UNIT I

KIRCHOFF'S

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INTRODUCTION KIRCHOFF'S LAW

HISTORY OF KIRCHOFF'S LAW

INTRODUCTION

TYPES OF KIRCHOFF'S LAW

HISTORY OF KIRCHOFF'S LAW

Gustav Robert Kirchhoff (German physicist)

described two laws that became central to electrical engineering in 1845

The laws were generalized from the work of Georg Ohm

It's can also be derived from Maxwell's equations, but were developed prior to Maxwell's work

INTRODUCTION

What ?

- A pair of laws stating general restrictions on the current and voltage in an electric circuit.

How ?

- The first of these states that at any given instant the sum of the voltages around any closed path, or loop, in the network is zero.
- The second states that at any junction of paths, or node, in a network the sum of the currents arriving at any instant is equal to the sum of the currents flowing away.

TYPES OF KIRCHOFF'S LAW

KVL

- Kirchoff Voltage Law

KCL

- Kirchoff Current Law

KIRCHOFF'S VOLTAGE LAW

INTRODUCTION KVL

MESH ANALYSIS

EXERCISE

INTRODUCTION KVL

Kirchhoff's Voltage Law - KVL - is one of two fundamental laws in electrical engineering, the other being Kirchhoff's Current Law (KCL)

KVL is a fundamental law, as fundamental as Conservation of Energy in mechanics, for example, because KVL is really conservation of electrical energy

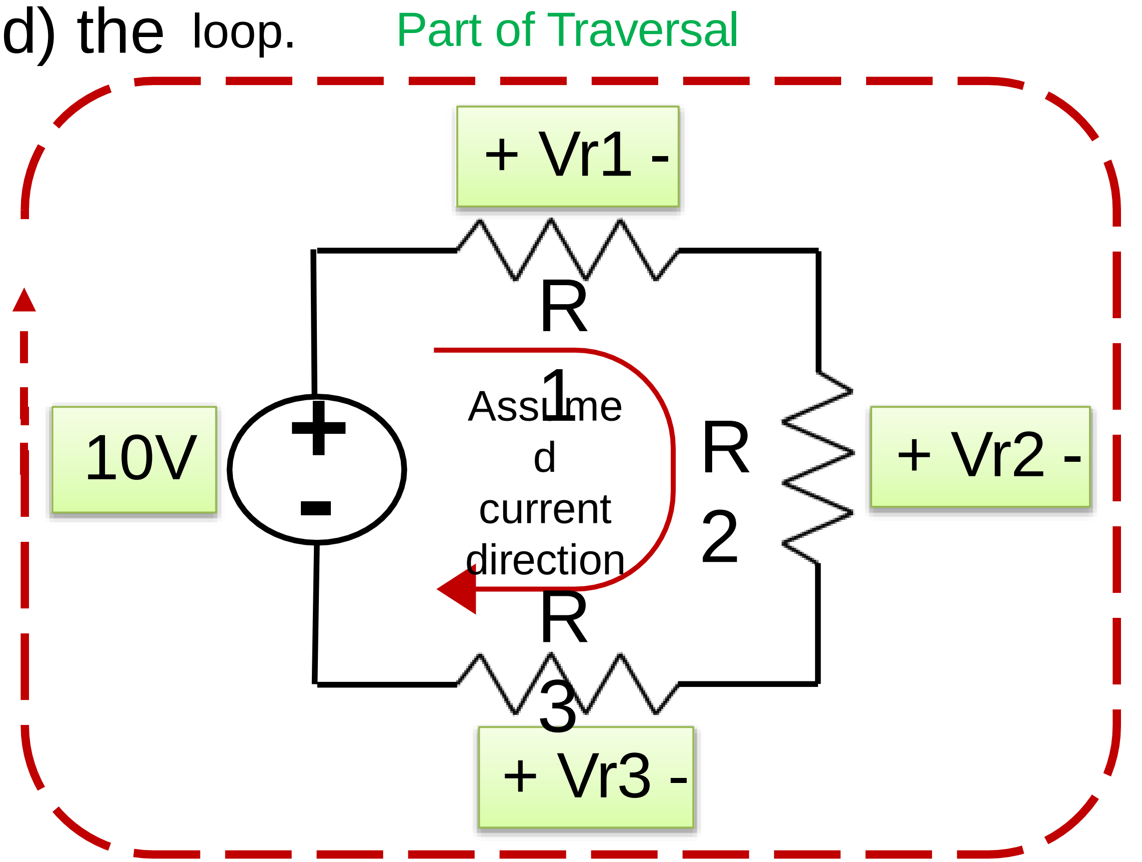
KVL and KCL are the starting point for analysis of any circuit

KCL and KVL always hold and are usually the most useful piece of information you will have about a circuit after the circuit itself

- Kirchoff’s Voltage Law (KVL) states that the algebraic sum of the voltages across any set of branches in a closed loop is zero. i.e.:

$$\sum V_{acrossbranches} = 0$$

- Below is a single loop circuit. The KVL computation is expressed graphically in that voltages around a loop are summed up by traversing (figuratively walking around) the loop.



Resulting KVL Equation: $V_{r1}+V_{r2}+V_{r3}-10=0$

- The KVL equation is obtained by traversing a circuit loop in either direction and writing down unchanged the voltage of each element whose “+” terminal is entered first and writing down the negative of every element’s voltage where the minus sign is first met.

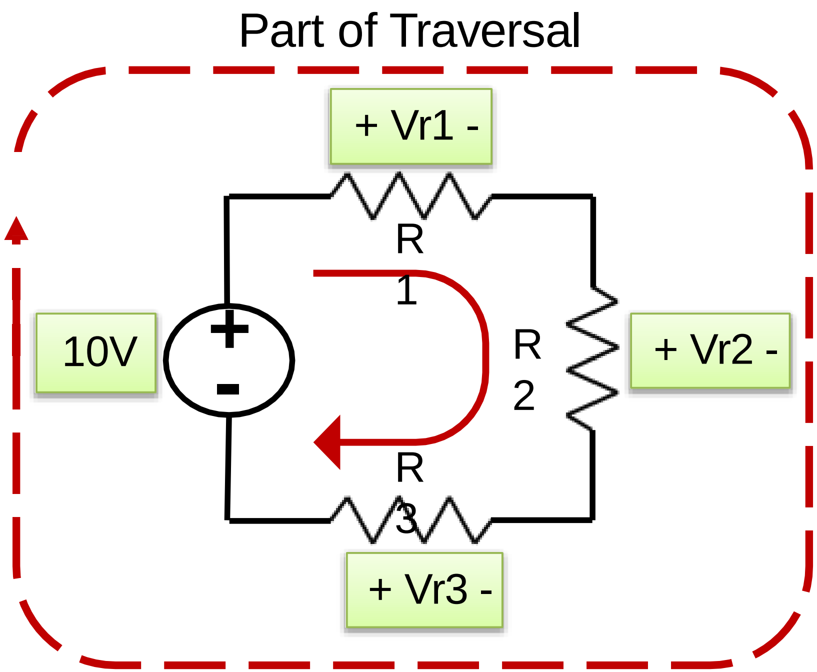
- The loop must start and end at the same point. It does not matter where you
start on the loop.

