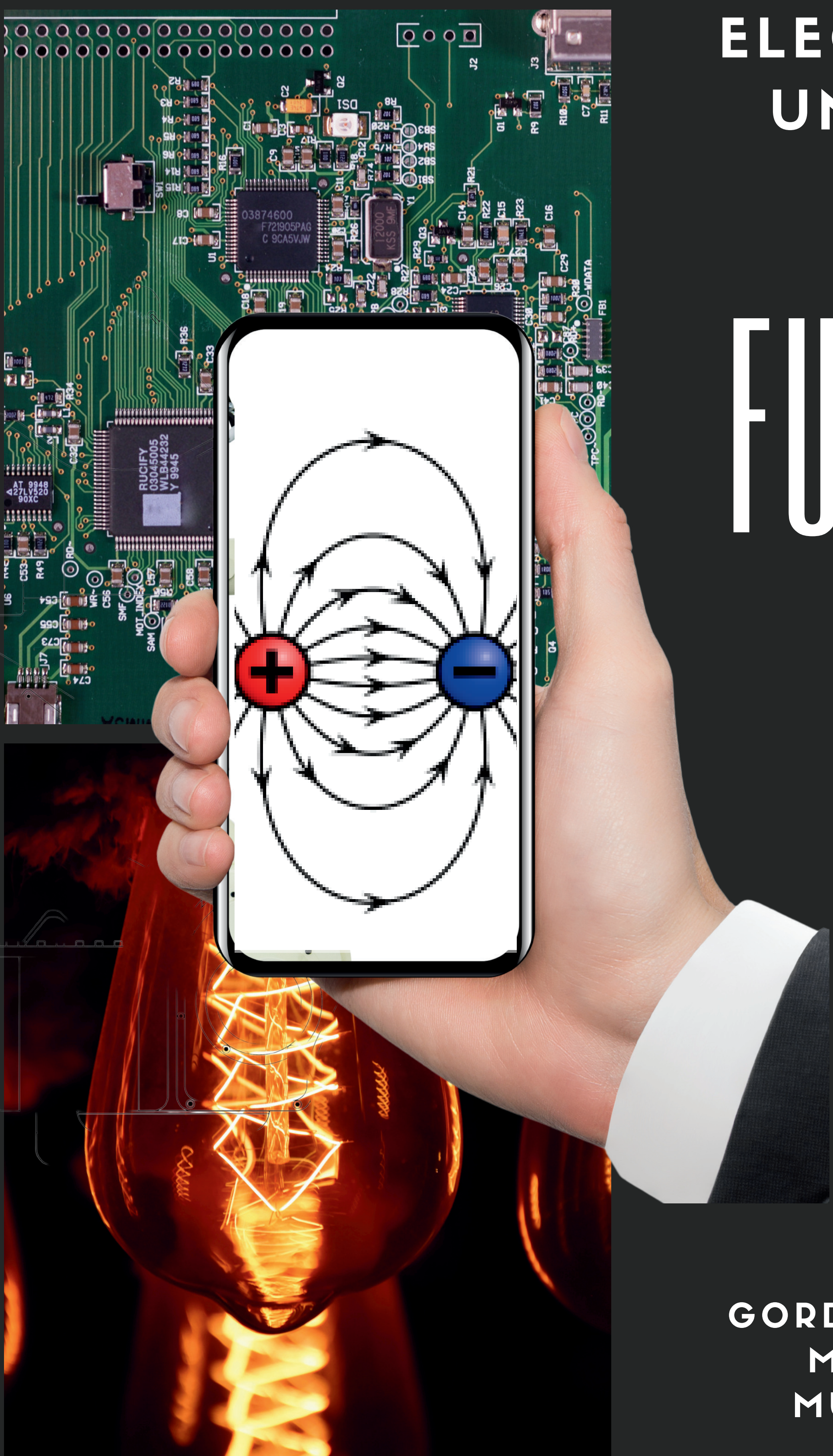

ELECTRICAL TECHNOLOGY UNIT, KOLEJ KOMUNITI BEAUFORT

FUNDAMENTAL OF ELECTRICAL TECHNOLOGY

VOLUME 2

GORDON KECHENDAI ANAK NYANGGAU
MUHAMMAD FARIS BIN HAMDANI
MUHAMMAD ABDUL HAQ BIN AZIZ

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VOLUME 2

UNIT TEKNOLOGI ELEKTRIK
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PREFACE

Fundamental of Electrical Technology — Volume 2 provides students with clear theory and practical calculation exercises to strengthen their understanding of electrical fundamentals.

This volume covers essential topics including introduction to electrical technology, Ohm's Law, delta–star connection, circuit conversion, and electrical power (Topic 1), followed by DC equivalent circuits and network theorems such as Kirchhoff's Laws, nodal and mesh analysis, Thevenin's and Norton's theorems (Topic 2).

To enhance learning, this edition introduces Augmented Reality (AR) features that allow students to explore key concepts through 3D models, circuit animations, and short video demonstrations. Simply scan the provided QR codes to view interactive content such as waveform simulations, circuit conversions, and practical tutorials.

We hope this interactive approach helps students visualize and apply electrical concepts more effectively, and serves as a valuable resource for both students and lecturers in the teaching and learning process.

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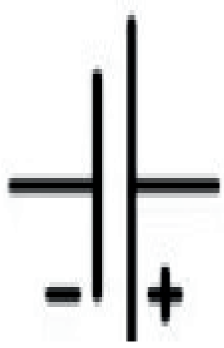
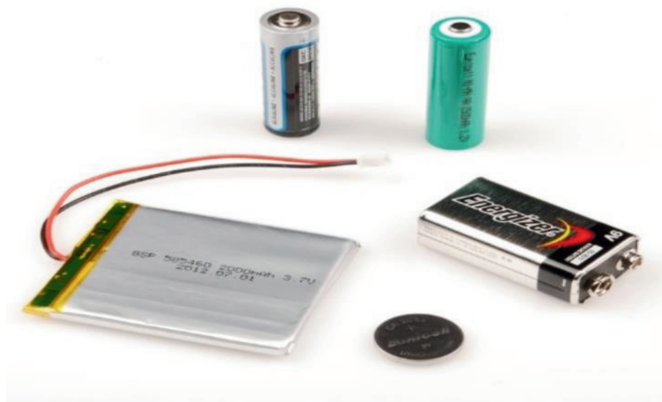
TOPIC 1 : INTRODUCTION TO ELECTRIC CIRCUIT

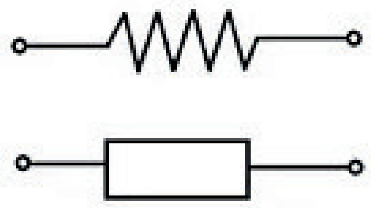
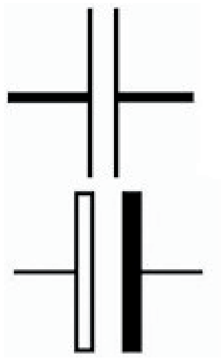
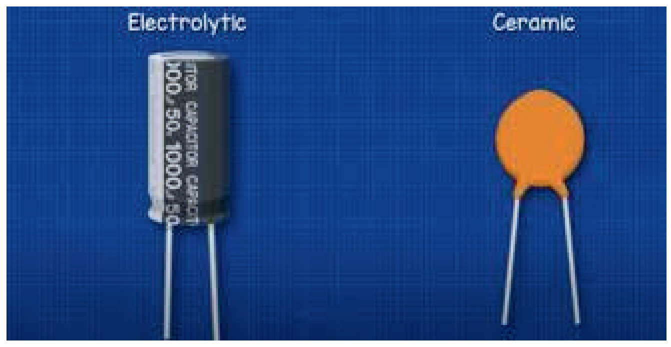
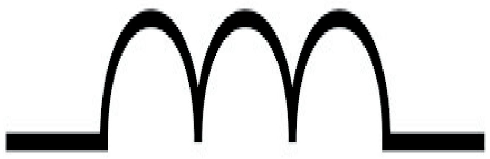
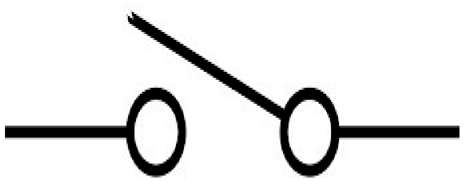
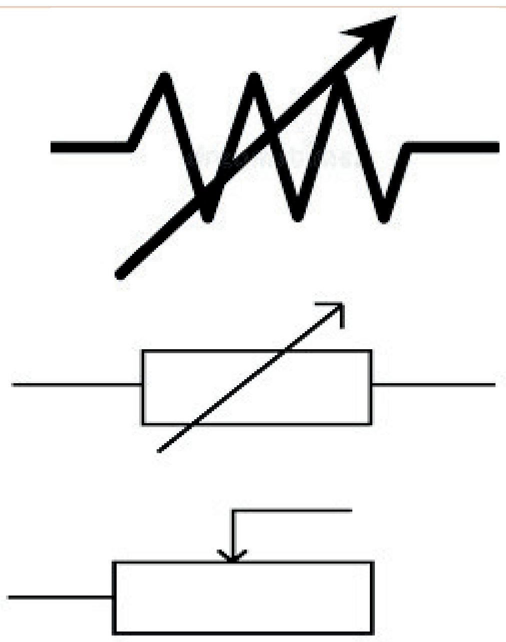
1.1 INTRODUCTION TO ELECTRICAL CIRCUIT

1.1.1 Identify common symbol for electrical components

Table 1.1: Electrical component and its symbol.

SYMBOL	Component Name	Component Picture
	1. DC Voltage Source 2. Battery	
	AC Voltage Source	

TOPIC 1 : INTRODUCTION TO ELECTRIC CIRCUIT

SYMBOL	Component Name	Component Picture
	Fixed Resistor	
	Capacitor	
	Inductor	
	Switch	
	Variable resistor	

1.2 APPLY THE GENERAL FEATURES OF CELLSS AND BATTERIES

1.2.1 Show the differences between cell and batteries.

Cell:

- One module of energy-storing device that converts chemical energy into electrical energy when connected to circuitry.
- The common types of cell are wet cell, dry cell and fuel that employed according to different arrangement.
- The positive electrode has a deficiency of electrons due to chemical reaction.
- The negative electrode has a surplus of electron due to chemical reaction
- The separator functions are to isolate the positive and negative electrode.

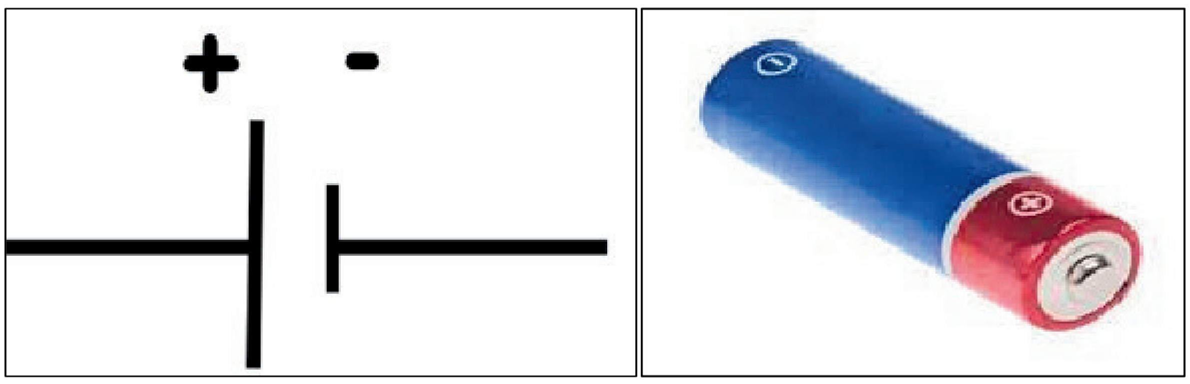


Figure 1.1: One Cell.

Battery:

- Voltage source that convert chemical energy to electrical energy.
- It consists of one or more electro-chemical cells that are electrically connected.
- Combination of more than one cell in series and parallel configuration produce battery.

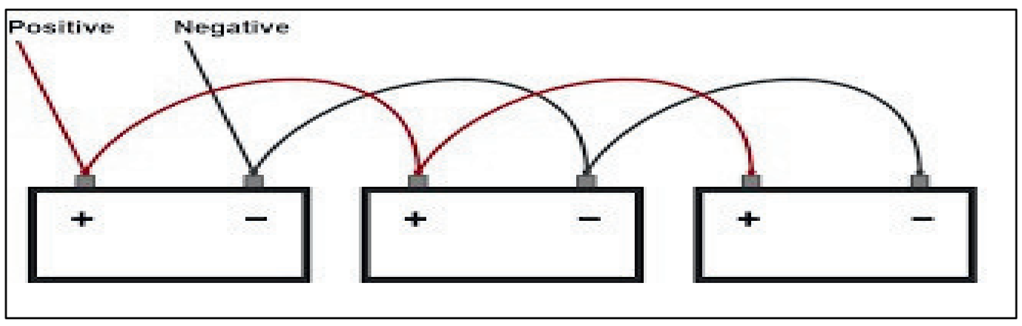
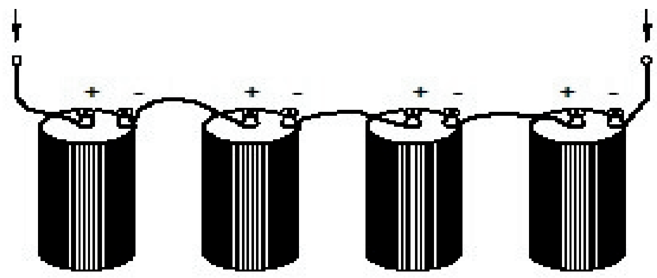


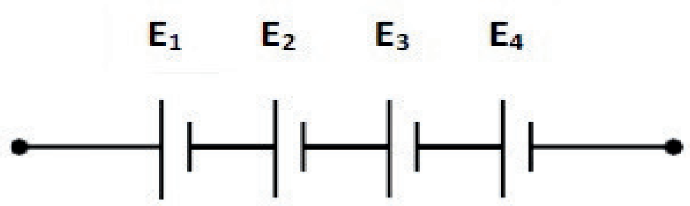
Figure 1.2: Battery connection example. (More than one cell connected)

1.2.2Show the effects of different cell connections

a. Series :

• Component connected in series, follows the same electrical path which cause the current that flows each of the component in the network are the same. Then the voltage across the component is the total of the voltage across each component.



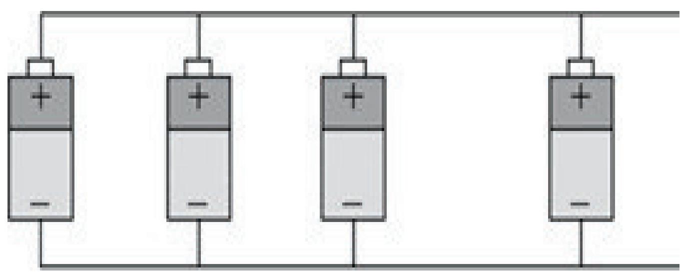


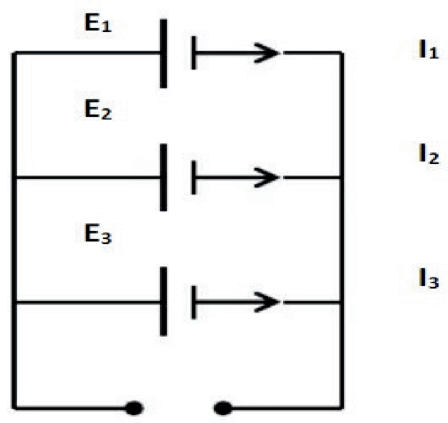
Total Voltage, $E = E_1 + E_2 + E_3 + E_4$

Total Current, $I = I_1 = I_2 = I_3 = I_4$

b. Parallel:

• Each component in a parallel connection is connected via a different path, and the voltage across each component is the same as the voltage across the network. The sum of the currents flowing through each component makes up the network's total current.



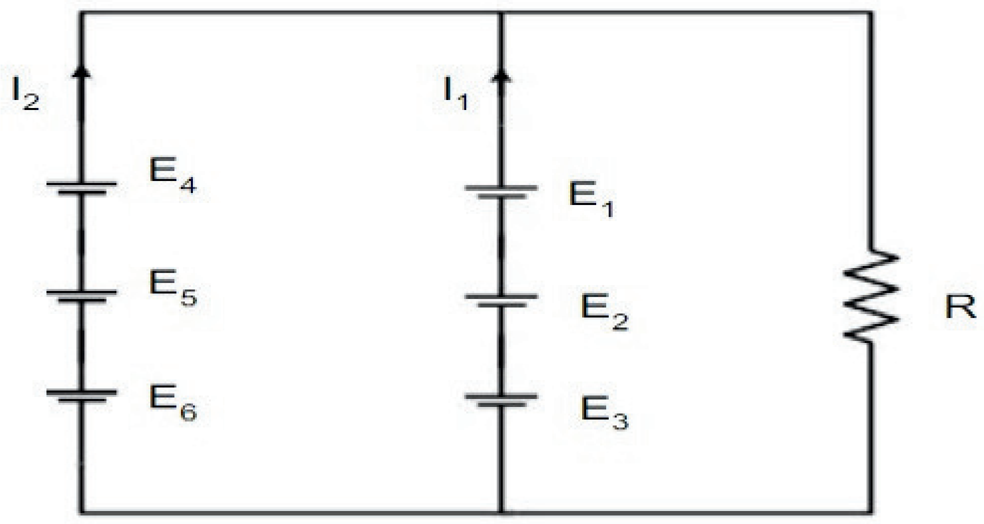


Total Voltage, $E = E_1 = E_2 = E_3$

Total Current, $I_O = I_1 + I_2 + I_3$

c. Series-Parallel

- A series-parallel circuit, often known as a combination circuit, combines parallel and series connections. This is the case for the majority of electronic circuits. When various voltage and current values from the same voltage source are required, series-parallel circuits are commonly utilised.



For Voltage:

EX = E1 + E2 + E3 EY = E4 + E5 + E6 Etotal = EX = EY Etotal = ER

For Current:

I_{total} = I1 +I2

I_{total} = IR

1.2.3 Calculate the total voltage of series sources

a. With same polarities:

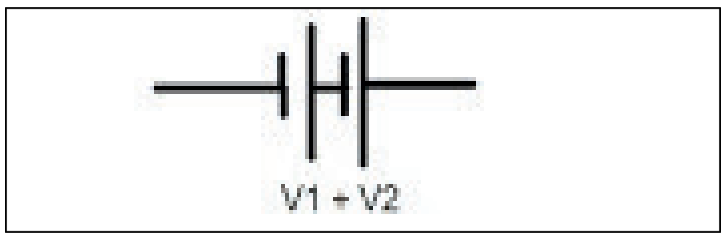


Figure 1.3: Voltage sources with same polarity.

- When voltage source connected in series in the same direction in terms of their polarity, all the voltage sign will be added. Example are shown on Figure 1.3 above and Figure 1.4 below.

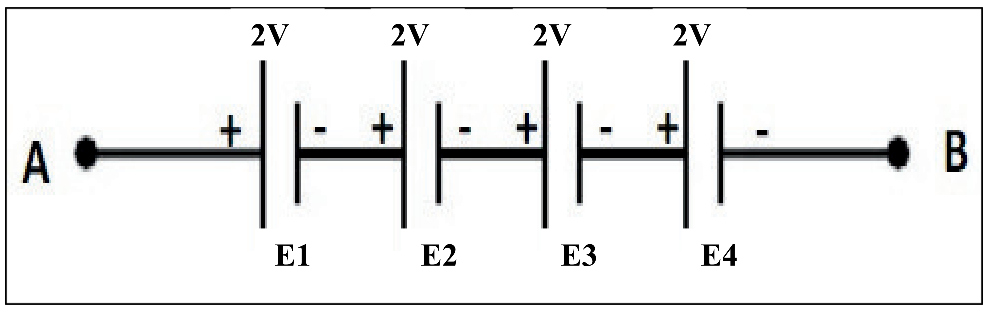


Figure 1.4: Voltage sources with same polarity with value.

From Figure 1.4 above, shows the voltage sourceswith same polarity. The example calculation is;

VAB = E1 +E2+ E3 + E4

VAB = 2V + 2V+2V + 2V = 8V

b. With opposite polarities.

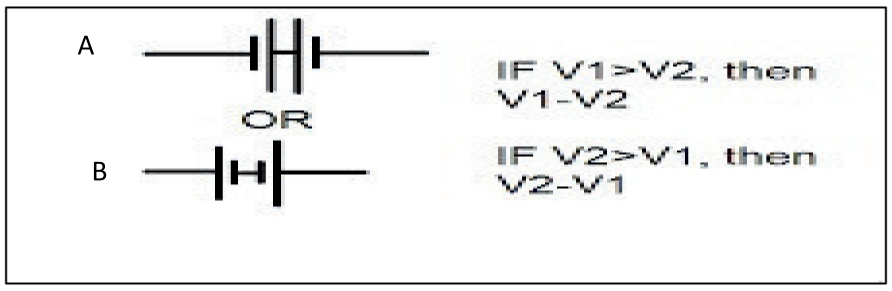


Figure 1.5: Voltage sources with opposite polarities.

Based on Figure 1.5 above, when voltage sources are with opposite polarities, it has two condition;

i. For A, if V1>V2 then V1-V2.

ii. For B, if V2>V1 then V2-V1.

Example calculation are as below;

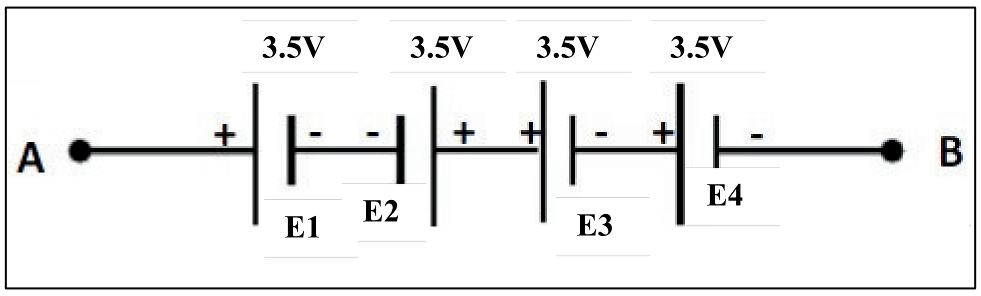
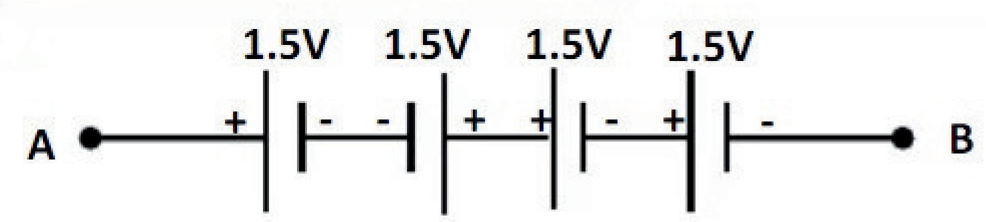


Figure 1.6: Voltage sources with opposite polarities with value.

From Figure 1.6 above, we can determine that;

$$VAB = E1 + E2 + E3 + E4$$
$$VAB = 3.5V + (-3.5V) + (+3.5V) + 3.5V$$
$$VAB = 3.5V - 3.5V + 3.5V + 3.5V = +7V.$$

QUICK EXERCISE: Calculate the voltage across AB.



TOPIC 1 : INTRODUCTION TO ELECTRIC CIRCUIT

1.3 REMEMBER ELECTRIC CURRENT AND QUANTITY OF ELECTRICITY

1.3.1 State the definition of electrical current.

- **An electric current is a flow of electric charge in a circuit.** More specifically, the electric current is the rate of charge flow past a given point in an electric circuit. The charge can be negatively charged electrons or positive charge carriers including protons, positive ions or holes.

> *Electrical current is the rate of flow of charge.*
> *One ampere (1A) is the amount of current that exists when a number of electrons having a total charge of one coulomb (1C) move through a given cross-sectional area in one second (1s).*

- When a voltage is supplied across a conductive or semi conductive material, one end become negative and the other positive. Negative force at the left end caused the free electron (negative charges) to moved towards the right by the repulsive force produced.
- The positive voltage at the right end pulls the free electron to the right by the attractive force produced, resulting a net movement of the free electrons to the positive end of material from the negative end.
- These free electrons from negative end of the material to the positive end movement is called as the **electrical current.**

1.3.2 State the unit of charge.

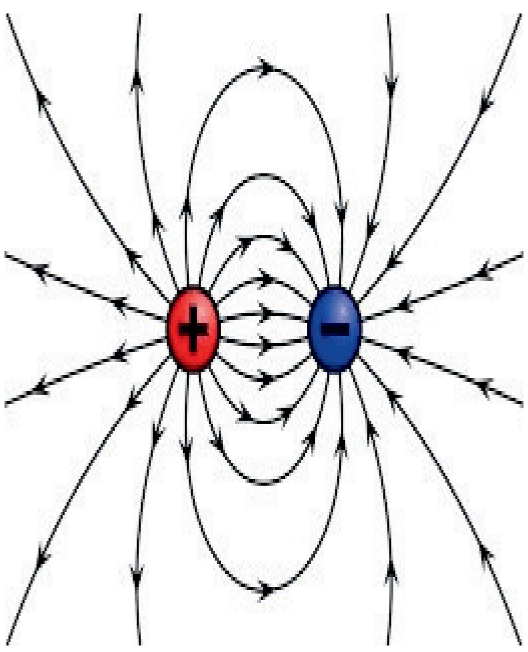
- An electromagnetic field exerts a force on matter as a result of the physical attribute of charge. Positive or negative charges can exist in an electric field. The matter is regarded as neutral or uncharged if there is no net electric charge present.

