Electrical Science: 2021-22
Lecture 3
Circuit Analysis and Kirchhoff's Laws

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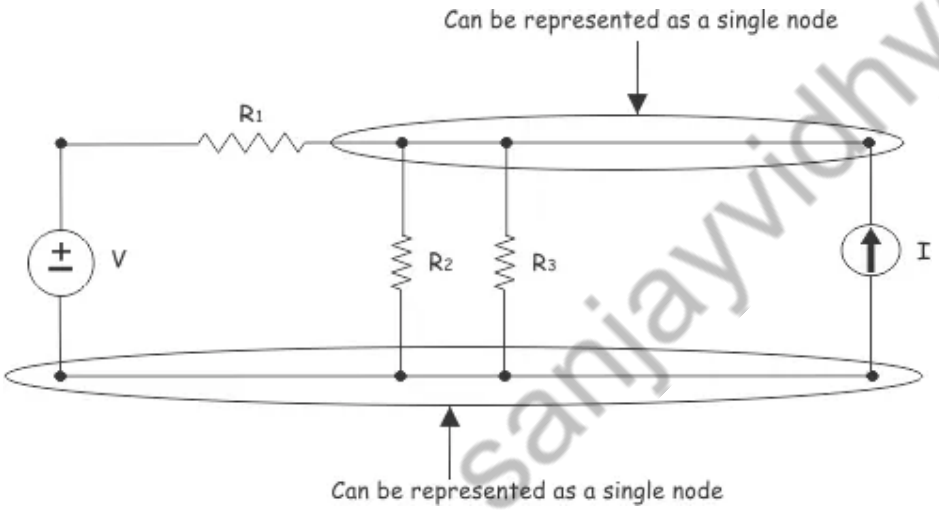
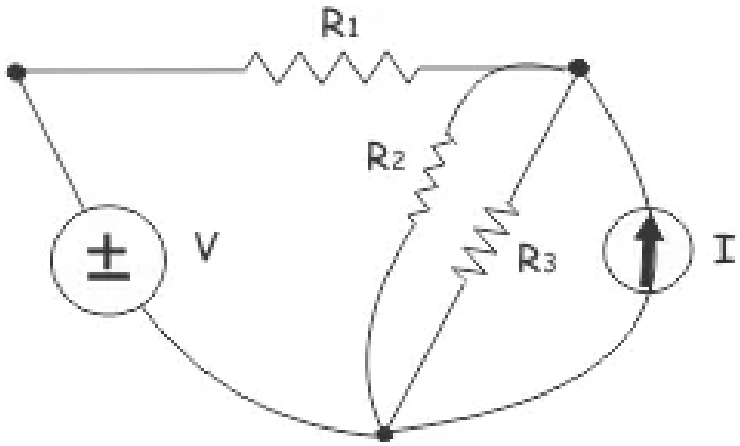
Nodes, Branches and Loops

- **Nodes**

The point through which a circuit element is connected to the circuit is called **node**.
Node is a point where, terminal of two or more circuit elements are connected.
Node is a junction point in the circuit.