- Note that a current direction must have been assumed. The assumed current creates a voltage across each resistor and fixes the position of the “+” and “-” signs so that the passive sign con-vention is obeyed.

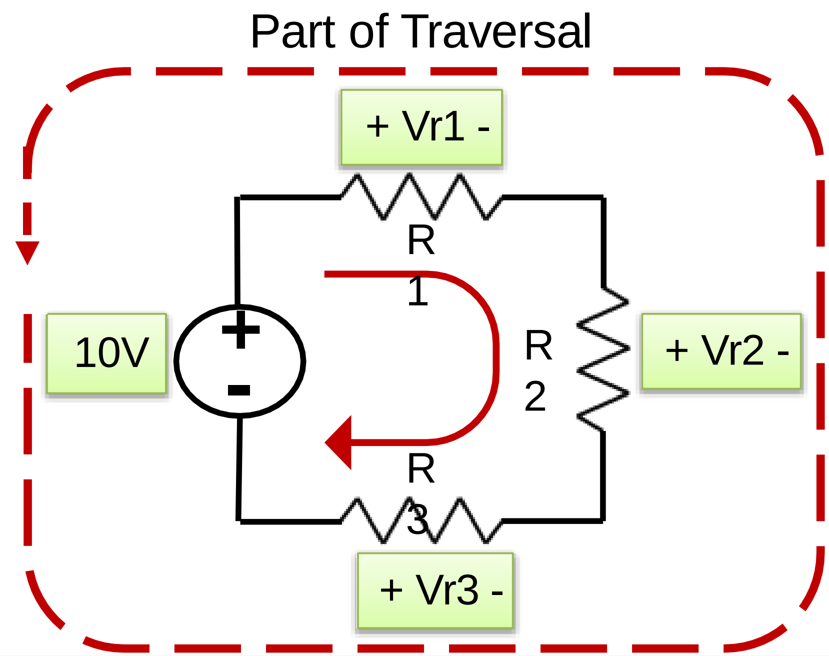
- The assumed current direction and polarity of the voltage across each resistor must be in agreement with the passive sign convention for KVL analysis to work.

- The voltages in the loop may be summed in either direction. It makes no difference except to change all the signs in the resulting equation. Mathematically speaking, its as if the KVL equation is multiplied by -1. See the illustration below.

Summation of voltage terms may be done in either direction



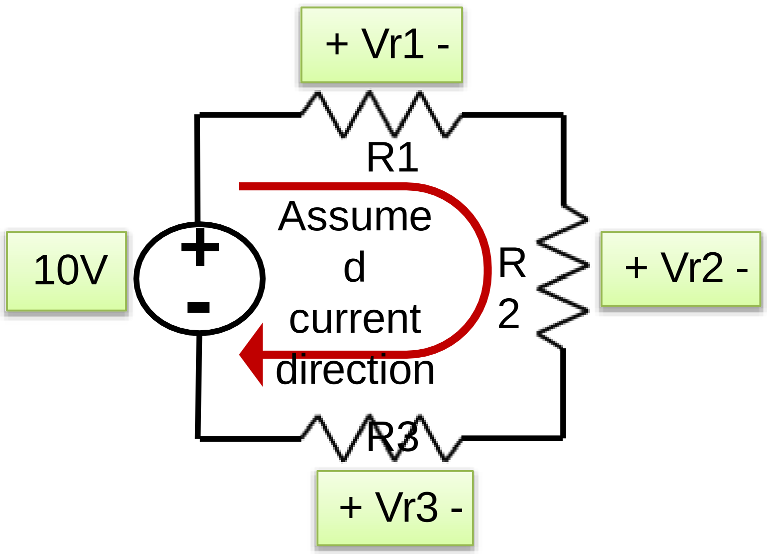
Resulting KVL Equation: $V_{r1}+V_{r2}+V_{r3}-10=0$



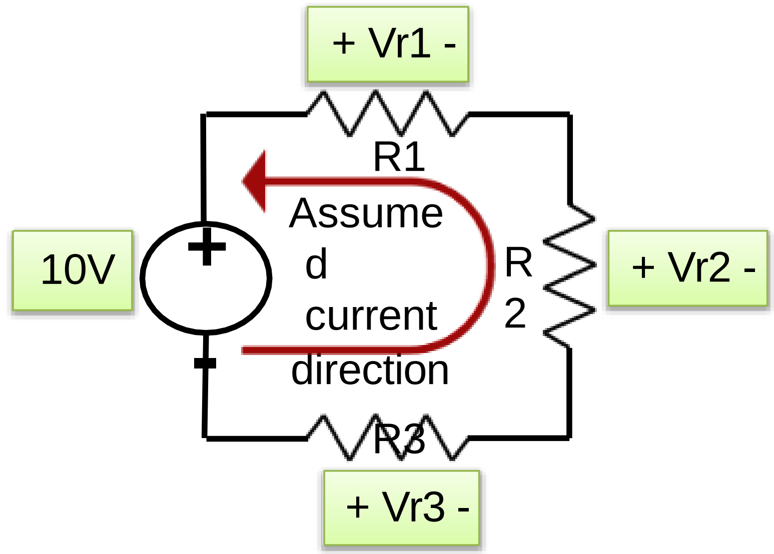
Resulting KVL Equation: $-V_{r1}-V_{r2}-V_{r3}+10=0$

For both summations, the assumed current direction was the same

Assuming the current direction fixes the voltage references



Resulting KVL Equation: $V_{r1}+V_{r2}+V_{r3}-10=0$



Resulting KVL Equation: $-V_{r1}-V_{r2}-V_{r3}-10=0$

For both cases shown, the direction of summation was the same

MESH ANALYSIS

- Analysis using KVL to solve for the currents around each closed loop of the network and hence determine the currents through and voltages across each elements of the network

