# Circuit Simulation :



INPUT SETUP

MODEL

Numerical Solver

- Formulation of circuit equations
- Solution of ODE.
- Solution of non-linear eqn.
- Solution of linear eqn.

Output
Voltage, Currents

# Circuit Analysis :



- Electrical circuit elements are idealized models of physical devices that are defined by relationships between their terminal voltages and currents.

- An electrical circuit is a connection of circuit elements into one or more closed loops

- Basic quantities are voltage, currents and power.

- Circuit elements can be active or passive.

- The "Sign Convention" is important in computing output.

## Kirchhoff's Current Law (KCL) :

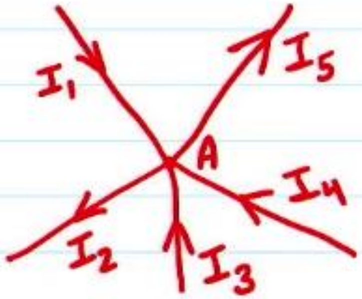
KCL states that the algebraic sum of currents entering a node (or a closed boundary) is zero.

- Before applying KCL, sign convention is very important.

Current entering the node "−"

Current leaving the node "+"

- Applying KCL to circuit :




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

$$\boxed{I_2 + I_5 = I_1 + I_3 + I_4}$$

$$\sum_{n=1}^{N} I_n = 0$$

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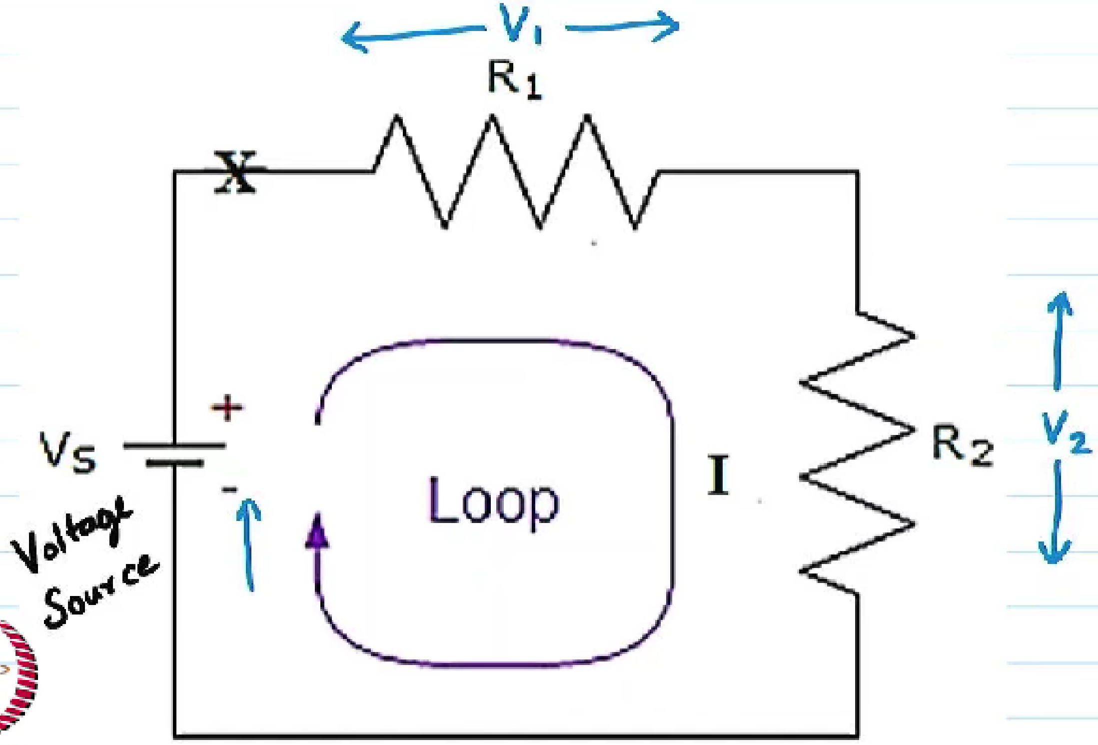
# Kirchhoff's Voltage Law (KVL)



- KVL states that the algebraic sum of all voltages around a closed path (or loop) is zero.

For example:




$$IR_1 + IR_2 - V_S = 0$$

$$\sum_{n=1}^{N} V_n = 0$$

## Why need KVL and KCL ?

- Ohm's law by itself is not sufficient to analyze circuits.
- Coupled with KCL and KVL to solve the circuits.
- KCL is based upon the law of conservation of charge.
- KVL is based upon the law of conservation of energy.
- KVL and KCL can be applied to AC circuits as well, provided we use phasor sums instead of algebraic sums.

How do we solve circuits ?



## MESH Analysis

- Loop : It is a closed path with no node passed more than once.