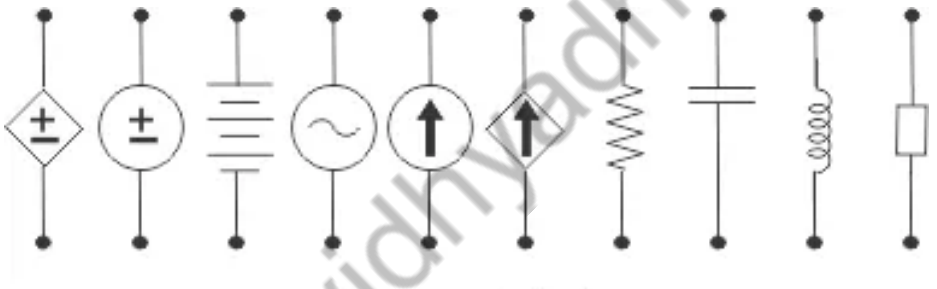




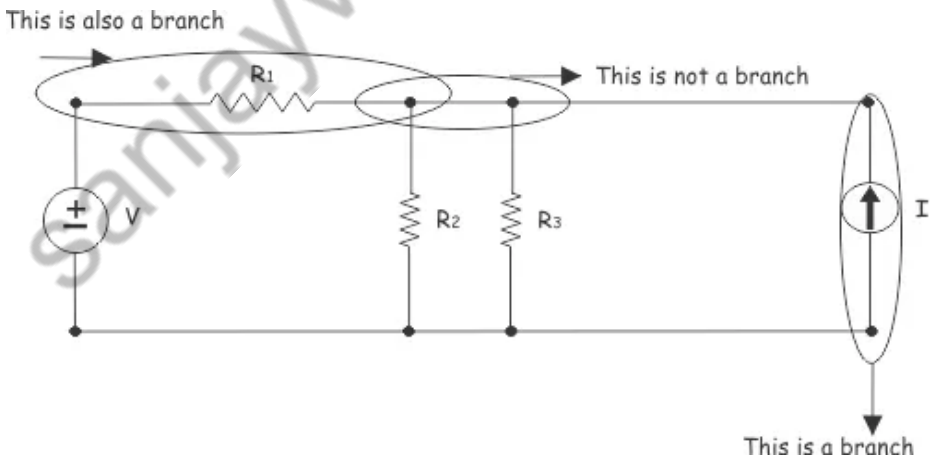
Nodes, Branches and Loops

- **Branches**

The branch of an electric circuit can be defined more precisely, as the portion of the circuit between two nodes which can deliver or absorb energy. As per this definition, the short circuit between two nodes is not referred as **branch** of electric circuit.



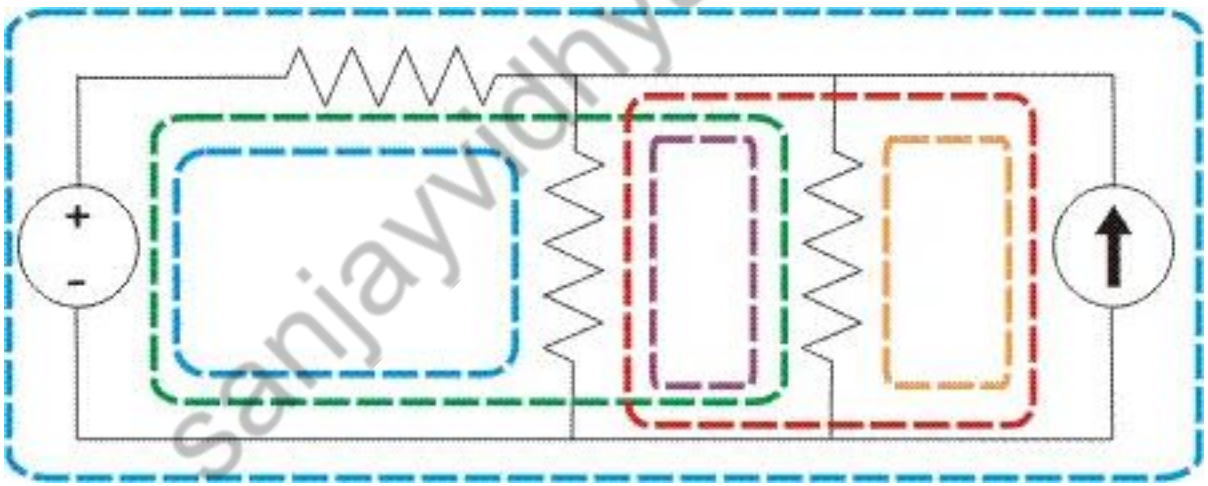
Elements of circuit



Nodes, Branches and Loops

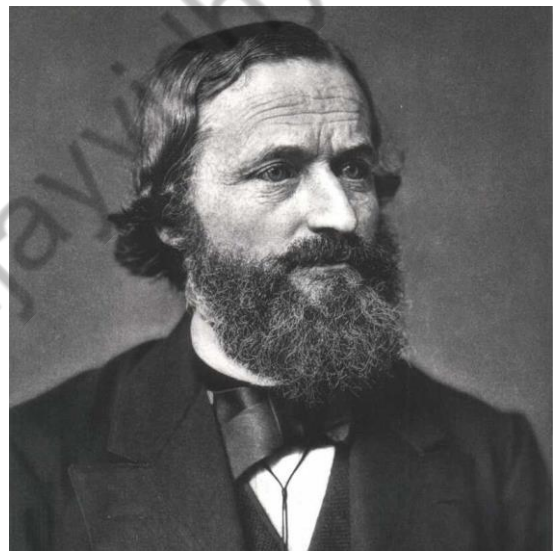
- **Loops**

An electric circuit has numbers of nodes. If one starts from one node and after going through a set of nodes returns to same starting node without crossing any of the intermediate node twice, he has travels through one **loop** of the circuit. Loop is any closed path in the circuit formed by branches.



