# ECEN101C

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# Contents

# Chapter 1

# Introduction to electric circuits

## 1.1 Volt classification

Electric volt can be classified into three categories: low, Medium and high.

| Low voltage | Medium voltage | High voltage |
|---|---|---|
| :1000V | 1kV:50kV | 50kV:500kv |

## 1.2 Electric circuit components

For an electric circuit to be one some elements need to be present.

1. Power supplies:
   A power supply is needed to create a potential difference to provide the circuit with a current.

2. A load:
   "loads" are energies converted in the circuit by elements that consume the power generated.

3. Wires:
   Wires are used to connect all the elements of the circuit together (Most commonly made of copper or aluminum).

4. Switches:
   Switches are used to "open" or "close" the circuit in order for current to pass.

## 1.3 Basic circuit quantities

1. The electric charge $q$ (C: Coulomb)

2. The electric current $I$ (A: Ampere):
   The current is the rate of change of the quantity of charge in a certain time period.

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

$$\therefore q = \int i(t).dt$$

   Example:

$$q = 12e^{-12t} \rightarrow I = (-12)12e^{-12t}$$

3. The potential difference (V = J/C: Volt/Joule per Coloumb):
   The potential difference is the energy affecting the charge moving it a certain distance.

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

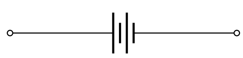
4. The electric energy (Joule)

5. The electric power (W = J/s: Watt/Joule per second):
   Power is the energy consumed/delivered in a certain period of time.

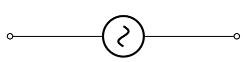
$$P = \frac{dW}{dt} = I \times V = I^2 \times R = \frac{V^2}{R}$$

## 1.4 Circuit types

1. DC circuits:
   Direct current circuits are circuits with constant voltage and current.



2. AC circuits:
   Alternating current circuits are circuits with alternating voltage and current.



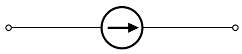
## 1.5 Basic circuit elements

- Passive elements:
  Elements that absorb the power generated by the active elements.

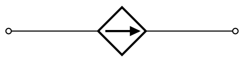
  Some of the common passive elements seen in circuits:

| Element | Unit | Found in |
|---|---|---|
| Resistors | Ohm ($\Omega$) | AC and DC |
| Electrical coils | Henry (L) | AC only |
| Capacitors | Farad (C) | AC only |

- Active elements:
  Elements that generate power for the circuit.
  - Current sources
    1. Independant Current sources:
       Independant sources provide constant current intensity.

    2. Dependant current sources:
       Dependant sources have variable current intensities and are either:

       * Voltage controlled ($V_x$)
       * Current controlled ($I_y$)

# Chapter 2

# Basic circuit laws

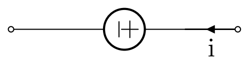
## 2.1 Ohm's law

$$\boxed{V = I \times R}$$

**Power types and the conventional sign rule**

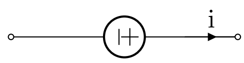
- Power absorbed

  Power is absorbed when the current's direction is into the positive terminal




- Power supplied

  Power is supplied when the current's direction is into the negative terminal




For any balanced (ideal) circuit, the sum of the power consumed equals the sum of power absorbed.

$$\sum P_{abs} = \sum P_{con}$$

Note: The conventional sign rule is only applied when both the current and the voltage are positive and allows the switching of either the direction of a current of the terminals of a voltage source in case the magnitude is a negative value.

## 2.2 Kirchhoff's laws

### 2.2.1 Kirchhoff's voltage law

In any loop in a circuit, the sum of voltages across the loop equals zero

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

### 2.2.2 Series connection

Circuit elements are in series only if the same current intensity passes through them as the voltage is divided between the elements (not equally).
Therefore the equivalent resistance of a number of resistors in series is:

$$R_{eq} = \sum_{n=1}^{r} R_n$$

#### Voltage division

As the voltage is divided between the elements in series in non-uniform quantities, the voltage of each element can be found as the voltage is directly proportional with the value of the resistance of each element. Therefore:

$$V_a = V_t \times \frac{R_a}{R_{eq}}$$

## 2.3 Kirchhoff's current law

- Junctions: points of connection that connect only two circuit elements.
- Nodes: points of connection that connect more than two circuit elements.