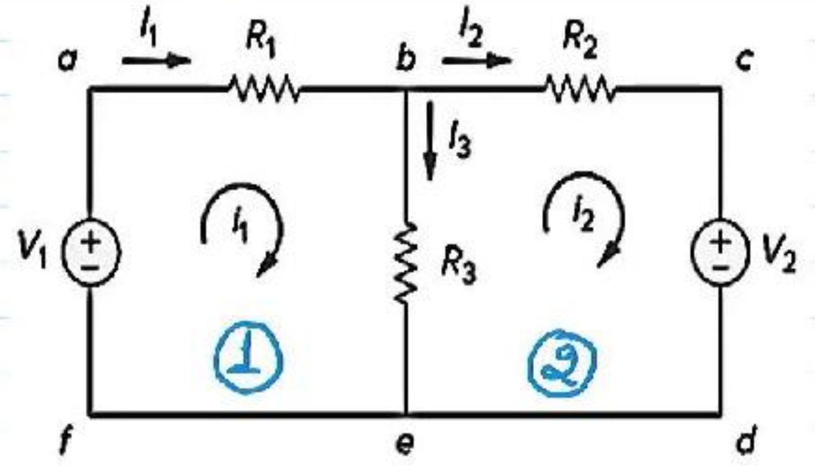
- Mesh : A mesh is a loop that does not contain any other loop within it.

- Mesh Analysis : is applicable to circuits that are planer.

- Planer Circuits : A planer circuit is one that can be drawn in a plane with no branch crossing one another.

- Non-planer circuits : A non-planer circuit is one that can be drawn in a plane with branches crossing one another.

Example :




Apply KVL in mesh 1.

$$-V_1 + i_1R_1 + i_3R_3 = 0 \quad \text{---- (1)}$$

Apply KCL at node b

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

$$i_3 = i_1 - i_2 \quad \text{---- (2)}$$

putting $i_3$ in eqn. 1,

$$\boxed{V_1 = (R_1 + R_3)\,i_1 - R_3 i_2}$$

Apply KVL in mesh 2.

$$R_2 i_2 + V_2 - R_3 i_3 = 0$$

$$R_2 i_2 + V_2 - R_3(i_1 - i_2) = 0$$

$$\boxed{V_2 = -R_3 i_3 + (R_1 + R_2)\,i_2}$$

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## Example:

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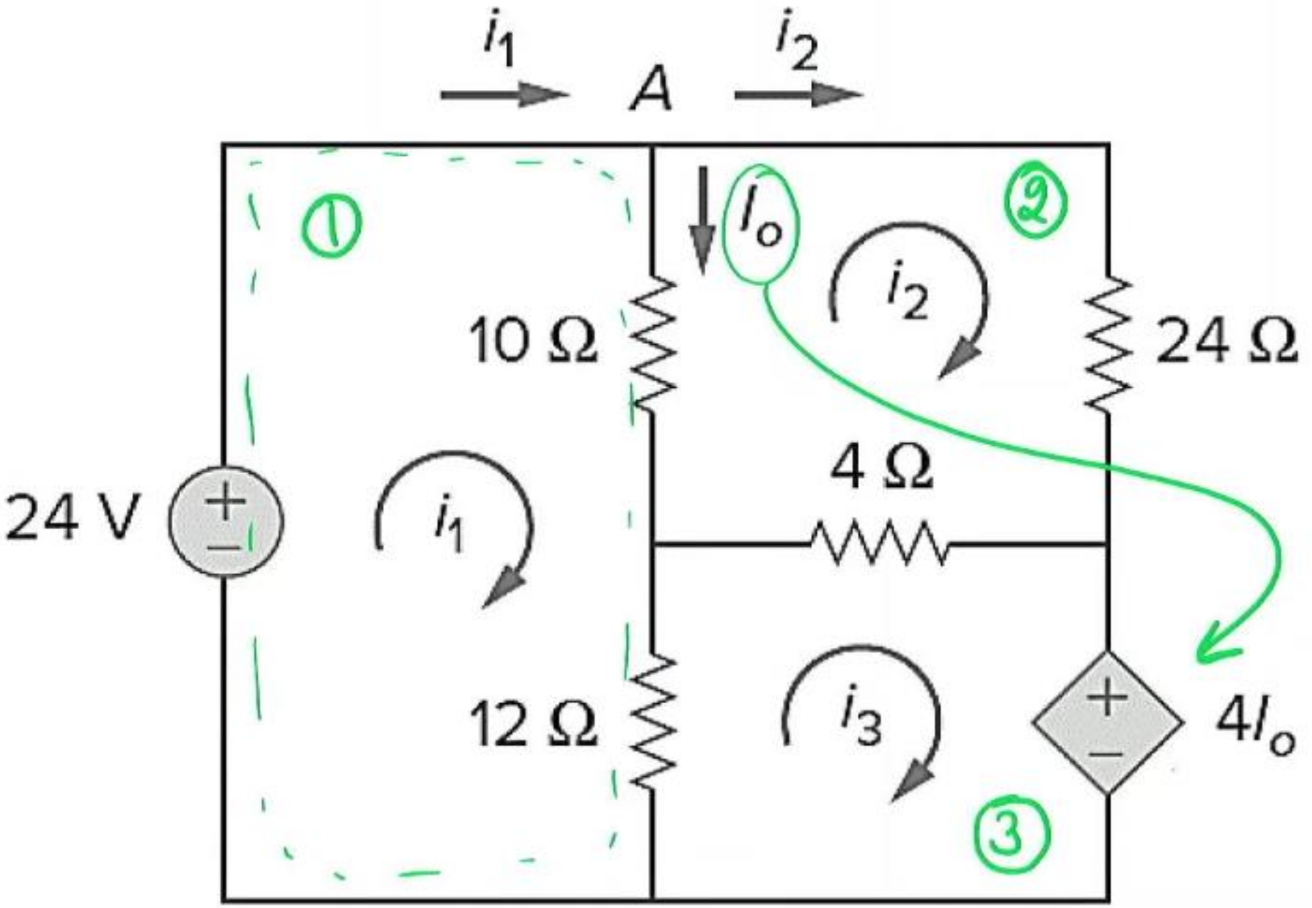
Find mesh currents $i_1$, $i_2$, $i_3$ *and* $i_o$ using mesh analysis.