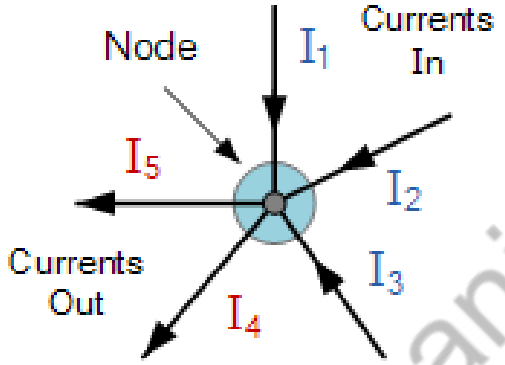
KIRCHHOFF ' S L AWS

- Kirchhoff's laws are two equalities that deal with the current and voltage in electrical circuits.
- They were first described in 1845 by German physicist Gustav Kirchhoff.
- Ohm's law by itself is not sufficient to analyze circuits.
- When it is coupled with Kirchhoff's laws, we have a sufficient, powerful set of tools for analyzing a large variety of electric circuits.



Kirchhoff's Current Law

- **Kirchhoff's Current Law (KCL)**: The algebraic sum of currents entering a node (or a closed boundary) is zero
- The sum of currents entering a node is equal to the sum of the currents leaving a node
- Based on law of conservation of charge

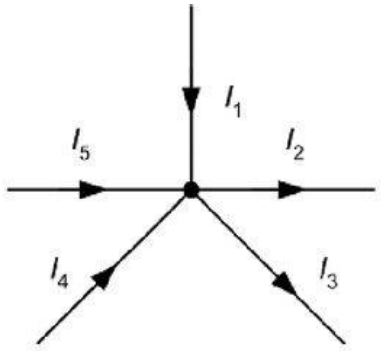


$$I_1 + I_2 + I_3 = I_4 + I_5$$

Current Entering the Node

=

Current Leaving the Node

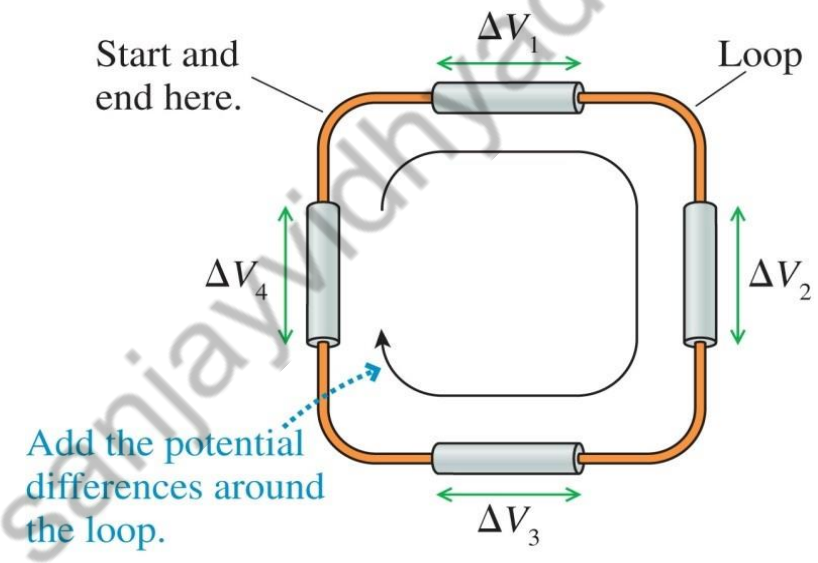


$$I_1 - I_2 - I_3 + I_4 + I_5 = 0$$

Convention:
Current flowing towards the junction is positive (+)
Current flowing away from the junction is negative (–)

Kirchhoff's Voltage Law

- **Kirchhoff's Voltage Law (KVL)**: The algebraic sum of voltages around a closed path (or loop) is zero
- Based on the conservation of energy.

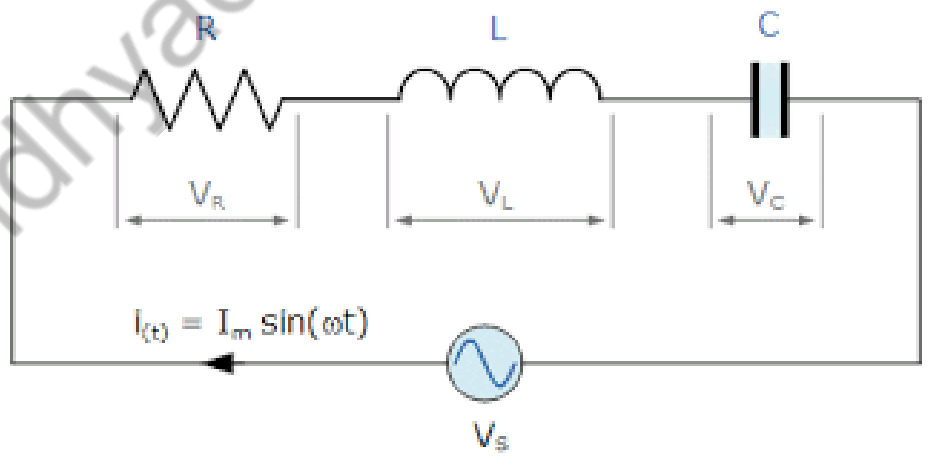


Loop law: $\Delta V_1 + \Delta V_2 + \Delta V_3 + \Delta V_4 = 0$

Limitations of KCL and KVL

KVL and KCL are a part, is just an approximation of classical theory of electromagnetism for **low frequencies and should not be used for high frequency analysis.**