- Mesh analysis procedure

STEP 1

Assign a distinct current to each closed loop of the network

STEP 2

Apply KVL around each closed loop of the network

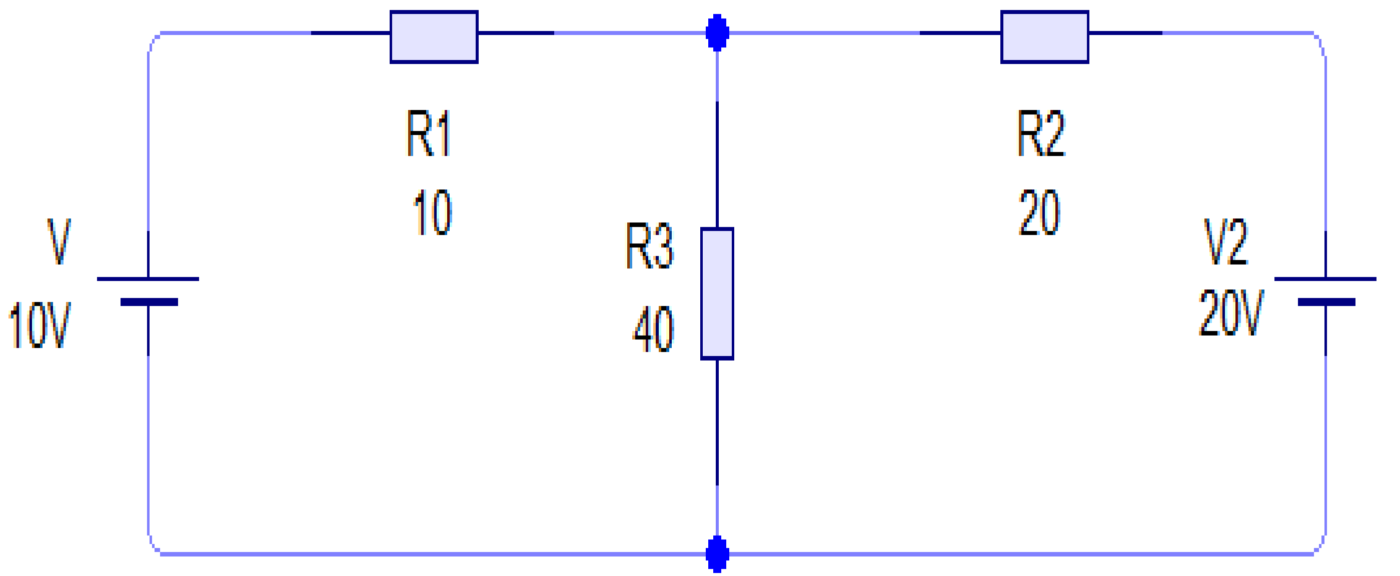
STEP 3

Solve the resulting simultaneous linear equation for the loop currents

EXERCISE

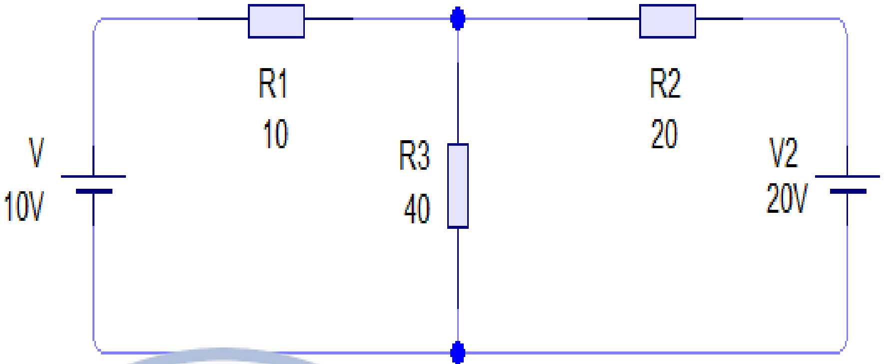
- Exercise 1

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



EXERCISE 1

❖ SOLUTION



STEP 1

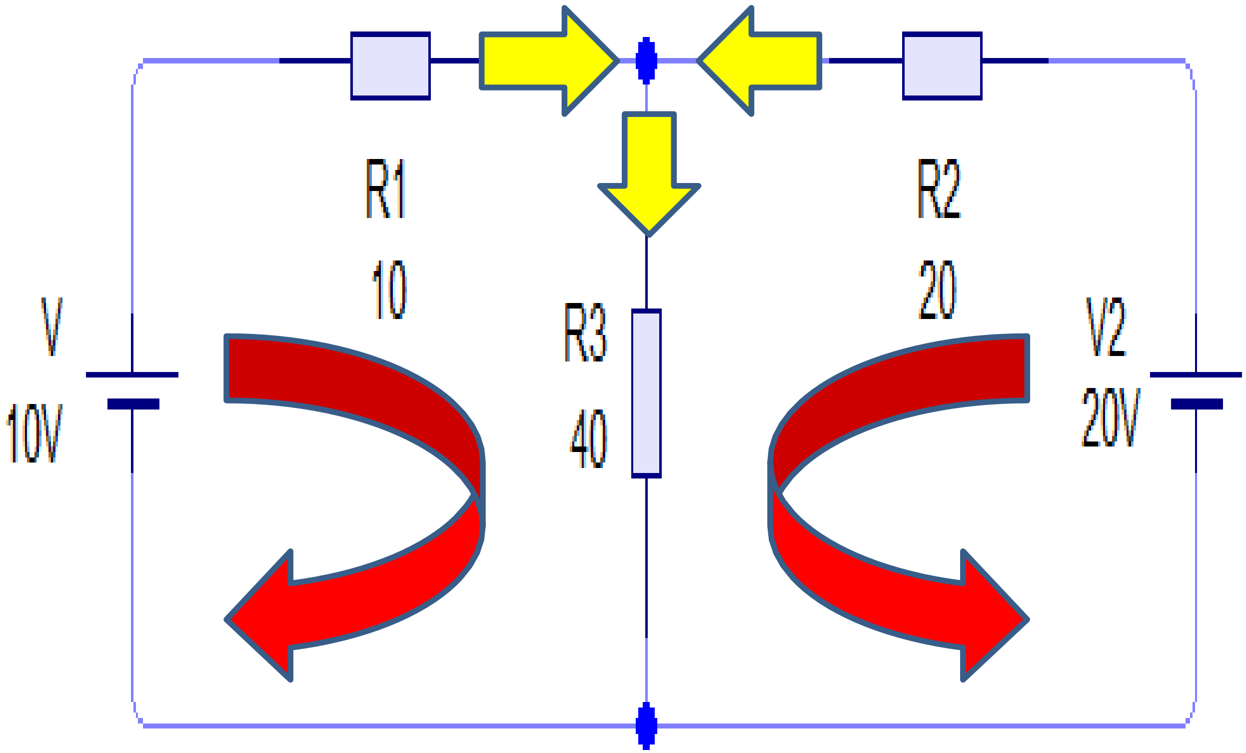
- Assign a distinct current to each closed loop of the network