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## Example:

Applying KVL in mesh 1.

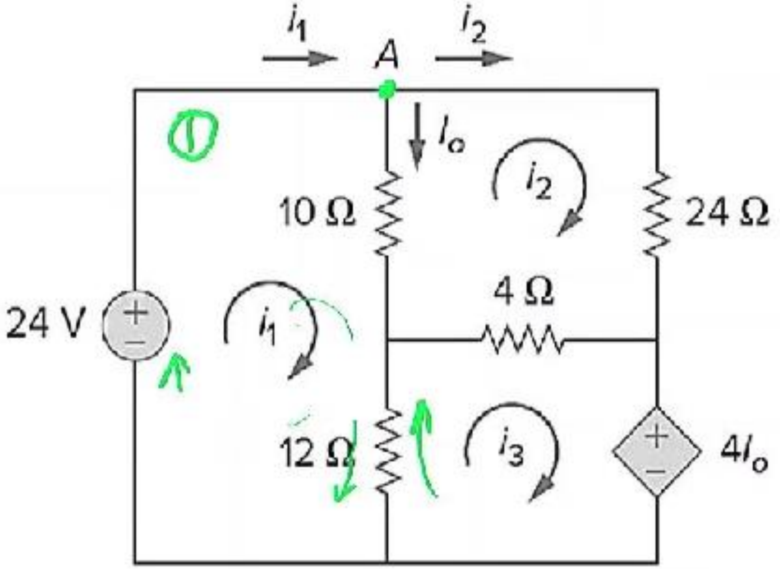
$$-24+10(i_1-i_2)+12(i_1-i_3)=0 \Rightarrow 11i_1-5i_2-6i_3=12 \qquad (1)$$

Applying KVL in mesh 2,

$$24i_2+4(i_2-i_3)+10(i_2-i_1)=0 \Rightarrow -5i_1+19i_2-2i_3=0 \qquad (2)$$

Applying KVL in mesh 3

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

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# Example:

But at node A, $I_o = i_1 - i_2$, so that

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

$$\Rightarrow -i_1 - i_2 + 2i_3 = 0 \quad (3)$$

Using cramers' rule to solve 3 unknown variables and writing in matrix form.

$$\begin{bmatrix} 11 & -5 & -6 \\ -5 & 19 & -2 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 12 \\ 0 \\ 0 \end{bmatrix}$$

$$\Delta = \det \begin{bmatrix} 11 & -5 & -6 \\ -5 & 19 & -2 \\ -1 & -1 & 2 \end{bmatrix} = 192$$

$$\Delta_1 = \det \begin{bmatrix} 12 & -5 & -6 \\ 0 & 19 & -2 \\ 0 & -1 & 2 \end{bmatrix} = 432$$

$$\Delta_2 = \det \begin{bmatrix} 11 & 12 & -6 \\ -5 & 0 & -2 \\ -1 & 0 & 2 \end{bmatrix} = 144$$

$$\Delta_3 = \det \begin{bmatrix} 11 & -5 & 12 \\ -5 & 19 & 0 \\ -1 & -1 & 0 \end{bmatrix} = 288$$

$$\boxed{\begin{aligned} i_1 &= \frac{\Delta_1}{\Delta} = 2.25A, i_2 = \frac{\Delta_2}{\Delta} = 0.75A \\ i_3 &= \frac{\Delta_3}{\Delta} = 1.5A \end{aligned}}$$

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