Electrical Science - I
(IEC-102)

Lecture-02

Types of Circuit Elements

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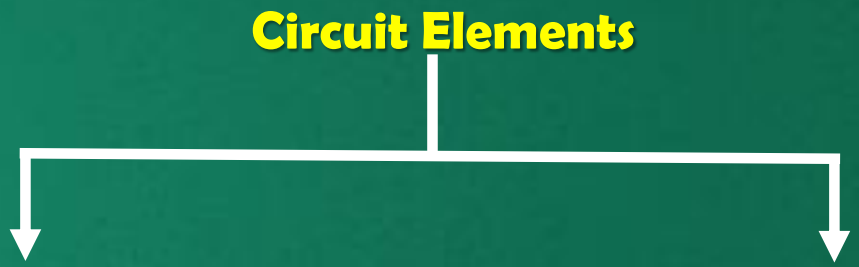

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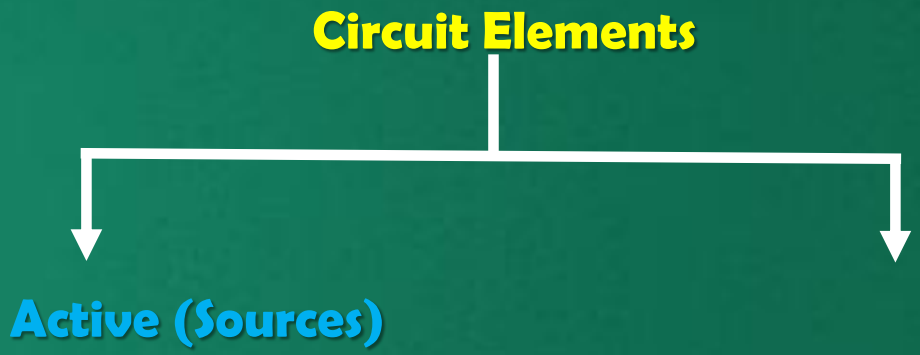

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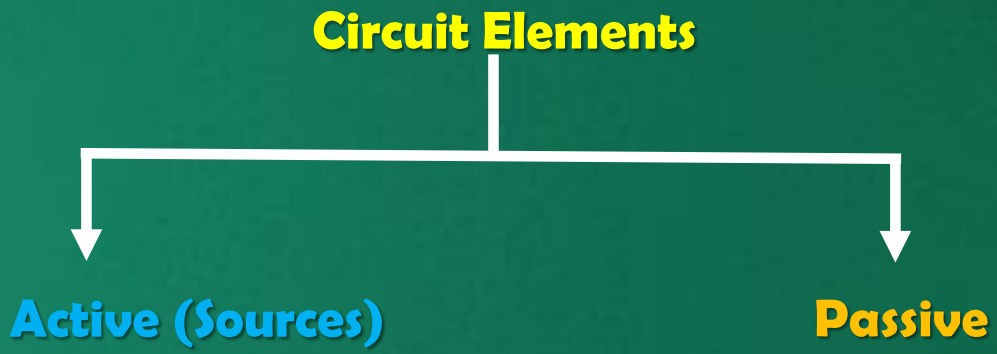