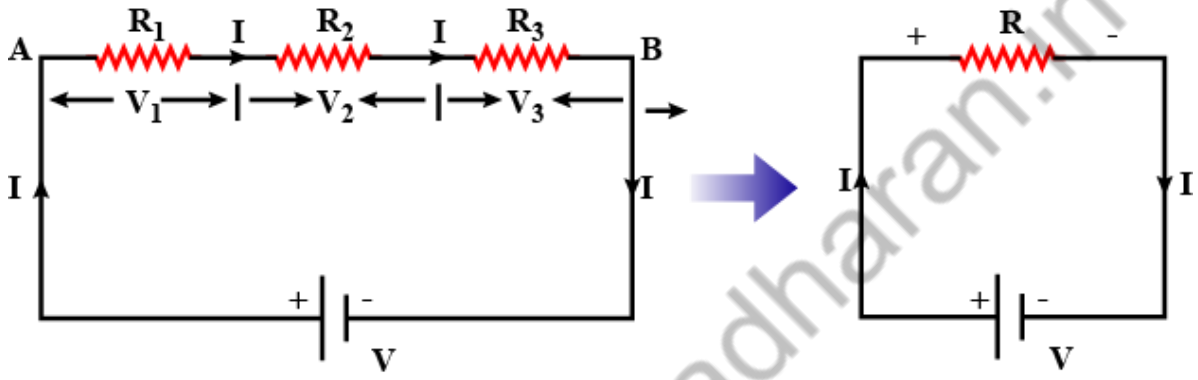
Frequency	Wavelength
1 MHz	300 meters
1 GHz	30 cm
10 GHz	3 cm



Ohm's Law, KCL and KVL

- $Ohm's\ Law: \quad V = IR$
- $KCL: \quad \sum I_n = 0$
- $KVL: \quad \sum V_{loop} = 0$

Resistors in Series



$V=V_1+V_2+V_3$ ……(i)

R_1 voltage drops across, $V_1 = I_{R1}$ ……..(iii)

R_2 voltage drops across, $V_2 = I_{R2}$ ……..(iv)

R_3 voltage drops across, $V_3 = I_{R3}$ ……..(v)

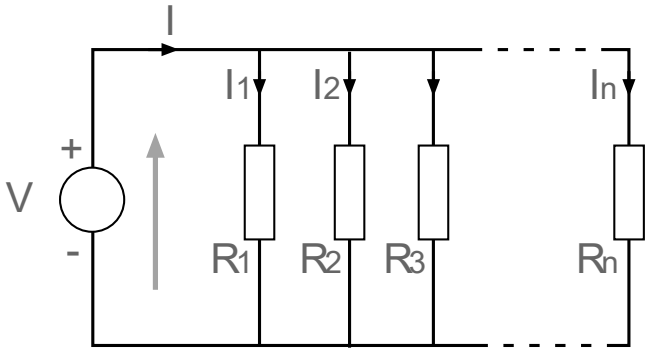
Adding (iii), (iv) and (v):

$V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$ ……(vi) Or,

$V = IR = I(R_1 + R_2 + R_3)$ Or,

$R = R_1 + R_2 + R_3$

Resistors in Parallel



Two resistors in parallel

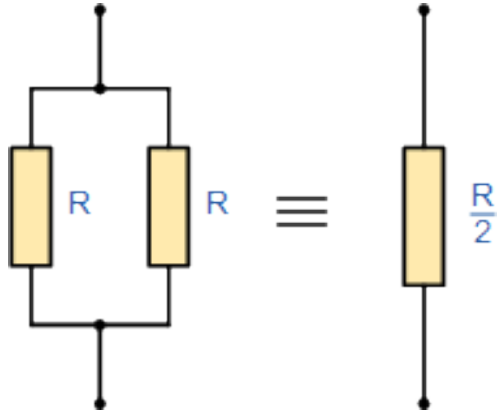
$$R_{total} = \frac{R_1 R_2}{R_1 + R_2}$$

$$I = I_1 + I_2 + I_3 + \ldots I_n$$

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + \ldots \frac{V}{R_n}$$

$$\frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \frac{1}{R_n}$$

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \frac{1}{R_n}$$



Voltage Division

V1 is the voltage across R1:

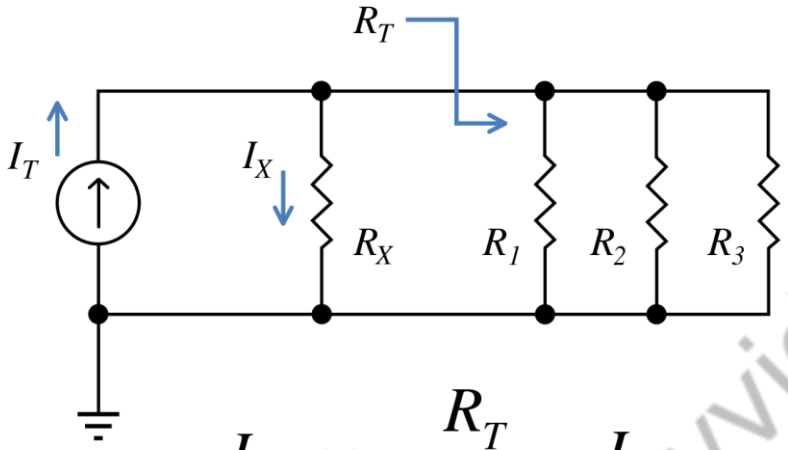
$$V1 = \frac{R1}{R1+R2} * V$$

V2 is the voltage across R2:

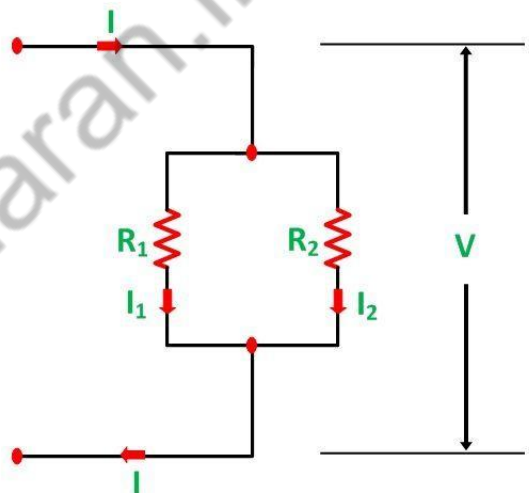
$$V2 = \frac{R2}{R1+R2} * V$$

Voltage division rule

Current Division



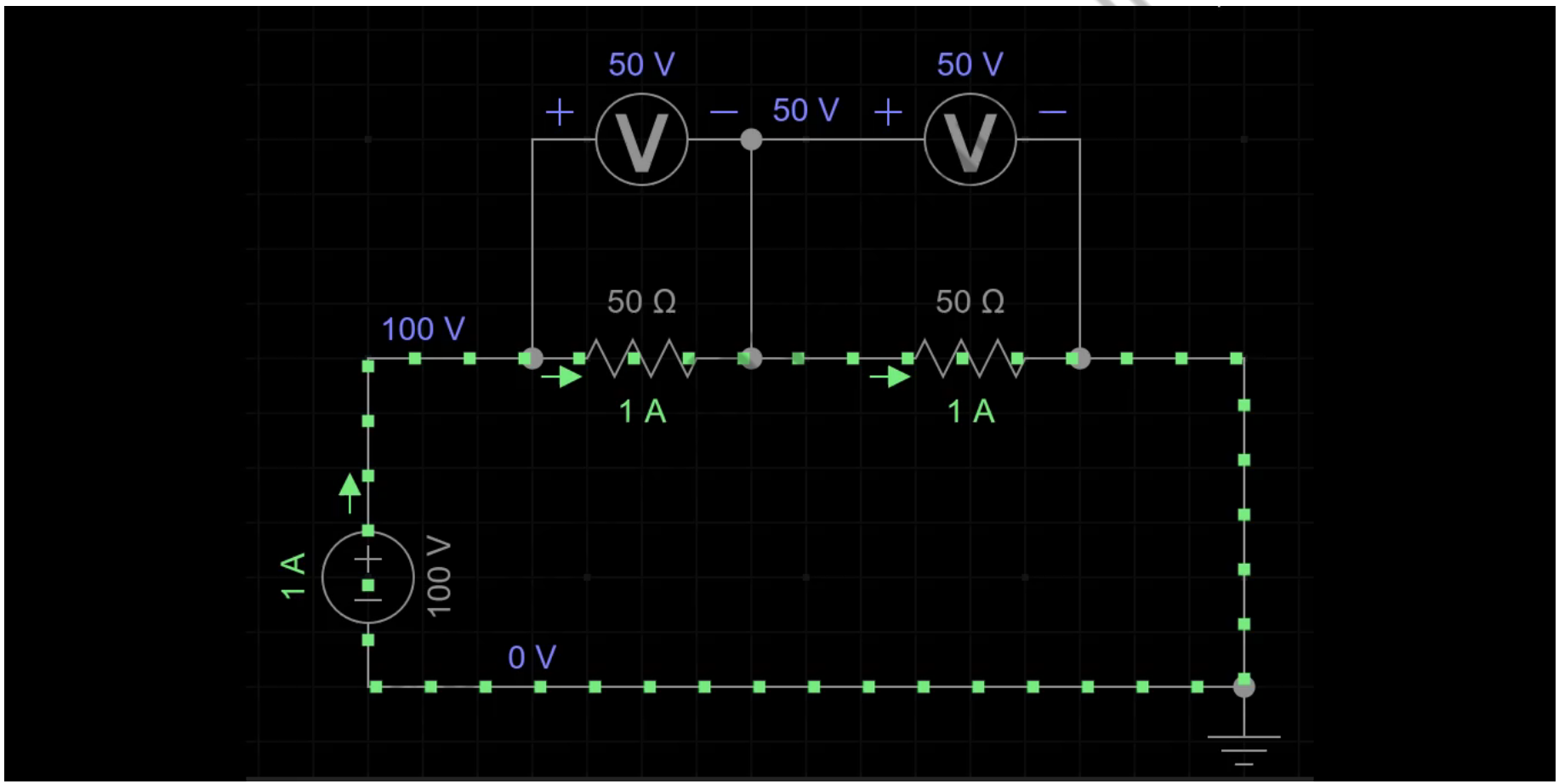
$$I_X = \frac{R_T}{R_X + R_T} I_T$$