STEP 2

- Apply KVL around each closed loop of the network

STEP 3

- Solve the resulting simultaneous linear equation for the loop currents



STEP 1

S T E P 2

$Loop1:$

$$I_1 R_1 + I_1 R_3 + I_2 R_3 = V_1$$

$$10I_1 + 40I_1 + 40I_2 = 10$$

$$50I_1 + 40I_2 = 10 ----equation1$$

$Loop2:$

$$I_2 R_2 + I_2 R_3 + I_1 R_3 = V_2$$

$$20I_2 + 40I_2 + 40I_1 = 20$$

$$40I_1 + 60I_2 = 20 ----equation2$$

Solve equation 1 and equation 2 using Matrix

STEP 3

$$50I_1 + 40I_2 = 10$$

$$40I_1 + 60I_2 = 20$$

$$Matrixform:$$

$$\begin{bmatrix} 50 & 40 \\ 40 & 60 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 20 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 50 & 40 \\ 40 & 60 \end{vmatrix} = 3000 - 1600 = 1400$$

$$\Delta I_1 = \begin{vmatrix} 10 & 40 \\ 20 & 60 \end{vmatrix} = 600 - 800 = -200$$

$$\Delta I_2 = \begin{vmatrix} 50 & 10 \\ 40 & 20 \end{vmatrix} = 1000 - 400 = 600$$

$$I_1 = \frac{\Delta I_1}{\Delta} = \frac{-200}{1400} = -0.143A$$

$$I_2 = \frac{\Delta I_2}{\Delta} = \frac{600}{1400} = 0.429A$$

$$FromKCL:$$

$$I_3 = I_1 + I_2 = -0.143A + 0.429A = 0.286A$$

KIRCHOFF'S CURRENT LAW

INTRODUCTION KCL

NODES ANALYSIS

EXERCISE

EXIT

INTRODUCTION OF KCL

1

Kirchhoff's Current Law is sometimes called "Kirchhoff's First Law" or "Kirchhoff's Junction Rule"

along with Kirchhoff's Voltage Law makes up the two fundamental laws of Electrical Engineering

2

In this lesson it will be shown how Kirchhoff's Current Law describes the current flow through a junction of a circuit

3

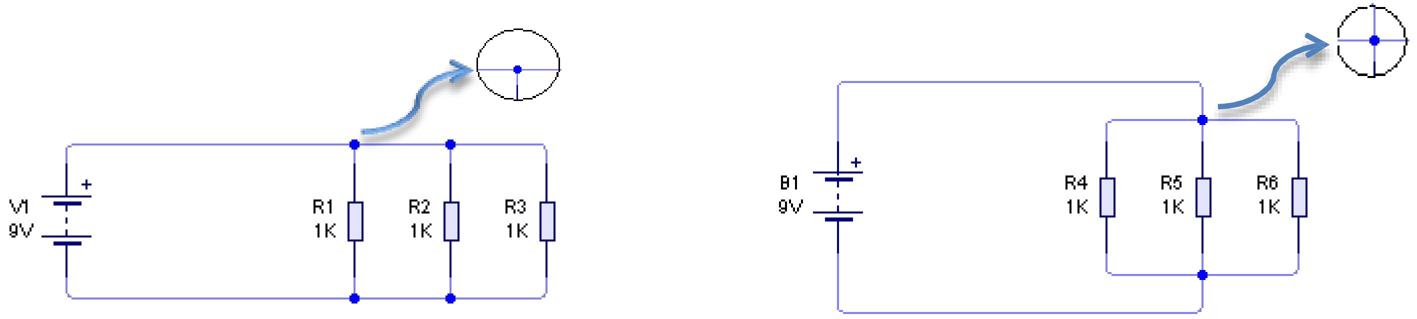
KCL helps to solve unknowns when working with electrical circuits

4

KCL with the addition of KVL and Ohm's Law will allow for the solution of complex circuits

- Definition that will help in understanding Kirchhoff's Current Law:

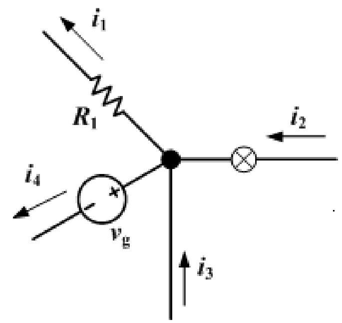
Junction - A junction is any point in a circuit where two or more circuit paths come together.



Examples of a Junction

- Kirchhoff's Current Law generally states:

The algebraic sum of all currents entering (+) and leaving (-) any point (junction) in a circuit must equal zero.

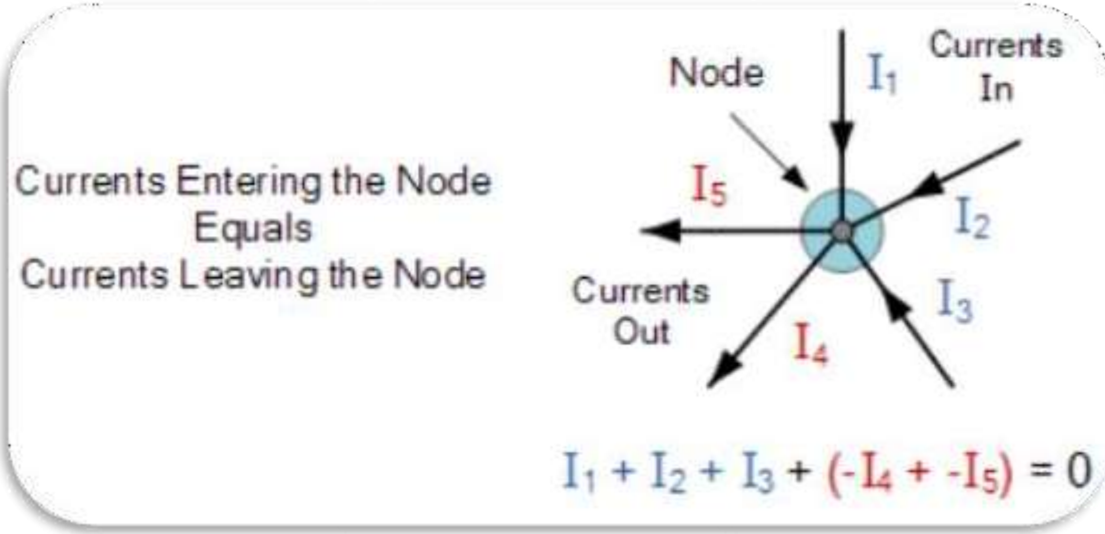


$$\sum_n i_n = i_1 + i_2 + i_3 + i_4 = 0$$

- Restated as:

The sum of the currents into a junction is equal to the sum of the currents out of that junction.