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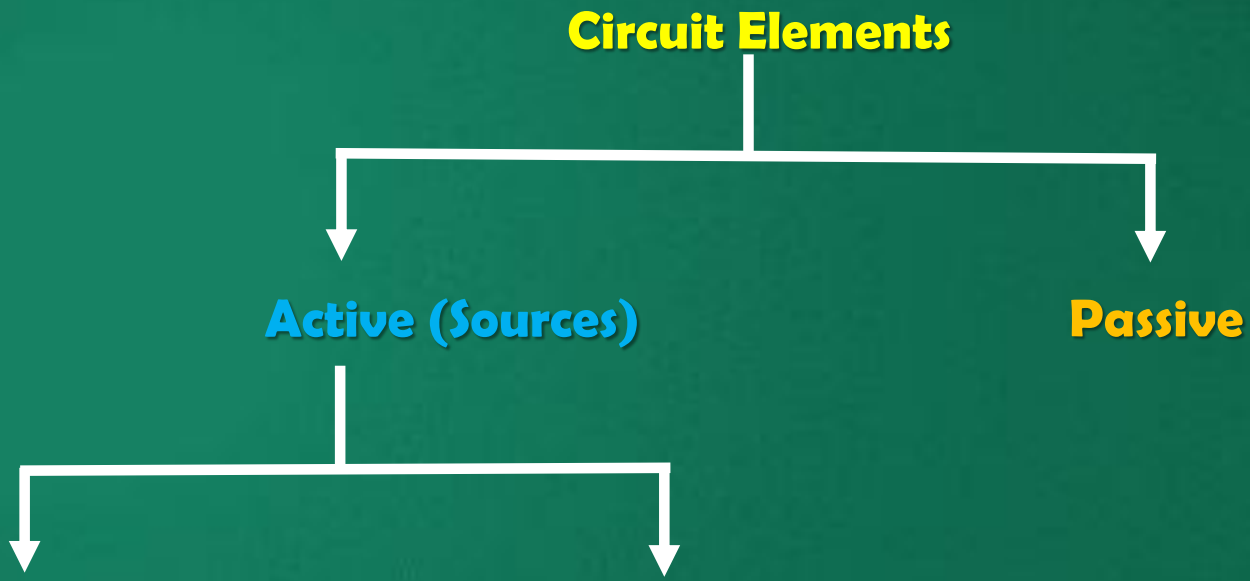

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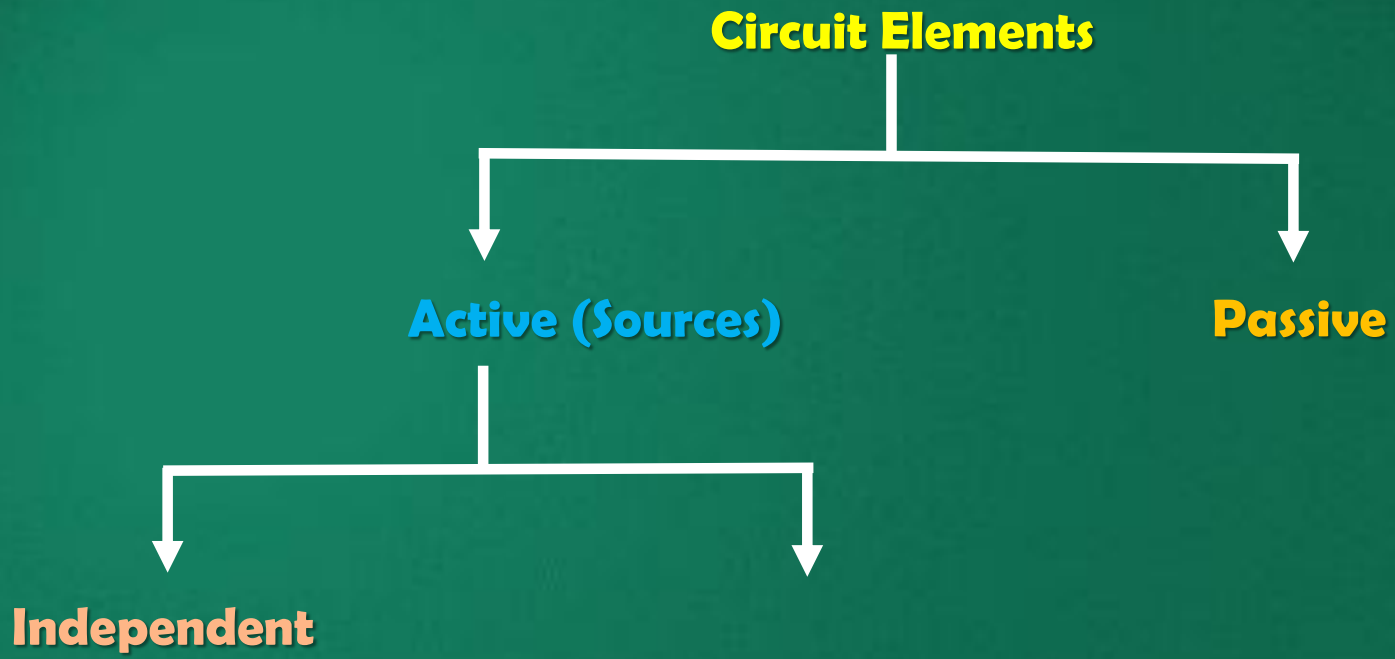