At any node, the sum of currents with a direction into the node equals to the sum of currents with a direction outside the node.

$$\sum I_{in} = \sum I_{out}$$

### 2.3.1 Parallel connection

Circuit elements are in parallel only if they share the same starting and ending node as the current is divided between each element while the voltage remains the same.
Therefore the equivalent resistance of a number of resistors in series is:

$$\frac{1}{R_{eq}} = \sum_{n=1}^{r} \frac{1}{R_n}$$

**Current division**

As the current is devided between the elements in parallel non-uniform quantities, the current through each element can be found as the current intensity is inversly proportional with the value of the resistance of each element. Therefore:

$$I_a = I_t \times \frac{R_b}{R_a + R_b}$$

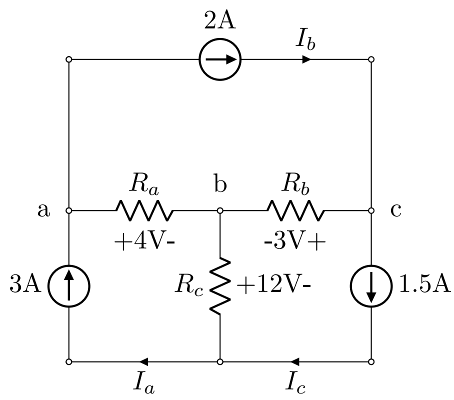
### 2.3.2 Conductance

Conductance ($G$) is the receprocal quantity to the electrical resistance and is measured in siemens ($S$)

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

## 2.4 Examples

1. Find the value of the resistors then verify the power balance.




KCL at node a:

$$\sum I_{in} = \sum I_{out} \rightarrow I_a + 2 = 3 \rightarrow I_a = 1A$$

$$\therefore R_a = \frac{4}{I_a}$$

KCL at node b:

$$\sum I_{in} = \sum I_{out} \rightarrow I_b + 1.5 = 2 \rightarrow I_b = 0.5A$$

$$\therefore R_b = \frac{3}{I_b}$$

KCL at node c:

$$\sum I_{in} = \sum I_{out} \rightarrow I_c + 1.5 = 3 \rightarrow I_c = 1.5A$$

$$\therefore R_c = \frac{12}{I_c}$$

By solving the three equations: $\rightarrow R_a = 4\Omega, \quad R_b = 6\Omega, \quad R_c = 8\Omega$
Verifying the power balance:

$$\sum P_{supplied} = \sum P_{abosrbed}$$

KVL at loop 1:

$$\Sigma V_{loop} = 0 \rightarrow -V_1 + 4 + 12 = 0 \rightarrow V_1 = 16V$$

$$\therefore P_{3A} = 16 \times 3 = 48W(supplied)$$

KVL at loop 2:

$$\Sigma V_{loop} = 0 \rightarrow -V_2 + 3 - 4 = 0 \rightarrow V_2 = -1V$$

$$\therefore P_{2A} = 2 \times 1 = 2W(absorbed)$$

KVL at loop 3:

$$\Sigma V_{loop} = 0 \rightarrow -V_3 - 12 - 3 = 0 \rightarrow V_2 = -15V$$

$$\therefore P_{1.5A} = 15 \times 1.5 = 22.5W(absorbed)$$

Power at $R_a$.

$$P_{R_a} = 4 \times I_a = 4W(absorbed)$$

Power at $R_b$.

$$P_{R_b} = 3 \times I_b = 1.5W(absorbed)$$

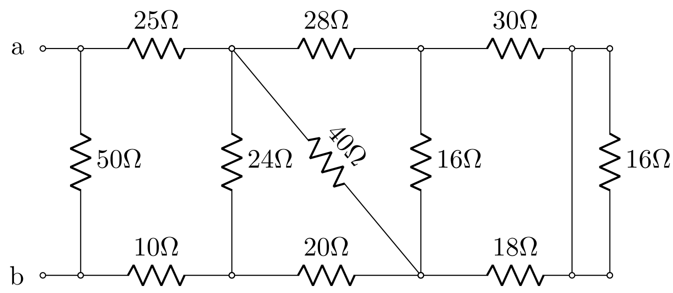
Power at $R_c$.