- The algebraic sum of all currents entering (+) and leaving (-) any point (junction) in a circuit must equal zero.



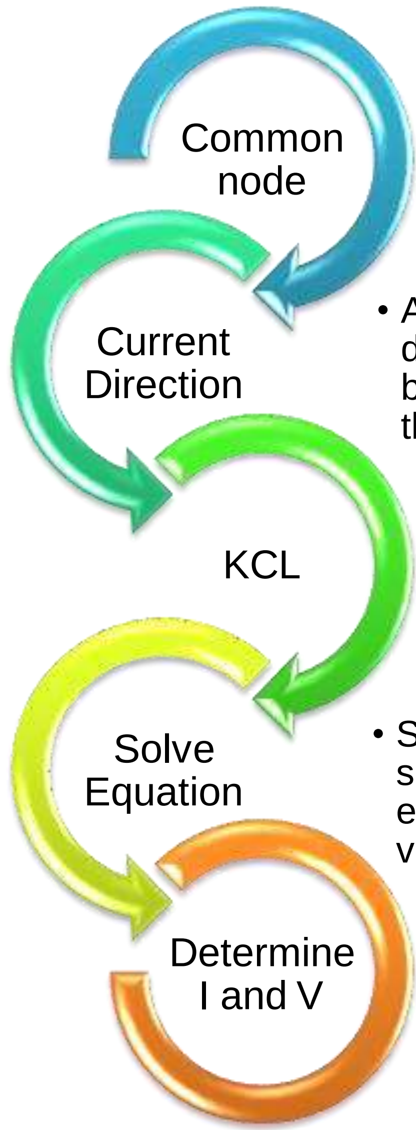
- Here, the 3 currents entering the node, I_1, I_2, I_3 are all positive in value and the 2 currents leaving the node, I_4 and I_5 are negative in value. Then this means we can also rewrite the equation as;

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

NODES ANALYSIS

Analysis using KCL to solve for voltages at each common node of the network and hence determine the currents though and voltages across each elements of the network.

Nodes Analysis Procedure

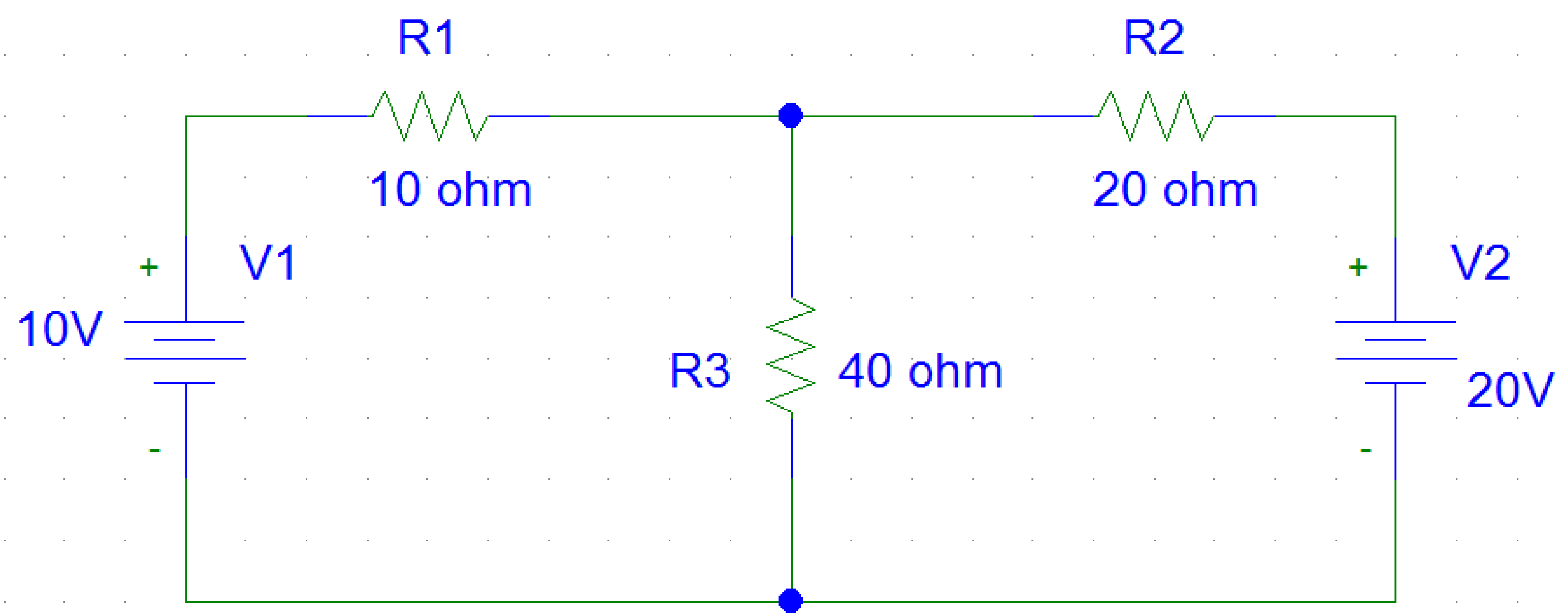


- Determine the number of common nodes and reference node within the network
- Assign current and its direction to each distinct branch of the nodes in the network
- Apply KCL at each of the common nodes in the network
- Solve the resulting simultaneous linear equation for the node voltage
- Determine the currents through and voltages across each elements in the network