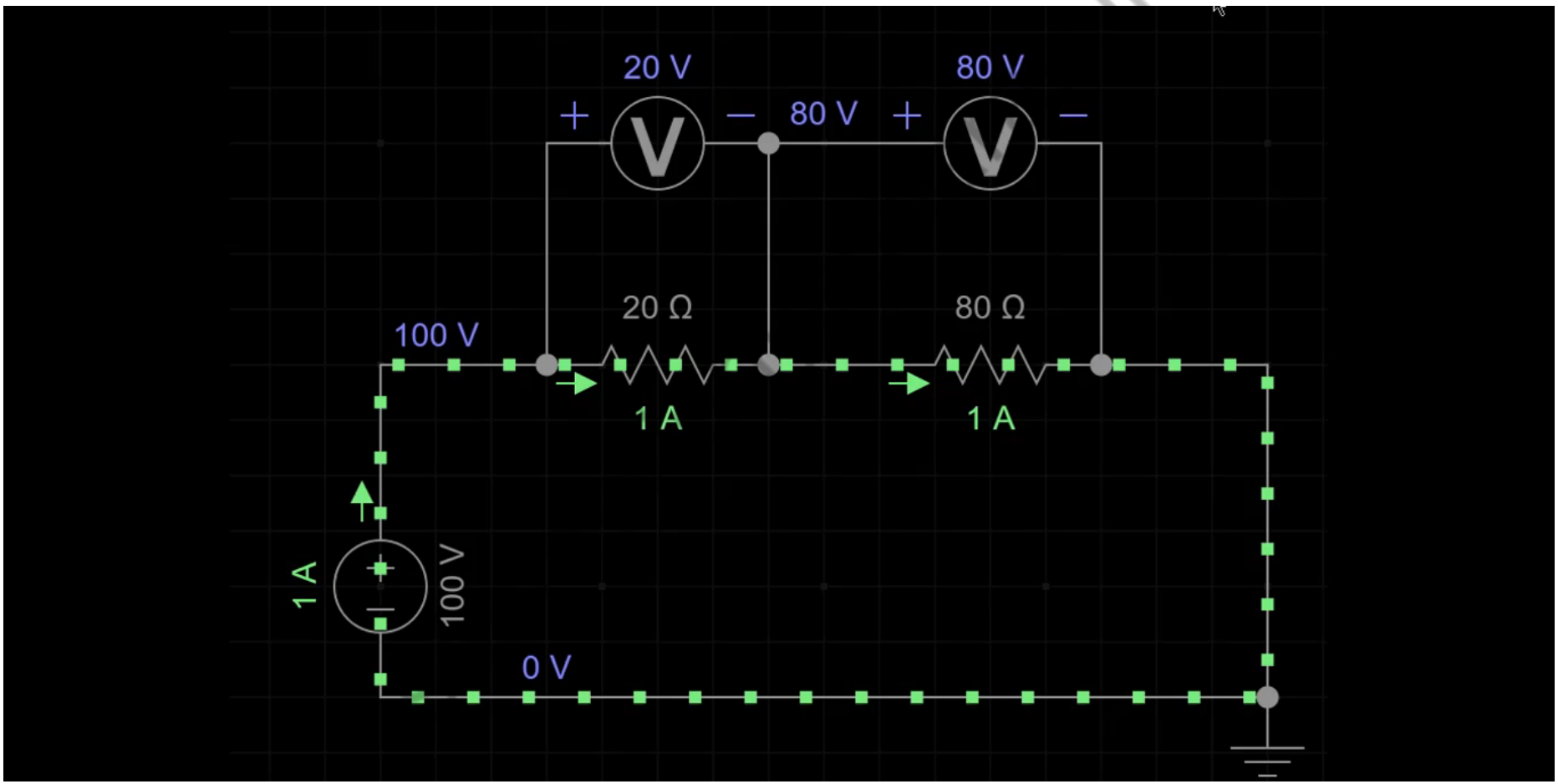
$$I_1 = \frac{R_2}{R_1 + R_2} I_T$$

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

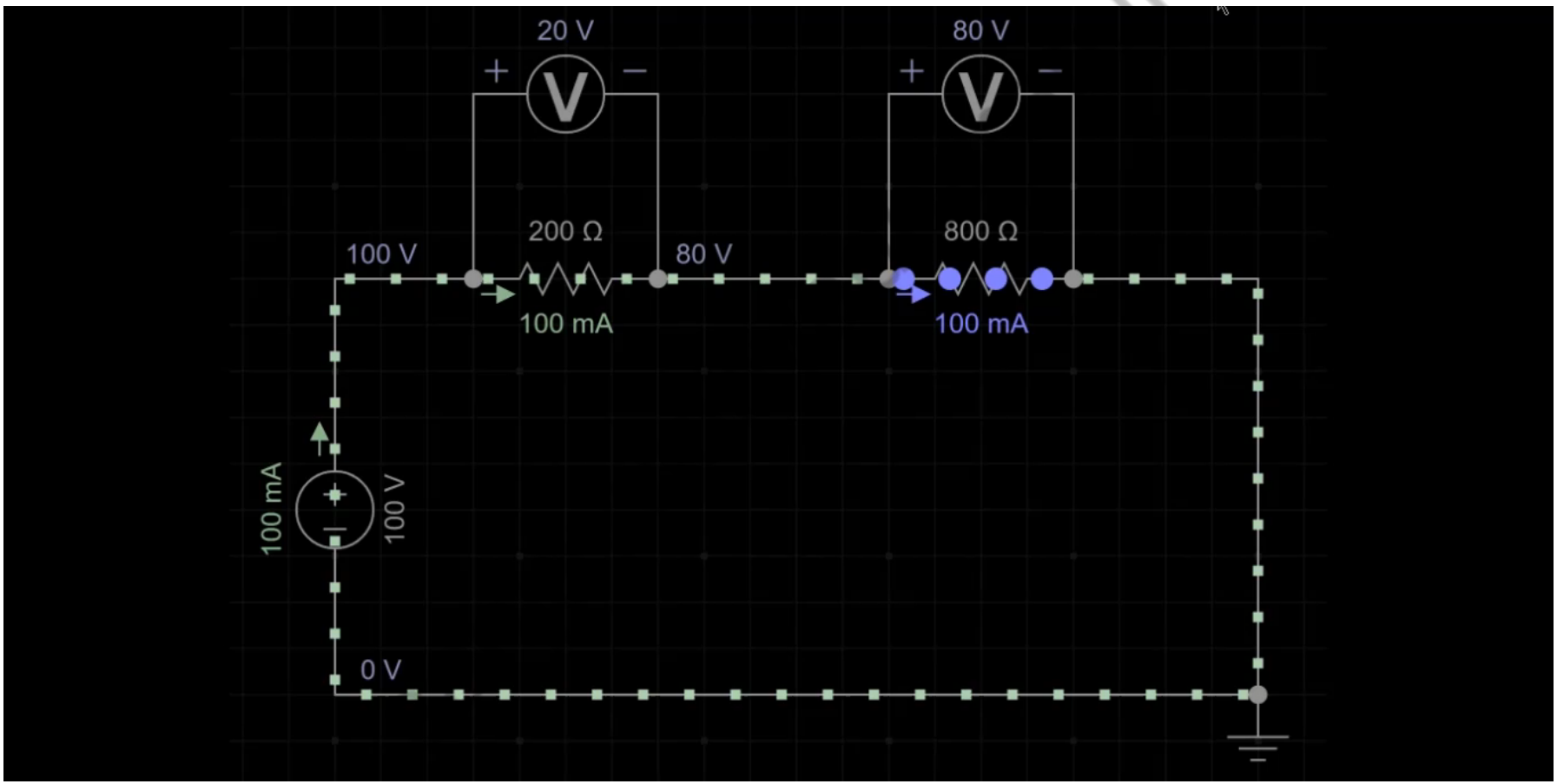