$$P_{R_a} = 12 \times I_c = 18W(absorbed)$$

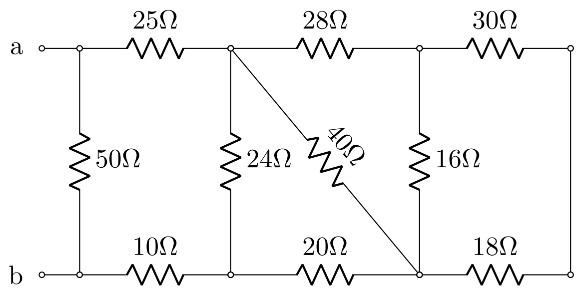
$$\therefore \Sigma P = -48 + 2 + 22.5 + 4 + 1.5 + 18 = 0$$

$$\therefore \text{The power balance verified.}$$

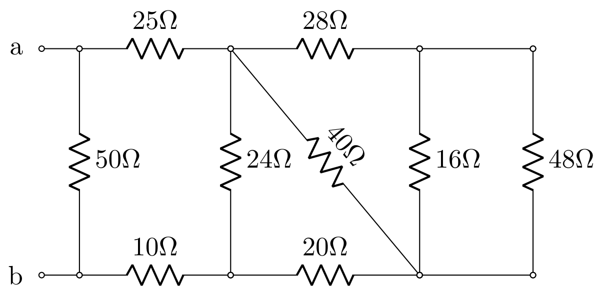
2. Find the equivalent resistance for the circuit given. If a power supply of 100V is connected to the circuit across a-b, find the total power absorbed by the circuit



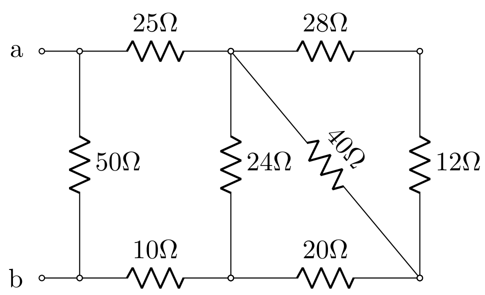

16 Ω is short circuited $\rightarrow \dfrac{0 \times 16}{0 + 16} = 0\Omega$



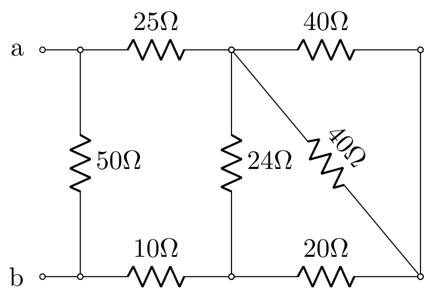

30 and 18 Ω are in series $\rightarrow 30 + 18 = 48\Omega$



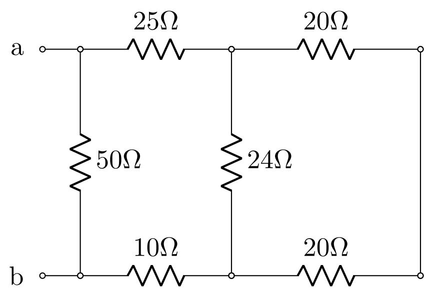

48 and 16 Ω are in parallel $\rightarrow \dfrac{48 \times 16}{48 + 16} = 12\Omega$



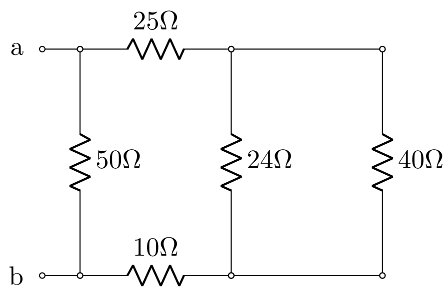
12 and 28 Ω are in series → $12 + 28 = 40\Omega$