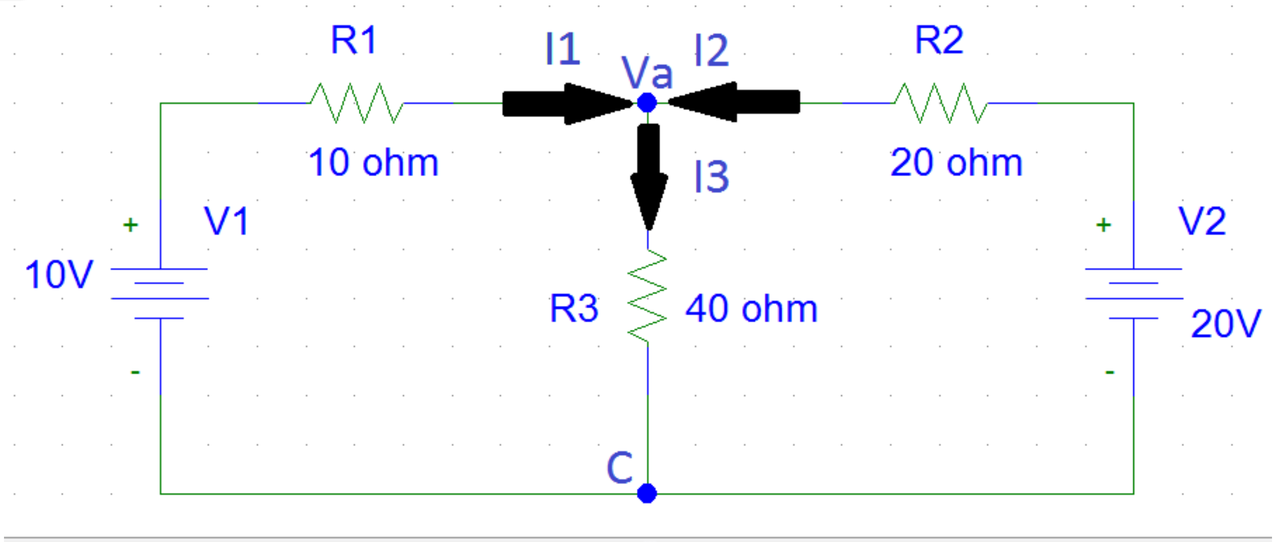
EXERCISE

Example 1:

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



EXERCISE



REMEMBER THE STEPS EARLIER??

Determine the number of common nodes and reference node within the network.

1 common node (Va) and 1 reference node C

Assign current and its direction to each distinct branch of the nodes in the network (refer o the figure)

Apply KCL at each of the common nodes in the network

KCL: I1 + I2 = I3

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

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

$$\frac{Va}{40}+\frac{Va}{10}+\frac{Va}{20}=2$$

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

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

$$Va = 11.428V$$

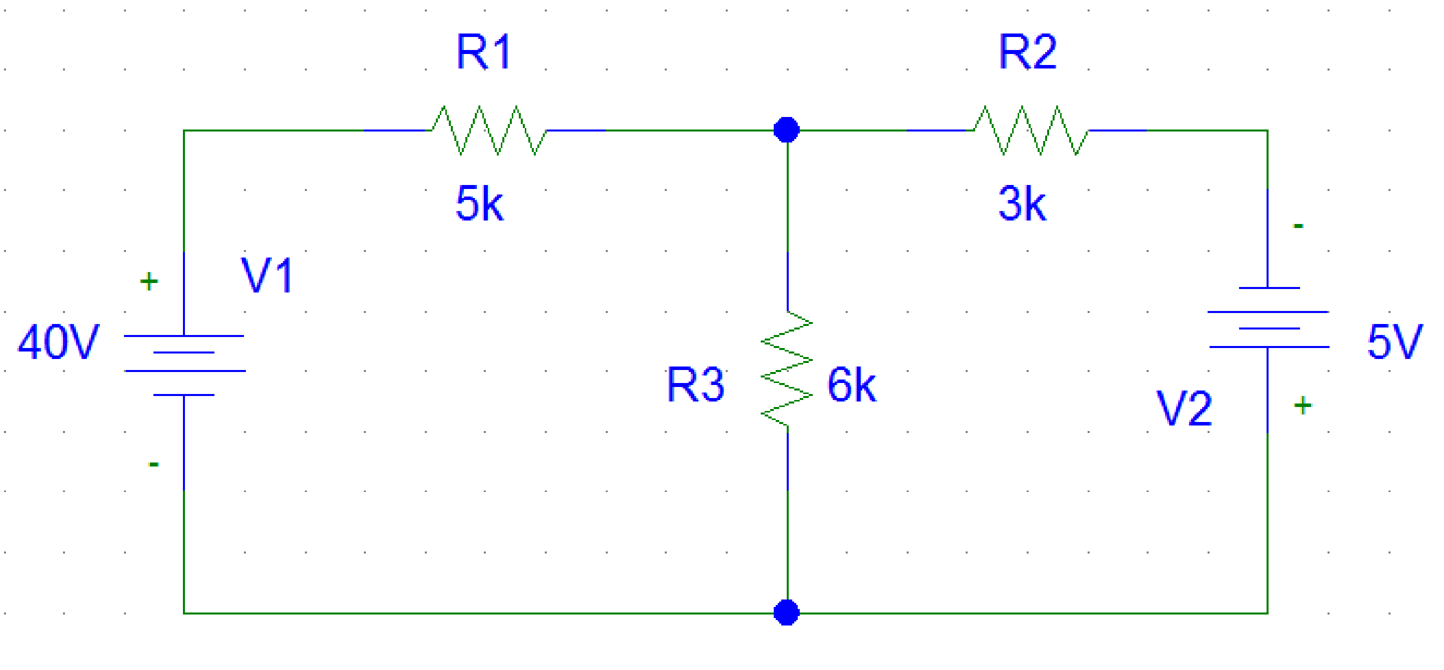
$$I_1 = \frac{(10-11.428)}{10} = -0.143A$$