1 electron = 1.6 X 1018 C

- The total charge Q, is expressed in coulombs (C), for a given number of electrons are shown as formula below:

$$Q = \frac{number\ of\ electrons}{1.6X10^{18}\ electrons/C}$$

1.3.3 Calculate charge or quantity of electricity Q from Q=It



Note that ,

Q	=	coulombs (C)
I	=	amperes (A)
t	=	seconds (s)

$Q = It$,(coulombs, C)

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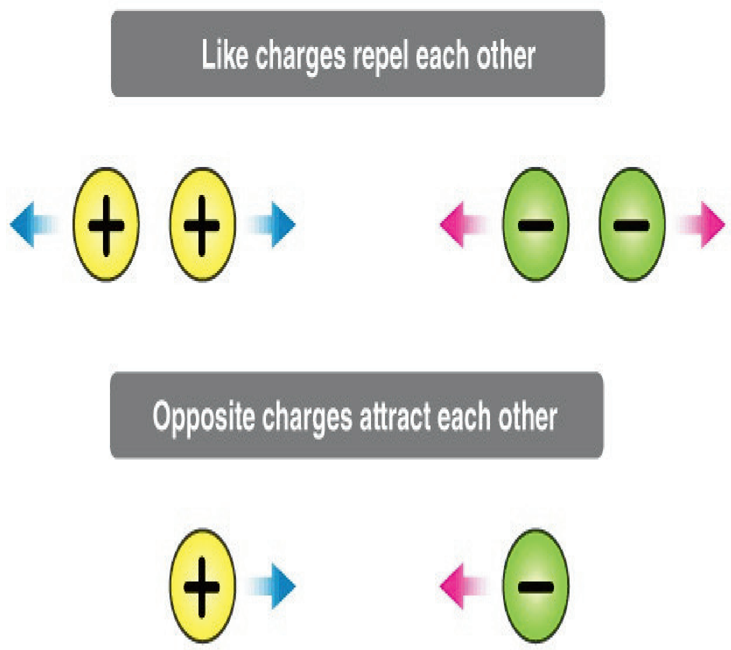

1.4 REMEMBER THE MAIN EFFECTS OF ELECTRIC CURRENT

1.4.1 Identify the three main effects of electric current, giving practical examples of each.

The three main effects of an electrical current are:

- Heating effect:

  Electron in the conductor moving, causing the conductor to generate heat. The amount of generated heat depends on amount of current flowing, dimension of conductors and types of conductor material used. For examples, radiant heaters which heat rooms or circuit protection fuses and MCBs which cut off supply when overcurrent flows.

Figure 1.7: Electrical appliances that convey the heating effects.

- Magnetic effect:

  A magnetic field is created around a conductor whenever current passes through it, acting as an extension of the insulation. The magnetic field is increased as the current is increased.
  The magnetic field collapses when the electricity is cut off. For examples, electric motors that turn as a result of the magnetic flux produced by the power source or due to the magnetic flux created by the electrical supply, door bells and buzzers to activate. Other application is such as relays, generators, transformers, car ignition, lifting magnets and many more.

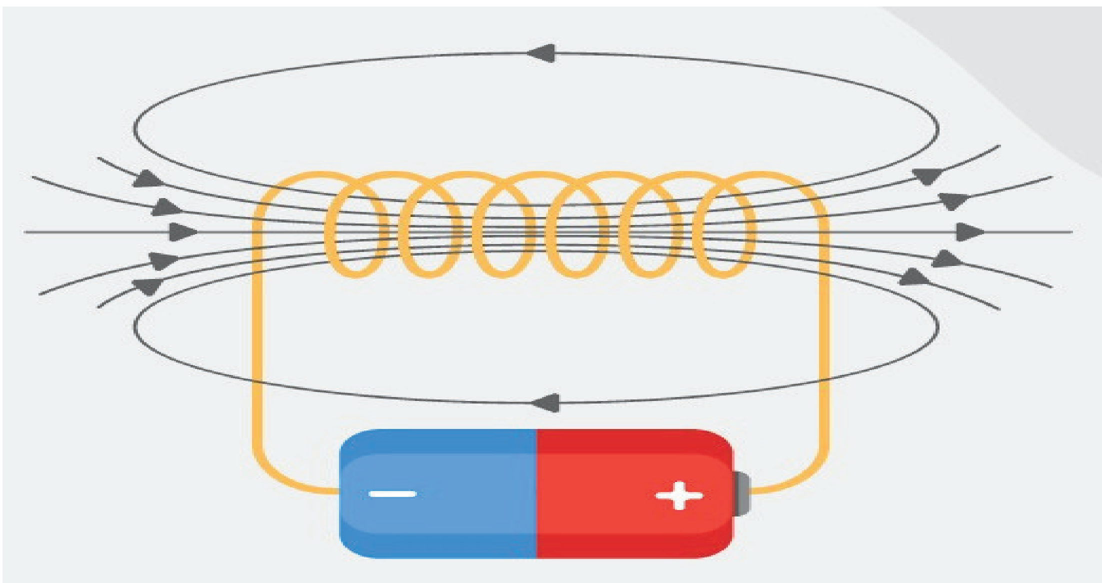

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Figure 1.8: Magnetic effects in conductor when current flows.

- Chemical effect: Electrolysis is the separation of a conducting liquid into its component chemicals when an electric current pass through it. As an alternative, when two metals are combined with a conducting liquid, a chemical reaction results in a voltage. For examples, industrial procedures like electroplating, which is used to silver plate cutlery and sporting trophies batteries used in motor vehicles for storing electricity.

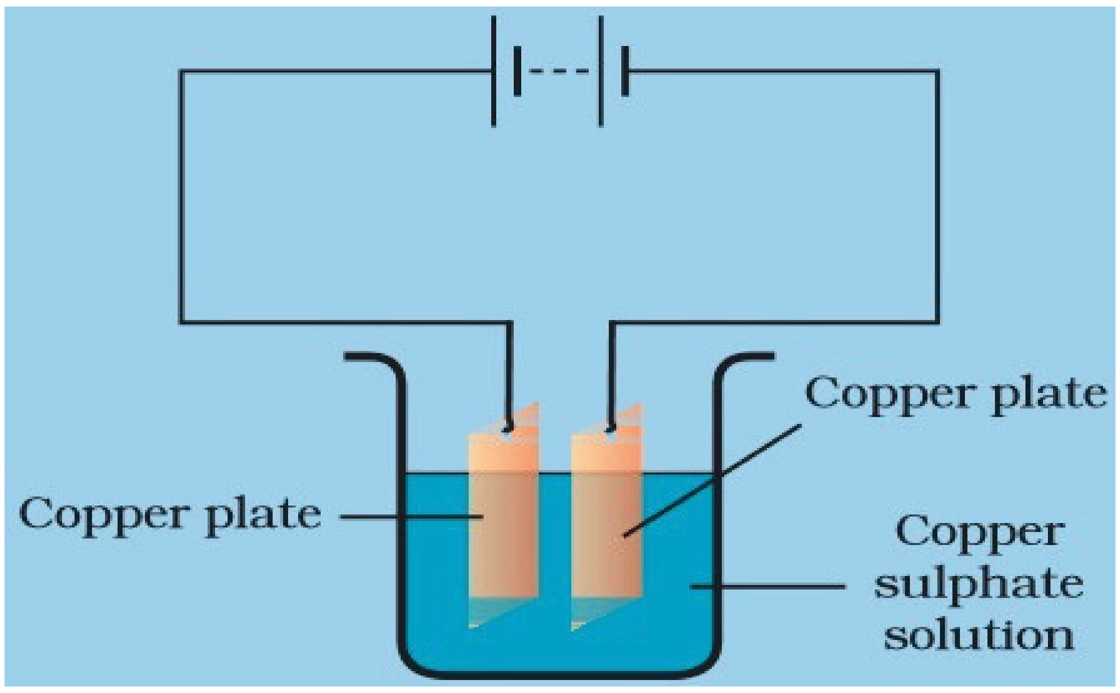

Figure 1.9: Illustration of simple electro plating.

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1.5 APPLY RESISTANCE AND RESISTIVITY

1.5.1 Explain the electrical resistance depends on four factors.

• The cross-sectional area, length, and type of material used to make the wire all affect the resistance of the wire. Less resistance exists between thick and thin wires. More resistance exists between longer and shorter wires. Thinner steel wire of the same size has less resistance than copper wire. Temperature has an impact on electrical resistance as well. For a certain material and at a specific temperature.

From the statement above, it can be summarized that the resistance of any material with a uniform cross-sectional area is determined by the following four factors:

i. Material (ρ); The higher the resistivity of conductor, the higher the resistance. ☞ $\rho = RA/L$

ii. Length (L); The longer the length of conductor, the higher the resistance. The resistance is directly proportional to the length of the wire. ☞ $R \alpha L$

iii. Cross-sectional area (A); The smaller the area of the conductor, the higher the resistance. The resistance is inversely proportional to the cross-sectional area. ☞ $R \alpha 1/A$

iv. Temperature; The higher the temperature of conductor, the higher is the resistance.

1.5.2Calculate that resistance, R= ρ $\frac{l}{A}$ where ρ is the resistivity.

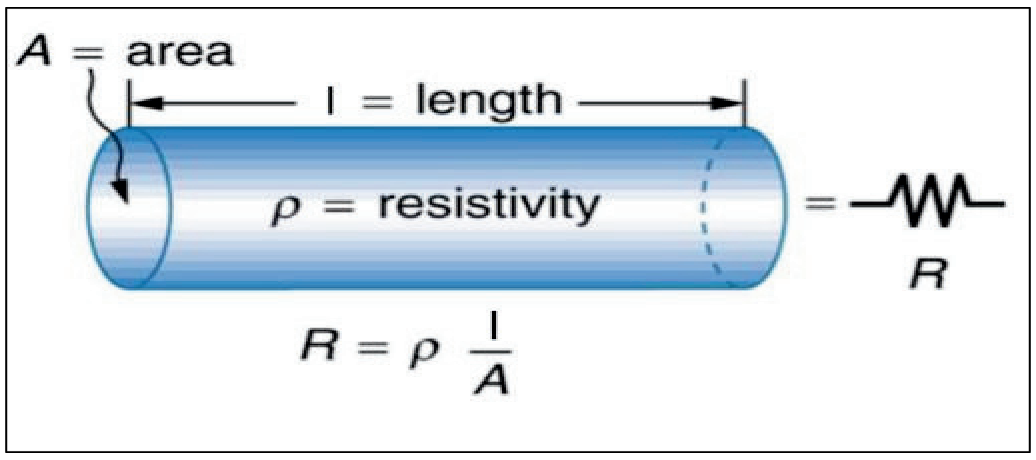


Figure 1.10: Illustration for R= ρ $\frac{l}{A}$

From Figure 1.9 above, at fixed temperature room, the resistance is related to the other three factors by;

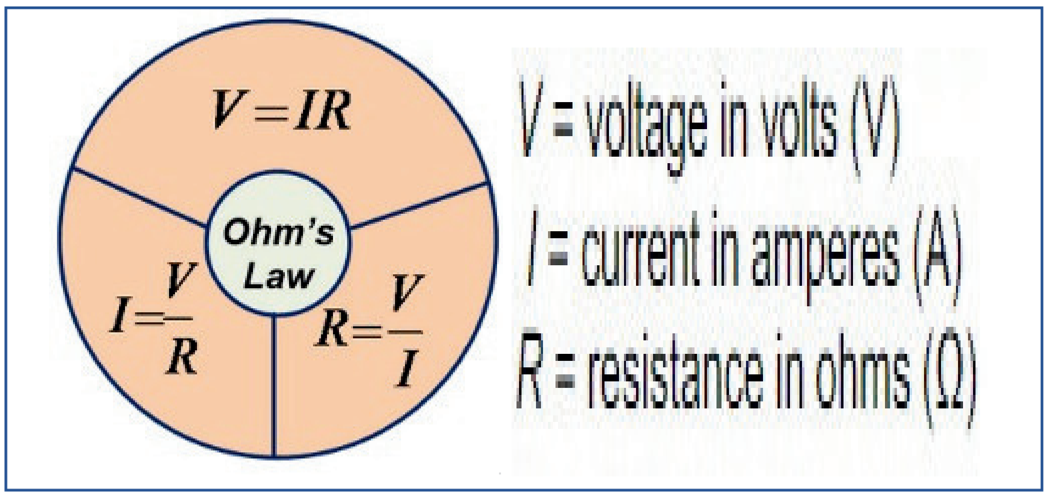
$$R= \rho \frac{l}{A}$$

Where ρ is a characteristic of the material called the resistivity. L is the length of the conductor and A is the cross-sectional area of the conductor.

1.6 UNDERSTAND OHM'S LAW

1.6.1 Explain Ohm's Law.

- Ohm'sLaw: Under the assumption that all physical parameters, including temperature, remain constant, the voltage across a conductor is directly proportional to the current flowing through it.



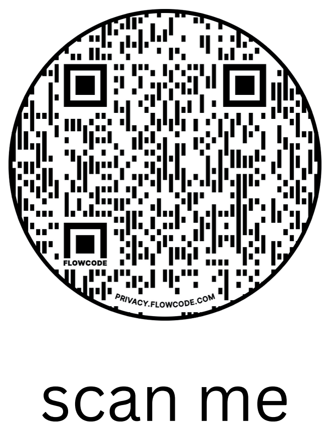


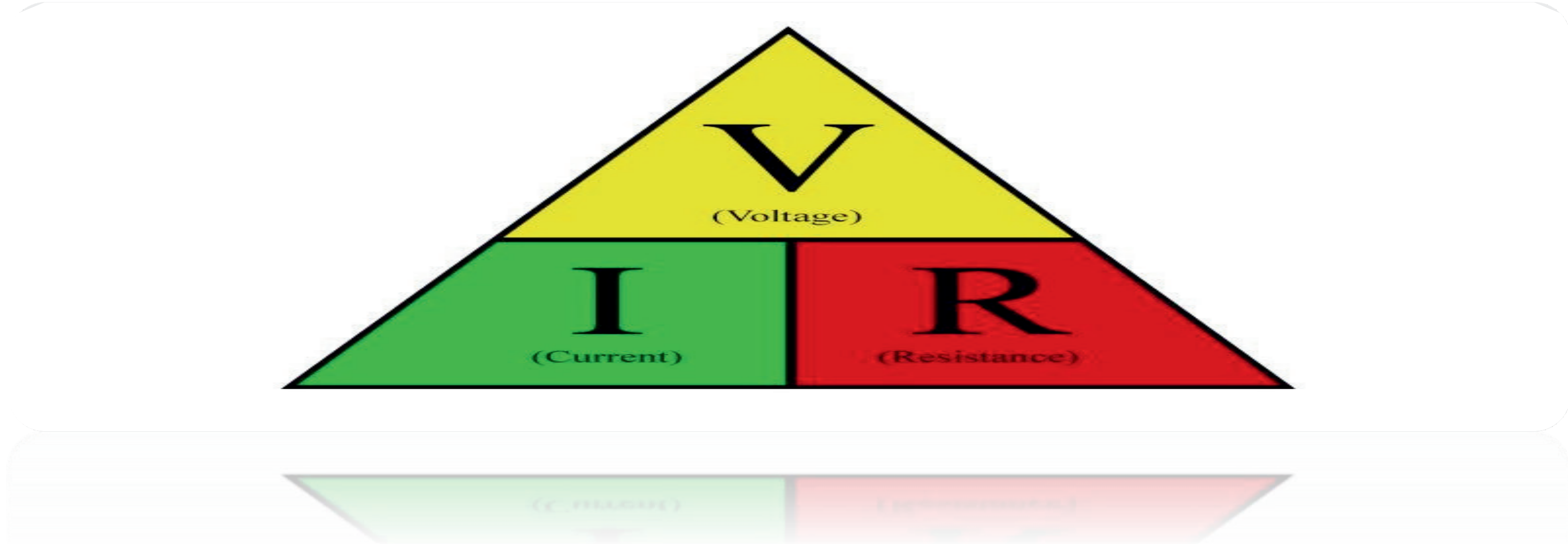
Figure 1.11: Ohm's Law equation

1.6.2 Outline the procedure adopted when using Ohm's Law.

To distinguish between current, voltage, and resistance, their basic definitions are given below:

- **Current** refers to the amount of charges that flow in any part of the conductor per time interval.
- **Voltage** is a measure of the potential difference between two points. It is applied across a wire or an electric component. A source of voltage, for example, is battery and is used to maintain a potential difference in the circuit but not to supply current.
- **Resistance** is the measure of the opposition to the current in a circuit.

Ohm's Law stated that the current is proportional to the applied voltage and inversely proportional to the resistance.



1.7 APPLY OHM’S LAW IN CIRCUIT

1.7.1 Construct circuit to explain Ohm’s Law.

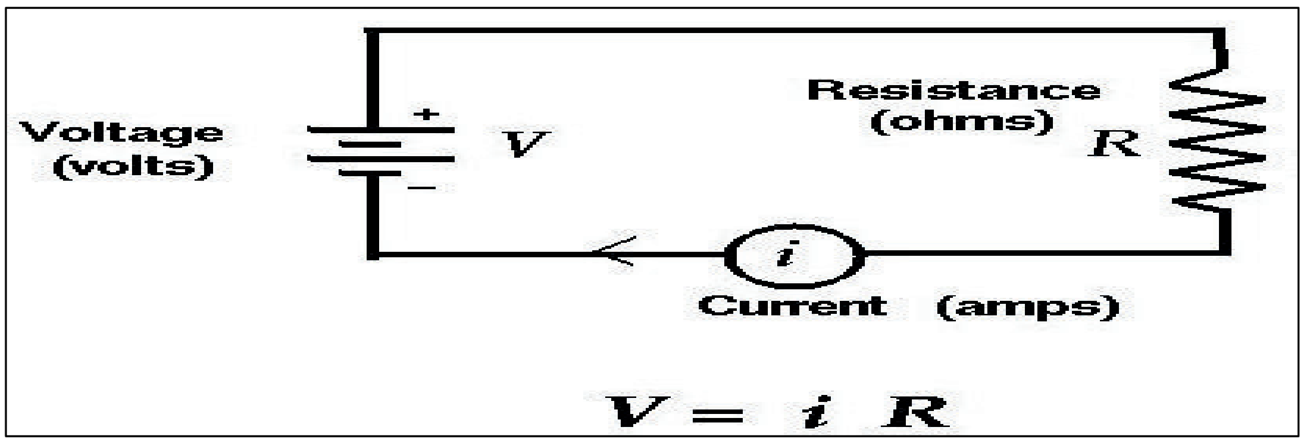


Figure 1.12: Circuit example to explain Ohm’s Law

Figure 1.12 above shows the equivalent circuit to explain Ohm’s Law. If you are aware of the voltage of the battery in the circuit and the amount of resistance there, you can use Ohm's Law to calculate a circuit's properties, such as how much current is flowing through it.To understand more regarding this, the theory value will be tested and measured in practical work.

1.7.2 Use Ohm’s Law to find current, voltage and resistance in circuit.

Example for resistance, R:
A light bulb of 10W with current flow of 350mA through the circuit and the applied voltage in the circuit are 150V. Calculate the value of resistance.

- From the equation of V=IR, to find the value of resistance R, R= V / I

  Hence, R= V/ I = 150V / 350mA = 428.571Ω

Example forvoltage, V:
Calculate thesupplied voltage in the circuit if the resistor value is 100Ω with the current flow of 2.1A.

- Fromthe equation of V=IR, to find the value of voltage V, V= IR

  Hence, V=IR = (2.1A) (100Ω) =210V

Example for current,I;
When the value of voltage is 12V and the resistance value are 15Ω, determine the value of current flow within the circuit.

- From the equation of V=IR, to find the value of current I, I= V / R

Hence, I= V / R = 12V / 15Ω = 0.8A

1.8 UNDERSTAND SERIES, PARALLEL AND SERIES-PARALLEL CONNECTIONS.

1.8.1 Identifyaseriescircuit.

i. By referring Figure 1.13 below, it shows three resistors connected in **series** connection.

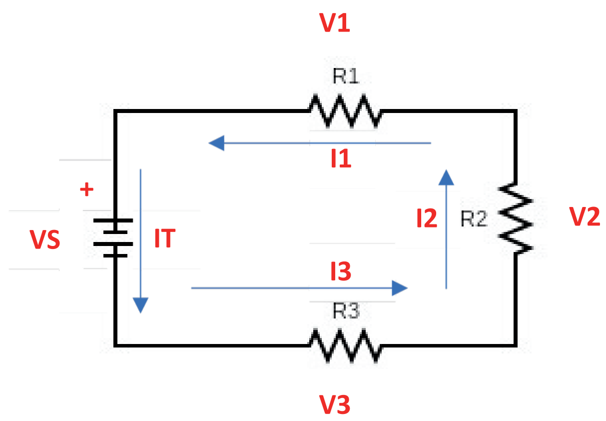


Figure 1.13: Series circuit connection

ii. In this series circuit, the sum of each individual values for the resistor are the **Total Resistance (RT)**.

RT = R1 +R2 + R3 + …… + RN where N is total number of resistor available in the circuit.

iii. The current flowing through each series resistor is the same in a series circuit because there is only one way for it to go between the two points.

1.8.2 Explain the flow of current and voltage division in the series circuit.

i. Current in series circuit; By referring to Figure 1.13, all the resistors are connected in series with a DC

- voltage source. The current
direction is as shown in the figure using current directional arrow. Based on the arrow direction, at any point in this circuit, the current that point must equal the current out of the point. A series circuit's overall
- current equals the current flowing through any resistance in the circuit. Through
every circuit resistor, the overall circuit current would stay constant. A potential difference, or voltage, is necessary for current to flow through a resistance.

Current is the same through out the circuit:

ITotal = I1 = I2 = I3 =……….. = IN

ii. Voltage in series circuit:

- As per Kirchoff's voltage law, the sum of all the voltage drops around a single closed path in a circuit is equal to the total source voltage in that loop. Hence, the voltage source (Vs) is equal to the sum of the three voltage drops across resistance R1, R2 and R3 as shown in Figure 1.13.

VS = V1 + V2 + V3+ ……….VN

1.8.3 Identifya parallel circuit.

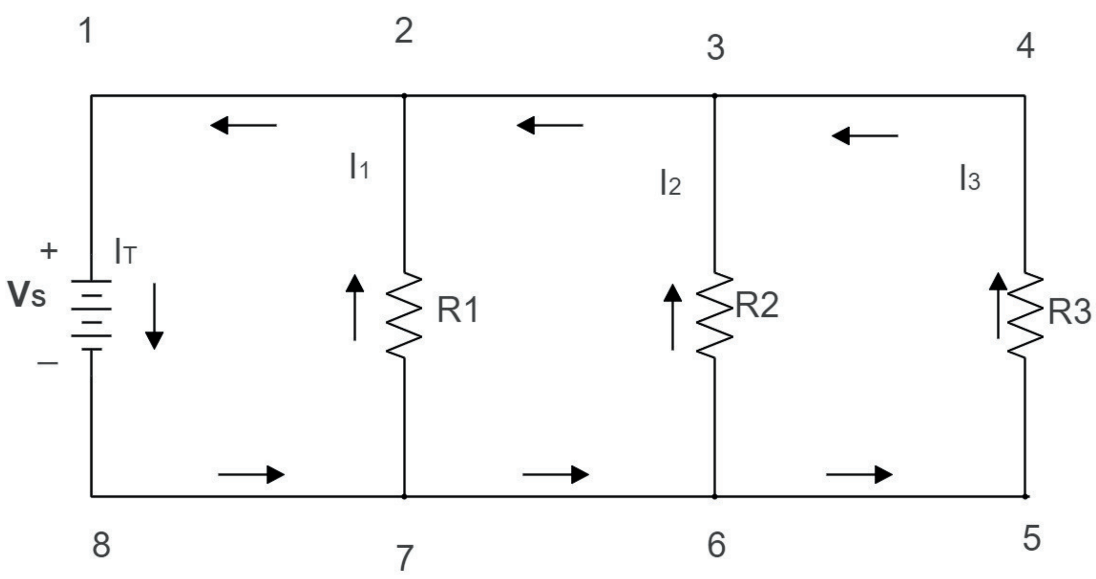


Figure 1.14: Parallelcircuit connection

- Based in Figure 1.14 above, show the parallel circuit connection. In a parallel circuit, the branches divide the current so that only a portion of it passes through each branch. In a parallel circuit, each branch has the same voltage or potential difference, but the currents may differ.

- The sum of resistance R for parallel circuit can be represented as;

$$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots\ldots\ldots \frac{1}{RN}$$

OR

For two resistor calculation;

$$RT = \frac{R1 \ X \ R2}{R1 + R2}$$

- **To identify parallel circuit connection, by referring to Figure 1.14, We have three resistors once more, but this time they create multiple uninterrupted paths for electrons to flow. There is only one way to get from 8 to 7 to 2 to 1 and then back to 8. Another one goes from 8 to 7 to 6 to 3 to 2 to 1 and then back to 8 once again. There is also a third route that goes from 8 to 7 to 6 to 5 to 4 to 3 to 2 to 1 and then back to 8. A branch is any distinct route (via R1, R2, and R3).**

- **The fact that all components of a parallel circuit are connected to the same set of electrically common locations is what distinguishes it from other types of circuits. We can observe from the schematic diagram that electrically common points 1, 2, 3, and 4 are all together. Points 8, 7, 6, and 5 are also true. Keep in mind that the battery is linked between these two groups of points, together with all resistors.**

1.8.4 Explain the voltage drop and the current division in the parallel circuit.

i. Voltage: Each component of the parallel circuit has the same voltage applied to it. The voltage is the same

- across all of the components in a parallel circuit, which is the first fundamental
- principle to understand. This is due to the fact that a parallel circuit only has two sets of electrically similar terminals and that the voltage between those sets must always be constant.

$$VS = V1 = V2 = V3 = \ldots\ldots\ldots VN$$

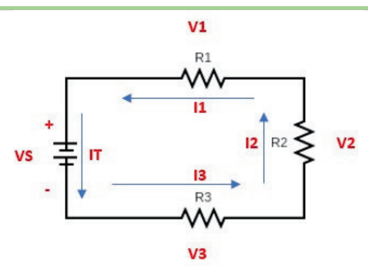
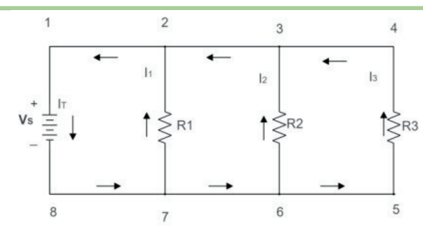
ii. Current:

- The sum of the currents passing through each component is the total current.
- Kirchoff's current law stated that the sum of all currents into a node (total current in) is equal to the sum of the currents out of that node (total current out).
- The current out of the source (IT) divide when I1 flow through R1 and I2 flow through R2.

$$IT = I1 + I2 + I3 + \ldots\ldots\ldots + IN$$

Summary for series connection and parallel connection.

