therefore I_2 = \frac{V_A - (-6)}{9K} = \frac{12.82 + 6}{9K} = 2.1mA$$

$$v(3k\Omega) = 2.1\times10^{-3} \times 3\times10^{3} = 6.27 \text{ Volt}$$

$$V_0 + 6 - 6.27 = 0 \Rightarrow V_0 = 0.27 \text{ volt}$$

EX: Find the power supplied from source (20V)



sol.

let $V_B = 0$ volt (ref.)

note :- $V_{ref}^{0} - V_1$ $\therefore V_1 = -10V$

$\therefore V_A - V_B^{0} = 20V$ $\therefore V_A = 20V$ $\therefore V_2 = 12V$

note :- $V_1 - V_c = 10$ $\therefore V_1 = 10 + V_c$

$V_2 - V_c = 30$ $\therefore V_2 = 30 + V_c$

at node c

$$\frac{10 + V_c - V_A}{2} + \frac{V_c - V_A}{4} + \frac{V_c - V_B^{0}}{6} + \frac{30 + V_c - V_B^{0}}{8} = 0$$

$$\left[\frac{10 + V_c - 20}{2} + \frac{V_c - 20}{4} + \frac{V_c}{6} + \frac{30 + V_c}{8} = 0\right] * 48$$

$$240 + 24V_c - 480 + 12V_c - 240 + 8V_c + 180 + 6V_c = 0$$

$$50V_c - 300 = 0 \qquad \therefore V_c = \frac{300}{50} = 6 \text{ Volt}$$

$$I(20V) = I(8\Omega) + I(6\Omega)$$

$$= \frac{30 + V_c - V_B^{0}}{8} + \frac{V_c - V_B^{0}}{6}$$

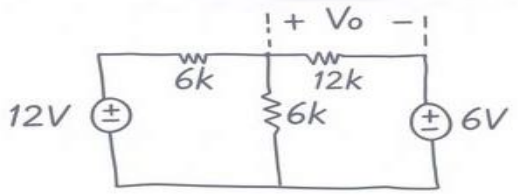
-44-

$$I(20V) = \frac{30 + 6}{8} + \frac{6}{6}$$

$$= \frac{36}{8} + 1$$

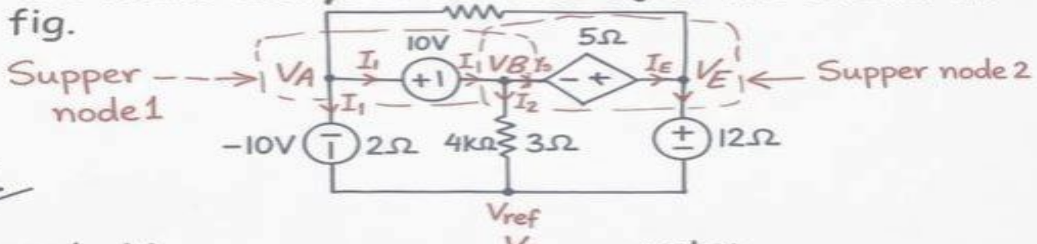
$$P(20V) = 20 \times 5.5 = 110 \text{ Watt}$$

H.W: Find V_o in the network in fig. using nodal analysis.



Ans : $V_o = 0$ Volt

Ex: use nodal analysis to find V_0 in the circuit in fig.



sol.

at node N

note:

$V_{ref}^{0} - V_1 = 10 \quad \therefore V_1 = -10V$
$V_2 - V_{ref}^{0} = 12 \quad \therefore V_2 = 12V$

$$I_1 + I_2 + I_3 = 0$$

$$\left[\frac{VA-(-10)^{\circ}}{6K} + \frac{VA-VE}{3K} + \frac{VB-V_C^{\circ}}{4} + \right]\frac{VE-V_C^{\circ}}{3} + \frac{VE-VA}{6} = 0$$

$$\frac{VA}{2} + \frac{VA}{6} - \frac{VE}{6} + \frac{VB}{4} + \frac{VE}{3} + \frac{VE}{6} - \frac{VA}{6} = 0$$

$$\therefore \frac{VA}{2} + \frac{VB}{4} + \frac{VE}{3} = 0 \quad \text{—— (1)}$$

$$\because VA - VB = 10 \Rightarrow \therefore VA = 10 + VB \quad \text{—— (2)}$$

$$\because VE - VB = 5i \quad \because i = \frac{VA}{2} \quad \therefore VE - VB = \frac{5\,VA}{2} \quad \text{—— (3)}$$

نعوض المعادلة (2) في المعادلة (3)

$$VE - VB = \frac{5}{2}(10 + VB)$$

$$VE = 25 + \frac{5}{2}VB + VB \quad \therefore VE = 25 + 3.5\,VB \quad \text{—— (4)}$$

نعوض المعادلة (4) و (2) في المعادلة (1)

$$\frac{10+VB}{2} + \frac{VB}{4} + \frac{25+3.5\,VB}{3} = 0$$

$$5 + 0.5\,VB + 0.25\,VB + 8.33 + 1.16\,VB = 0$$

$$VB = \frac{-13.33}{1.91} = -6.979\,V$$

نعوض VB في المعادلة (4)

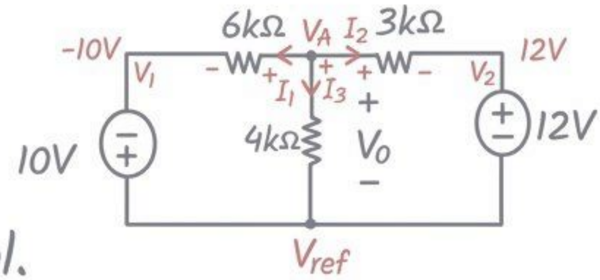
$$VE = 25 + 3.5 * -6.979$$

$$= 0.573\ \text{Volt}$$

$$P(3\Omega) = \frac{V^2}{R} = \frac{(VE - VC)^2}{3}$$

$$= \frac{(0.573 - 0)^2}{3} = 0.109\ \text{watt}$$

Ex: use nodal analysis to find V_0 in the circuit in fig.



note:

$\cancel{V_{ref}}^0 - V_1 = 10 \quad \therefore V_1 = -10V$

$V_2 - \cancel{V_{ref}}^0 = 12 \quad \therefore V_2 = 12V$

sol.

at node N

$$I_1 + I_2 + I_3 = 0 \quad \left[\frac{V_A - (-10)}{6K} + \frac{V_A - 12}{3K} + \frac{V_A}{4K}\right] * 12k$$

$$2V_A + 20 + 4V_A - 48 + 3V_A = 0$$

$$V_A = \frac{28}{9} = 3.11 \text{ Volt}$$

$$\therefore V_0 = V_A - V_{ref} = 3.11 - 0 = 3.11 \text{ Volt}$$

at node A $\quad \dfrac{V_A - V_C}{2} + \dfrac{V_A - V_E}{6} + I_1 = 0 \quad$ ——(1)

at node B $\quad \dfrac{V_B - V_C}{4} - I_1 + I_2 = 0 \quad$ ——(2)

at node E $\quad \dfrac{V_E - V_C}{3} + \dfrac{V_E - V_A}{6} - I_2 = 0 \quad$ ——(3)

نعوض المعادلة (3) في المعادلة (2)

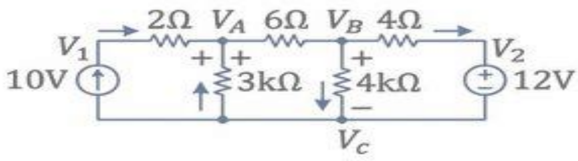
$$\frac{V_E - V_C}{3} + \frac{V_E - V_A}{6} + \frac{V_B - V_C}{4} - I_1 = 0 \quad \text{——(4)}$$

