EE1101: Circuits and Network Analysis

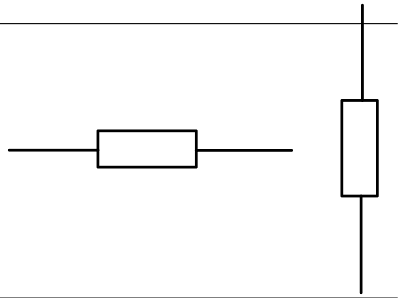
Lecture 04: DC Circuit Analysis

August 4, 2025

Topics :

1. Resistance

2. KCL and KVL



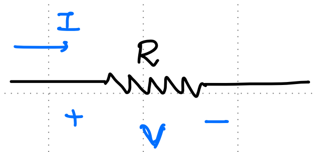
Resistance - Open Circuit and Short Circuit

$(R \longrightarrow \infty)$ $(R \longrightarrow 0)$

from a ckt point of view: Two terminal element whose v & i ← Current through it
↳ Voltage across the element

$v \propto i$ ⟶ The Const of Prop is Resistance (R)
↓
geometry & the material prop

ckt representation :



for a Conductor : $R = \dfrac{\rho l}{A}$ where

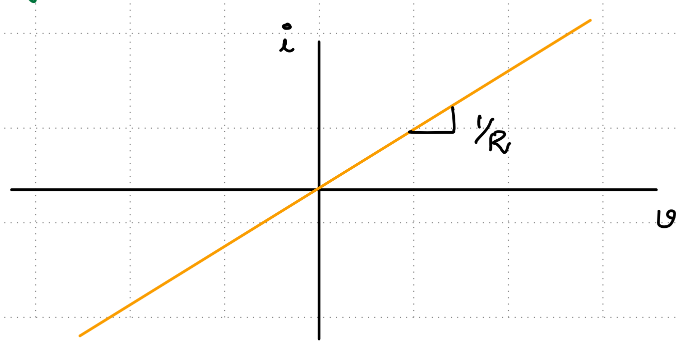
ρ = Resistivity

l = length of the Cond.

A = area of Cross section.

governing Eqn for a Resistor $V = IR$ or $v = iR$ (under Passive sign Convention)

v-i characteristic :-



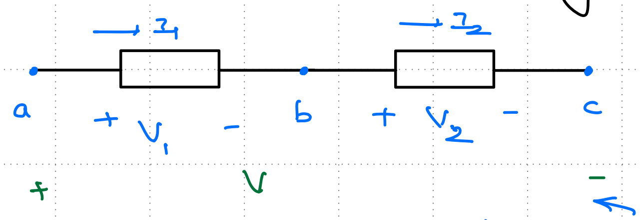
Operating Points are in Quad I or Quad III

$\underbrace{P = VI > 0 \qquad P = VI > 0}$ → Sink / Load.

under Passive sign Convention

Elements in Series and Parallel

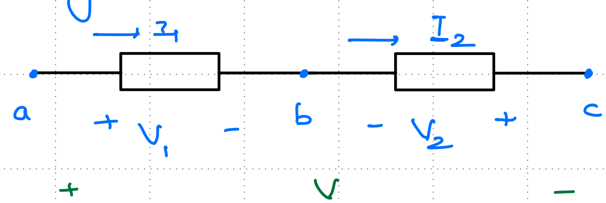
Series Connection:- Two elements that are connected in an end-to end manner & have the same current flow through them.



only under chosen convention

$I_1 = I_2$

What will be the voltage across the combination? $V = ?$ $= V_1 + V_2$.



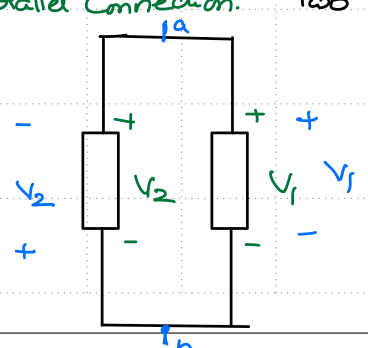
$\Rightarrow V = V_1 - V_2$.

$$V = -\int_c^a \vec{E}\cdot\vec{dl} = -\underbrace{\int_c^b \vec{E}\cdot\vec{dl}} - \underbrace{\int_b^a \vec{E}\cdot\vec{dl}}$$

$$= -V_2 + V_1$$

$$= V_1 - V_2.$$

Parallel Connection: Two elements connected b/w the same nodes.



Same potential across the elements (account for sign convention)

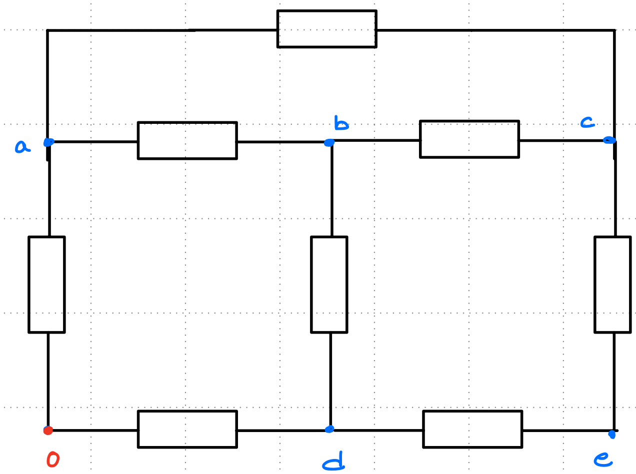
for ref in green: $V_1 = V_2$

for ref in blue: $V_1 = -V_2$

Guidelines for Circuit Analysis

→ given a N/w built using Circuit elements

goal: To be able to compute the desired voltages | currents



① Node Naming : use lower case alphabets
(for this Course)