Table 1.1: Comparison between series and parallel connection.

SERIES CONNECTION	PARALLEL CONNECTION
	
$R_T = R_1 + R_2 + R_3 + \ldots\ldots + R_N$ $I_{Total} = I_1 = I_2 = I_3 = \ldots\ldots\ldots\ldots = I_N$ $V_S = V_1 + V_2 + V_3 + \ldots\ldots\ldots V_N$ **Current Same, Voltage Different**	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots\ldots \frac{1}{R_N}$ For two resistor calculation; $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$ $V_S = V_1 = V_2 = V_3 = \ldots\ldots\ldots V_N$ $I_T = I_1 + I_2 + I_3 + \ldots\ldots\ldots + I_N$ **Voltage Same, Current Different**

1.8.5 Explain the equivalent resistance in the series and parallel circuits.

Figure 1.15: Series resistance

- From Figure 1.15, shows that both resistorsexperience the same current I flow. Because if this weren't the case, any one of the resistors would start tobuild up with charge, which would not be consistent with a steady-state situation. Assume that there could be a voltage V drop from point B to point A. This drop is the total of the potential decreases across thetwo resistors, R1 and R2, of V1 and V2, respectively. Hence,

$$V = V_1 + V_2$$

- Ohm's rule states that the ratio of the potential drop volatage V across these locations to the current I that flows between them determines the equivalent resistance REQ between B and A. Hence,

$$R_{eq} = \frac{V}{I} = \frac{V_1 + V_2}{I} = \frac{V_1}{I} + \frac{V_2}{I},$$

leads to,

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

- From this, it can be determined that current I, is common to all resistor, therefore the rule is;

The equivalent resistance of two resistors connected in series is the sum of the individual resistances.

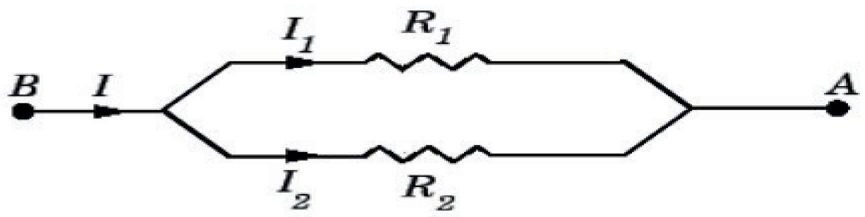


Figure 1.16: Parallel resistance

- The potential drop voltage V across the two resistorsisevidently the sameasshown in the Figure 1.16. The currents I1 and I2 that pass-through resistors R 1 andR2, respectively,aregenerally, nevertheless, different. Ohm's law states that the equivalent resistanceRbetween pointsBandAis proportional to the current I that flows between them and the potential dropvoltage V betweenthosesites. In order to prevent charge from accumulating at one or both of the circuit'sjunctions, this currentmustbe equal to the sum of the currents I1 and I2 flowing through the two resistors.

$$I = I_1 + I_2$$

Followed by,

$$\frac{1}{R_{eq}} = \frac{I}{V} = \frac{I_1 + I_2}{V} = \frac{I_1}{V} + \frac{I_2}{V},$$

Leads to,

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

- From this, we can determine that potential drop, voltage Vis the same across all three resistors. Hence, the rule is;

The reciprocal of the equivalent resistance of two resistances connected in parallel is the sum of the reciprocals of the individual resistances.

1.8.6 Identify a combination of series and parallel circuit.

i. Series and parallel connections are combined in a series-parallel circuit, also known as a combination circuit. This is how the majority of electronic circuits are classified. When multiple voltage and current values are needed from the same voltage source, series-parallel circuits are commonly utilised.

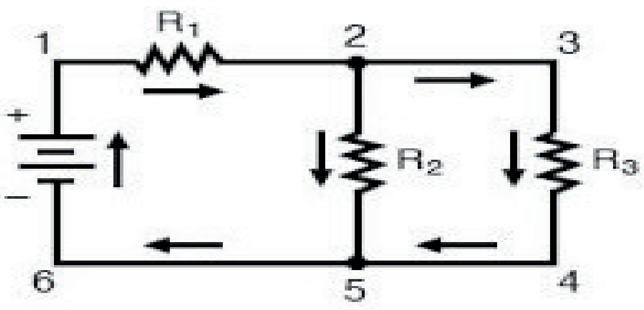


Figure 1.17: Basic Series Parallel combination circuit.

1.8.7 Explain the total resistance for the combination of series and parallel circuit.

i. From Figure 1.17, show the most basic series parallel combination circuit. From that circuit, it can be determined that;

Total resistance (RT) of the circuit. RT = R1 + (R2R3 / R2+R3)

Where R1 is in series with the parallel connected R2 and R3.

ii. Another example is as below, shown in Figure 1.18.

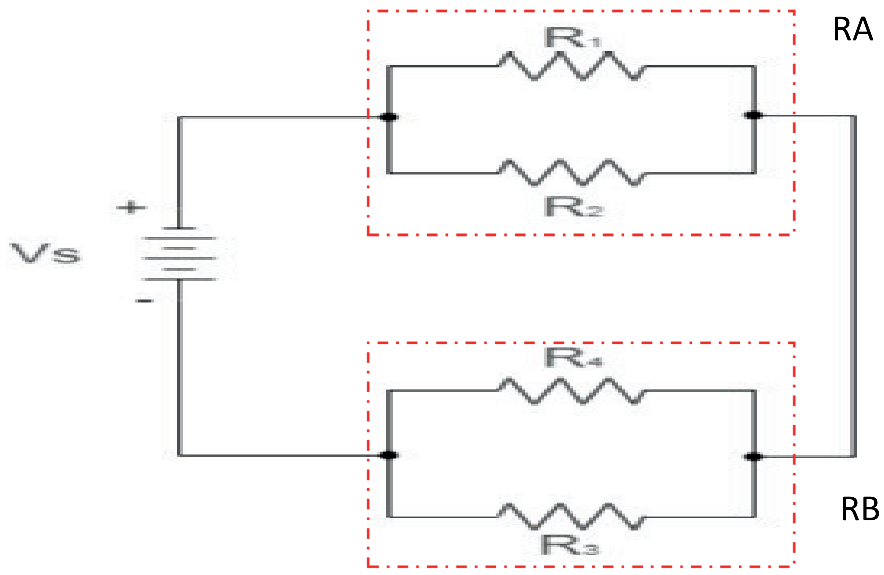


Figure 1.18: Series Parallel combination circuit.

The total resistance (RT) for the series parallel circuit in Figure 1.18;

RA= (R1R2)/(R1+R2), where R1 is parallel with R2

RB=(R3R4)/(R3+R4), where R3 is parallel with R4

Hence the total resistance is;

RT = RA + RB, where RA is series with RB

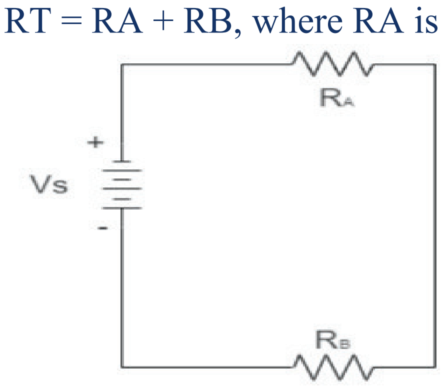
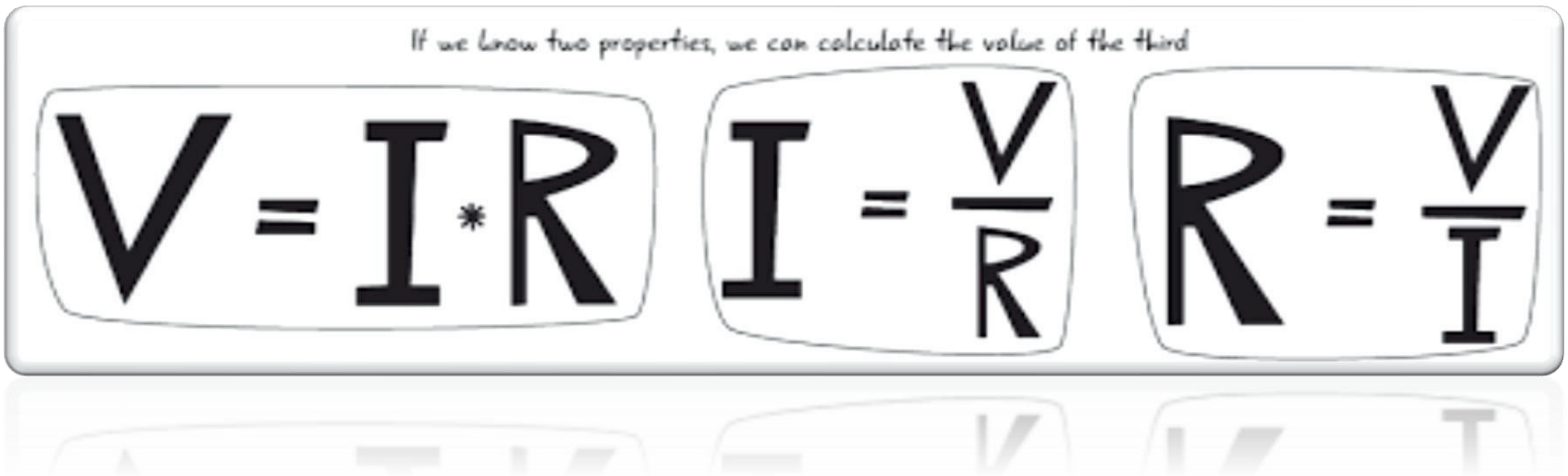


Figure 1.19: Equivalent circuit for series parallel combination circuit from Figure 1.18.



1.9 APPLY SERIES, PARALLEL AND SERIES-PARALLEL CONNECTIONS TO DC CIRCUIT.

1.9.1 Construct a series connection circuit.

i. Construct a series connection circuit that contain Vs = 12V, R1= 10Ω, R2= 15Ω, R3=25Ω and R4=40Ω.

ii. Construct a complete circuit that consist of eight resistors connected in series and label them accordingly.

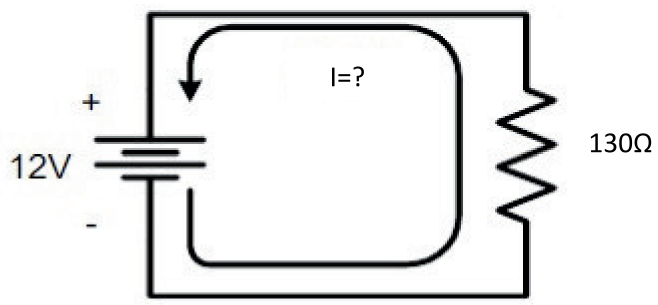
1.9.2 Calculate the flow of the current and voltage division in the series circuit.

i. A current flow of 50mA through a 4.7kΩ resistor, find the voltage value.

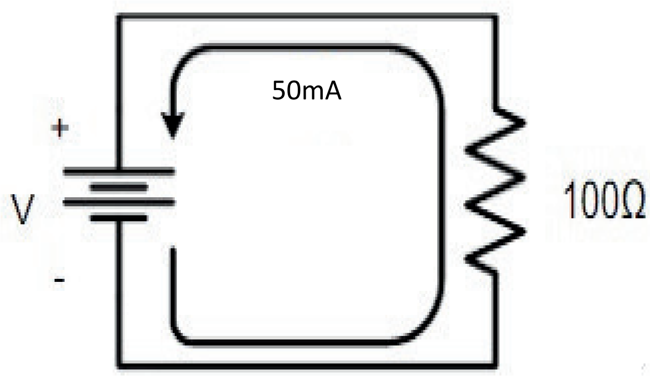
ii. Calculate the current produced in a circuit with the voltage of 110V and resistor value of 15kΩ.

iii. From the reading of a voltmeter, indicates that the voltage supplied in a circuit are 240V, then the value from ammeter indicates that the value of current is 15A. What is the value of R?

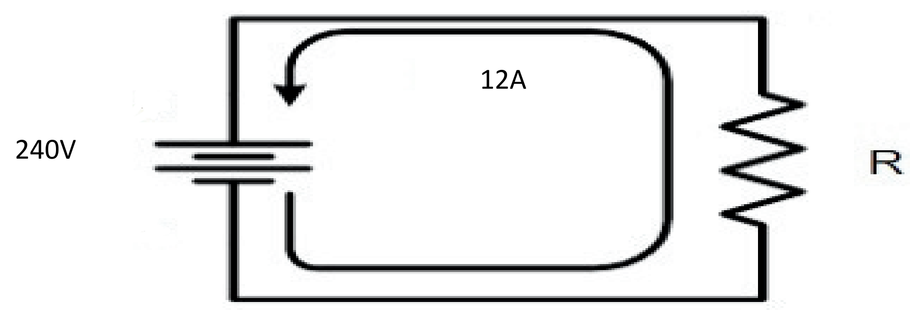
iv. Find the value of current, I;



v. Find the value of voltage, V;



vi. Find the value of resistance, R;

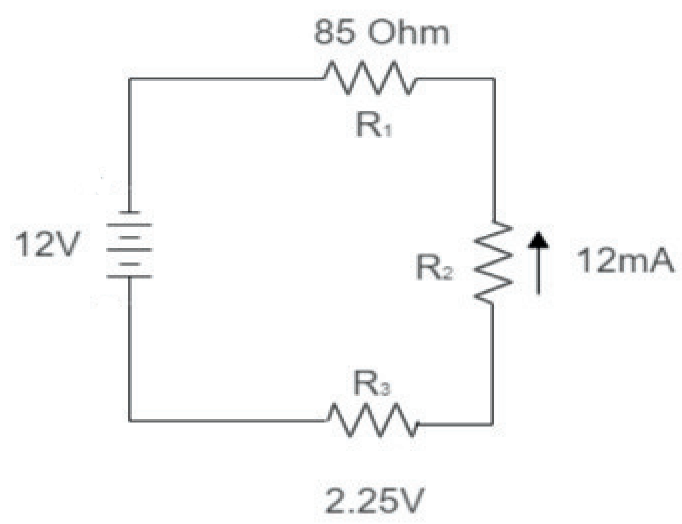


vii. A circuit with three resistors connected in series with the value of 0.47kΩ each and a voltage source of 54V;

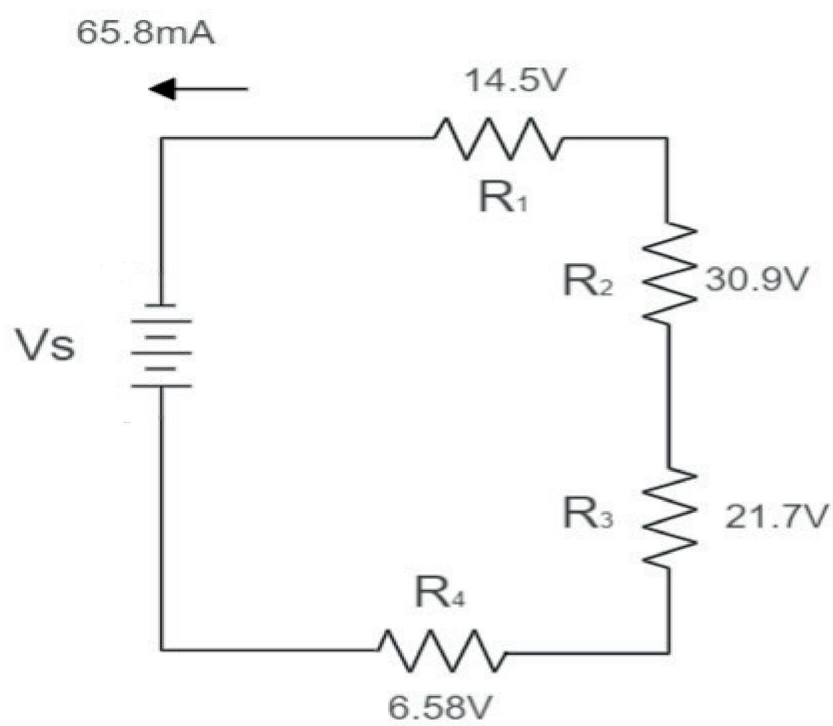
- What is the current in the circuit?
- Calculate the voltage across each resistor.

viii. A series circuit with five equal value resistor and voltage supply of 10V and 1.20mA was measured. Calculate the value of each resistor.

ix. From the circuit diagram below, determine the value of VR1, R2 and R3;



x. From the circuit diagram below and given values, calculate the value of each resistors.



1.9.3 Construct a parallel circuit.

i. Construct a complete circuit with six resistors connected in parallel connection them, label them accordingly.

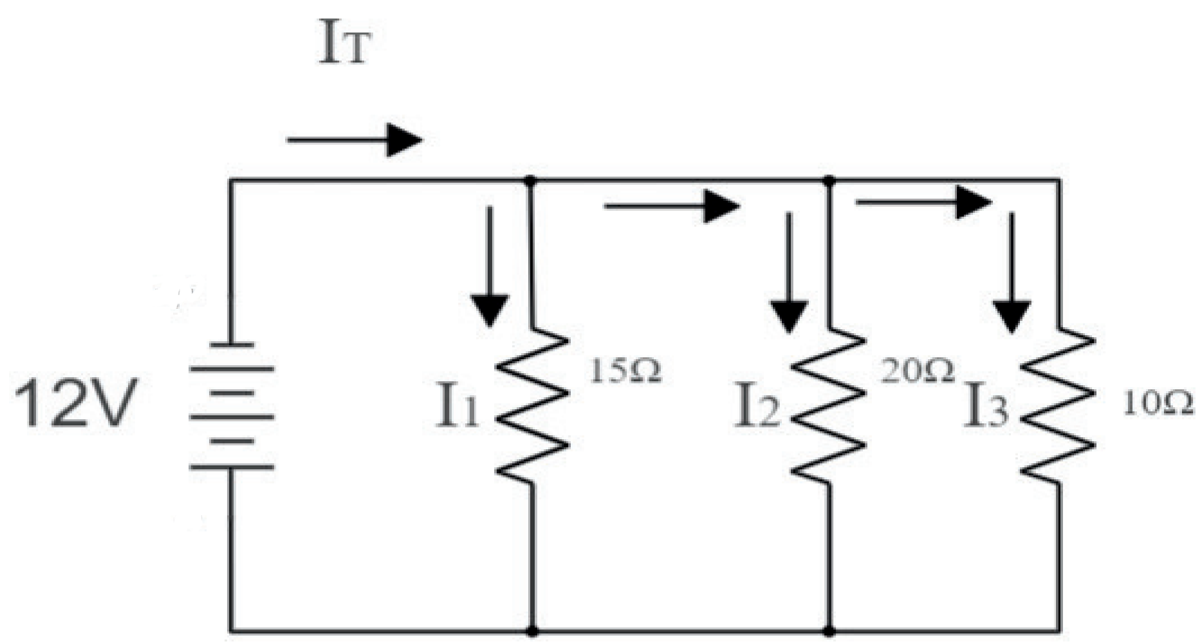
ii. Construct a parallel connection circuit that contain Vs = 12V, R1= 10Ω, R2= 15Ω, R3=25Ω and R4=40Ω.

1.9.4 Calculate the voltage drop and the current division in the parallel circuit.

i. Calculate the value of Vs when I1= 0.25A, I2=0.3A, I3=0.05A and I4=0.1A with the total resistance value of 200 Ω.

ii. If an input voltage of a parallel circuit is 24V, what is value of voltage across for each resistor, R1=10 Ω, R2=20 Ω and R3=30 Ω connected in parallel connection?

iii. From the circuit diagram below, calculate the value for current flowing through each resistor.



1.9.5 Construct a series-parallel connection circuit.

i. Take note that there is no fixed design for the combination of series-parallel circuit. The minimum requirement for the circuit to be combination of series and parallel circuit is it must contain more than three resistors in the circuit.

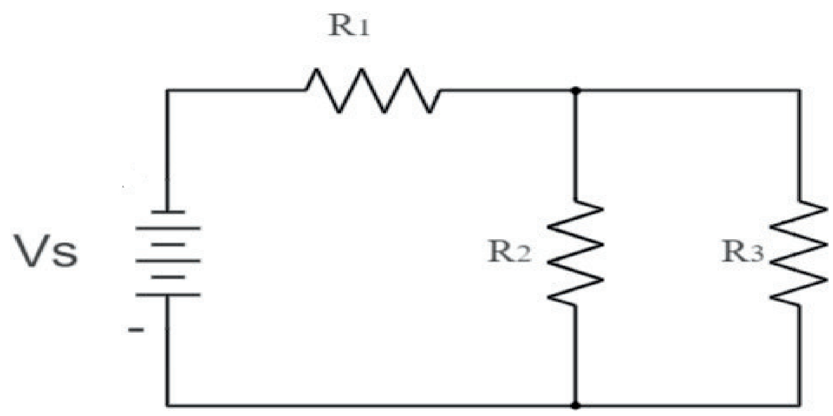
i. A circuit with 20V input voltage has three resistors in the system. Resistor R1 are connected in series with parallel connected R2 and R3. Construct the circuit based on the information given.

ii. In one circuit contain four resistors. R1 and R2 are connected in series, then R3 and R4 are also connected in series. When the series connected R1 and R2 are connected parallel with the series connected R3 and R4, construct the circuit when the supply voltage for the circuit are 25V.

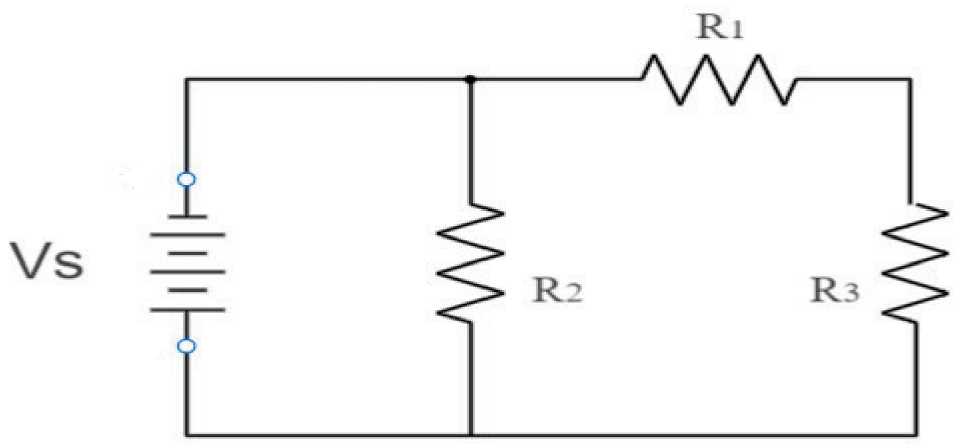
1.9.6 Calculate the equivalent resistance in series and parallel circuits.

Find the R_{EQ} for the circuits below;

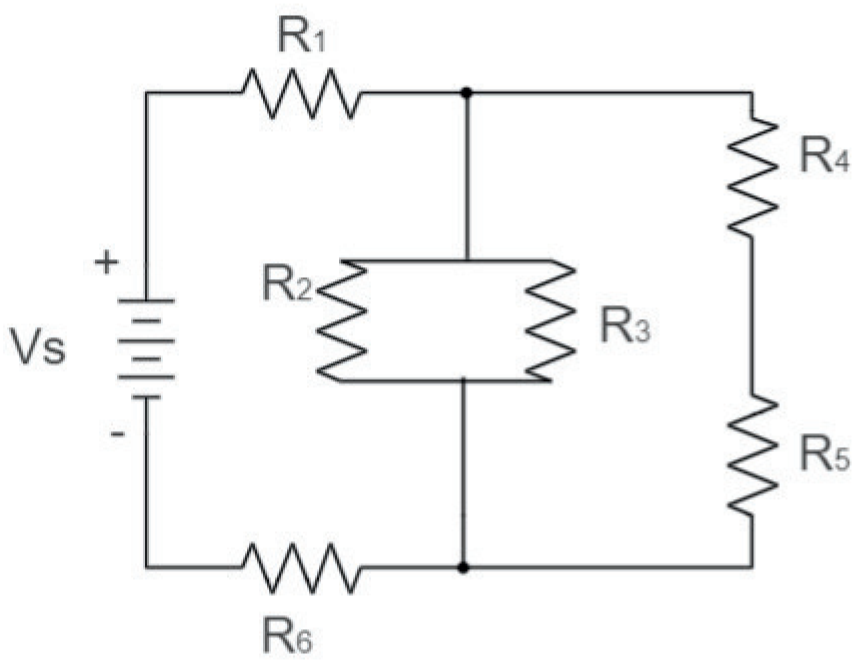
i.



ii.



iii.