نعوض المعادلة (4) في المعادلة (1)

$$\frac{V_A - \cancel{V_C}^0}{\cancel{2}} + \frac{V_A - \cancel{V_E}}{\cancel{6}} + \frac{V_E - \cancel{V_C}^0}{\cancel{3}} + \frac{V_E - \cancel{V_A}}{\cancel{6}} + \frac{V_B - \cancel{V_C}^0}{\cancel{4}} = 0$$

$$\frac{V_A}{2} + \frac{V_E}{3} + \frac{V_B}{4} = 0 \longleftarrow \text{Supper node (1\&2)}$$

Ex: Use nodal analysis to find V_o in the circuit in fig.



sol.

note:

$V_{ref}^0 - V_1 = 10 \ \therefore V_1 = -10V$

$V_2 - V_{ref}^0 = 12 \ \therefore V_2 = 12V$

at node N

$$I_1 + I_2 + I_3 = 0$$

$$\left[\frac{V_A - (-10)}{6K} + \frac{V_A - 12}{3K} + \frac{VA - -VC^0}{7} = 0\right] * 12k$$

$$3V_A - 30 + V_A - V_B + \frac{6}{7}V_A = 0$$

$$6V_A = 30 + V_B \qquad \therefore V_A = \frac{30 + V_B}{6} \text{ —— } (1)$$

at node B

$$\left[\frac{V_B - V_A}{6} + \frac{V_B - V_C^0}{8} + \frac{V_B - 15}{4} = 0\right] * 48$$

$$8V_B - 8V_A + 6V_B - 6V_C^0 + 12V_B - 180 = 0$$

$$26V_B - 8V_A - 180 = 0 \text{ —— } (2)$$

نعوض المعادلة (1) في المعادلة (2)

$$26V_B - 8\left[\frac{30 + V_B}{6}\right] - 180 = 0$$

$$26V_B - 40 - 1.33V_B - 180 = 0$$

$$\therefore V_B = \frac{220}{24.667} = 8.918 \, Volt$$

$$\therefore V_A = \frac{30 + 8.918}{6} = 6.486 \, Volt$$

$$p(6\Omega) = \frac{v^2}{R} = \frac{(V_B - V_A)^2}{6}$$

$$= \frac{(V_B - V_A)^2}{6} = \frac{(8.918 - 6.486)^2}{6} = 985mw$$

Department: Electronic Technologies

Subject: DC circuits

Lecture: Source Transformation

Instructor: Asst-Lect :Zahraa Hassan Hadi

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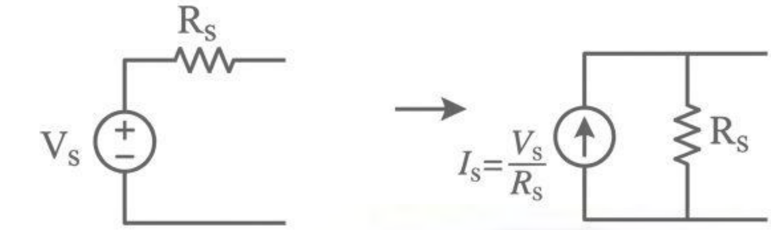
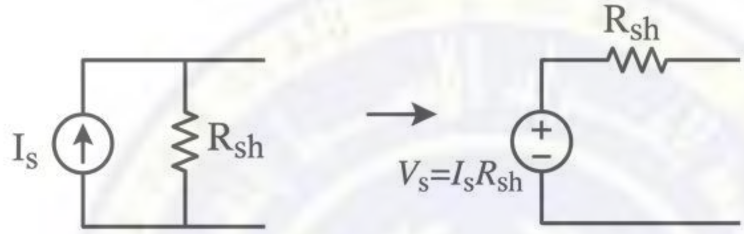
[8. Source Transformation]

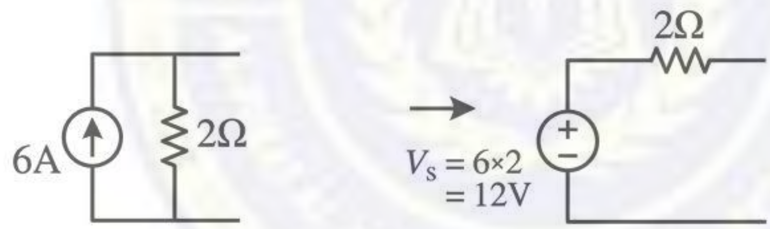
Source transformation is a powerful technique used in circuit analysis to simplify complex networks by switching between voltage and current sources. According to Ohm's Law, a real voltage source in series with a resistor can be replaced by an equivalent ideal current source in parallel with the same resistor. This method is particularly useful when performing nodal or mesh analysis, as it can reduce the number of nodes or loops in a circuit. The transformation is bidirectional, meaning a parallel current-resistor combination can also be converted back into a series voltage-resistor setup. By repeatedly applying this process, engineers can transform a daunting circuit into a much simpler form to find unknown voltages or currents. Ultimately, it serves as a fundamental tool for streamlining the calculation process in electrical engineering.