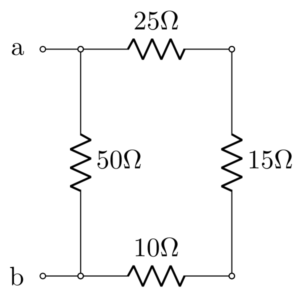

40 and 40 Ω are in parallel → $\frac{40 * 40}{40 + 40} = 20\Omega$



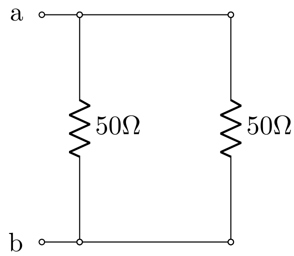

20 and 20 Ω are in series → $20 + 20 = 40\Omega$



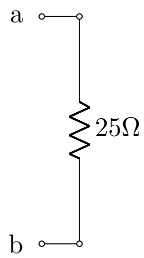

40 and 24 Ω are in parallel → $\frac{40 \times 24}{40 + 24} = 15\Omega$



15, 25 and 10 $\Omega$ are in series $\rightarrow 15 + 25 + 10 = 50\Omega$




50 and 50 $\Omega$ are in parallel $\rightarrow \dfrac{50 \times 50}{50 + 50} = 25\Omega$




Therefore the equivelent resistance of the circuit:

$$R_{ab} = 25\Omega$$

Therefore the total power absorbed by the circuit if 100V is connected to the circuit is:

$$P_{ab} = \frac{V^2}{R} = \frac{100^2}{25} = 400W$$

# Chapter 3

# Techincal methods for solving electrical circuits

## 3.1 Mesh analysis

To find the current in a circuit using mesh analysis:

1. Find the number of meshes in the circuit.
2. Assume a the current's direction in each mesh.
3. Apply KVL (mesh equations) accross each mesh's elements to find the value of each assumed current.

### 3.1.1 Mesh equations

- The left hand side of the equation:

  The left hand side contains the value of the voltage supplied by a source in a certain mesh.
  If the voltage source supplies current (assumed current) then it's positive:

$$+V_a = \dots$$

- The right hand side of the equation:

  The right hand side contains the current (assumed) multiplied by all elements' resistance it passes through:

$$\dots = I_a(R_{ab} + R_{ac}) \dots$$

  If another current from a different mesh passes through some elements from the mesh started with:

$$\dots - I_b(R_{ab})$$

Therefore the full mesh equation:

$$+V_a = I_a(R_{ab} + R_{ac}) - I_b(R_{ab})$$

## 3.2 Nodal analysis

To find the voltages in a circuit using nodl analysis:

1. Find the number of nodes in the circuit.
2. Find the node connecting the most elements. (ground $\rightarrow V_{ref} = 0$)
3. Apply KCL (Node equations) at each node to find the voltages.

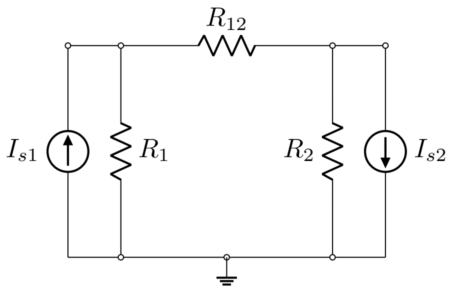



Figure 3.1: Nodal analysis example

### 3.2.1 Node equations

(Using the previous figure "Figure 1")

- The left hand side of the equation: The left hand side contains the current (from a current source) at the node.

  If the current is entering the node then it's positive:

$$+I_{s1} = \ldots$$

- The right hand side of the equation: The right hand side contains the value of the current passing through each branch between two nodes in terms of the voltage and the resistance.