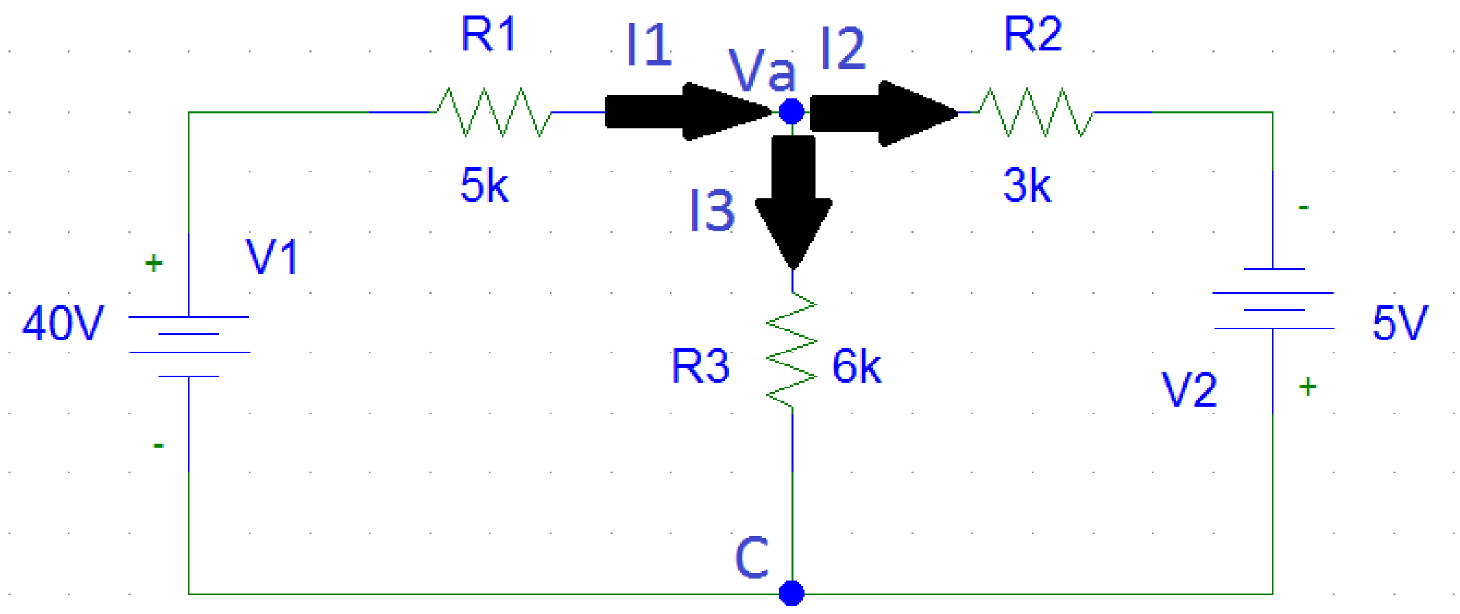
$$I_2 = \frac{(20-11.428)}{20} = 0.429A$$

$$I_3 = \frac{11.428}{40} = 0.286V$$

Example 2:

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





REMEMBER THE STEPS EARLIER??

Determine the number of common nodes and reference node within the network.

1 common node (Va) and 1 reference node C

Assign current and its direction to each distinct branch of the nodes in the network (refer o the figure)

Apply KCL at each of the common nodes in the network

KCL: I1 = I2 + I3

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

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

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

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

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

$$V_a = -14.757V$$

$$I_1 = \frac{(40-(-14.757))}{5k} = 10.95mA$$

$$I_2 = \frac{(-14.757+55)}{3k} = 13.41mA$$

$$I_3 = \frac{(-14.757)}{6k} = -2.46mA$$

EXIT

Q1

Q2

Q3

Q4

Q5

Q6

Q7

Q8

Q9

Q10

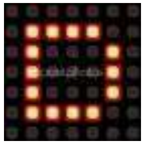
Kirchhoff's First Law says that:

Question 1

Current loses strength as it flows about a circuit

Voltage loses strength as it flows about a circuit

Wires need insulation to stop electrons from leaking out of the wire



Total current flowing into a point is the same as the current flowing out of that point

Question 2

KCL is used when solving circuits with . . .

A. Closed loops

B. Sufficient nodes/ junctions

C. Capacitors

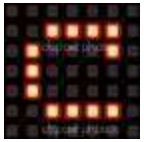
D. None

Question 3

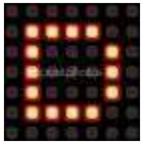
Nodal Analysis applies the following principles…

KVL & Ohm's Law

KCL & Ohm's Law



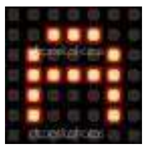
KVL & Superposition



KCL & Superposition

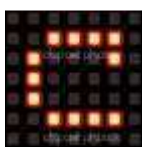
Question 4

Which of the following statements is true?

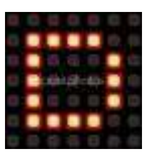


Mesh Analysis is easiest when a circuit has more than two nodes

Mesh Analysis is more difficult than Nodal Analysis



Mesh Analysis employs KVL to solve loop currents



All of t All of the above

Question 5

If a circuit contains three loops, how many *independent* equations can be obtained with Kirchhoff's Second laws?

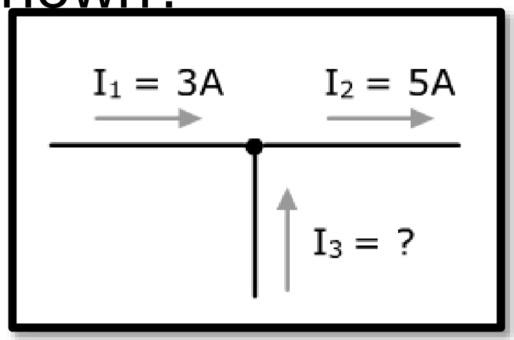
Three

Four

Five

Six

How much is current I_3 in the node shown?

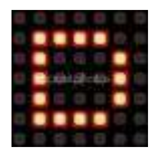


Question 6

2A

-2A

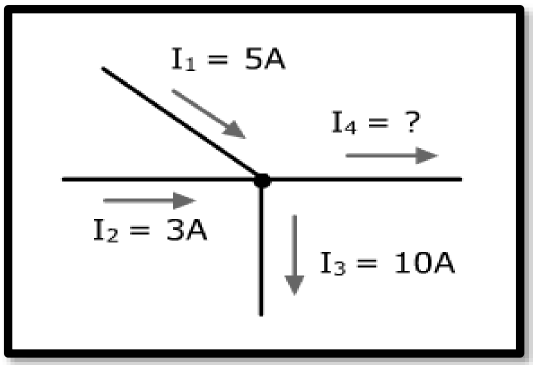
0A



8A

Question 7

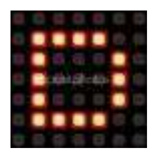
How much is current I_4 in the node shown?