Kirchhoff's Voltage Law



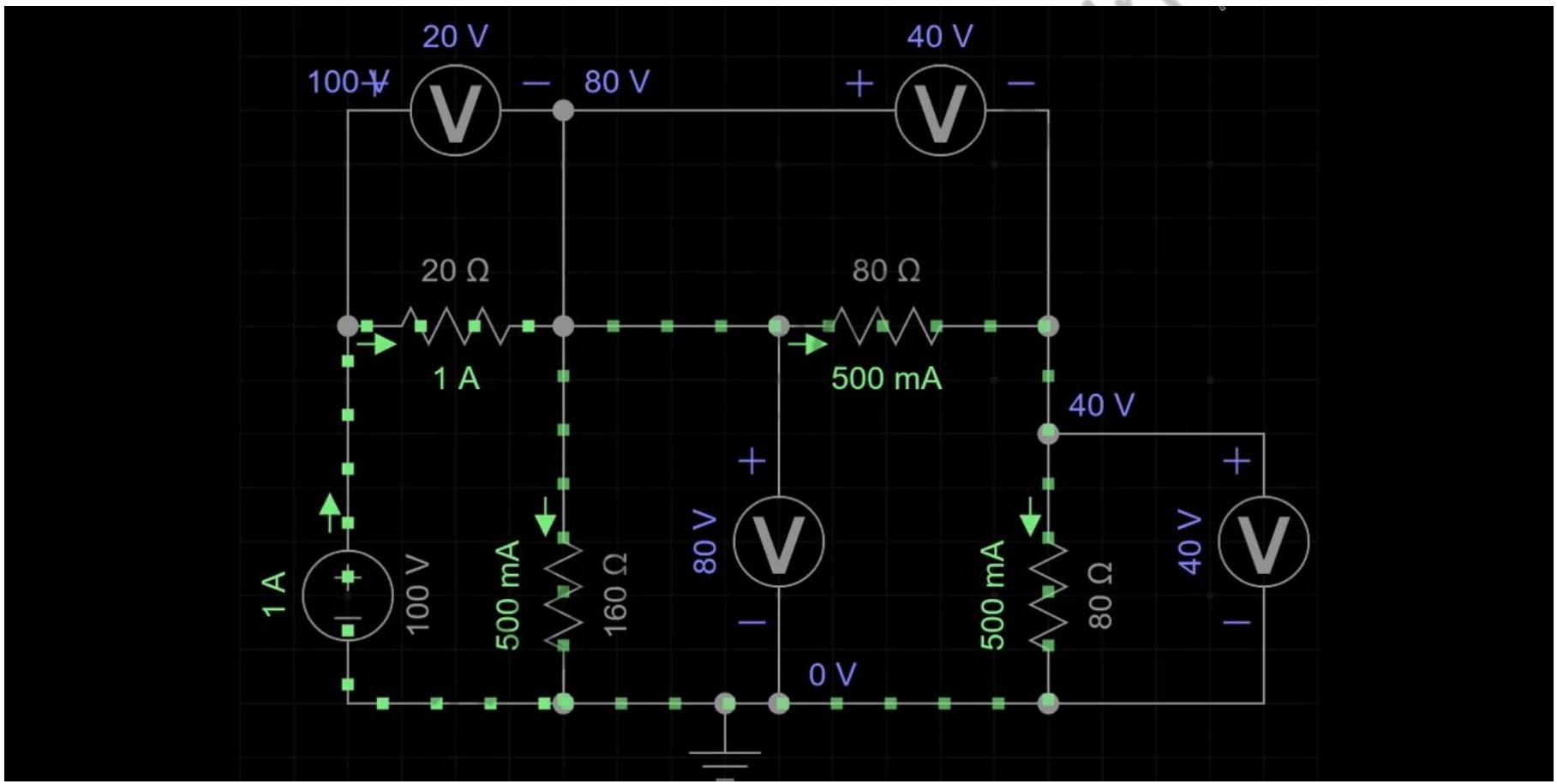
Kirchhoff's Voltage Law



Kirchhoff's Voltage Law



Kirchhoff's Voltage and Current Law



Thank you