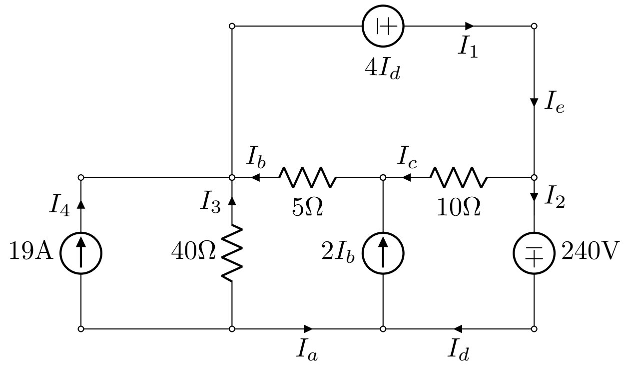
$$\ldots = \frac{V_1 - 0}{R_1} + \frac{V_1 - V_2}{R_{12}}$$

Therefore the full node equation:

$$+I_{s1} = \frac{V_1 - 0}{R_1} + \frac{V_1 - V_2}{R_{12}}$$

### 3.2.2 Examples

1. Using mesh analysis, find the value and type of each power source given the currents a, b, c, d and e.




By assuming the currents $I_{1\to 4}$ and their directions.

$$I_4 = 19A. \qquad I_a = I_4 - I_3 = 19 - I_3. \qquad I_b = I_1 - I_3.$$

$$I_c = I_1 - I_2. \qquad I_d = I_2. \qquad I_e = I_1$$

Mesh equation at $I_1$ (1):

$$4I_d = I_1 \times (10+5) - I_3 \times (5) - I_2 \times (10)$$

$$\to 4I_2 = I_1 \times (10+5) - I_3 \times (5) - I_2 \times (10)$$

Between $I_2$ and $I_3$ (2): (Super mesh)

$$2I_b = 2I_1 - 2I_3 = I_2 - I_3$$

$$\therefore 2I_1 - I_2 - I_3 = 0$$

Super mesh equation (3):

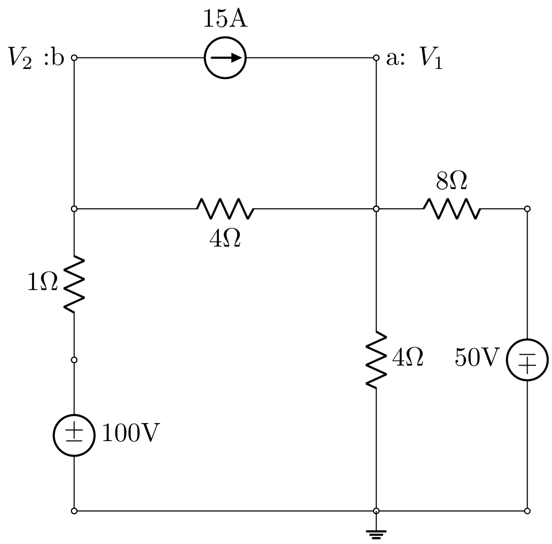
$$240 = I_2 \times (10) + I_3 \times (5+40) - I_4 \times (40) - I_1 \times (15)$$

$$1000 = I_2 \times (10) + I_3 \times (5+40) - I_1 \times (15)$$

By solving the three equations:

$$\begin{aligned} 15I_1 - 14I_2 - 5I_3 &= 0 & & I_1 = 18A \\ 2I_1 - I_2 - I_3 &= 0 & \to \quad & I_2 = 10A \\ 15I_1 - 10I_2 - 45I_3 &= -1000 & & I_3 = 26A \end{aligned}$$

2. Find the voltages across the following circuit.




Nodal equation at node $a$ ($V_1$):

$$15 = \frac{(V_1 + 50)}{8} + \frac{(V_1 - 0)}{4} + \frac{(V_1 - V_2)}{4}$$

Nodal equation at node $b$ ($V_2$):

$$-15 = \frac{(V_2 - V_1)}{4} + \frac{(V_1 - 100)}{1}$$

By solving the two equations:

$$\begin{aligned} 120 &= 5V_1 - 2V_2 + 50 \quad && \rightarrow \quad V_1 = -16.667 \\ 60 &= -5V_1 - V_2 - 100 && \phantom{\rightarrow} \quad V_2 = -76.667 \end{aligned}$$

# Chapter 4

# Technical theorems

## 4.1 Superposition

## 4.2 Source transfer

## 4.3 Thevenin's theory

## 4.4 Norton's theory

# Chapter 5

# Energy storing elements

# Chapter 6

# Diodes

## 6.1 Diode operations

## 6.2 Diode analysis