Sources transformation

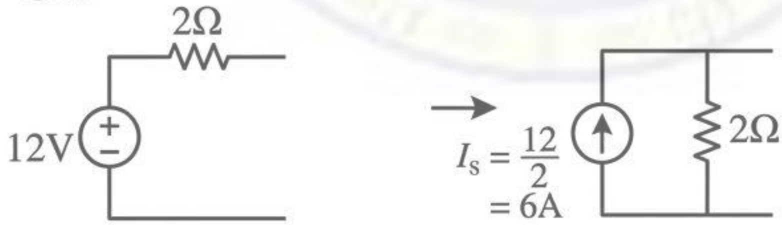




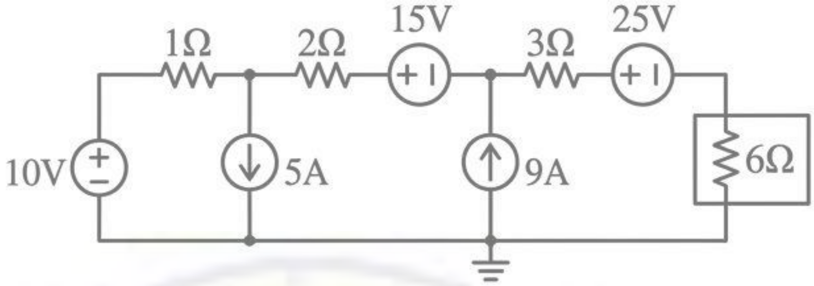
For example



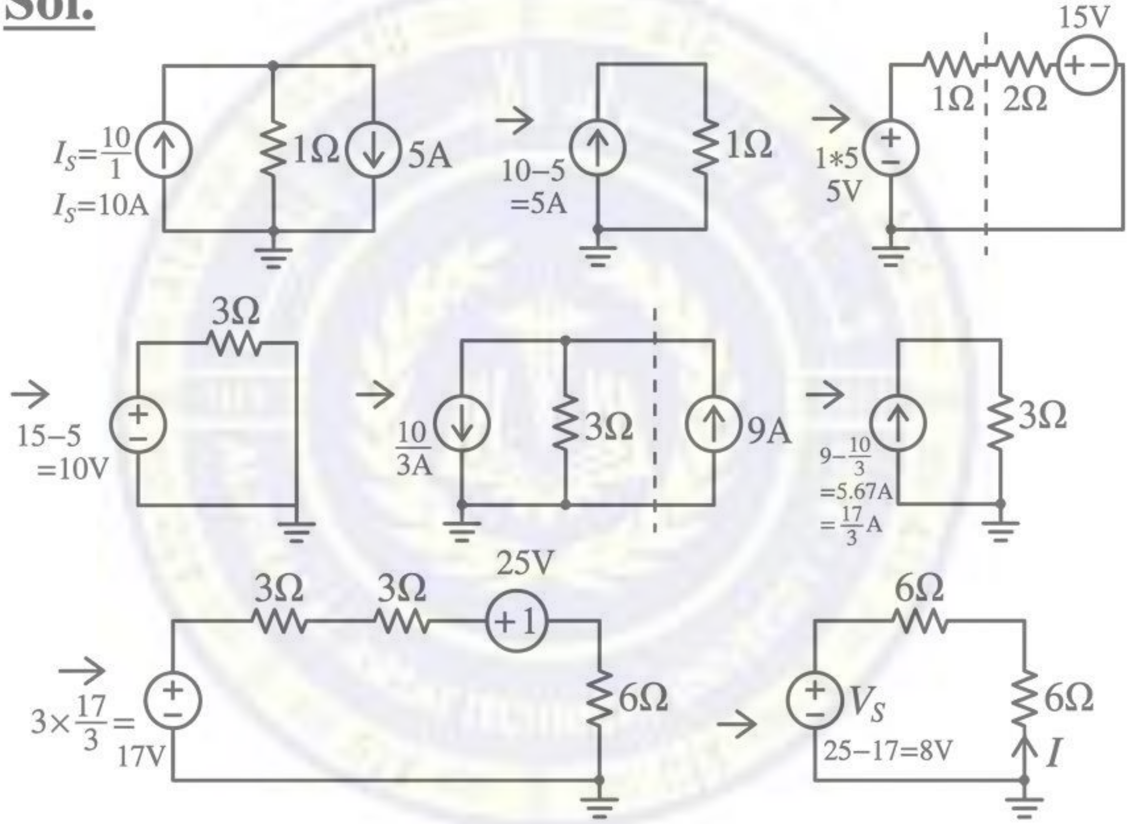
OR



Ex: Find the current in resistance (6Ω) using Sources transformation

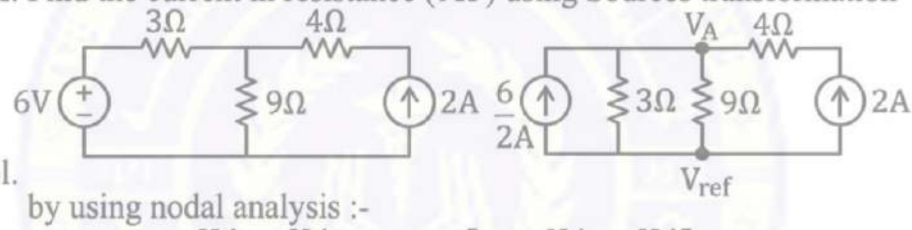


Sol.



$$I(6\Omega) = \frac{8}{6+6} = \frac{8}{12} = 0.6A$$

EX: Find the current in resistance (9Ω) using Sources transformation



Sol.

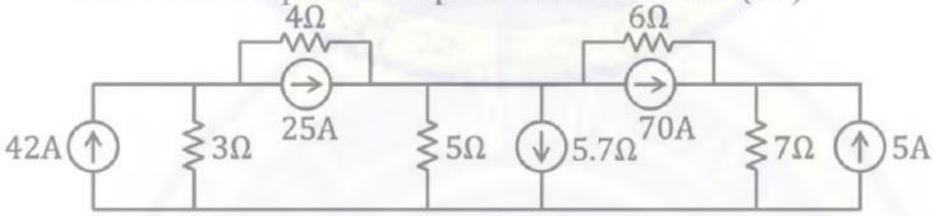
by using nodal analysis :-

$$2+2=\frac{VA}{9}+\frac{VA}{3} \quad \Rightarrow \quad \left[4=\frac{VA}{9}+\frac{VA}{3}\right]*9$$

$$36 = VA + 3VA \qquad \therefore VA=\frac{36}{4}=9\ volt$$

$$\therefore I(9\Omega)=\frac{VA}{9}=\frac{9}{9}=1A$$

H.w : Find the power dissipated in the resistance (7Ω)



Department: Electronic Technologies

Subject: DC circuits

Lecture: Superposition Theorem

Instructor: Asst-Lect :Zahraa Hassan Hadi

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[9. Superposition Theorem]

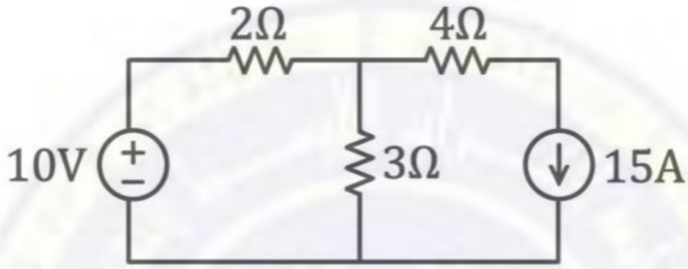
The Superposition Theorem is a fundamental principle in circuit analysis used to solve linear circuits with multiple independent sources. It states that the total current or voltage in any branch of a bilateral network is the algebraic sum of the effects produced by each source acting alone. To apply this theorem, all other independent sources must be "turned off" or replaced by their internal resistances. Specifically, independent voltage sources are replaced by short circuits, while independent current sources are replaced by open circuits. This method simplifies complex problems by breaking them down into several individual sub-circuits, each containing only one active source. It is an essential tool for engineers to understand the individual contribution of every power source within a system.

Superposition theorem

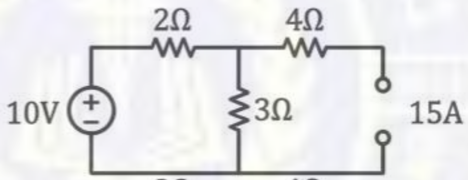
"In any Linear network containing more than one source. The current in or the voltage across any branch is equal to the algebraic sum of the current or the voltages in the same branch resulting from the effect of each source alone"

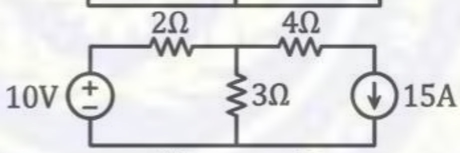
Ex: Find the current in resistance (3Ω) using Superposition theorem.

Sol



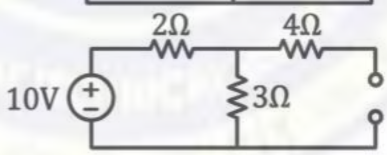
effect of 10V





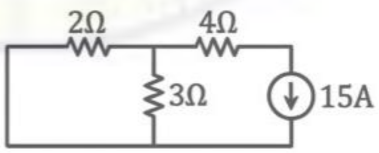
effect of 10V

$$I'\,(3\Omega) = \frac{10}{2+3} = 2A \downarrow$$



effect of 15A

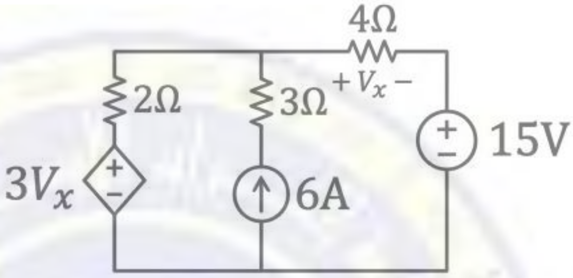
$$I''\,(3\Omega) = 15 * \frac{2}{2+3} = 6A \uparrow$$



$$I\,(3\Omega) \;=\; \bar{I}\uparrow - \;\hat{I}\downarrow = 6 - 2 = 4\,\dot{A}\uparrow$$

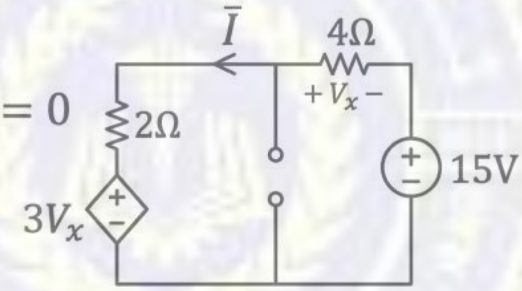
$$p\,(3\Omega) \;=\; \bar{I}^2 * R = 4^2 * 3 = 48\,watt$$

EX: *Find the power dissipated in resistance* (2Ω)



sol.