We need to identify a ref node
↓
mark as '0'

Assumption : $V_0 = 0$ (reference node)

When def potential $= -\int_{\infty}^{P} \vec{E} \cdot \vec{dl}$

$\infty \leftarrow$ ref node. (0)

Node Potential $V_{P0} = -\int_{0}^{P} \vec{E} \cdot \vec{dl}$ → Simply put it as V_P instead of V_{P0}

Potential diff b/w nodes $= V_{ab} = V_a - V_b$ (a & b need not be connected directly)

② Clearly mark the polarity & reference. Source (V, I) → Active sign convention.

Sink (R) → Passive sign convention

③ Clearly mark the mesh/loops.

Krichhoff's Voltage Law (KVL)

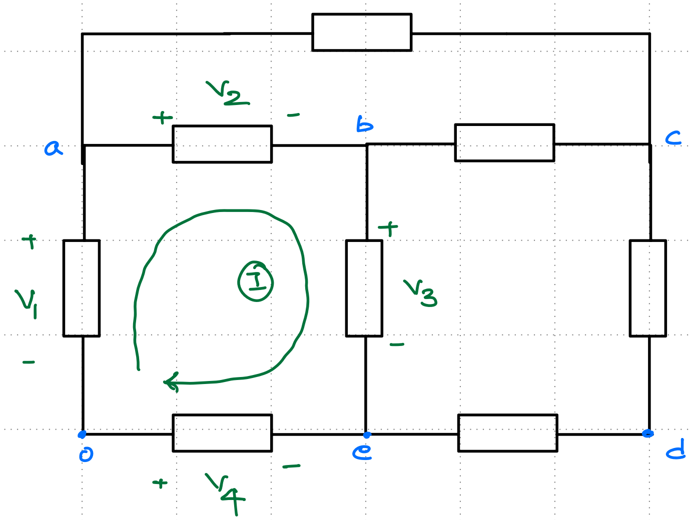
Application of Maxwell's 2nd Equation

(for DC ckts)
(static fields)

$\oint \vec{E} \cdot \vec{dl} = 0$

closed path

referred to as a loop | Mesh in ckt analysis.



for loop 1 : by 2nd Eqn $\oint \vec{E} \cdot \vec{dl} = 0$

$$\underbrace{\int_o^a \vec{E} \cdot \vec{dl}} + \int_a^b \vec{E} \cdot \vec{dl} + \int_b^e \vec{E} \cdot \vec{dl} + \int_e^o \vec{E} \cdot \vec{dl} = 0$$

$$V_{oa} + V_{ab} + V_{be} + V_{eo} = 0 \Rightarrow \underbrace{\Sigma}\, V = 0$$

algebraic sum of voltages in a closed loop is '0'.

When polarity is specified :

for loop 1 →

$$\int_o^a \vec{E} \cdot \vec{dl} + \int_a^b \vec{E} \cdot \vec{dl} + \int_b^e \vec{E} \cdot \vec{dl} + \int_e^o \vec{E} \cdot \vec{dl} = 0$$

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

Kirchhoff's Current Law (KCL)

Application of Maxwell's 4^{th} Eqn.

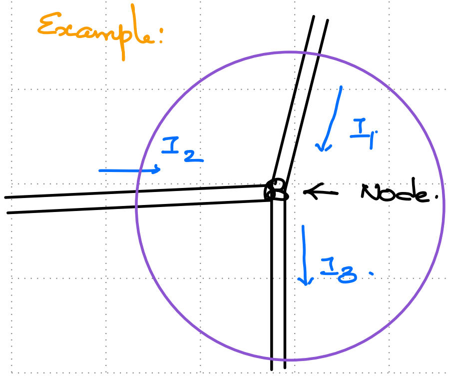
$$\nabla \times \vec{H} = \vec{J} + \cancel{\vec{J}_d} \quad 0 \text{ (for DC ckts)}$$

from vec. calculus $\nabla \cdot (\nabla \times \vec{H}) = 0 \Rightarrow \nabla \cdot \vec{J} = 0$

$$\Rightarrow \underbrace{\oint \vec{J} \cdot \vec{ds}}_{} = 0 \longrightarrow (1)$$

flux of $\vec{J}$ (or alg. sum of currents) $= 0$

Example:



Application of (1) to specific example for a spherical surface.

$$\underbrace{\int \vec{J} \cdot \vec{ds}}_{} = 0$$

$\vec{ds}$ → outward normal

3 contributions namely $\underbrace{-I_1, -I_2}$ and I_3

bec of the ref for current & choice of $\vec{ds}$

mark reference for currents

by def $I_1 = \int \vec{J}_1 \cdot \vec{ds}_1$, $I_2 = \int \vec{J}_2 \cdot \vec{ds}_2$

and $I_3 = \int \vec{J}_3 \cdot \vec{ds}_3$

$$\int \vec{J} \cdot \vec{ds} = -I_1 - I_2 + I_3 = 0$$

$\Downarrow$

alg. sum of currents leaving a node $= 0$

or alternately Sum of currents entering = Sum of currents leaving a node.