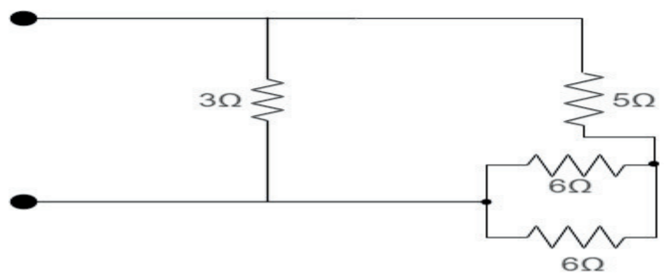


1.9.7 Calculate the total resistance for the combination of series and parallel circuit.

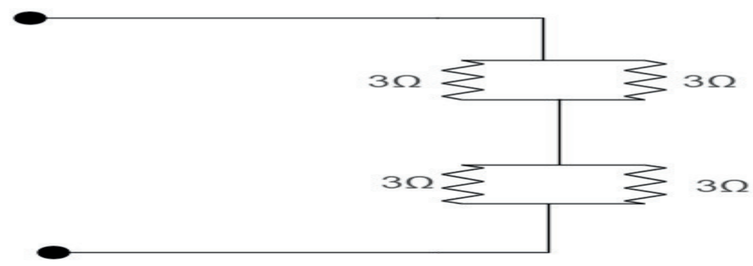
i. From the circuit diagram in 1.9.6, calculate the total resistance if the value of R1=10kΩ, R2=900Ω, R3=1000Ω, R4=500Ω, R5=20Ω and R6=100Ω respectively.

ii. Find RT for circuits below;

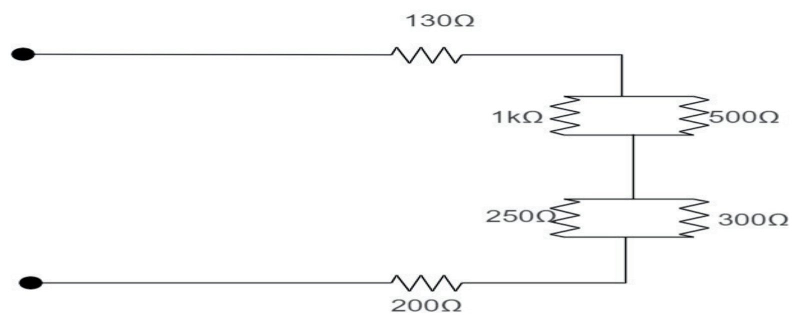
a)



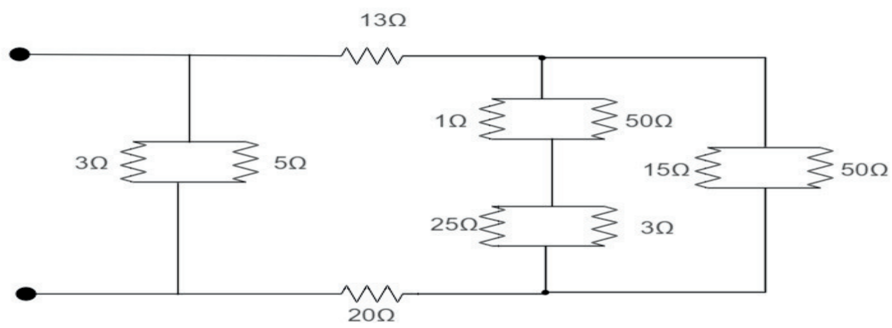
b)



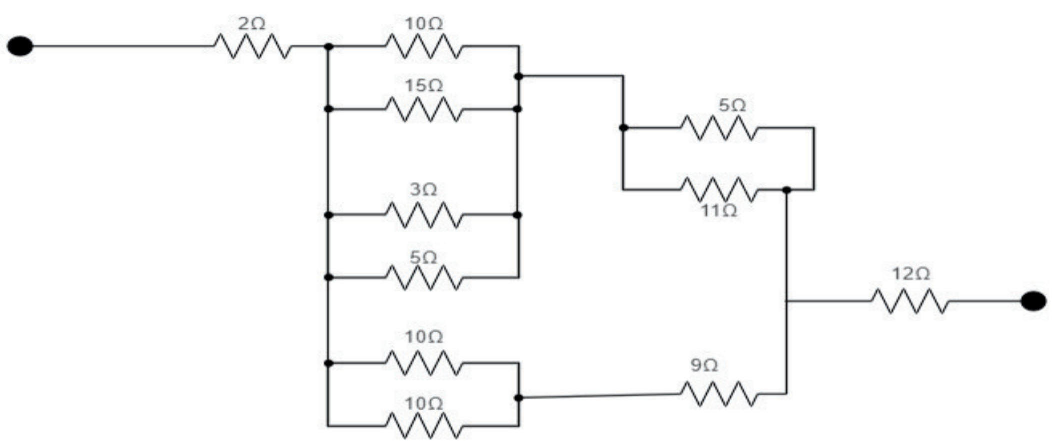
c)



d)



e)



1.9.8 Use of voltage divider in series circuit and use of current divider in parallel circuits.

a) Voltage divider;

i. In order to simplify the solution, circuits are solved using the voltage divider rule. This rule can also be used to thoroughly resolve basic circuits. This voltage divider rule's primary idea is that "the voltage is divided between two resistors that are linked in series in direct proportion to their resistance."

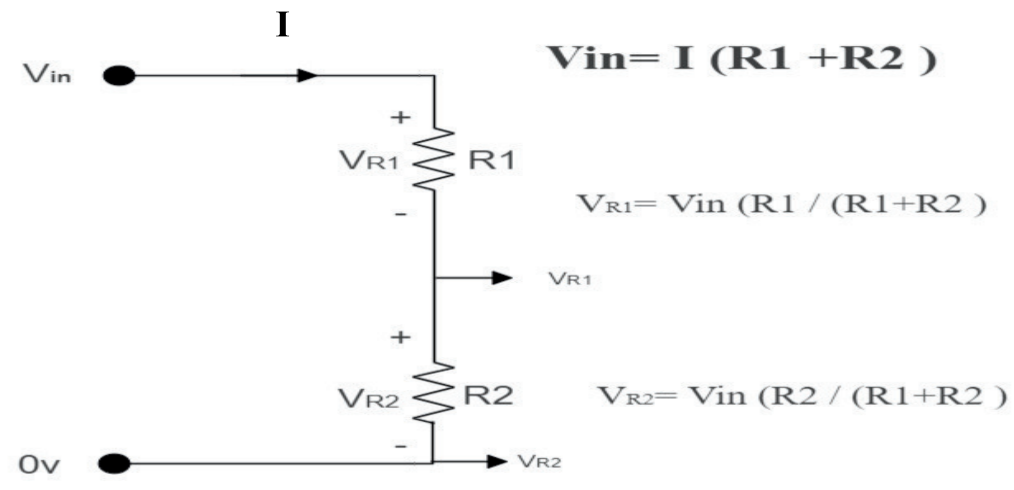


Figure 1.20: Voltage divider rule

ii. Applying Ohm's Law

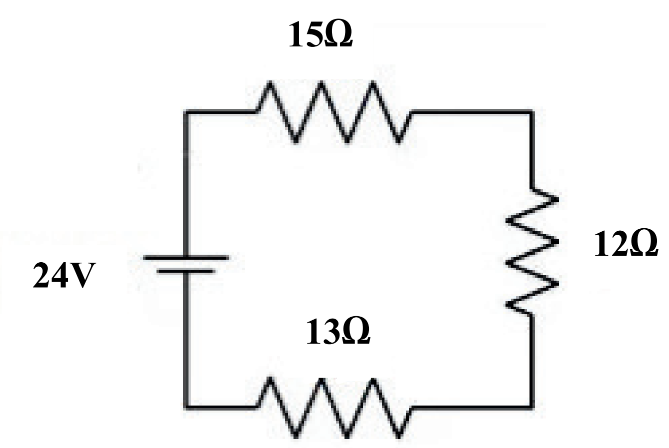
$$V1 = VR1 = IR1$$
$$V2 = VR2 = IR2$$
$$Vn = VRn = IRn$$

iii. Applying voltage divider

$$V1 = \frac{R1}{R1 + R2 + R_n} \text{Vin}$$
$$V2 = \frac{R2}{R1 + R2 + R_n} \text{Vin}$$
$$Vn = \frac{Rn}{R1 + R2 + R_n} \text{Vin}$$

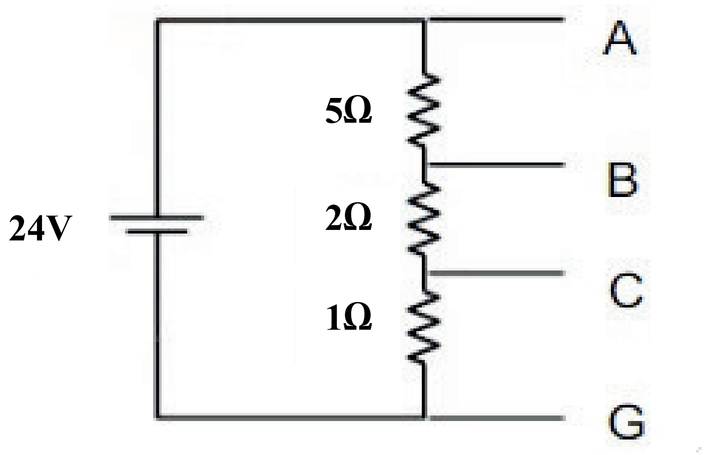
Exercise 1:

Based on the circuit diagram, find the value of RT, IT andV1, V2, V3 using Ohm's Law and Voltage Divider rules



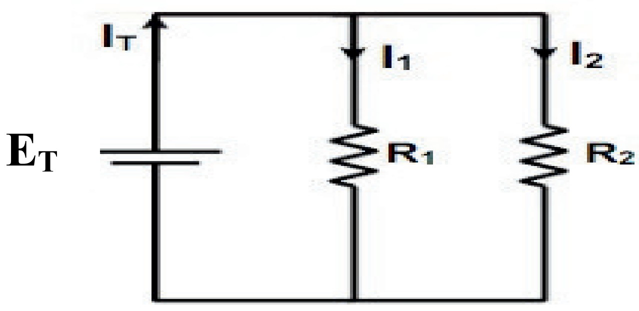
Exercise 2:

Calculate the value of VAB, VBC, V_{CG}, V_{BG}, V_{AC}, VAG.



b) Current Divider:

i. The current divider rule can be used to determine the currents travelling through different parallel circuit branches.



ii. Ohm's Law for current:

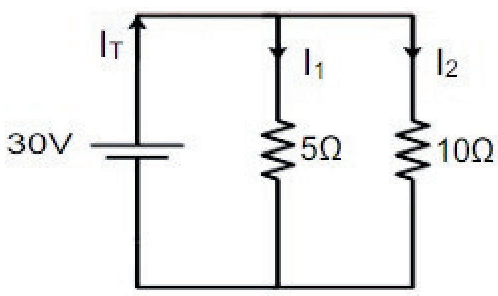
$I_1 = V_1/R_1$ $\qquad$ $I_2 = V_2/R_2$

iii. Applying Current divider:

$$I_1 = \frac{R_2}{R_1 + R_2} I_T \qquad I_2 = \frac{R_1}{R_1 + R_2} I_T$$

Example 1:

Find I1 and I2,



Solution:

$R_T = \frac{R_1 \times R_2}{R_1 + R_2} = 3.33\Omega$

$I_T = \frac{V}{R_T} = \frac{30\ V}{3.33\Omega} = 9\ A$

Ohm's Law

$I_1 = V/R_1 = 30/5 = 6\ A$

$I_2 = V/R_2 = 30/10 = 3\ A$

Current Divider Rules

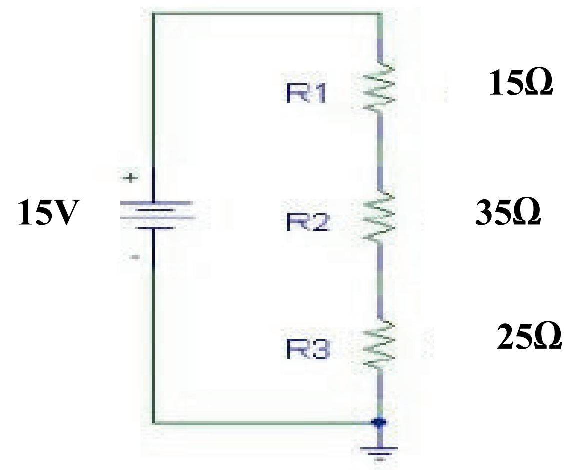
$I_1 = (10\Omega / (5\Omega + 10\Omega)) \times 9A = 6A$

$I_2 = (5\Omega / (5\Omega + 10\Omega)) \times 9A = 3A$

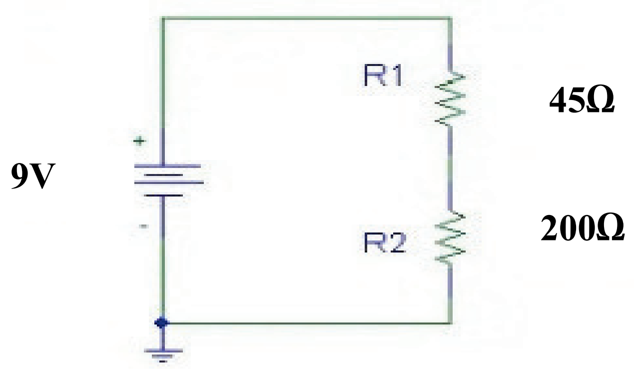
1.9.9 Solve problems related to series, parallel and combination of series and parallel circuits.

Tutorial Exercise:

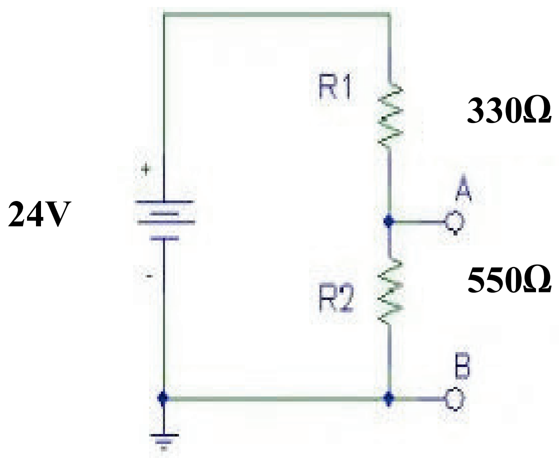
i. Calculate the voltage drop across each resistor.

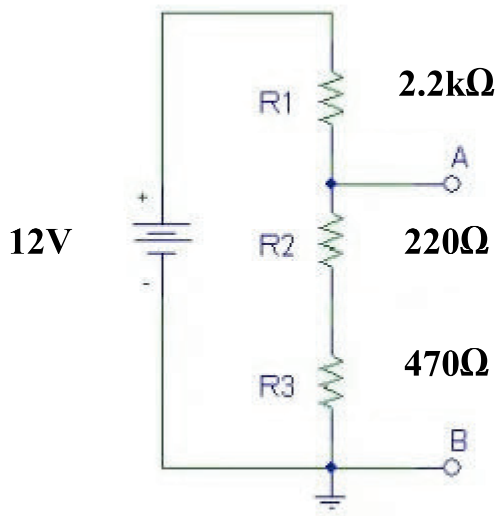


ii. Determine V1(voltage at R1) and V2(voltage at R2) using voltage divider.

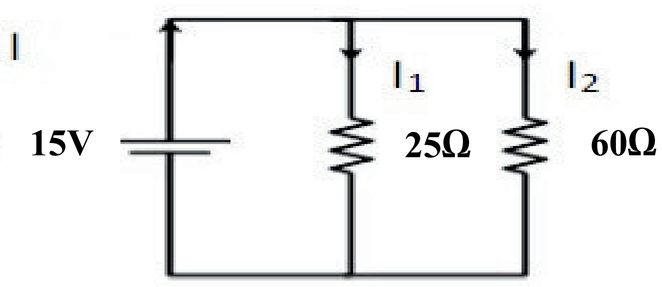


iii. Determine the voltage output at A, B for each voltage divider circuit.

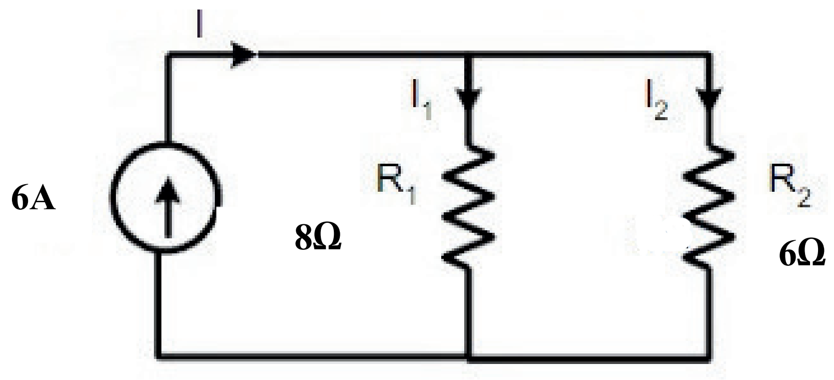




iv. Find I1 and I2.



v. Referring to th ecircuit below, calculate the current at each node.



1.10 UNDERSTAND DELTA-STAR TRANSFORMATION

1.10.1 Show formula required to transform from DELTA to STAR and STAR to DELTA.

a) Delta (Δ) to Star (Y) conversion

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

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

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

b) Star (Y) to Delta (Δ) conversion

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

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

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

1.10.2 Illustrate circuits to show STAR and DELTA connections.

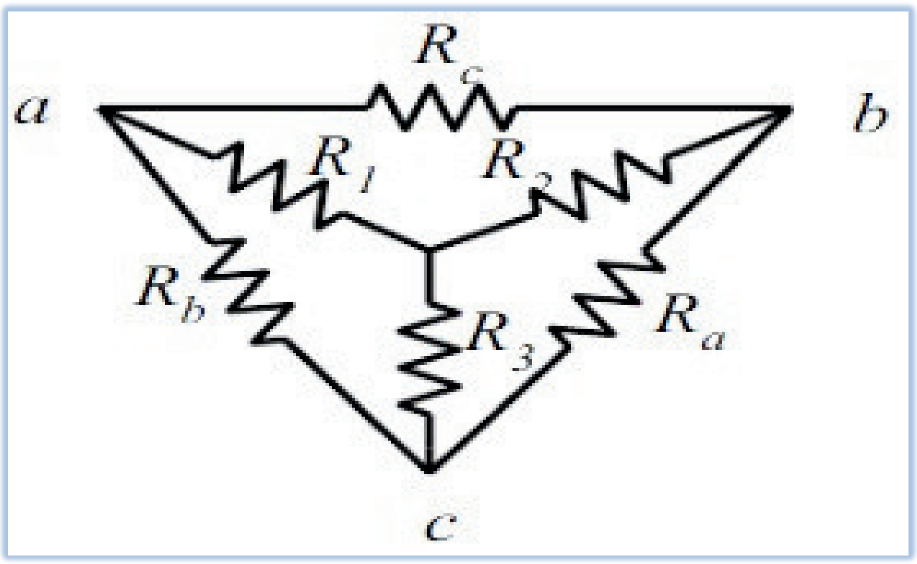


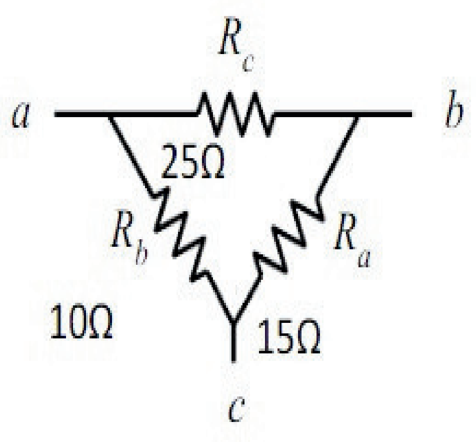
Figure 1.21: Delta andStar circuit connection

1.11 APPLY THE CONCEPT OF DELTA STAR TRANSFORMATION.

1.11.1 Construct circuits to show STAR and DELTA connections. (To be conduct in practical work)

1.11.2 Solve problems involving STAR-DELTA transformation.

Solution example:



Solution:

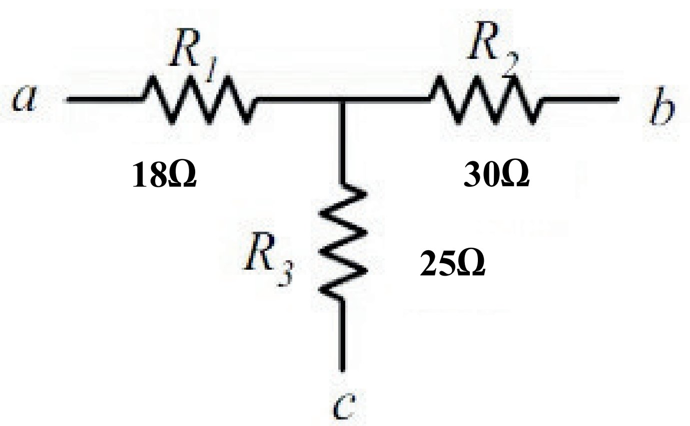
$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} = \frac{10 \times 25}{15 + 10 + 25} = \frac{250}{50} = 5\Omega$$

$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c} = \frac{25 \times 15}{15 + 10 + 25} = \frac{375}{50} = 7.5\Omega$$

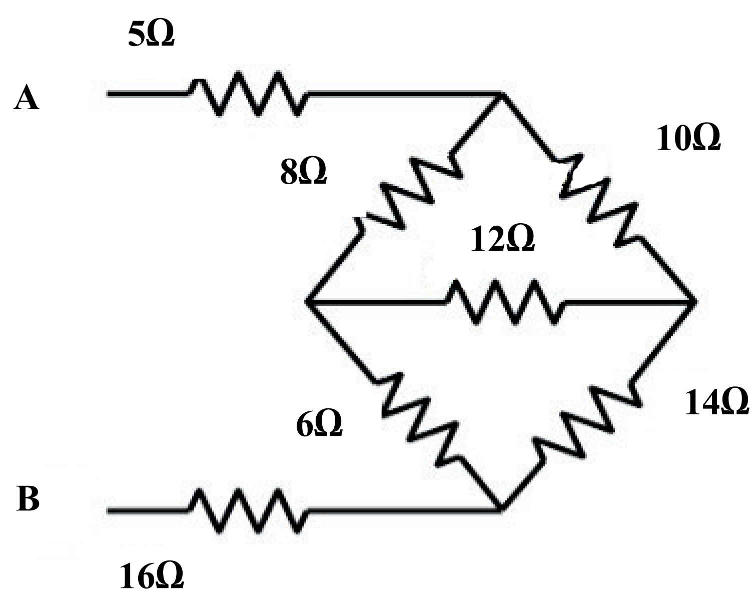
$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c} = \frac{15 \times 10}{15 + 10 + 25} = \frac{150}{50} = 3\Omega$$

Tutorial Exercise:

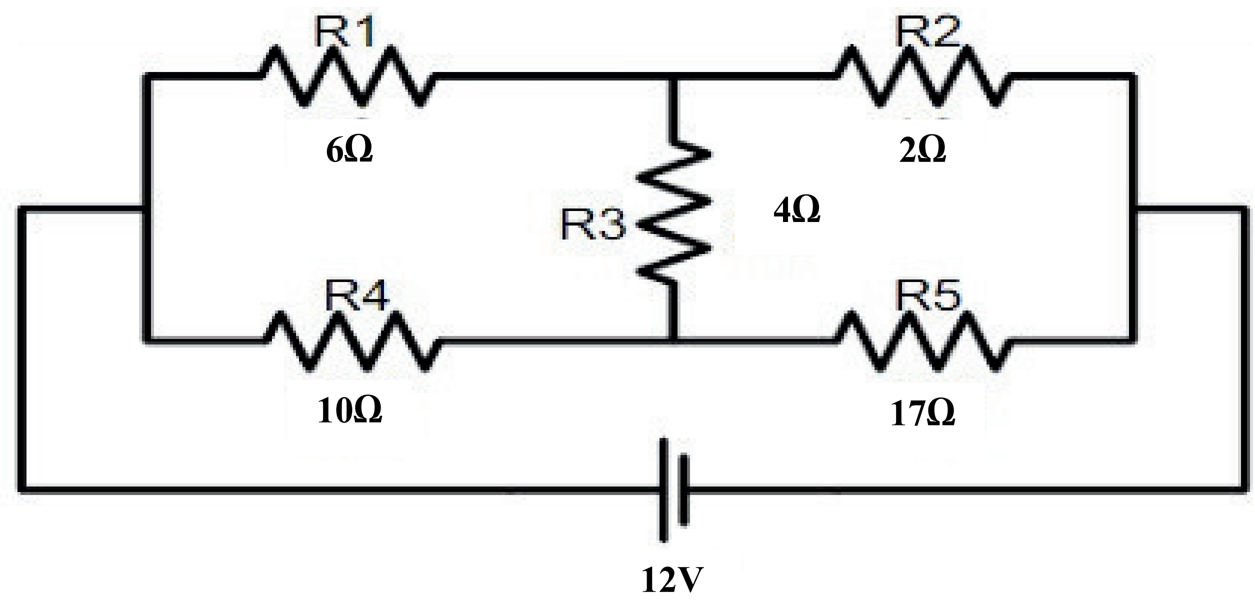
a) Transform the star connection below into a delta network.



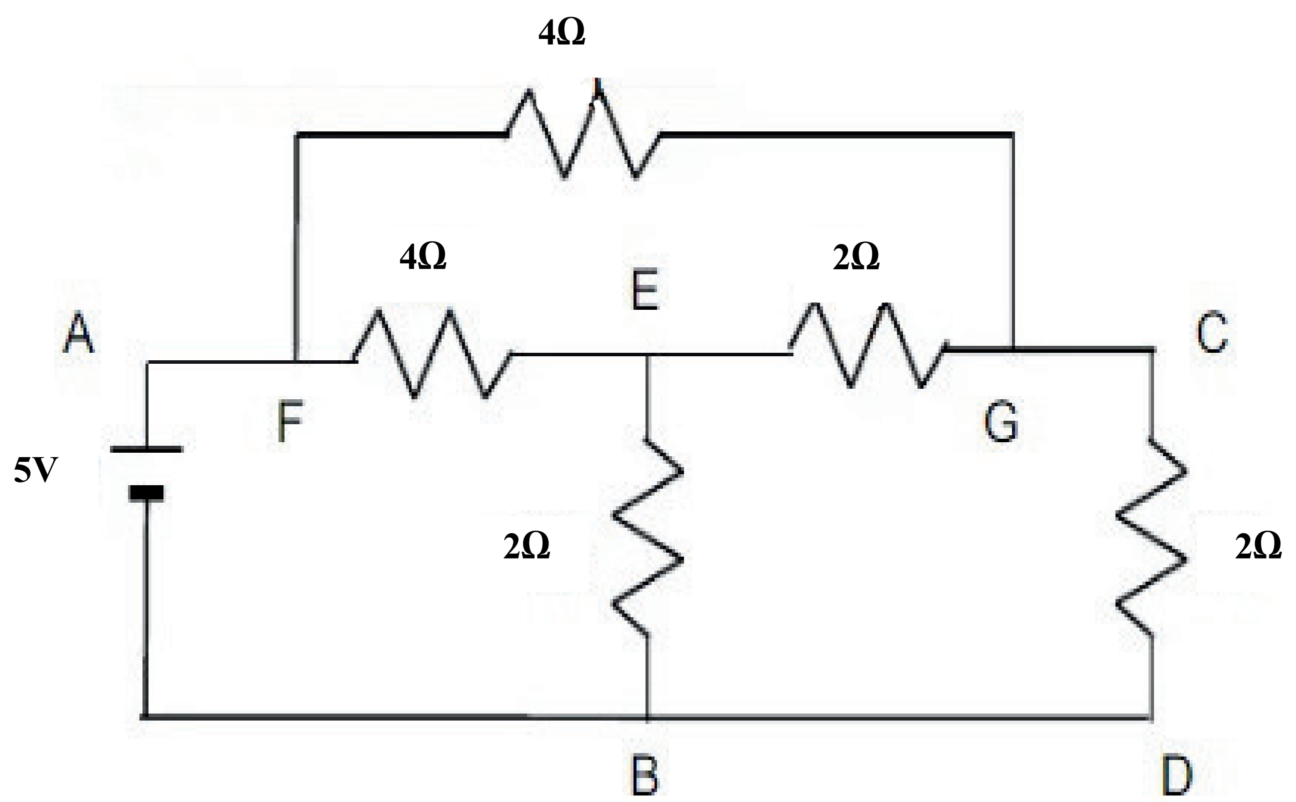
b) Referring to figure below, determine the $R_{equivalent}$ between terminal A andB.



c) Based on the schematic diagram below, tabulate the current value across 17 Ω resistor using Star – Delta transformation.



d) Find current flowing through RCD:



1.12 APPLY ELECTRICAL POWER AND ENERGY

- **Electrical energy is transformed into heat or other forms of energy, such as light, when a current flow past a resistance. A common illustration of this is when a lightbulb gets too hot to touch.**

- **Because a filament has resistance, the same current that causes it to emit light also causes the filament to heat. A specified amount of energy must be able to dissipate electrical components in a specific length of time.**

1.12.1 Explain electrical power and energy.

a) Electrical power:

- Energy produced by converting other types of energy, such mechanical, thermal, or chemical energy. Electric energy is unmatched for many applications, including lighting, computer operation, propulsion, and entertainment. It is competitive for numerous applications, including many industrial heating ones, cooking, space heating, and railroad traction.