effect of 15V



$$-15 + 4\bar{I} + 2\bar{I} + 3V_x = 0$$

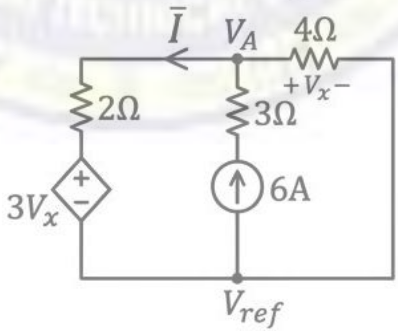
$$\because\; V_x = -4 * \bar{I}$$

$$\therefore\;\; -15 + 6\bar{I} + 3(-4\bar{I}) = 0$$

$$6\bar{I} = -15 \quad\Rightarrow\quad \bar{I} \;=\; \frac{-15}{6}\;A$$

effect of 6A

we using nodal analysis



$$\frac{V_A}{4} + \frac{V_A - 3\overline{V_x}}{2} = 6 \qquad \overline{V_x} = V_A - V_{ref}^0$$

$$\left[\frac{V_A}{4} + \frac{V_A - 3V_A}{2} = 6\right] * 24$$

$$6V_A - 24V_A = 144$$

$$\therefore V_A = \frac{-144}{18} = -8\,Volt$$

$$\overline{\overline{I}}\,(25\Omega) = \frac{V_A - 3\overline{V_x}}{2} = \frac{V_A - 3V_A}{2} = -V_A$$

$$= -\,(-8) = 8\,A$$

$$\therefore\ I\,(2\Omega) = \overline{\overline{I}}\,(2\Omega) + \overline{\overline{I}}\,(2\Omega)$$

$$= 8 - \frac{15}{6} = 5.5\,A \downarrow$$

$$p\,(2\Omega) = I_k^2 \times R$$

$$= (5.5)^2 \times 2 = 60.5\,watt$$

Department: Electronic Technologies

Subject: DC circuits

Lecture: Thevenin Theorem

Instructor: Asst-Lect :Zahraa Hassan Hadi

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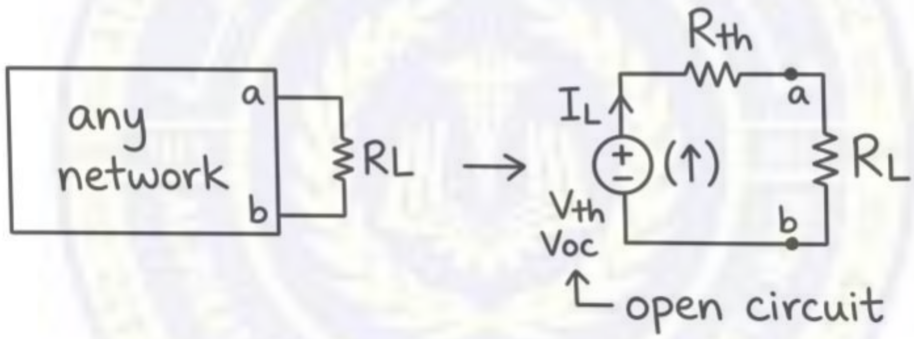
[10. Thevenin Theorem]

Thevenin’s Theorem is a powerful analytical tool used to simplify any linear electrical network into a single voltage source and a series resistor. It states that a complex combination of voltage sources, current sources, and resistors can be replaced by an equivalent circuit known as the Thevenin equivalent. This equivalent consists of an open-circuit voltage, called V_{th}, in series with an internal resistance, labeled as R_{th}. By reducing a massive network to these two components, engineers can easily calculate the current or voltage across any specific load resistor connected to the terminals. This method is exceptionally useful for circuits where the load is frequently changed, as it avoids recalculating the entire network from scratch. Ultimately, it streamlines the design process and enhances the understanding of power delivery in electronic systems

Thevenin theorem

"Any network can be replaced by an equivalent circuit composed of a voltage source in series with a resistance. The voltage of the source is the voltage a cross the branch in which the current is required, when the branch replaced by open circuit. The series resistance is the equivalent resistance a cross the same branch with voltage and current sources replaced by the short and open circuit respectively."



Thevenin equivalent circuit

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

In thevenin theorem, we study three cases:

1 - when circuit contain independent sources only.

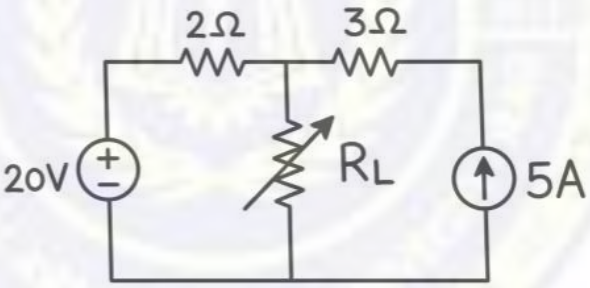
2 - when circuit contain independent and dependent sources.

3 - when circuit contain dependent sources only.

Case 1

Ex: Find the current in R_L when $R_L = 0$, 5, 75, 100, 500 Ω

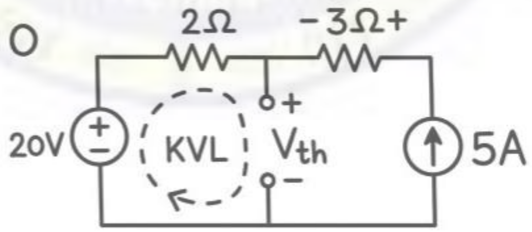
sol



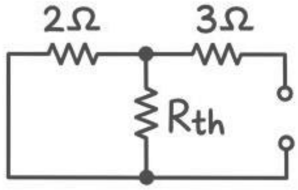
To find V_{th}

$$-20 - 2\times 5 + V_{th} = 0$$

$$V_{th} = 30 \text{ volt}$$

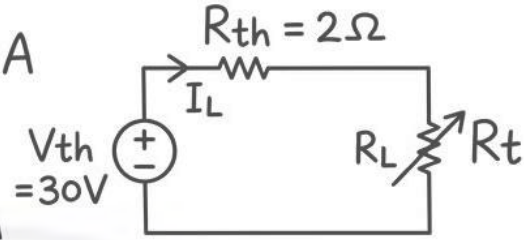


$\therefore R_{th} = 2\Omega$



$$I_L(0\Omega) = \frac{V_{th}}{R_{th} + R_L}$$

$$= \frac{30}{2+0} = 15A$$



$$I_L(5\Omega) = \frac{30}{2+5} = 4.29A$$

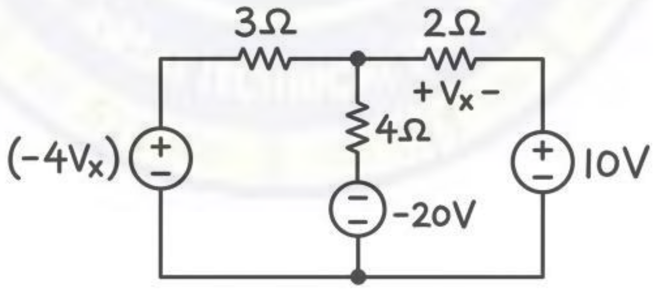
$$I_L(75\Omega) = \frac{30}{2+75} = 0.38A$$

$$I_L(100\Omega) = \frac{30}{2+100} = 0.29A$$

$$I_L(500\Omega) = \frac{30}{2+500} = 0.059A \sim 59mA$$

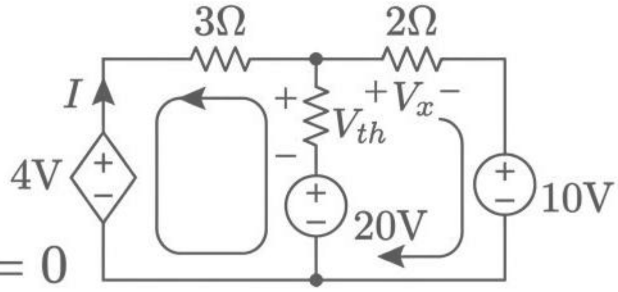
Case 2

Ex: Find the current in resistance (4Ω) using thevenin theorem.



sol

KVL at outer loop



$$-10 - 4V_x + 3I + 2I = 0$$

$$V_x = 2I$$

$$\therefore -10 - 8I + 3I + 2I = 0 \quad \therefore I = \frac{-10}{3}\text{ A}$$

at inner loop (KVL)