2A

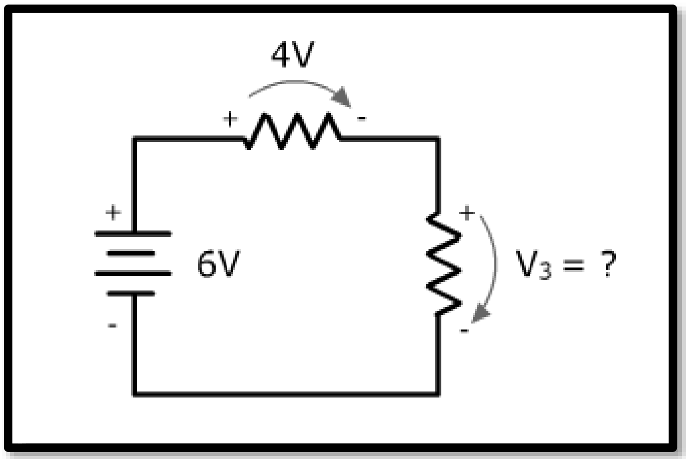
-2A

18A



8A

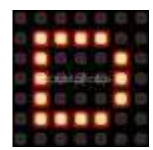
How much is voltage V_3 in the closed loop circuit shown?



2A

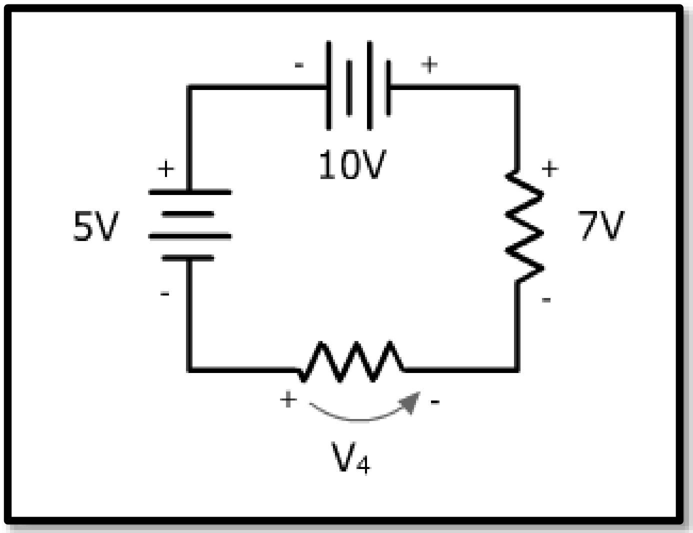
-2A

10A



-10A

How much is voltage V_4 in the closed loop circuit shown?



4A

-4A

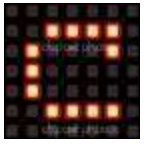
8A

-8A

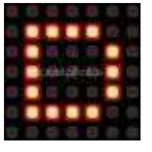
Using KVL, find the value of R_x in the circuit shown

8Ω

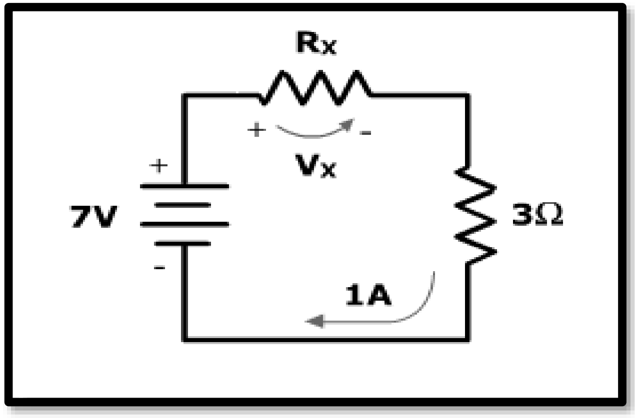
4Ω



2Ω



1Ω



GO BACK TO QUESTION

Q
Q2
Q3
Q
Q5
Q6
Q7
Q
Q
Q10

GO BACK TO QUESTION

Q

Q2

Q3

Q

Q5

Q6

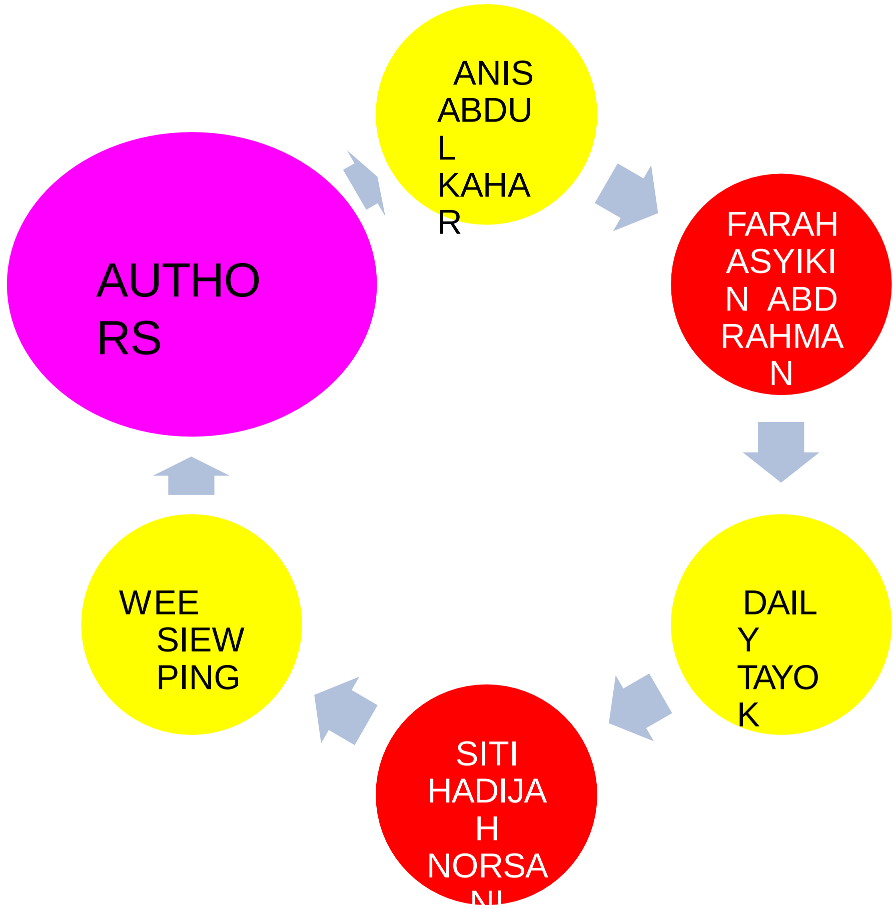
Q7

Q

Q

Q10

❑ REFERENCES



MUKAH KOTA KINABALU MUADZAM SHAH KOTA BAHRU

SPECIAL THANKS TO

- JABATAN PENGAJIAN POLITEKNIK
- CeLT
- CIDOS
- POLITEKNIK MUKAH, SARAWAK
- POLITEKNIK KOTA KINABALU, SABAH
- POLITEKNIK MUADZAM SHAH, PAHANG
- POLITEKNIK KOTA BHARU, KELANTAN