- Power(P) is a certain amount of energy (W) used in a certain period of time(t). It is expressed as below:

$$P = \frac{W}{t}$$

where : P = power in watts (W)
W = energy in joules (J)
t = time in seconds (s)

- One watt (W) is the amount of power when one joule of energy is used in one second.

b) Energy

- Power is the rate at which energy is used, whereas energy is the capacity for work.
- Energy is measured in joules (J), the SI unit. Energy can also be expressed in different ways, though. Kilowatt-hours (kWh), which are units of energy, can be used.
- You are charged according to how much energy you consumed when you pay your electric bill.

1.12.2 Show electrical power expression from Ohm's Law and its unit.

- As a result of the conversion of electrical energy when a current flow through a resistance, the collision of the electrons generates heat. According to the following expression, the quantity of power wasted in an electrical circuit depends on the amount of resistance and the amount of current:

$$P = I^2R$$

where : P = power in watts (W)
I = current in amperes (A)
R = resistance in ohms (Ω)

- Equivalent expression for power in terms of voltage and current can be gain by substituting from the Ohm's Law.

$$V = IR$$
$$P = I^2 R$$
$$P = (I \times I)R$$
$$P = I(IR)$$
$$P = IV$$

- Another equivalent expression can be gain by substituting from the Ohm's Law.

$$I = \frac{V}{R}$$
$$P = IV$$
$$P = \left(\frac{V}{R}\right)V$$
$$P = \frac{V^2}{R}$$

- The relationship between power and current, voltage and resistance expressed in the preceding formula are known as Watt's Law.

1.13 CALCULATE THE ELECTRICAL POWER AND ENERGY IN A CIRCUIT.

Tutorial Exercise:

i. **An electronic device consumes 200mW of power. If the device runs for 24 hours, how much joules of energy does it consumes?**
ii. **A 24V source is connected across 15Ω resistor. Determine how much energy does it utilised in two minutes. Then, if the resistor is disconnected after one minute, conclude that whether the power during the first minute are greater than, less than or equal to the power during two minutes interval.**
iii. **What is the power when there are 700mA of current through at 2.2kΩ resistor?**
iv. **How many seconds must there be for 7A of current through 150Ω resistor in order to consume 25J?**
v. **An electric heater works on 240V and draw 6A of current. How much power does it use?**
vi. **A resistor with the rating of 2A and 100W and assume that the voltage can be adjusted to any required value. What is the value of the resistor?**
vii. **A 10kΩ resistor is carrying 100uA of current. Determine the power dissipated in the resistor.**

2.0 DC Equivalent Circuit and Network Theorem

This chapter will discuss aboutothersmethodtosolveunidentified voltage and current values other than usual calculation such as Ohm's Law, series and parallel. However, there a lot methodthatcanbeusedtocalculate the value voltage and current that apply in varies type of circuit application especially circuit that contain a lot point of connectionandloopinsideit.

2.1 Understanding methods of analysis for resistive circuit

2.1.1 Differentiate between nodes and mesh

2.1.1.1 Nodes

Node refers to a circuit that contain two or more joint point of connection between branches of circuit that connected to each other.

2.1.1.2 Mesh

Mesh is a loop that contain as group of branches circuits which a network is joined together to perform a complete cycle of loops inside it.

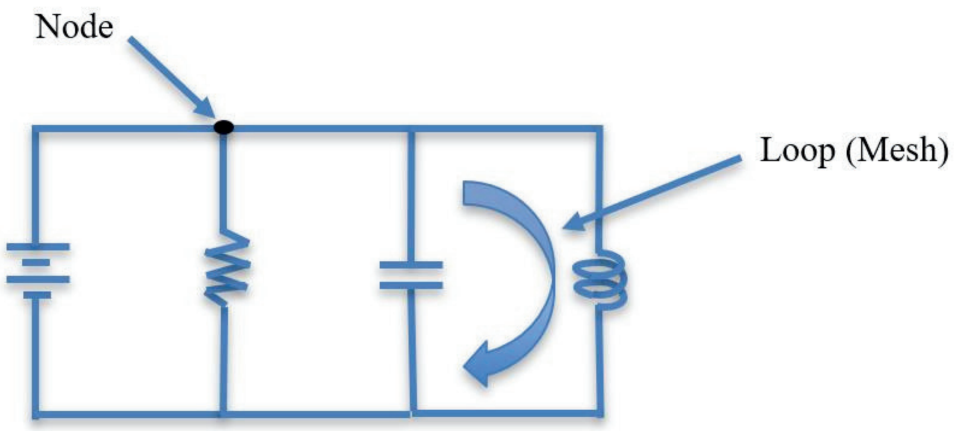


Figure 2.1:Node point and mesh

2.2Understand Kirchoff's Current Law and Kirchoff's Voltage Law

2.2.1 Kirchoff's Current Law (KCL)

Kirchoff's Current Law states that an any junction the total current flowing towards is equal with total current flowing away from the junction.

$$\Sigma I^{in} = \Sigma I_{out}$$

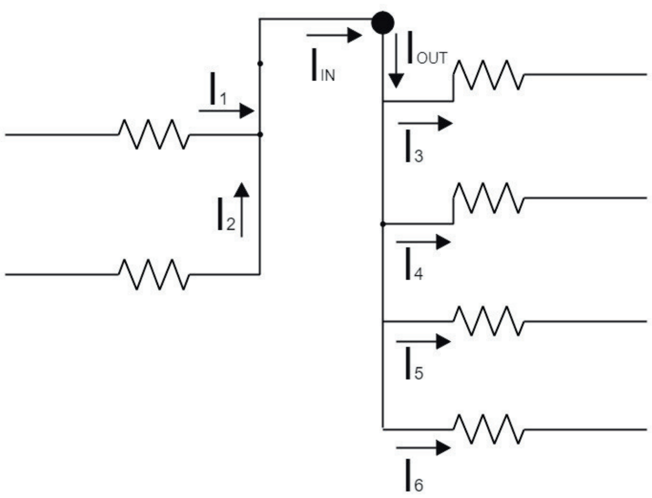


Figure 2.2 : Kirchoff'sCurrent Law Circuit

$$I_1 + I2 = I3 + I4 + I5 + I6$$

$$I_1 + I2 \ -I3 - I4 - I5 - I6 = 0$$

2.2.1.1 Example 1

The diagram given below shows branch currents of an electric circuit. For some branches, the values of currents are given. Find the unknown branch currents using Kirchoff's Current Law.

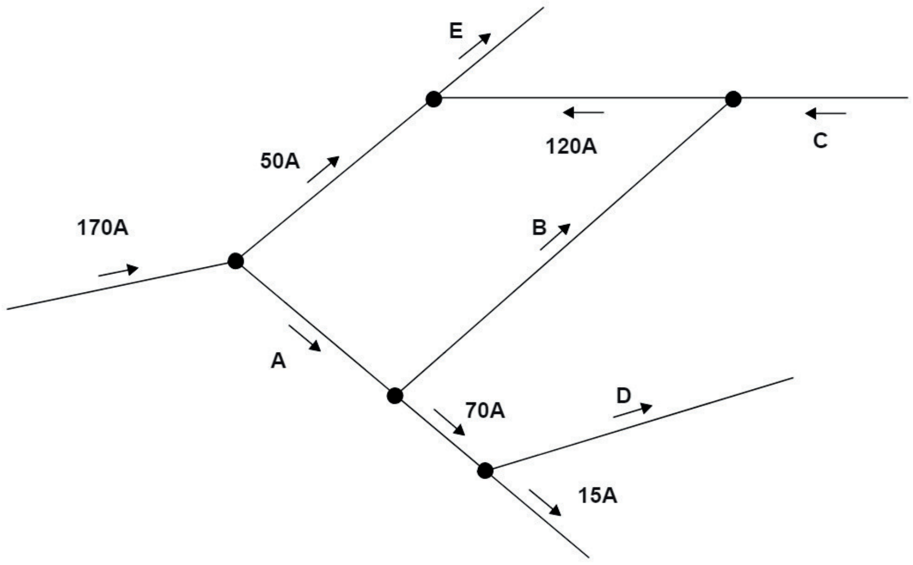


Figure 2.3: Kirchoff Current Law Exercise

Solution

170A = 50A + *A*
A = 170A – 50A
A = 120A

120A = 70A + *B*
B = 120A – 70A
B = 50A

50A = 120A + *C*
C = 120A – 70A
C = 50A

70A = 15A + *D*
D = 70A – 15A
D = 55A

E = 120A + 50A
E = 170A

2.2.1.2 Example 2

Derive the equation Kirchhoff's Current Law (KCL) in the circuit of Figure 2.2.3.

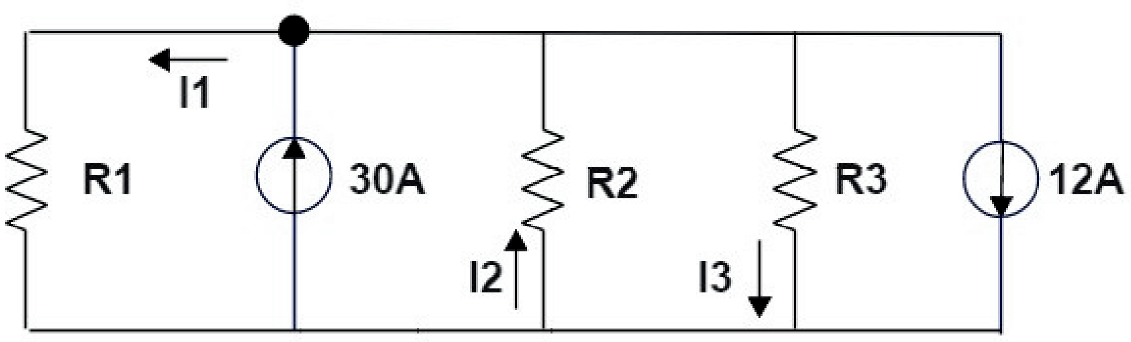


Figure 2.4: Current Flow Circuit

Solution

$-I1 + 30A + I2 - I3 - 12A = 0$

2.2.1.3 Example 3

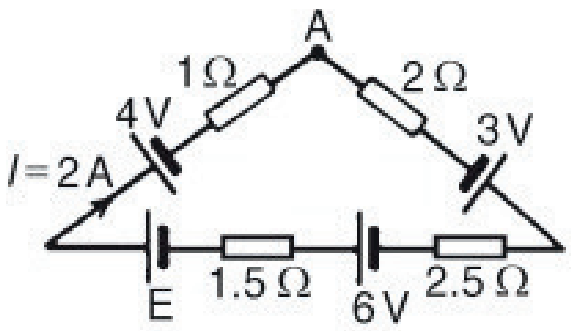


Figure 2.5: Circuit Kirchorff's Law

Solution.

$3 + 6 + E - 4$ =I(2) + I(2.5) + I(1.5) + I(1)

=I(2 + 2.5+1.5 + 1)

5+E=I(7)

Since I=2A ;

E=14–5 = 9V

2.2.2Kirchoff's Voltage Law (KVL)

Kirchoff's Voltage Law states that voltage supply at any close loop or mesh complete circuit is equal with voltage drop across conductors.

$$E_{SOURCE} = V1 + V_2 + V_3$$

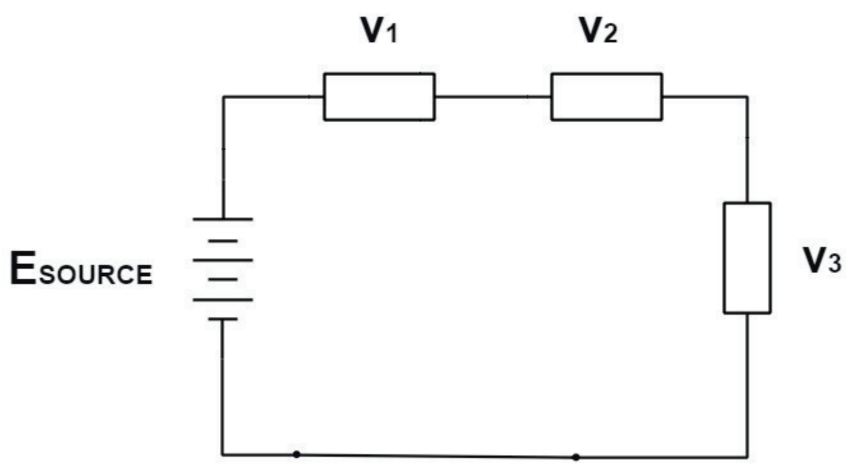


Figure 2.6 Kirchoff's Voltage Law Circuit.

2.2.2.1 Example 1

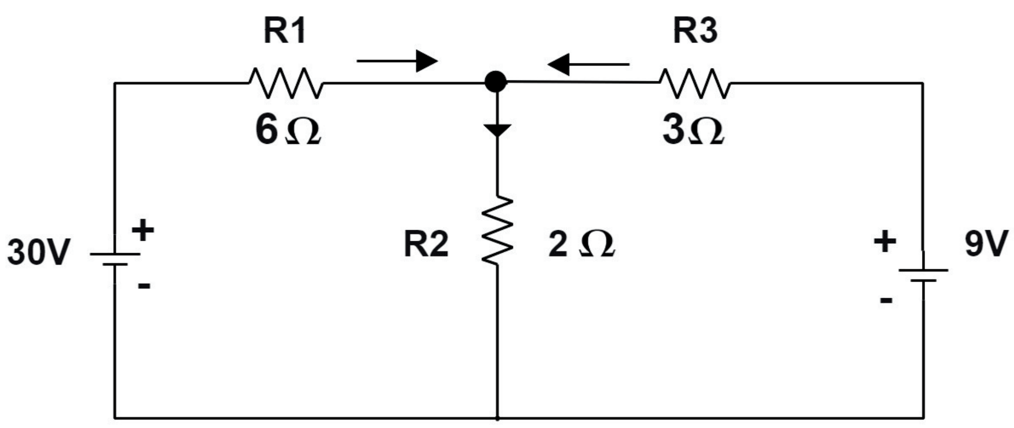


Figure 2.7:Kirchoff's Voltage Law Circuit.

Solution

Voltage drop across $R_1 = 6I_1$
Voltage drop across $R_2 = 2I_2$
Voltage drop across $R_3 = 3I_3$

Step 1- Calculate First Cycle in Left Side

$-30V + 6I_1 + 2I_2 = 0$

Summarizeas:-

$6I1 + 2I2 = 30V$

Step 2- CalculateSecond's Cycle in Right Side

$-9V + 3I3 + 2I2 = 0$

Summarizeas:-

$3I3 + 2I2 = 9V$

2.2.2.2 Example 2

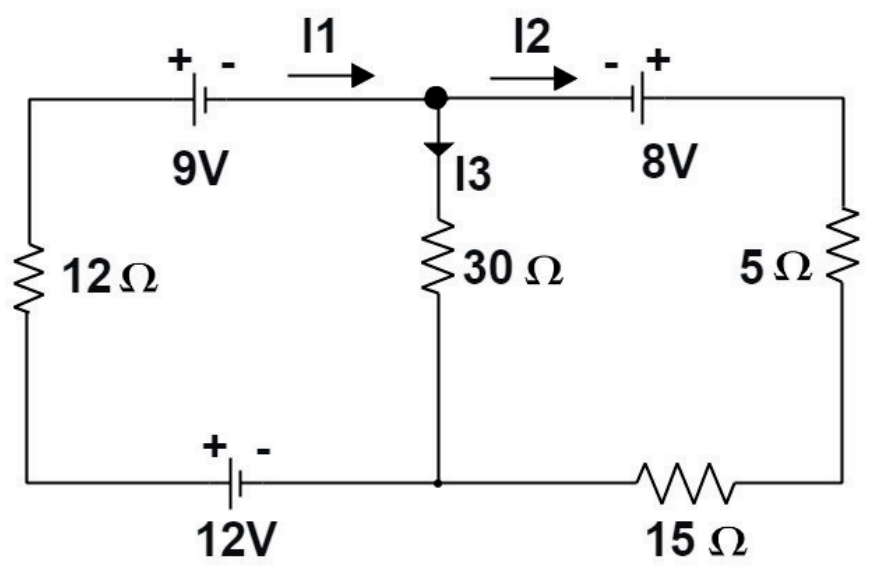


Figure 2.8: Kirchoff's Voltage Law Circuit.

Solution

Voltagedrop across 12Ω = $6I1$
Voltagedrop across 30Ω = $30I3$
Voltagedrop across 5Ω = $5I2$
Voltagedrop across 15Ω = $15I2$

Step 1- Calculate First Cycle in Left Side

$-12V + 12I1 + 9V + 30I3 = 0$

Summarize as :-

$12I1 + 30I3 = 12V - 9V$

$12I1 + 30I3 = 3V$

Step 2- Calculate Second's Cycle in Right Side

$-8V + 5I2 + 15I2 + 30I3 = 0$

Summarize as :-

$20I2 + 30I3 = 8V$

2.3 Applying Kirchoff 's Law (KVL and KCL) in DC circuit

Step 1 :- Write Kirchoff's Current Law (KCL) at nodes that are connected to respective branches

Step 2 :- Write Kirchoff's Voltage Law (KVL) for all loops. Step 3 :- Determine the unknow current or voltage value following the required in the question.

2.3.1 Example 1

From Kirchhoff's current law

$$I3 = I1 + I2$$

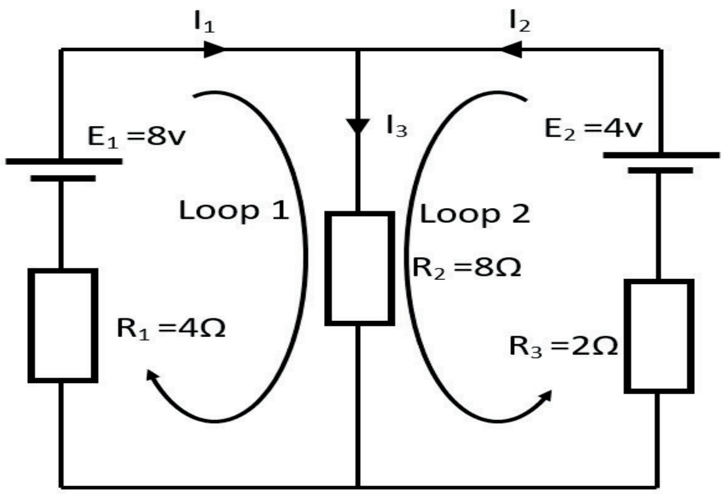


Figure 2.9: Kirchoff's Law (KVL and KCL) in DC Circuit.

Solution

Equation for Loop 1

$$\boldsymbol{E1 = I1.R1 + I3.R2}$$
$$\boldsymbol{E1 = I1.R1 + (I1 + I2).R2}$$
$$\boldsymbol{E1 = I1.R1 + I1.R2 + I2.R2}$$
$$\boldsymbol{8 = 4I1 + 8I1 + 8I2}$$
$$\boldsymbol{8 = 12I1 + 8I2} \; ....(\boldsymbol{1})$$

Equation for Loop 2

$$\boldsymbol{E2 = I2.R3 + I3.R2}$$
$$\boldsymbol{E2 = I2.R3 + (I1 + I2).R2}$$
$$\boldsymbol{E2 = I2.R3 + I1.R2 + I2.R2}$$
$$\boldsymbol{4 = 2I2 + 8I1 + 8I2}$$
$$\boldsymbol{4 = 8I1 + 10I2} \; ....(\boldsymbol{2})$$

Solve Equation (1) and (2)

$$\boldsymbol{8 = 12I1 + 8I2} ....(\boldsymbol{3})$$

$$\boldsymbol{4 = 8I1 + 10I2} .... (\boldsymbol{4})$$

To find I_1 and $I2$ by using Cramer's rule (2x2) from equation Eq(3) – Eq(4) gives:

$$\begin{bmatrix} \boldsymbol{12} & \boldsymbol{8} \\ \boldsymbol{8} & \boldsymbol{10} \end{bmatrix} \begin{bmatrix} \boldsymbol{I1} \\ \boldsymbol{I2} \end{bmatrix} = \begin{bmatrix} \boldsymbol{8} \\ \boldsymbol{4} \end{bmatrix}$$

From Equation (1)

$$\Delta = \begin{vmatrix} \boldsymbol{12} & \boldsymbol{8} \\ \boldsymbol{8} & \boldsymbol{10} \end{vmatrix} = 120 - 64 = 56$$

$$\Delta\, \boldsymbol{1} = \begin{vmatrix} \boldsymbol{8} & \boldsymbol{8} \\ \boldsymbol{4} & \boldsymbol{10} \end{vmatrix} = 80 - 32 = 48$$

$$\Delta\, \boldsymbol{2} = \begin{vmatrix} \boldsymbol{12} & \boldsymbol{8} \\ \boldsymbol{8} & \boldsymbol{4} \end{vmatrix} = 48 - 64 = -16$$

$$\boldsymbol{I1} = \frac{\Delta\, 1}{\Delta} = 48/56 = 0.8571$$

$$\boldsymbol{I2} = \frac{\Delta\, 2}{\Delta} = -16/56 = -\,0.2857$$

$$\boldsymbol{I3} = \boldsymbol{I1} + \boldsymbol{I2}$$

$I3$ = 0.8571 + (-0.2857)

$I3$ = 0.5714

2.4 Applying Nodal and Mesh Analysis for resistive circuit.

2.4.1 Applying Mesh Analysis in DC Circuit

Step 1 :- Write Kirchoff's Voltage Law for a chosen loop

Step 2 :- Write another Kirchoff's Voltage Law for another loop

Step 3 :- Determine the unknown current using simultaneous equation derived from the first and second.

2.4.1.1 Example 1

Find the current flow through each resistor using mesh analysis for circuit below

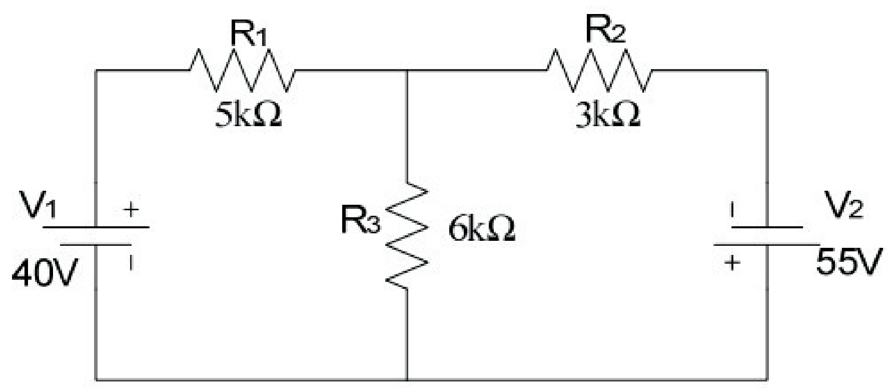


Figure 2.10: Kirchoff's Law (KVLand KCL) in DC Circuit

Solution

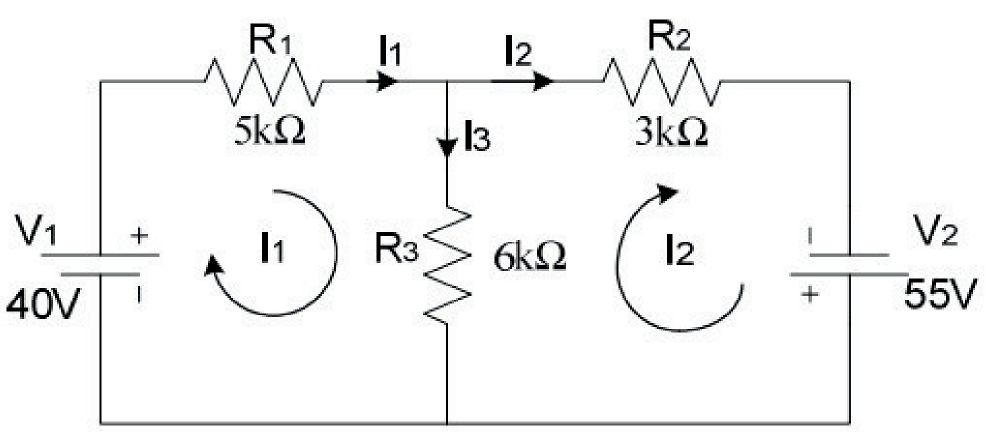


Figure 2.11: Kirchoff's Law (KVL and KCL) in DC Circuit

Equation for current

$$I1 = I2 + I3$$

Equation for Loop 1

$E1 = I1.R1 + I3.R3$

$E1 = I1.R1 + (I1 - I2).R3$
$E1 = I1.R1 + I1.R3 - I2.R3$
$40 = 5kI1 + 6kI1 - 6kI2$
$40 = 11kI1 - 6kI2$ …………….(1)

Equation for Loop 2

$E2 = I2.R2 + I3.R3$
$E2 = I2.R2 + (I2 - I1).R3$
$E2 = I2.R2 + I2.R3 - I1.R3$
$55 = 3kI2 + 6kI2 - 6kI1$
$55 = 9kI2 - 6kI1$ …………….(2)

Solve Equation (1) and (2)

$40 = 11kI1 - 6kI2$ ....(3)

$55 = -6kI1 + 9kI2$ .... (4)

To find I_1 and $I2$ by using Cramer's rule (2x2) from equation Eq(3) – Eq(4) gives:

$$\begin{bmatrix} 11k & -6k \\ -6k & 9k \end{bmatrix} \begin{bmatrix} I1 \\ I2 \end{bmatrix} = \begin{bmatrix} 40 \\ 55 \end{bmatrix}$$

From Equation (1)

$$\Delta = \begin{vmatrix} 11k & -6k \\ -6k & 9k \end{vmatrix} = 99000k - 36000k = 63000k$$

$$\Delta 1 = \begin{vmatrix} 40 & -6k \\ 55 & 9k \end{vmatrix} = 360k - (-330k) = 690k$$

$$\Delta 2 = \begin{vmatrix} 11k & 40 \\ -6k & 55 \end{vmatrix} = 605k - (-240k) = 845k$$

$I_1 = \frac{\Delta 1}{\Delta} = 690k/63000k = 10.95mA$

$I_2 = \frac{\Delta 2}{\Delta} = 845k/63000k = 13.41mA$

$I3 = I1 - I2$

$I3 = 10.95mA - 13.41mA$

$I3 = -2.46mA$

2.4.2 Apply Nodal Analysis in a DC Circuit

Another method to calculate current or voltage besides using Kirchoff's Law is used apply Nodal analysis.