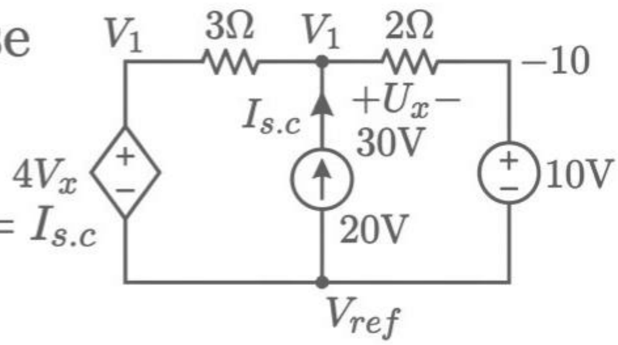
$$-V_{th} - 20 + 2 * \frac{-10}{3} - 10 = 0$$

$$V_{th} = -36.67\ volt$$

note:-
when the circuit contain dependent and independent sources, we find R_{th} from the below equation

$$R_{th} = \frac{V_{th}}{I_{s.c}}$$

To find $I_{s.c}$, we use modal analysis.



$$\frac{V_1 - 4V_x}{3} + \frac{V_1 + 10}{2} = I_{s.c}$$

$\because V_1 = 20$ Volt

$\because U_x = V_1 - (-10)$

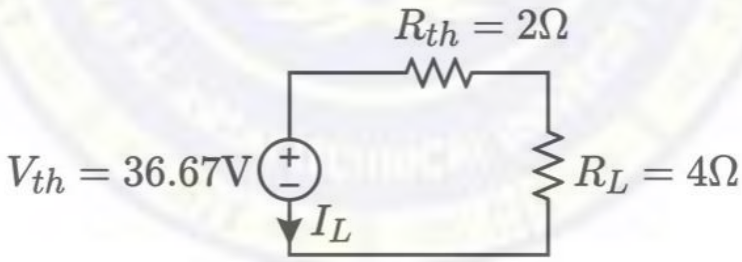
$\therefore U_x = V_1 + 10 = 30$ volt

$$\frac{20 - 4 * 30}{3} + \frac{20 + 10}{2} = I_{s.c}$$

$$\therefore I_{s.c} = -18.33\ A$$

$$R_{th} = \frac{V_{oc}}{I_{s.c}} - \frac{V_{th}}{I_{s.c}}$$

$$= \frac{-36.67}{-18.33} = 2\Omega$$



$$I_L(4\Omega) = \frac{36.67}{2 + 4} = 6.11\ A$$

Department: Electronic Technologies

Subject: DC circuits

Lecture: Thevenin Theorem

Instructor: Asst-Lect :Zahraa Hassan Hadi

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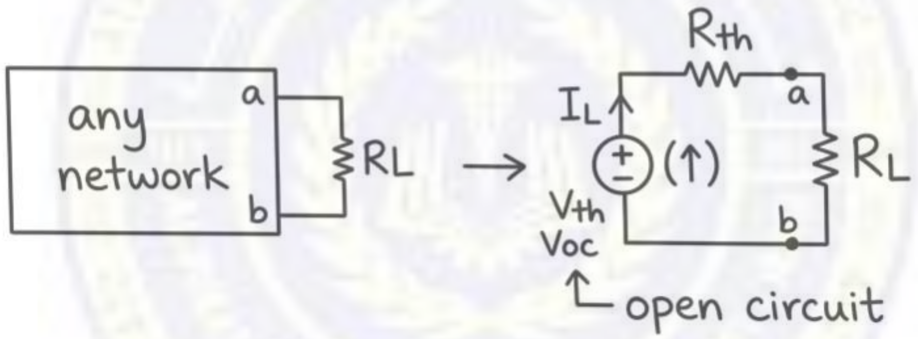
[10. Thevenin Theorem]

Thevenin's Theorem is a powerful analytical tool used to simplify any linear electrical network into a single voltage source and a series resistor. It states that a complex combination of voltage sources, current sources, and resistors can be replaced by an equivalent circuit known as the Thevenin equivalent. This equivalent consists of an open-circuit voltage, called V_{th}, in series with an internal resistance, labeled as R_{th}. By reducing a massive network to these two components, engineers can easily calculate the current or voltage across any specific load resistor connected to the terminals. This method is exceptionally useful for circuits where the load is frequently changed, as it avoids recalculating the entire network from scratch. Ultimately, it streamlines the design process and enhances the understanding of power delivery in electronic systems

Thevenin theorem

"Any network can be replaced by an equivalent circuit composed of a voltage source in series with a resistance. The voltage of the source is the voltage a cross the branch in which the current is required, when the branch replaced by open circuit. The series resistance is the equivalent resistance a cross the same branch with voltage and current sources replaced by the short and open circuit respectively."



Thevenin equivalent circuit

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

In thevenin theorem, we study three cases:

1 - when circuit contain independent sources only.

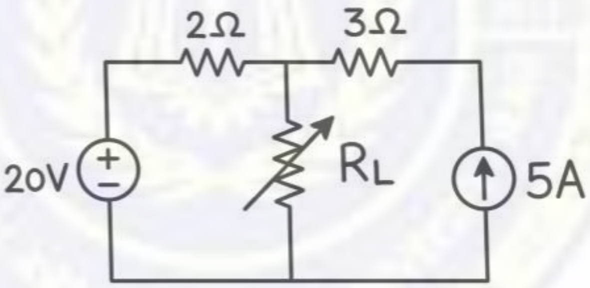
2 - when circuit contain independent and dependent sources.

3 - when circuit contain dependent sources only.

Case 1

Ex: Find the current in R_L when $R_L = 0, 5, 75, 100, 500\ \Omega$

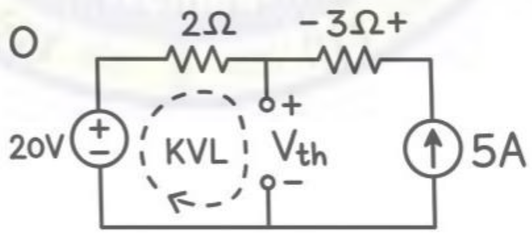
sol



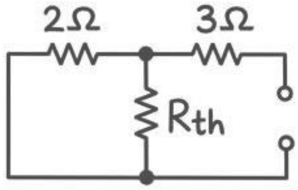
To find V_{th}

$$-20 - 2\times5 + V_{th} = 0$$

$$V_{th} = 30 \text{ volt}$$

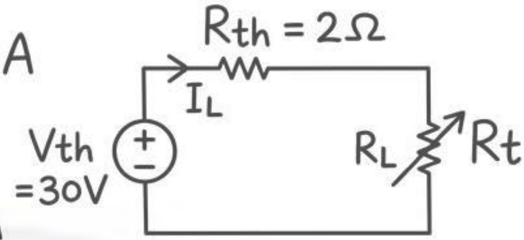


$\therefore R_{th} = 2\Omega$



$$I_L(0\Omega) = \frac{V_{th}}{R_{th} + R_L}$$

$$= \frac{30}{2 + 0} = 15A$$



$$I_L(5\Omega) = \frac{30}{2+5} = 4.29A$$

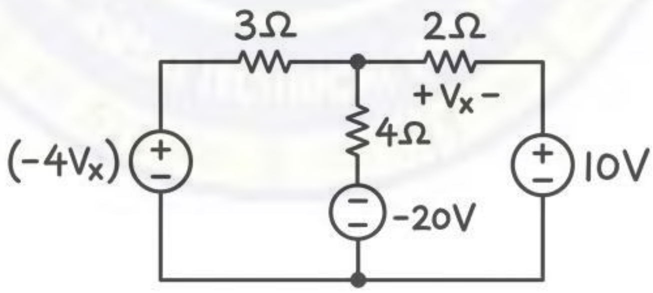
$$I_L(75\Omega) = \frac{30}{2+75} = 0.38A$$

$$I_L(100\Omega) = \frac{30}{2+100} = 0.29A$$

$$I_L(500\Omega) = \frac{30}{2+500} = 0.059A \sim 59mA$$

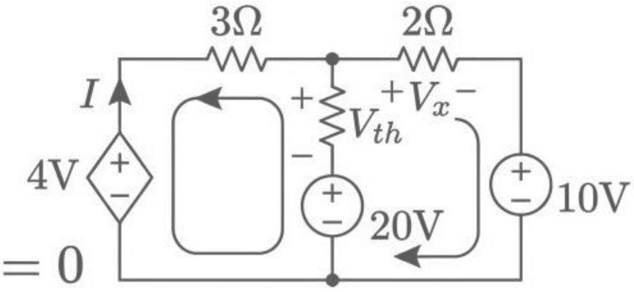
Case 2

Ex: Find the current in resistance (4Ω) using thevenin theorem.



sol

KVL at outer loop



$$-10 - 4V_x + 3I + 2I = 0$$

$$V_x = 2I$$

$$\therefore -10 - 8I + 3I + 2I = 0 \quad \therefore I = \frac{-10}{3}\,\text{A}$$

at inner loop (KVL)

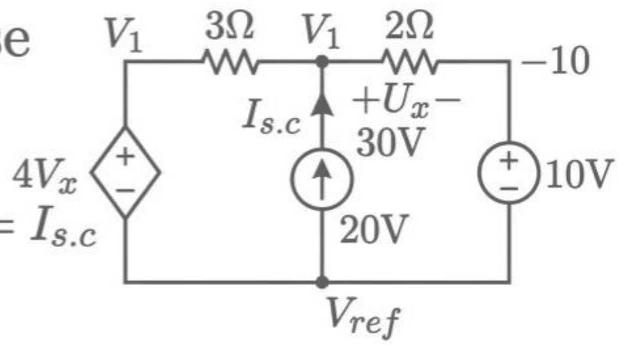
$$-V_{th} - 20 + 2 * \frac{-10}{3} - 10 = 0$$

$$V_{th} = -36.67\ volt$$

note:-
when the circuit contain dependent and independent sources, we find R_{th} from the below equation

$$R_{th} = \frac{V_{th}}{I_{s.c}}$$

To find $I_{s.c}$, we use modal analysis.



$$\frac{V_1 - 4V_x}{3} + \frac{V_1 + 10}{2} = I_{s.c}$$

$\because V_1 = 20$ Volt

$\because U_x = V_1 - (-10)$

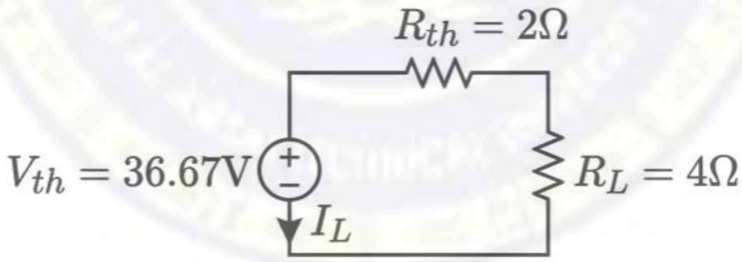
$\therefore U_x = V_1 + 10 = 30$ volt

$$\frac{20 - 4 * 30}{3} + \frac{20 + 10}{2} = I_{s.c}$$

$$\therefore I_{s.c} = -18.33\ A$$

$$R_{th} = \frac{V_{oc}}{I_{s.c}} - \frac{V_{th}}{I_{s.c}}$$

$$= \frac{-36.67}{-18.33} = 2\Omega$$



$$I_L(4\Omega) = \frac{36.67}{2 + 4} = 6.11\ A$$

Department: Electronic Technologies

Subject: DC circuits

Lecture: Norton Theorem

Instructor: Asst-Lect :Zahraa Hassan Hadi

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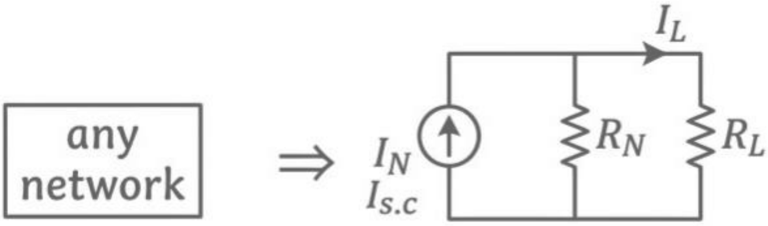
[11. Norton Theorem]

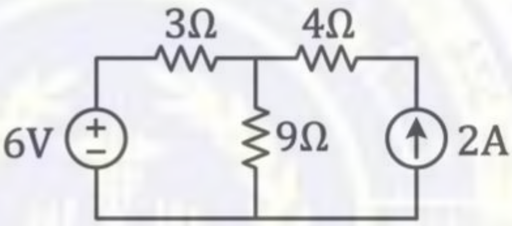
Norton's Theorem is a vital analytical method used to simplify any linear electrical network into a streamlined equivalent circuit. It states that any collection of voltage sources, current sources, and resistors can be replaced by a single ideal current source, known as I_N, in parallel with a single resistor, R_N. To find the Norton current, one must calculate the short-circuit current flowing between the two output terminals of the original network. The Norton resistance, R_N, is identical to the Thevenin resistance and is found by looking back into the terminals with all independent sources turned off. This theorem is particularly advantageous when analyzing the behavior of a circuit connected to varying parallel loads. By using this approach, complex power distribution problems can be solved much more efficiently by focusing on current division rather than mesh equations.

Norton theorem



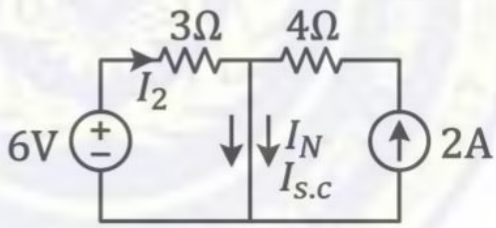
$$I_L = I_N * \frac{R_N}{R_N + R_L} \qquad \text{(current divider law)}$$

Ex: Find the current in resistance (9Ω) using Norton theorem.



sol

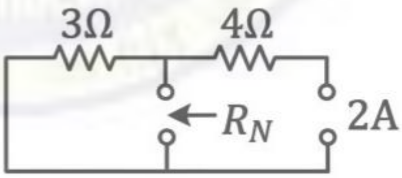
To find $I_{s.c}$



$$I_{s.c} = \frac{6}{3} + 2$$

$$= 4\,A$$

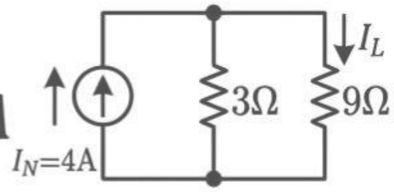
To find R_N



$$R_N = 3\Omega$$

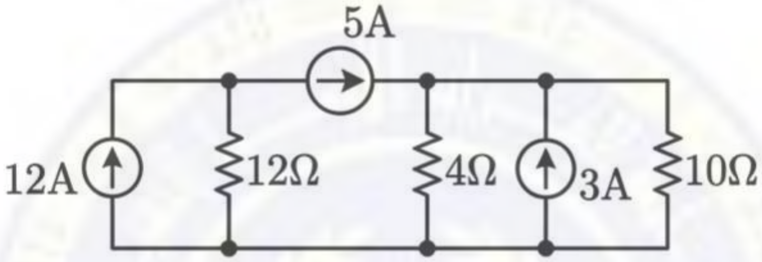
$$I_L(9\Omega) = I_N * \frac{R_N}{R_N + R_L}$$

$$4 * \frac{3}{3+9} = 1A$$



norton equivalent circuit

<u>EX:</u> Find the current in resistance (10Ω) using Norton theorem.