Step 1:- Write Kirchoff's Current Law at selected nodes.

Step 2:- Using Ohms Law rule to apply in Nodal Analysis. Using between two point of voltage that consist resistance which is current flow through its.

Figure 2.12: Nodalanalysis network.

So,

$$I1 = \frac{Va - Vb}{R1}$$

Step 3 :- Write all the current equations for all the branches at the respective nodes.

Step 4 :- Solve the unknown currents for the node chosen.

2.4.2.1 Example 1

Findthecurrentflowthrougheachresistorusing node analysis for the circuit below.

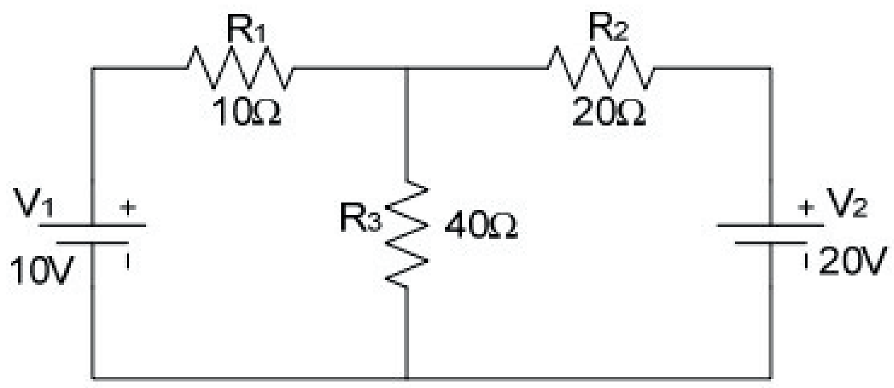


Figure 2.13:Node Analysis Circuit

Solution

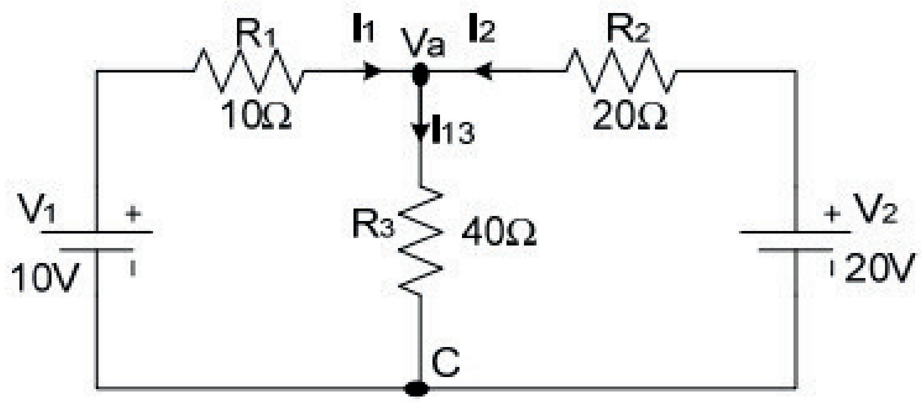


Figure 2.14:Node Analysis Circuit

Kirchoff's Current Law (KCL) :

$$I1+I2=I3$$

Solve the resulting simultaneous linear equation for the nodal voltages

$$\frac{10-Va}{10}+\frac{20-Va}{20}=\frac{Va}{40}$$

$$\frac{10-Va}{10}+\frac{20-Va}{20}=\frac{Va}{40}$$

$$1-\frac{Va}{10}+1-\frac{Va}{20}=\frac{Va}{40}$$

$$1-\frac{Va}{10}+1-\frac{Va}{20}=\frac{Va}{40}$$

$$1+1=\frac{Va}{40}+\frac{Va}{10}+\frac{Va}{20}$$

$$2=Va\left(\frac{1}{40}+\frac{1}{10}+\frac{1}{20}\right)$$

$$2=Va\left(\frac{7}{40}\right)$$

$Va=11.428$V................(1)

Determinethecurrentsthrougheachelements by insert the value (1) into equation between two point of voltage that consist resistance which is current flow through its.

$I1 = \frac{10 - Va}{10}$

$I1 = \frac{10 - 11.428}{10} = -0.143\text{A}$

$I2 = \frac{20 - Va}{20}$

$I2 = \frac{20 - 11.428}{20} = 0.429\text{A}$

$I3 = \frac{Va}{40}$

$I3 = \frac{11.428}{40} = 0.2869\text{A}$

2.4.1.1 Example 2

Find the current flow through each resistor using node analysis for the circuit below.

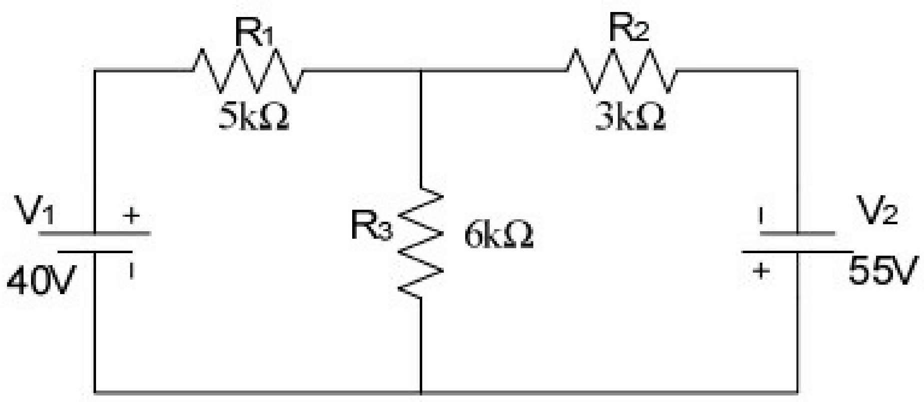


Figure 2.15: NodeAnalysis Circuit

Solution

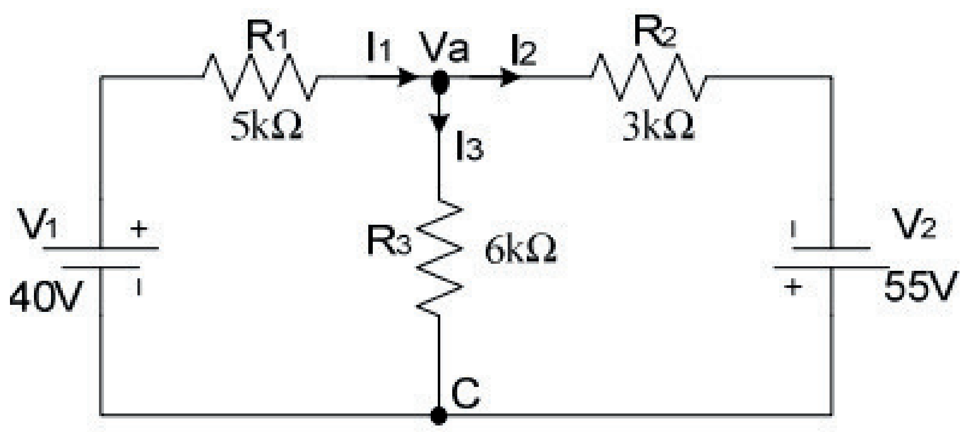


Figure 2.16: Node Analysis Circuit

Kirchoff's Current Law (KCL) :

$$I1 = I2 + I3$$

Solve the resulting simultaneous linear equation for the nodal voltages

$\frac{40 - Va}{5k} = \frac{Va - (-55)}{3k} + \frac{Va}{6k}$

$\frac{40}{5k} - \frac{Va}{5k} = \frac{Va}{3k} + \frac{55}{3k} + \frac{Va}{6k}$

$-\frac{Va}{5k} - \frac{Va}{3k} - \frac{Va}{6k} = \frac{55}{3k} - \frac{40}{5k}$

$-Va\left(\frac{1}{5k}+\frac{1}{3k}+\frac{1}{6k}\right)=\frac{55}{3k}-\frac{40}{5k}$

$-Va\,(700 \times 10^{-6})=10.33 \times 10^{-3}$

$Va=-14.757$V................(1)

Determine the currents through each elements by insert the value (1) into equation between two point of voltage that consist resistance which is current flow through its.

$I1=\frac{40-Va}{5k}$

$I1=\frac{40-(-14.757)}{5k}=10.95mA$

$I2=\frac{Va-(-55)}{3k}$

$I2=\frac{-14.757-(-55)}{3k}=13.41mA$

$I3=\frac{Va}{6k}$

$I3=\frac{-14.757}{6k}=-2.46mA$

2.5 Understand Thevenin's Theorem

A technique for replacing a given electrical network by using single voltage source (Vth) in series connection with single Resistance Thevenin's (Rth) and Resistor Load (RL). The current in any branch of a network is the current that would result from the introduction of an electromagnetic force (e.m.f) equal to the potential difference across the break made in the branch, all other electromagnetic force (e.m.f) being removed and represented by the internal resistances of the sources.

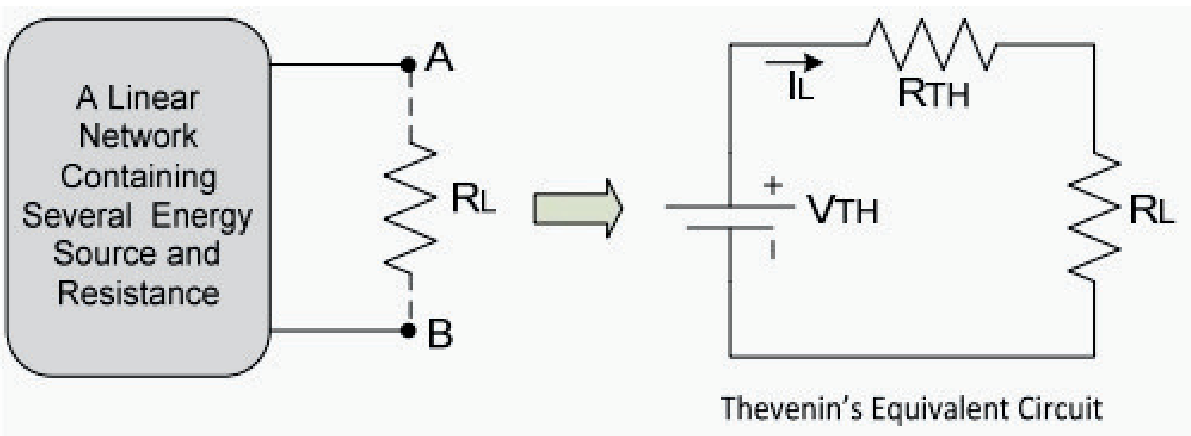


Figure 2.17: Thevenin's Equivalent Circuit

The steps taken to apply Thévenin's theorem are outlined below. To ascertain the current in any branch of an active network (i.e., one that contains an e.m.f. source):

Step 1:- Remove the selected Resistor Load (RL) and become to open circuit state

Step 2:- Replacing voltage source with short circuit

Step 3:- Short circuit the voltage power supply and open circuit the selected Resistor Load (RL) to determine the value of Resistor Thevenin's (Rth) by calculating total resistance in circuit.

Step 4:- Replacing back voltage source in initial state.

Step 5:- Calculate Voltage Thevenin at open circuit state in step 1

Step 6:- Draw Thevenin's Equivalent Circuit in series connection.

Step 7:- Insert back Resistor Load (RL) into Thevenin's Equivalent Circuit.

Step 8:- Calculate the current flows through the Resistor Load (RL) using Ohm's Law.

2.5.1 Example 1

Use Thévenin's theorem to find the current flowing in the 10Ω resistor for the circuit.

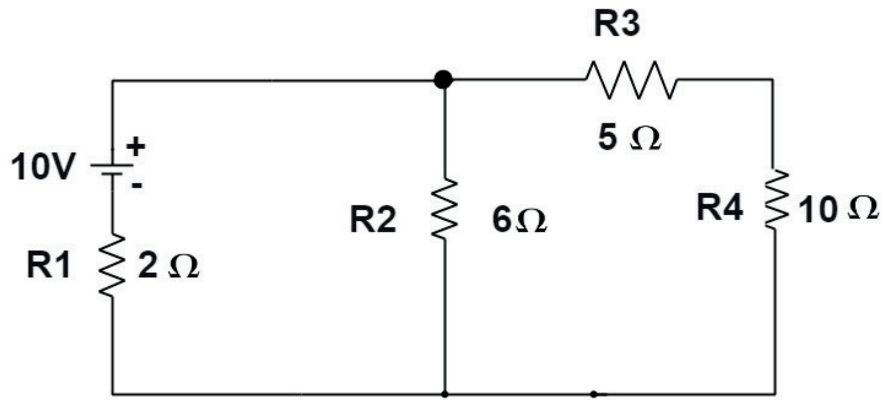


Figure 2.18:Circuit Diagram

Step 1:- Remove the selected Resistor Load (*RL*) and become to open circuit state

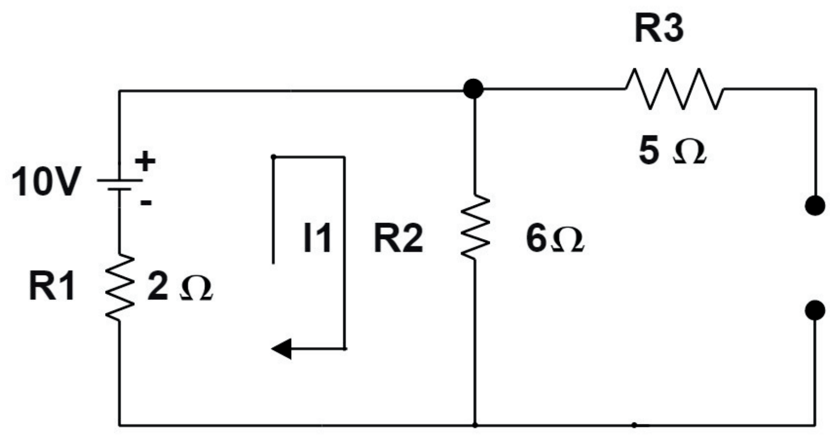


Figure 2.19:Thevenin's Circuit when R_{LOAD} Remove

$$I1 = \frac{10}{R1 + R2}$$

$$I1 = \frac{10}{2 + 6} = 1.25A$$

Step 2:- Replacing voltage source with short circuit

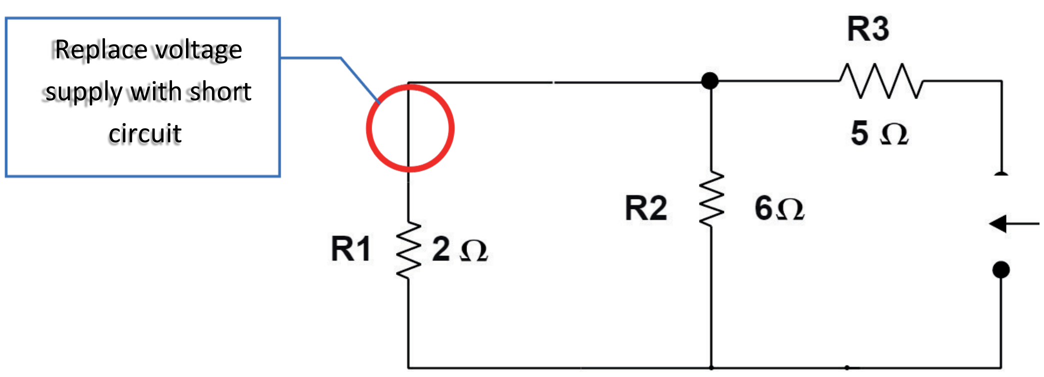


Figure 2.20:Thevenin's Circuit when voltage short-circuit.

Step 3:- Short circuit the voltage power supply and open circuit the selected Resistor Load (RL) to determine the value of Resistor Norton (R_{th}) by calculating total resistance in circuit.

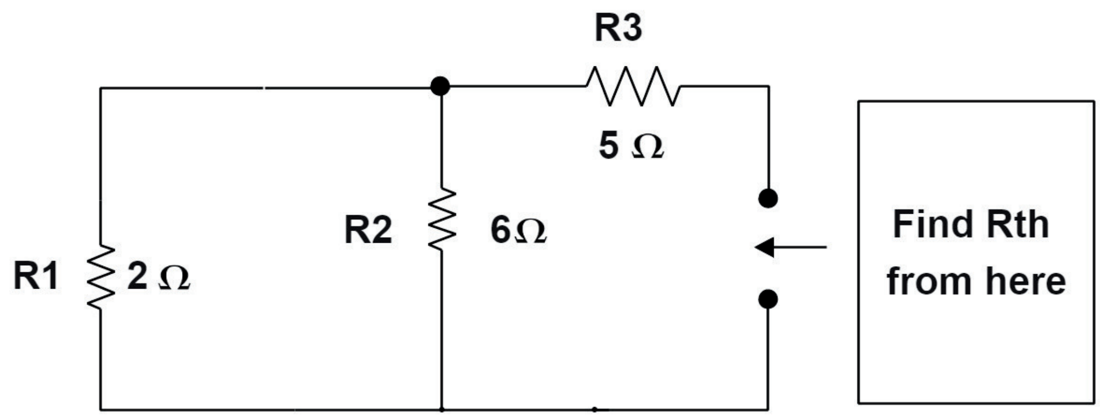


Figure 2.21:Thevenin's Circuit for determine R^{th}

R_{TH} = **(2 // 6) + 5**

$R_{TH} = \frac{2 \times 6}{2+6} + 5$

R_{TH} = **6.5 Ω**

Step 4:- Replacing back voltage source in initial state.

Step 5:- Calculate Voltage Thevenin at open circuit state in step 1

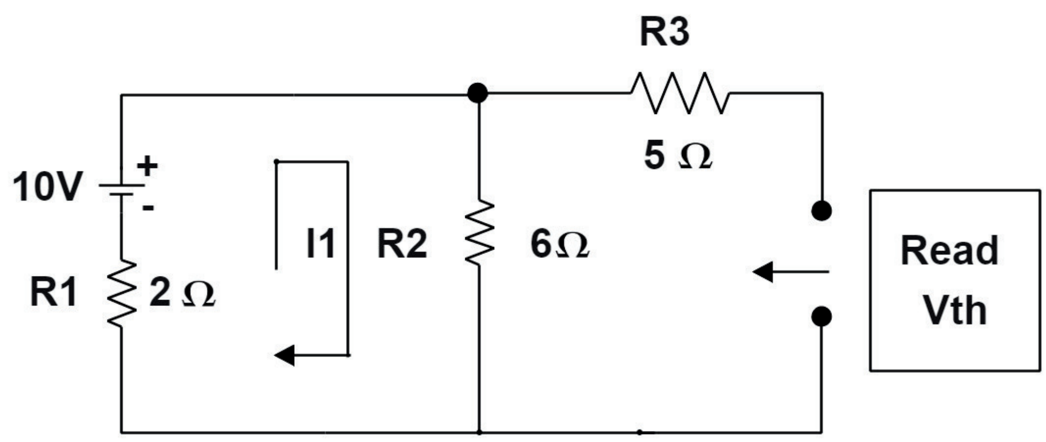


Figure 2.22:Thevenin'sCircuit for determine V^{th}

$Vth = V6\Omega = I1 \times R2$

$Vth = 1.25A \times 6\Omega = 7.5V$

Step 6:- Draw Thevenin's Equivalent Circuit in series connection.

Step 7:- Insert back Resistor Load (*RL*) into Thevenin's Equivalent Circuit.

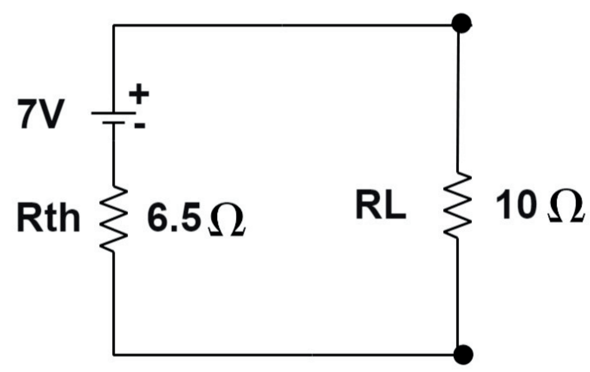


Figure 2.23:Thevenin's Equivalent Circuit

Step 8:- Calculate the current flows through the Resistor Load (*RL*) using Ohm's Law.

$IL = \frac{7.5}{6.5+10} = 0.455A$

2.6 Apply Thevenin's Theorem to simplify a circuit for analysis

2.4.1.1 Example 1

Find the current flow through RL equal to 30Ω for the circuit in Figure 21

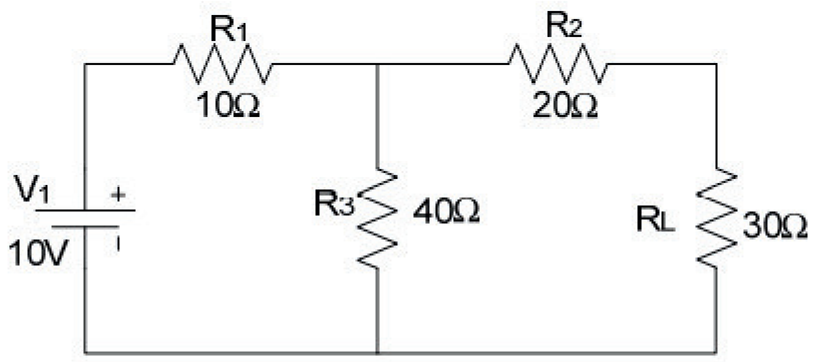


Figure 2.24:Circuit Diagram

Open circuit RL and find Thevenin's voltage (V_{TH}).

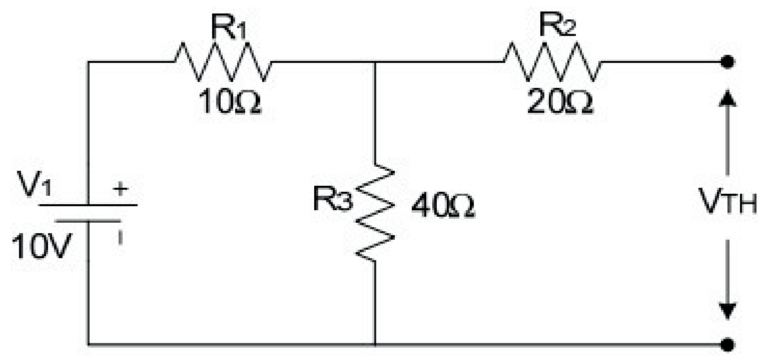


Figure 2.25:Thevenin'sCircuit for determine V^{th}

$Vth = V40\Omega$

Using Voltage Divider Rule (VDL) :

$V_{TH} = \frac{40}{40+10} X\ 10 = 8v$

Find Thevenin's resistance (R_{TH}) when voltage source is short circuit

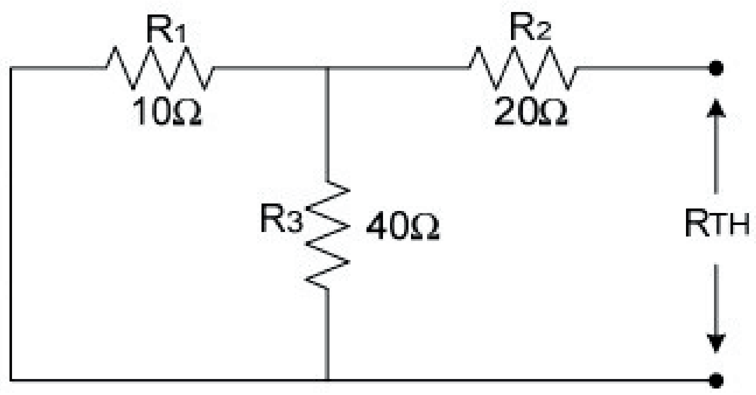


Figure 2.26:Thevenin's Circuit for determine R^{th}

R_{TH} = (10 // 40) + 20

$R_{TH} = \frac{10 \times 40}{10+40} + 20$

R_{TH} = 28 Ω

Draw the Thevenin's equivalent circuit with the value of V_{TH} and R^{TH}

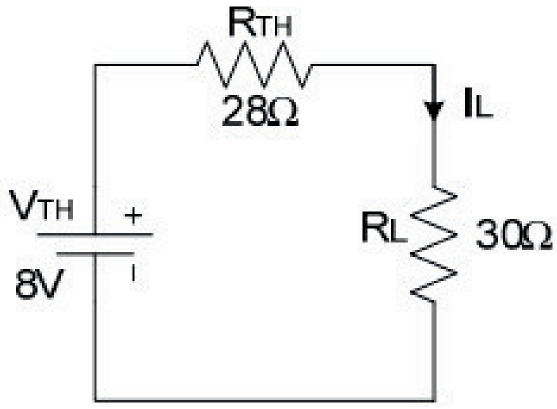


Figure 2.27:Thevenin's Equivalent Circuit.

$IL = \frac{VTH}{RTH + RL}$

$IL = \frac{8}{28 + 30}$

$IL = \frac{8}{28 + 30}$

$IL = 0.138A$

Example 2

Find current flow through R4.

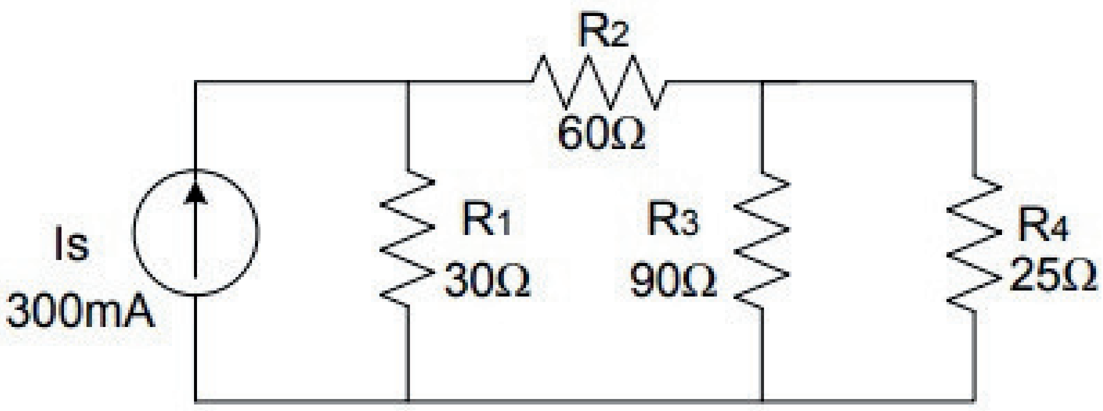


Figure 2.28:Circuit Diagram

Open circuit RL and find Thevenin's voltage (VTH)

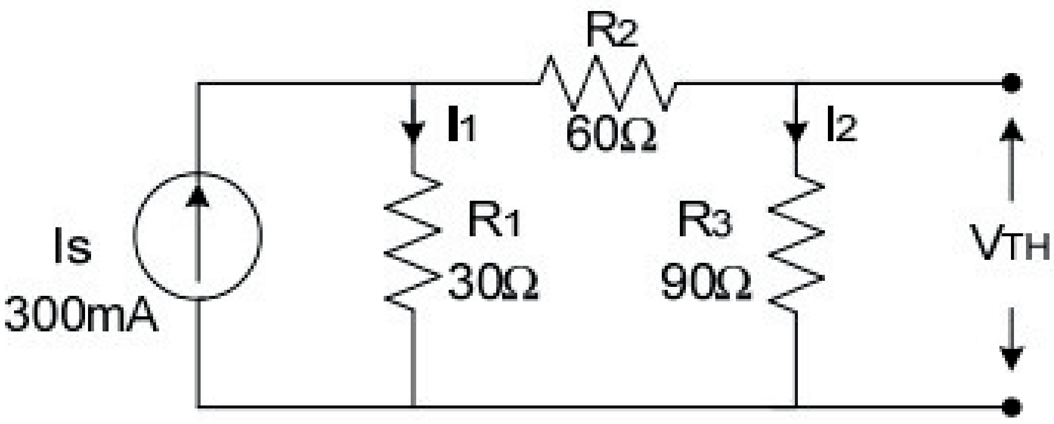


Figure 2.29:Thevenin's Circuit for determine V^{th}

$Vth = V90\Omega = I2 \times 90$

Using Current Divider Rule (CDL) :

$I2 = \frac{R3}{R1+R2+R3} \times I_S$

$I2 = \frac{30}{30+60+90} \times 300 = 50mA$

$V_{TH} = 50mA \times 90 = 4.5V$

Find Thevenin's resistance (RTH) when current source,IS is open circuit

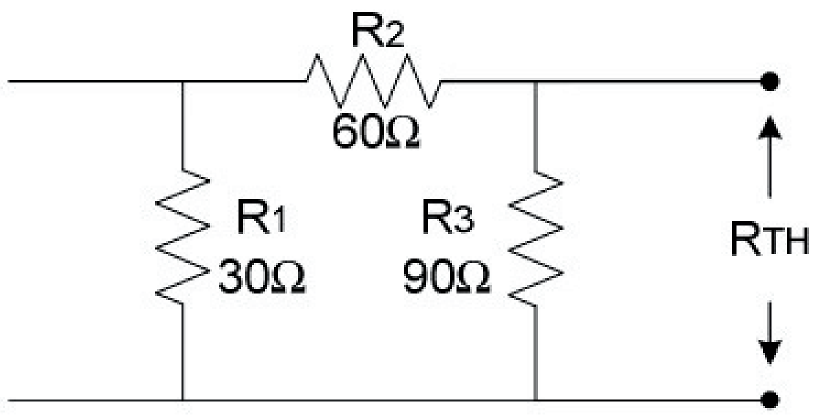


Figure 2.30:Thevenin's Circuit for determine R^{th}

$R_{TH} = (R1 + R2) // R3$

$R_{TH} = (30+60) // 90$

$R_{TH} = \frac{90 \times 90}{90+90}$

$R_{TH} = 45\ \Omega$

Find Thevenin's resistance (RTH) when current source,IS is open circuit

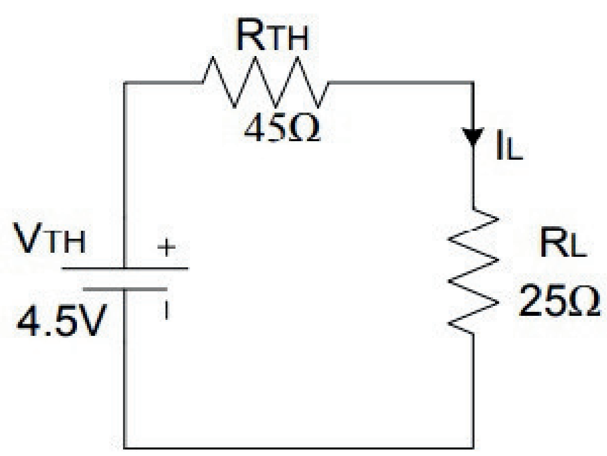


Figure 2.31:Thevenin's Equivalent

$IL = \frac{V_{TH}}{RL + R_{TH}}$

$IL = \frac{4.5}{45+25}$

$IL = 0.064A$

2.7 Understand Norton's Theorem

Atechnique for replacing agivenelectricalnetworkbyusing single Current Norton (*IN*) in parallel connection with Resistance Norton (*RN*) and Resistor Load (). Any branch of anetwork hasaninternalresistanceequal to the resistance that is visible across the open-circuited branch terminals, a short-circuit current

RL

equal to the current that would flowinthebranchifitwere connected across a source of electrical energy, and a short-circuit current equal to the current that would flow in the branch in a short-circuit.

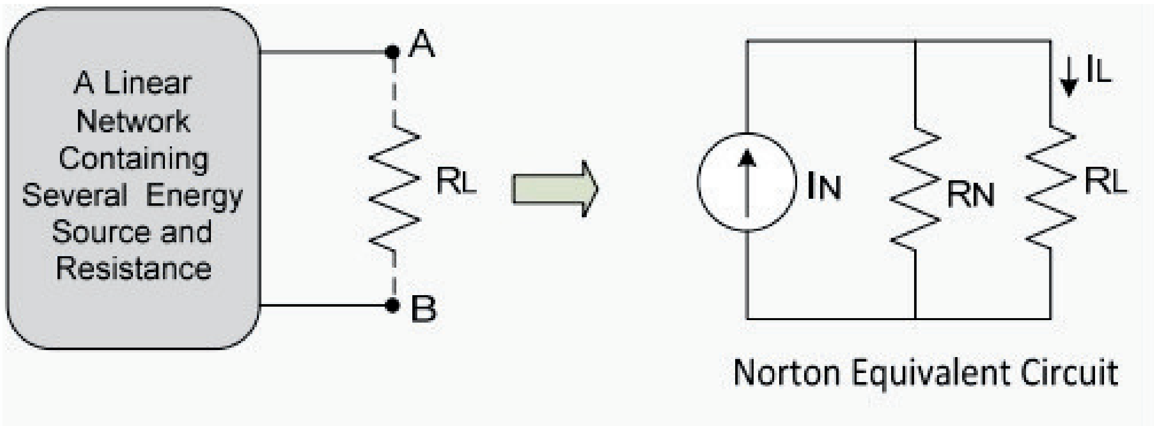


Figure 2.32:Norton'sEquivalent Circuit

The steps taken to apply Norton's theorem are outlined below. To ascertain thecurrent in any branch of an active network (i.e., one that contains an internal current source):

Step 1:- Remove the selected Resistor Load (*RL*) and become short circuit state

Step 2:- Calculate total resistance (*RTotal*).

Step 3:- Calculate total current using ohm's law.

Step 4:- Calculate Current Norton (*IN*) by using current divider.

Step 5:- Short circuit the voltage power supply and open circuit the selected Resistor Load (*RL*) to determine the value of Resistor Norton (*RN*) by calculating total resistance in circuit.

Step 6:- Draw the Norton Equivalent Circuit in parallel connection.

Step 7:- Insert back Resistor Load (*RL*) into Norton Equivalent Circuit.

Step 8:- Calculate the current flows through the Resistor Load (*RL*) using Ohm's Law or Current Divider.

2.7.1 Example 1

Use Norton's theorem to find the current flowing in the 10Ω resistor for the circuit.

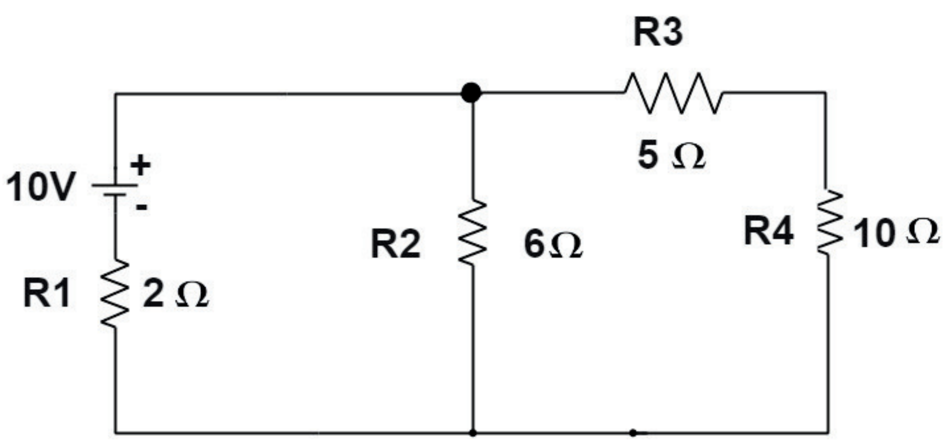
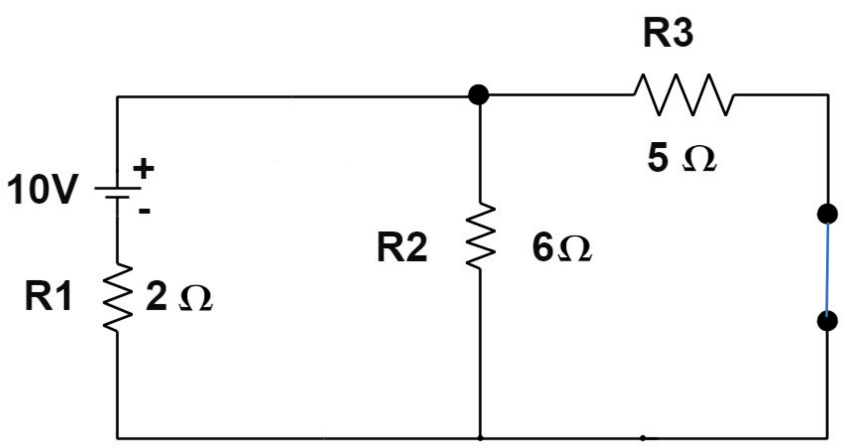


Figure 2.33:Circuit Diagram

Step 1:- Remove the selected Resistor Load (*RL*) and become short circuit state



Step 2:- Calculate total resistance ($RTotal$)

Figure2.34 : Norton's Circuit for determine IN

R_{Total} = 2 + (5 // 6)

$R_{Total} = 2 + \frac{5 \times 6}{5 + 6}$

R_{Total} = 4.727Ω

Step 3:- Calculate total current using ohm's law.

$IT = \frac{V}{R_{Total}} = \frac{10}{4.727} = 2.12A$

Step 4:- Calculate Current Norton (I_N) by using current divider.

$IN = \frac{6}{6 + 5} X\ 2.12A = 1.156A$

Step 5:- Short circuit the voltage power supply and open circuit the selected Resistor Load (RL) to determine the value of Resistor Norton (R_N) by calculating total resistance in circuit.

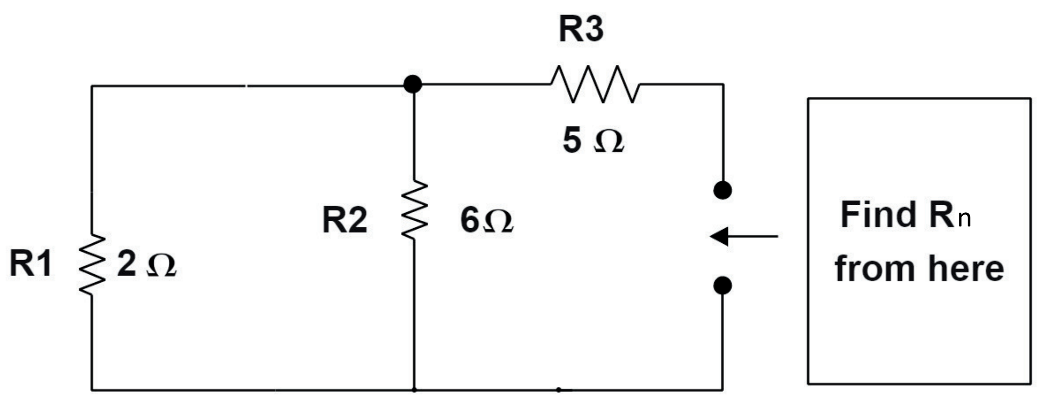


Figure 2.35:Norton's Circuit for determine R_N

RN= (2 // 6) + 5

$RN = \frac{2 \times 6}{2 + 6} + 5$

RN= 6.5 Ω

Step 6:- Draw the Norton Equivalent Circuit in parallel connection.

Step 7:- Insert back Resistor Load (RL) into Norton Equivalent Circuit.

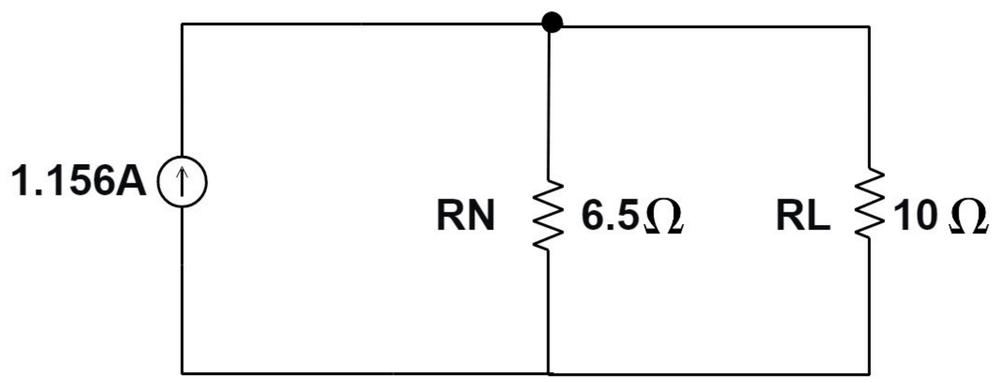


Figure 2.36:Norton's Equivalent Circuit

Step 8:- Calculate the current flows through the Resistor Load (RL) using Ohm's Law or Current Divider.

$IL = \frac{RN}{R_N + R_L} x\ I_N$

$IL = \frac{6.5}{6.5+10} x\ 1.156 = 0.455A$

TIPS: The example procedure in Thevenin's Theorem (2.5.1) and Norton's Theorem (2.7.1) is a same question. The different is a technique that was applied in each question. Student be able to get exactly same answer on Current Load (IL) either using

2.8 Apply Norton's Theorem to simplify a circuit

2.8.1 Example 1

Find the current flow through RL equal to 30Ω for the circuit using Norton Theorem.

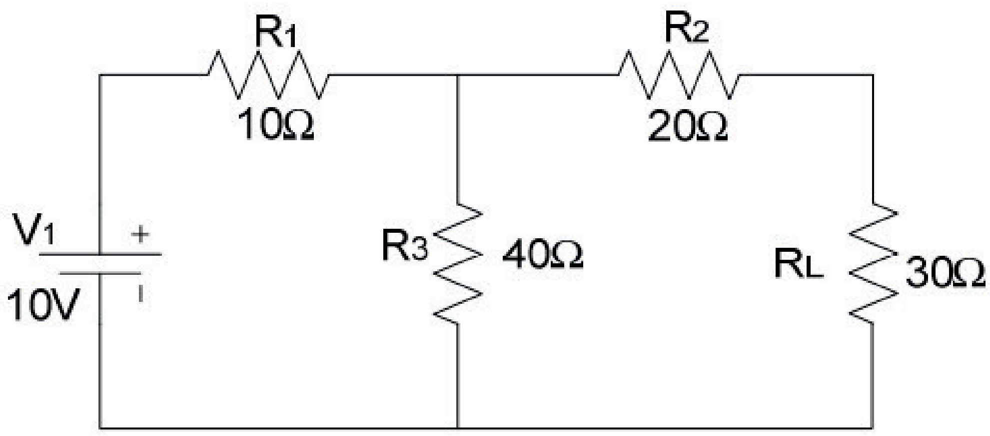


Figure 2.37:Circuit Diagram

Remove RL from the circuit. Find IN by shorting links output terminal.

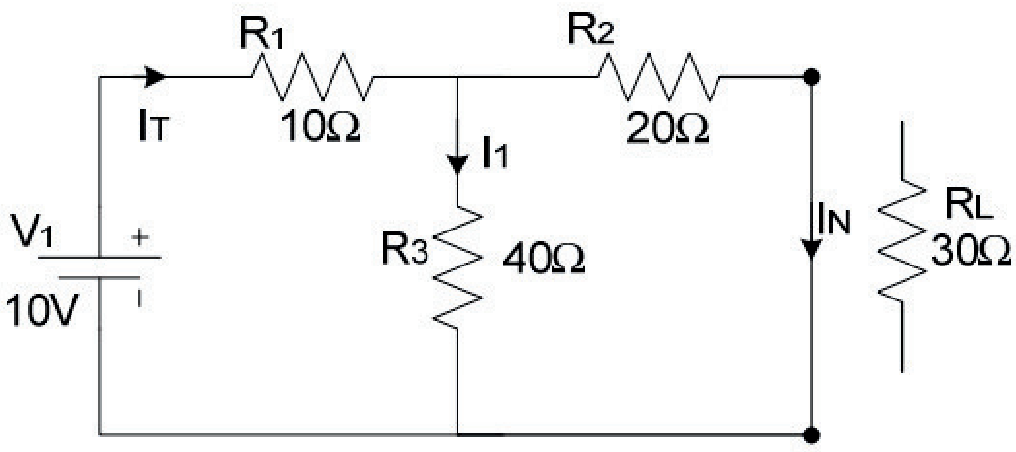


Figure 2.38:Norton's Circuit for determine I_N

R_{Total} = 10 + (20 // 40)

$R_{Total} = 10 + \frac{20 \times 40}{20 + 40}$

R_{Total} = 23.33 Ω

$IT = \frac{V}{R_{Total}} = \frac{10}{23.33} = 0.429A$

$IN = \frac{40}{40+20} X\ 0.429\ A = 0.286A$

Find RN by short-circuit voltage source

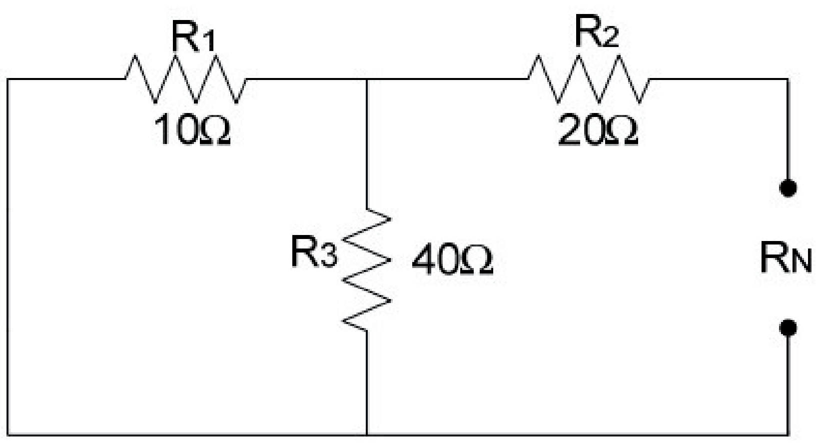


Figure 2.39:Norton's Circuit for determine R_N

R_N = (10 // 40) + 20

$R_N = \frac{10 \times 40}{10 + 40} + 20$

$R_N = 28\ \Omega$

Draw the Norton's equivalent circuit with the value of IN and RN. Find the IL which current flow through the RL .

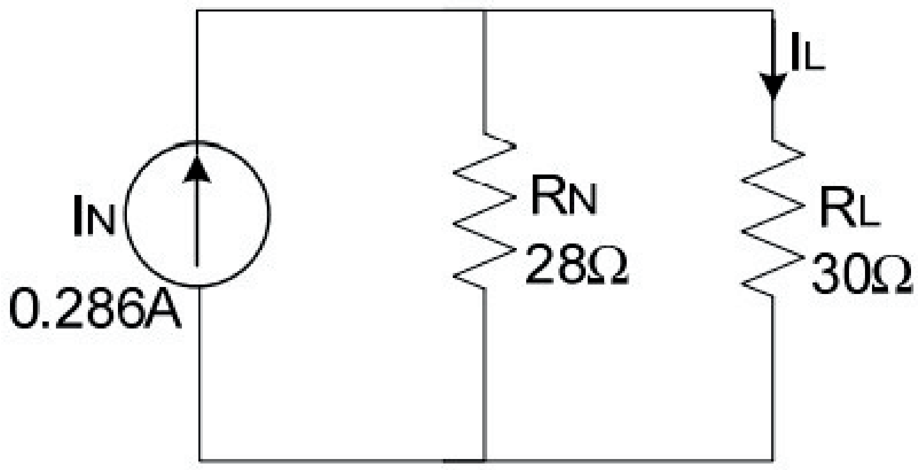


Figure 2.40:Norton's Equivalent Circuit

Using Current Divider Rule (CDR), find IL

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

$I_L = \frac{28}{28+30}\ x\ 0.286 = 0.138A$

2.8.2 Example 2

Find current flow through R4 by using Norton's Theorem.

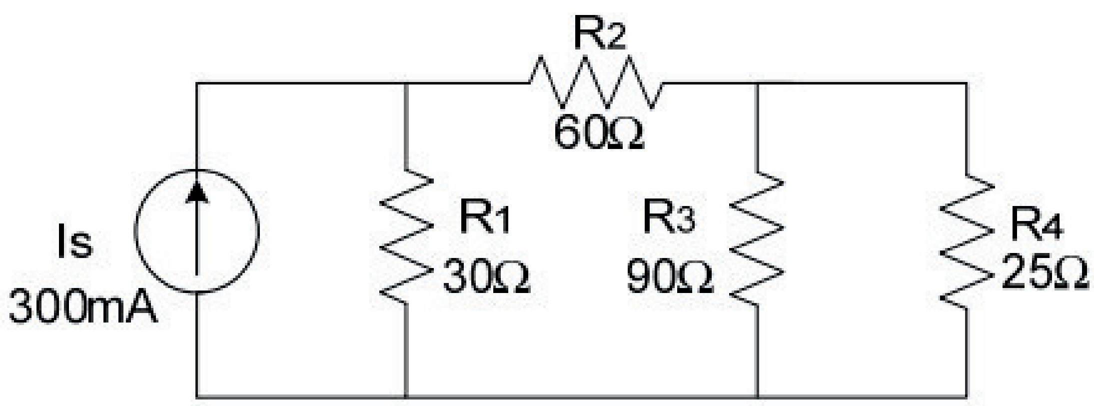


Figure 2.41:Circuit Diagram

Remove RL from the circuit. Find IN by shorting links output terminal.

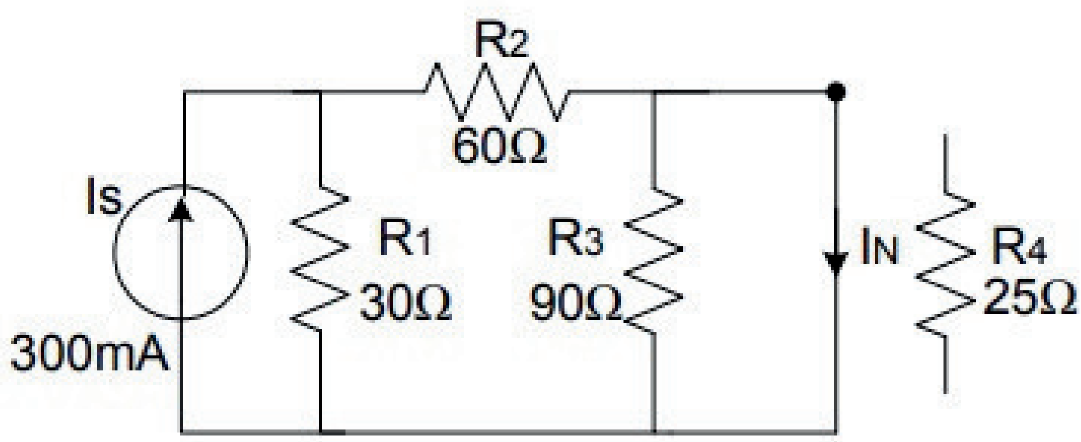


Figure 2.42:Norton's Circuit for determine I_N

Current flow at 90Ω is 0A, so $IN= I60Ω$.

$$IN = \frac{R_1}{R1 + R3} x\, I_S$$

$$IN= \frac{30}{30+60} x\, 300m = 100mA$$

Find RN by open-circuit current source.