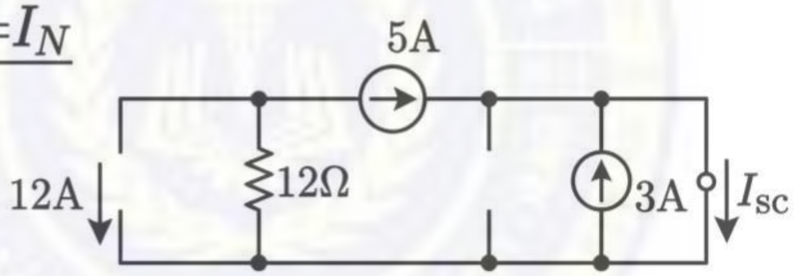


<u>Sol</u>

<u>To find $I_{sc}=I_N$</u>

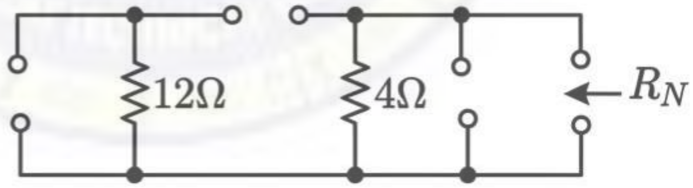
$$I_{sc} = 5 + 3$$

$$= 8A$$

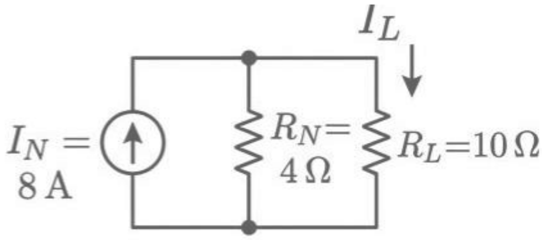


<u>To find R_N</u>

$$R_N = 4\Omega$$



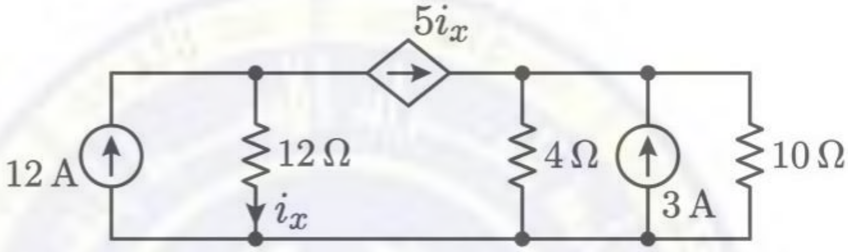
$$I_L = I_N * \frac{R_N}{R_N + R_L}$$



$$= 8 \times \frac{4}{4+10} = 2.28\ A$$

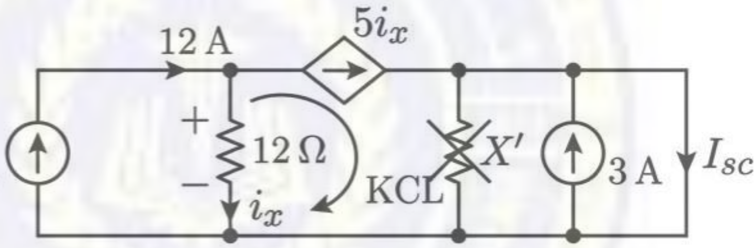
Ex: Find the power dissipated in the resistance (10 Ω) using Norton theorem.

Sol



To find I_{sc}

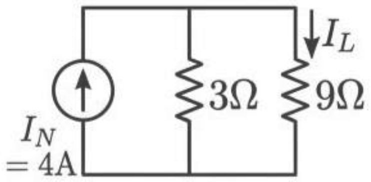
we using KCL
at outer loop 12 A



$$-12\,i_x + 5\,i_x = 0$$
$$i_x = 0\ \text{A}$$

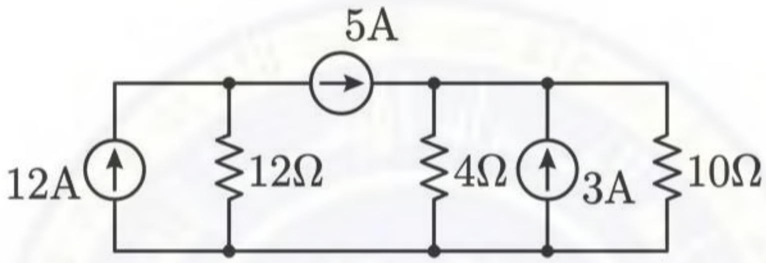
$$I_{sc} = 3 + (12 - i_x)$$
$$= 15\ \text{A}$$

$$I_L(9\Omega) = I_N * \frac{R_N}{R_N + R_L}$$
$$= 4 \times \frac{3}{3+9} = 1\ A$$



norton equivalent circuit

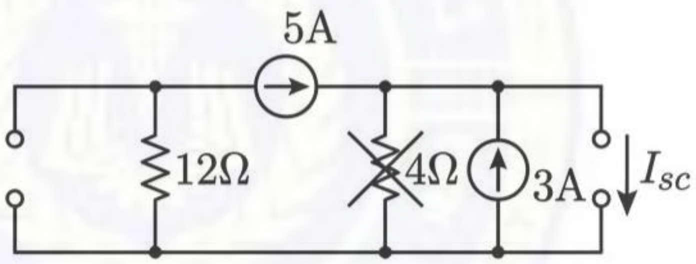
EX: Find the current in resistance (10Ω) using Norton theorem.



<u>Sol</u>

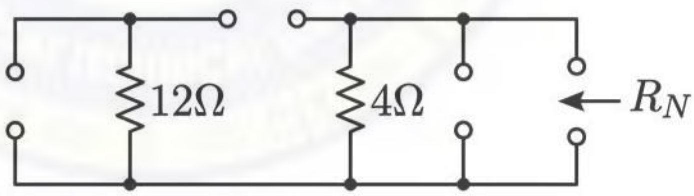
<u>To find $I_{sc}=I_N$</u>

$$I_{sc} = 5 + 3$$
$$= 8\text{A}$$



<u>To find R_N</u>

$$R_N = 4\ \Omega$$



Department: Electronic Technologies

Subject: DC circuits

Lecture: Maximum Power Transfer Theorem

Instructor: Asst-Lect :Zahraa Hassan Hadi

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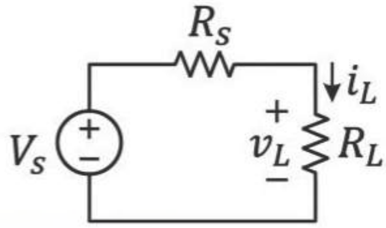
[12. Maximum Power Transfer Theorem]

The Maximum Power Transfer Theorem is a critical principle in electrical engineering used to determine the conditions for peak power efficiency. It states that a network will deliver the maximum possible power to an external load when the resistance of that load is exactly equal to the internal resistance of the source. In practical terms, this means the load resistance R_L must be matched with the Thevenin resistance R_{th} of the driving circuit. While this condition ensures the highest power transfer, it is important to note that the overall efficiency of the system at this point is only 50%. This theorem is widely applied in communications and audio systems to ensure that signals are transmitted with the greatest possible intensity. By matching impedances, engineers can optimize the performance of various electronic components, from amplifiers to radio transmitters.