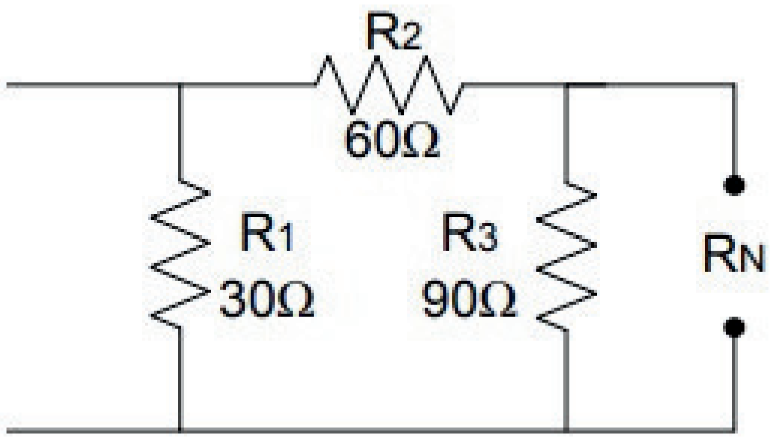


Figure 2.43:Norton's Circuit for determine R_N

$RN= (R1+ R_2)// R3$

$RN= (30+60)// 90$

$$RN= \frac{90 \times 90}{90+90}$$

$RN= 45\ Ω$

Draw the Norton's equivalent circuit with the value of IN and RN. Find the IL which current flow through the RL .

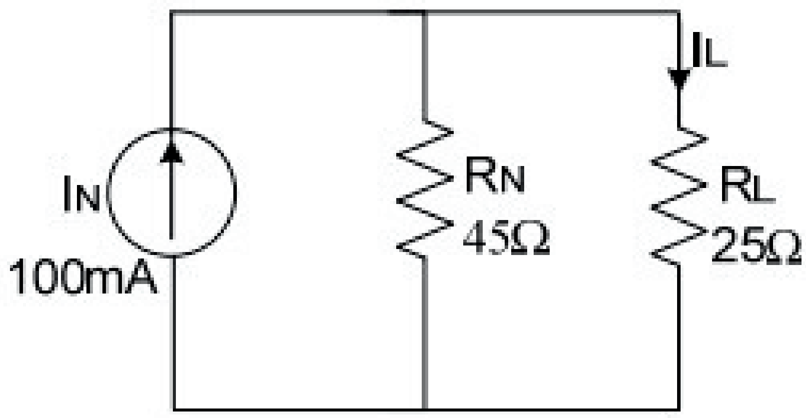


Figure 2.44:Norton's Equivalent Circuit

$$IL= \frac{RN}{RN+RL} x\, I_N$$

$$IL= \frac{45}{45+25} x\, 100m = 0.064A$$

2.9 Change Thevenin's Equivalent Circuit to Norton's Equivalent Circuit and vice versa

The networks for Thevenin and Norton displayed here are equal. In every network, there is the same resistance "looking-in" at terminals AB.

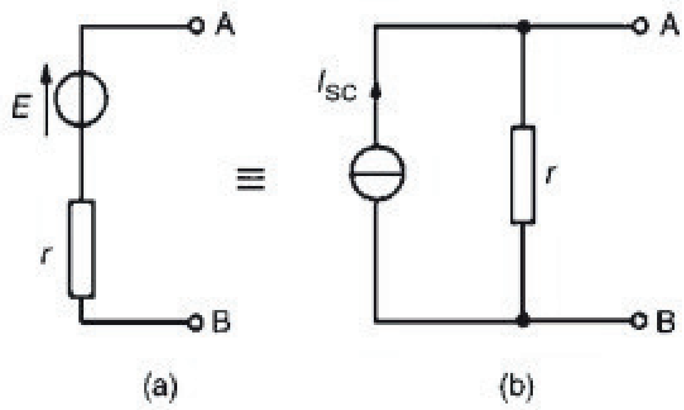


Figure 2.45 : Thevenin's Equivalent Circuit to Norton's EquivalentCircuit.

If terminals AB in Figure 2.45(a) are short-circuited, the short-circuit current is given by E/r. If terminals AB in Figure 2.45(b) are short-circuited, the short-circuit currentis I_{sc}.For the circuit shown in Figure 2.45(a) to be equivalent to the circuit in Figure 2.45(b) the same short-circuit current must flow. Thus I_{sc}=E/r.

2.9.1 Example 1
Convert the circuit to an equivalent Norton network.

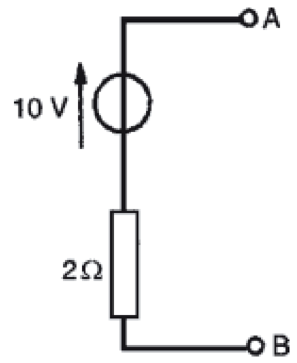


Figure 2.46 : Norton Circuit

Ifterminals AB in Figure 2.46 are short-circuited, the resistance is 2Ω. Then short-circuit current I_{sc} =10/2=5A using ohm's law.

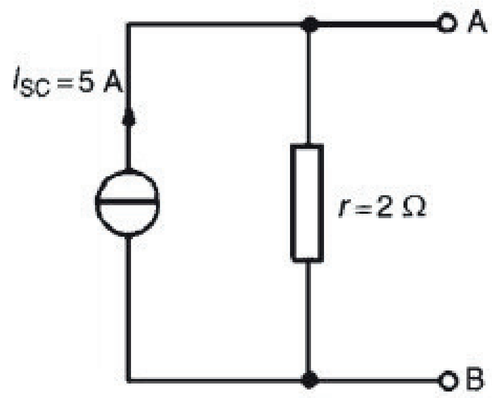


Figure 2.47 : Norton Circuit Equivalent

Thus, Figure 2.47 shows the corresponding Norton network.

2.9.2 Example 2
Convert the circuit to an equivalent Thevenin network.

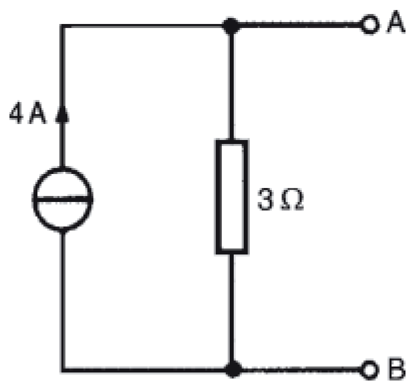


Figure 2.48 : Thevenin Circuit

Ifterminals AB in Figure 2.48 are open-circuited, the resistance is 3Ω. Then short-circuit current V_{supply} = 4 x 3 =12V using ohm's law.

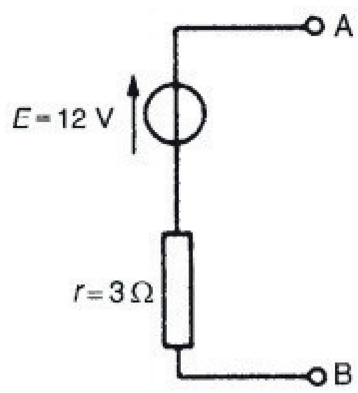


Figure 2.49: Norton Circuit Equivalent

Thus, Figure 2.49 shows the corresponding Norton network.

2.9.3 Example 3

Convert the circuit to the left of terminals AB in Figure 2.50 to an equivalent Thévenin circuit by initially converting to a Norton equivalent circuit.

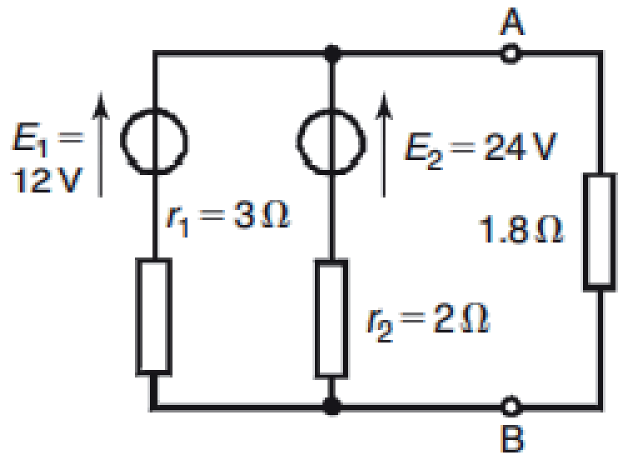


Figure 2.50 : Example circuit transformation Norton

Solution

$I1 = \frac{E1}{r1}$

$I1 = \frac{12}{3} = 4A$

$I2 = \frac{E2}{r2}$

$I2 = \frac{24}{2} = 12A$

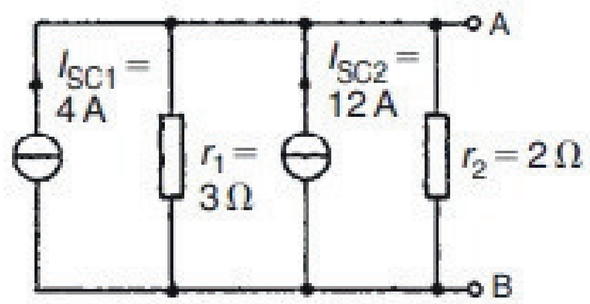


Figure 2.51: Example circuit transformation Norton

$I_{sc(total)} = 4+12=16A$

$r_{total} = 3 \,//\, 2$

$r_{total} = \frac{3 \times 2}{3+2} = 1.2\Omega$

$V_{TH} = 16 \times 1.2 = 19.2V$

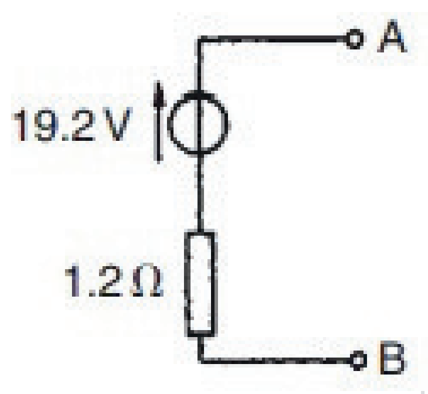


Figure 2.52: Equivalent Circuit Norton Transformation.

Thus, Figure 2.9.8 shows the corresponding Thevenin network after transformation.

2.10 Conclusion

This topic learnt how to solve unknown current and voltage in electrical circuit. There is various way to be apply which is Kirchoff's Law, Nodal Analysis, Mesh Analysis, Thevenin's Theorem, Norton's Theorem and Superposition Theorem. All method has exactly same purpose to determine the unknown current and voltage which means all method apply will get the same answer.

1. Findthecurrentthrougheachresistorfornetworking below using Mesh Analysis and Nodal Analysis.

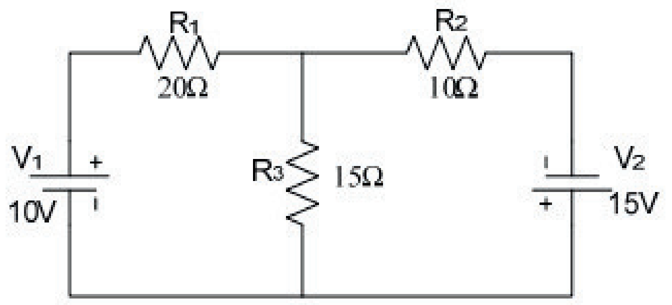


Figure 2.53: Circuit Diagram

2. Find the current through each resistor for networking below using Mesh Analysis and Nodal Analysis.

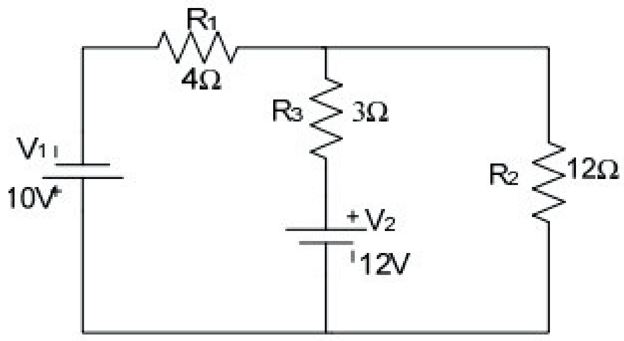


Figure 2.54: Circuit Diagram

3. Find the current through each resistor for networking below using MeshAnalysis and Nodal Analysis.

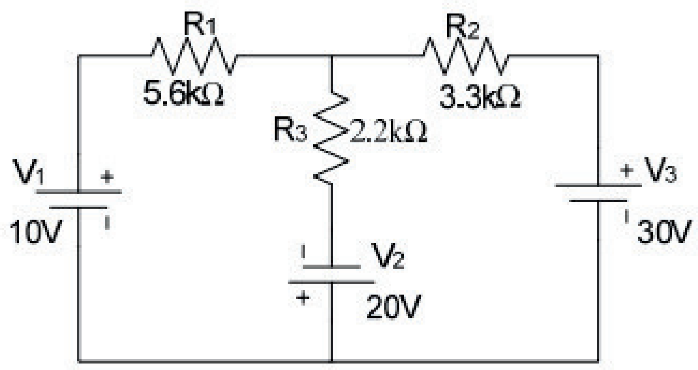


Figure 2.55: CircuitDiagram

4. Determine, using Kirchhoff's laws, each branch current for the network.

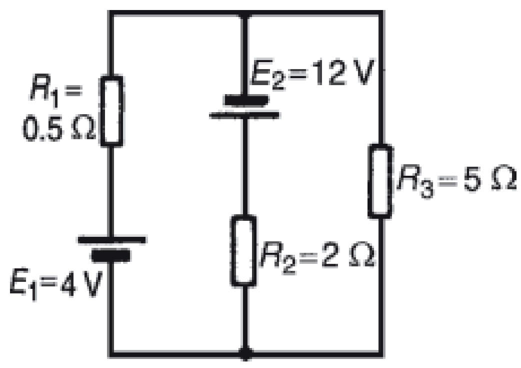


Figure 2.56: Circuit Diagram

5. Find the current flow through resistor 15Ω for the circuit in figure 2.57 using Thevenin's Theorem.

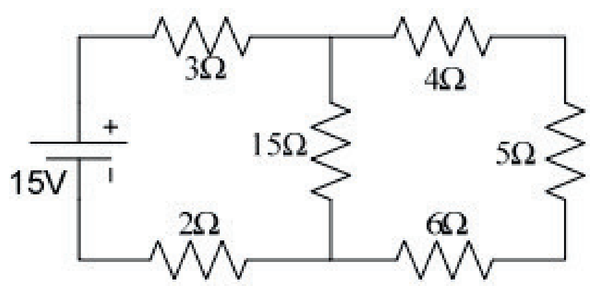


Figure 2.57: Circuit Diagram

6. Count value stream I_L by using Thevenin's Theorem.

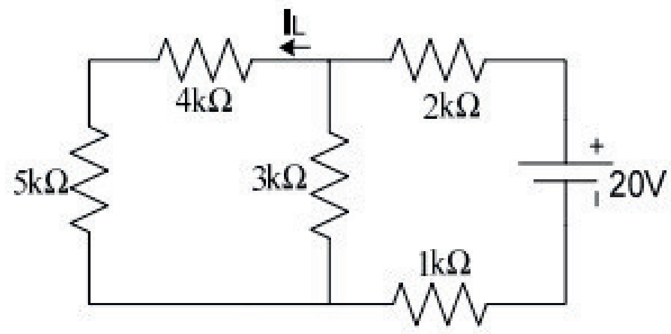


Figure 2.58: Circuit Diagram

7. Use Thevenin's Theorem to find the current flowing in 5Ω resistor showninfigure 2.59.

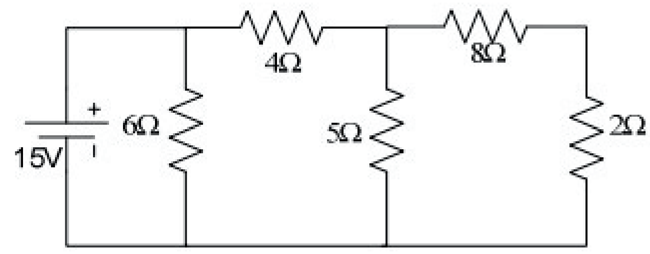


Figure 2.59: Circuit Diagram

8. Refer to figure 2.60, find the current flow through 50Ω using Thevenin's Theorem.

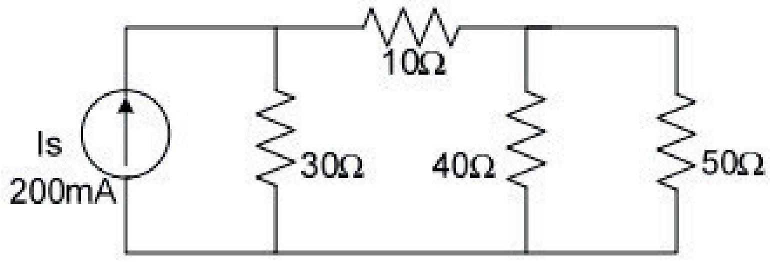


Figure 2.60: Circuit Diagram

9. Use Thevenin's Theorem, find the current flow through resistor R=10Ω.

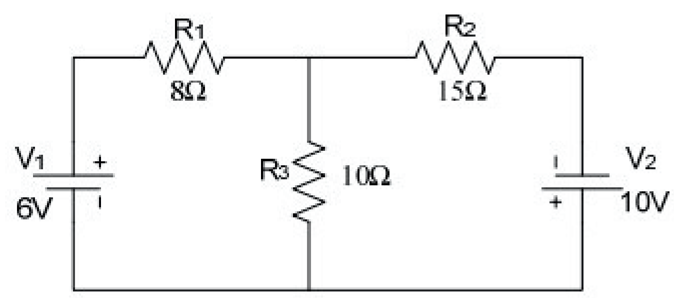


Figure 2.61: Circuit Diagram

10. Refer to figure 2.62, find the current flow through resistor 12Ω using Norton's Theorem.

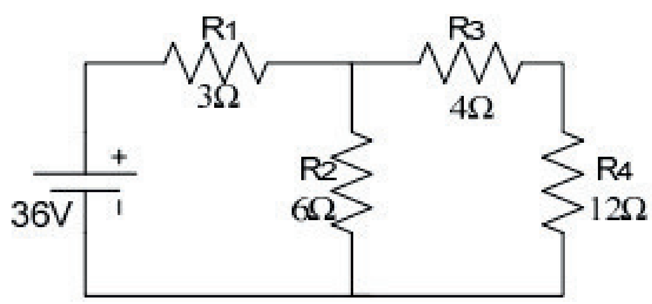


Figure 2.62: Circuit Diagram

11. Count value stream I_L by using Norton Theorem.

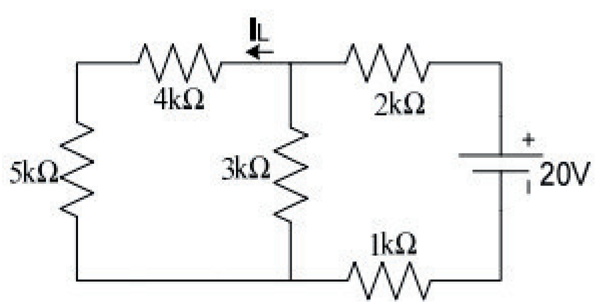


Figure 2.63: Circuit Diagram

12.Use Norton Theorem to find the current flowing in 5Ω resistor shown in figure 2.64.

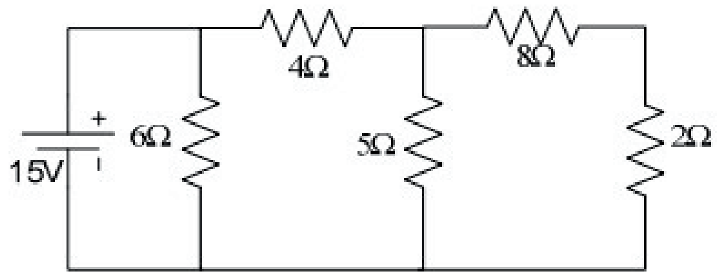


Figure 2.64: Circuit Diagram

13. Calculate the current flow in 30Ω resistor for the circuit in figure 2.65 using Norton Theorem.

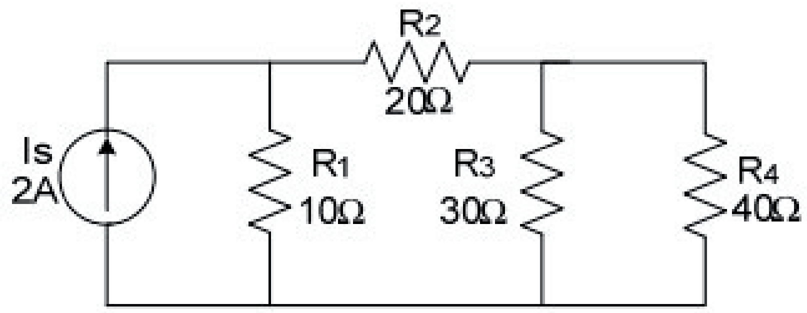


Figure 2.65: Circuit Diagram

14. Use Norton Theorem, find the current flow through resistor R=10Ω.

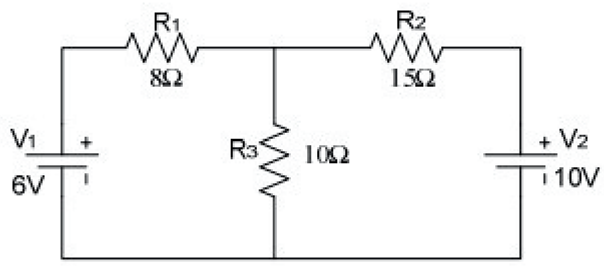


Figure 2.66: Circuit Diagram

15. Determine, by successive conversions between Thévenin and Norton equivalent networks, a Thévenin equivalent circuit for terminals AB of Figure 2.67. Hence determine the current flowing in a 6Ω resistor connected between A and B.

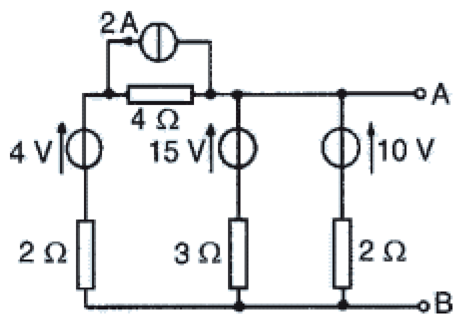


Figure 2.67: Circuit Diagram

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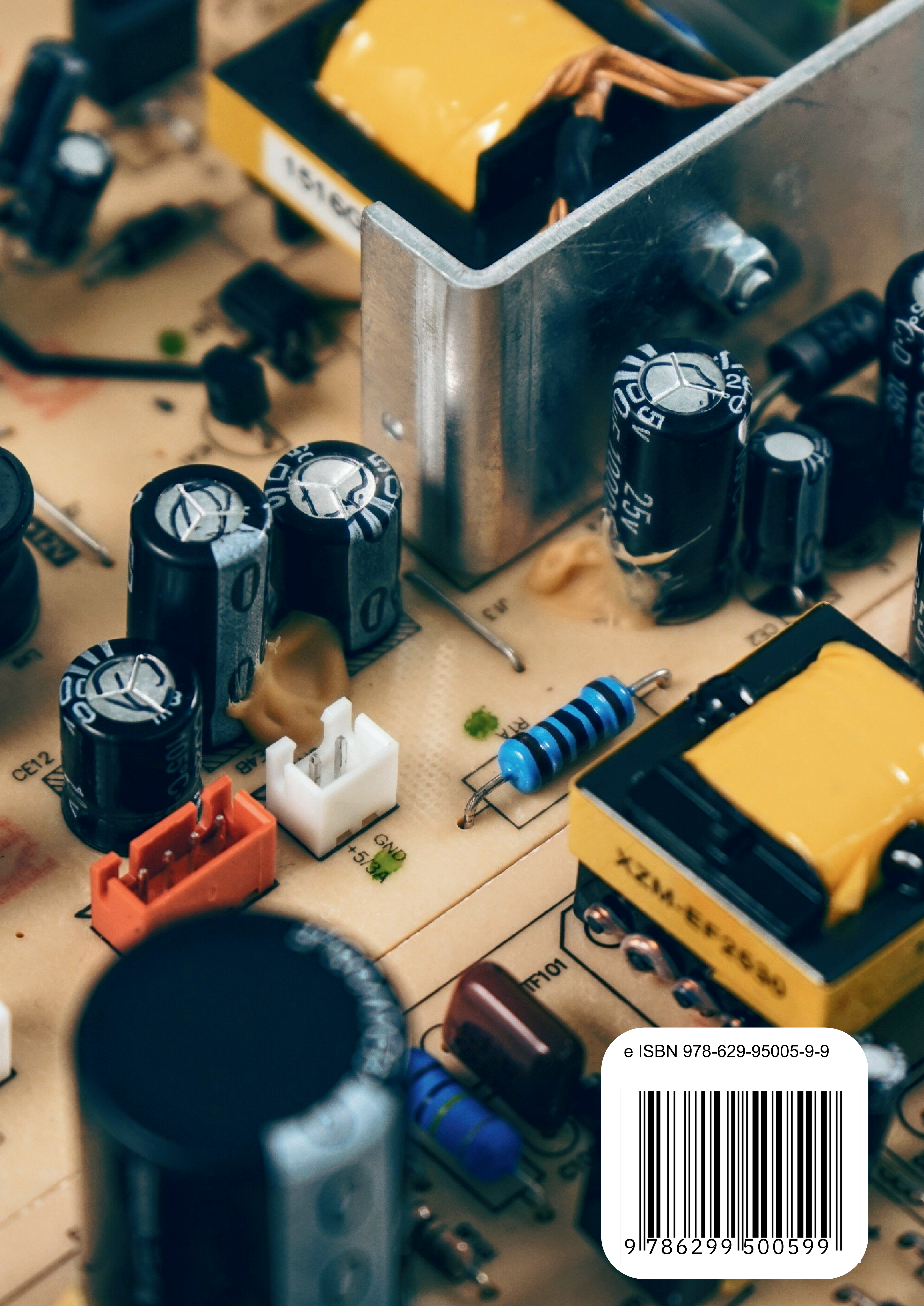

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