Maximum power transfer theorem

For the practical voltage source in fig. below, the power delivered to the Load R_L is:

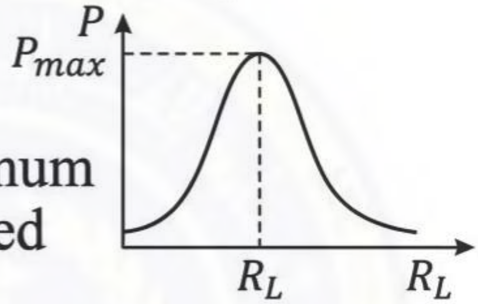
$$P_L = i_L^2 * R_L$$



$$\because\ i_L = \frac{V_s}{R_s + R_L}$$

$$\therefore\ P_L = \frac{{V_s}^2}{(R_s + R_L)^2} * R_L$$

$0 < R_L < \infty$



when $R_s = R_L$, the maximum power transfer is delivered to the Load R_L.

$$P_{max}\Big|_{R_s=R_L} = \frac{{V_s}^2 \cdot R_s}{(R_s + R_s)^2} = \frac{{V_s}^2 \cdot R_s}{4 \cdot {R_s}^2} = \frac{{V_s}^2}{4R_s}$$

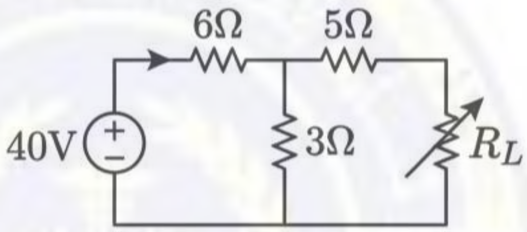
$$\therefore\quad P_{max} = \frac{{V_s}^2}{4R_s} \quad \text{OR} \quad \frac{{V_s}^2}{4R_L}$$

In thevenin theorem, if the thevenin resistance is equal to the thevenin resistance of the network to which it is connected, it will receive maximum power from that network.

$$R_L = R_s = R_{th}$$

$$\therefore P_{max}\Big/_{\substack{delivered\ to\\ Load}} = \frac{{V_s}^2}{4R_s} = \frac{{V_{th}}^2}{4R_{th}}$$

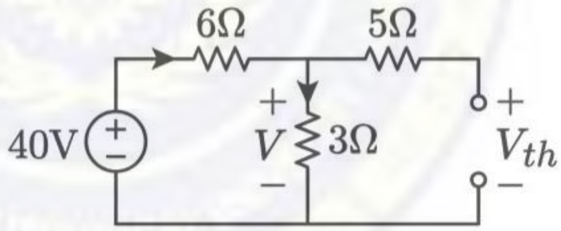
EX: Find the maximum power transferred to R_L.



Sol

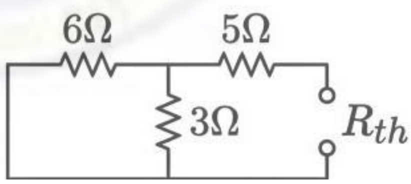
To transfer max power to R_L

$R_L = R_{th}$



$$V(3\Omega) = V_{th} = \frac{40 * 3}{3 + 6}$$

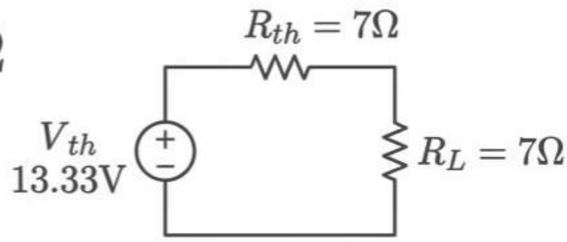
$$V_{th} = 13.33\ Volt$$



$$R_{th} = \left[\frac{6 * 3}{6 + 3}\right] + 5$$

$$= 7\,\Omega$$

$$R_{th} = R_L = 7\Omega$$



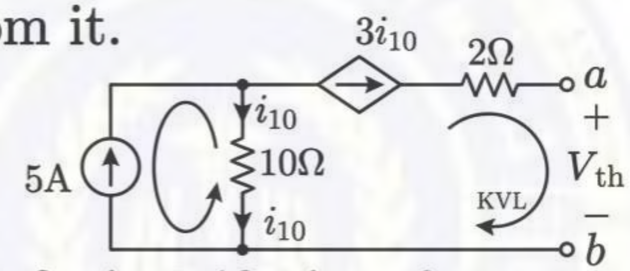
$$P_{max} = \frac{{V_{th}}^2}{4 * R_{th}}$$

$$= \frac{(13.33)^2}{4 * 7} = 6.35 \text{ watt}$$

Ex: Determine the thevenin equivalent of the network shown in fig. below and find the maximum power that can be drawn from it.

Sol: $i_{10} = 5\text{A}$

$i_{10} = 5\text{A}$

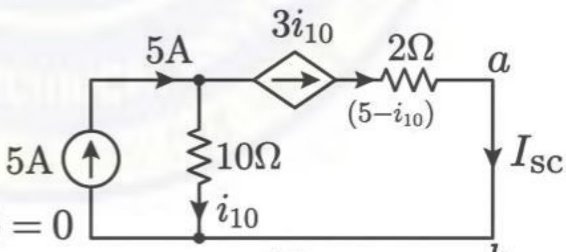


$$-V_{\text{th}} - 2 * 0 + 3 * i_{10} + 10 * i_{10} = 0$$

$$V_{\text{th}} = 3 * 5 + 10 * 5$$

$$= 65 \text{ Volt}$$

To find R_{th}, we must first find I_{sc}.

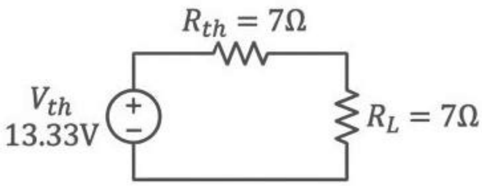


$$-10 * i_{10} - 3 * i_{10} + 2 * (5 - i_{10}) = 0$$

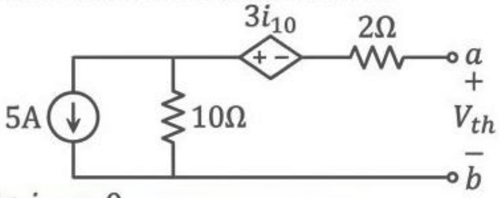
$$-10 * i_{10} - 3 * i_{10} + 10 - 2 * i_{10} = 0 \quad \therefore i_{10} = \frac{10}{15} = 0.667A$$

$R_{th} = R_L = 7\Omega$

$P_{max} = \dfrac{V_{th}^2}{4R_{th}} = \dfrac{(13.33)^2}{4 * 7}$
$= 6.35\ watt$



Ex: Determine the thevenin equivalent of the network shown in fig. below and find the maximum power that can be drawn from it.



Sol: $i_{10} = 5A$

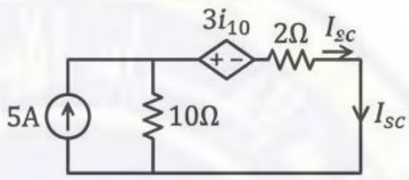
KVL around the loop:

$-V_{th} - 2 * 0 + 3 * i_{10} + 10 * i_{10} = 0$

$V_{th} = 3 * 5 + 10 * 5$

$= 65$ Volt

To find R_{th}, we must first find I_{sc}.



KVL equation:

$-10 * i_{10} - 3 * i_{10} + 2 * (5 - i_{10}) = 0$

$-10 * i_{10} - 3 * i_{10} + 10 - 2 * i_{10} = 0$

$\therefore i_{10} = \frac{10}{15} \quad = 0.667A$

$I_{s.c} = (5 - i_{10})$

$= 5 - 0.667 = 4.33A$

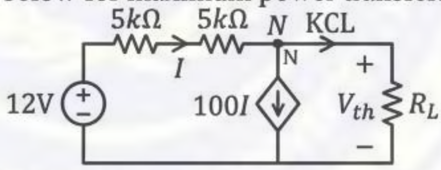
$R_{th} = \dfrac{V_{th}}{I_{s.c}} = \dfrac{65}{4.33} \approx 15\Omega$

$R_{th} = R_L = 15\Omega$

$P_{max}\big|_{RL=15} = \dfrac{V_{th}^2}{4R_{th}} = \dfrac{(65)^2}{4 * 15} = 70.42$ watt

Ex: Choose RL in the network of fig. below for maximum power transfer.

Sol:



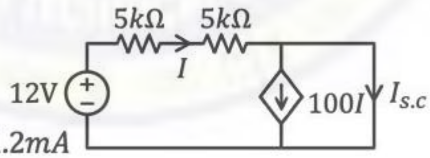
For max power transfer R_L=R_{th}

at node N (KCL)

$I + 100I = 0$

$\therefore I = 0A$

$\therefore V_{o.c} = 12$ Volt



$\therefore I_{s.c} = I + 100I$

$-12 + 10k * I = 0 \ \therefore I = \dfrac{12}{10k} = 1.2mA$