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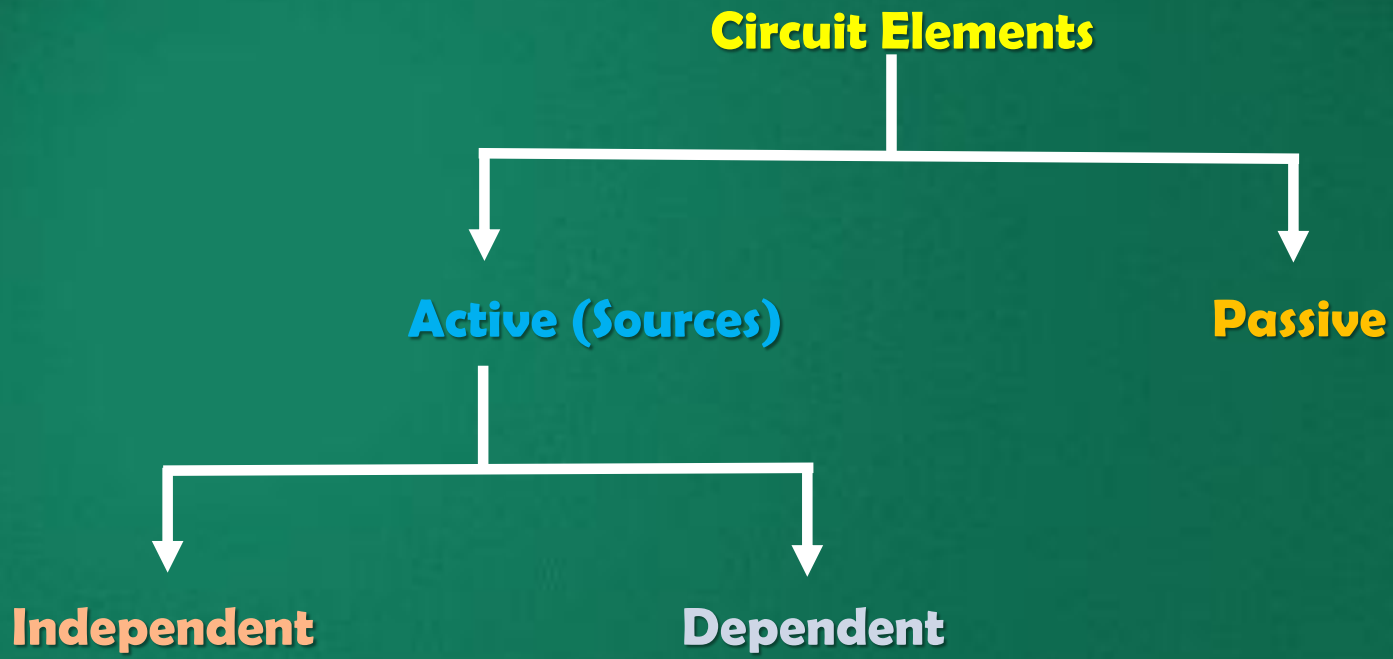

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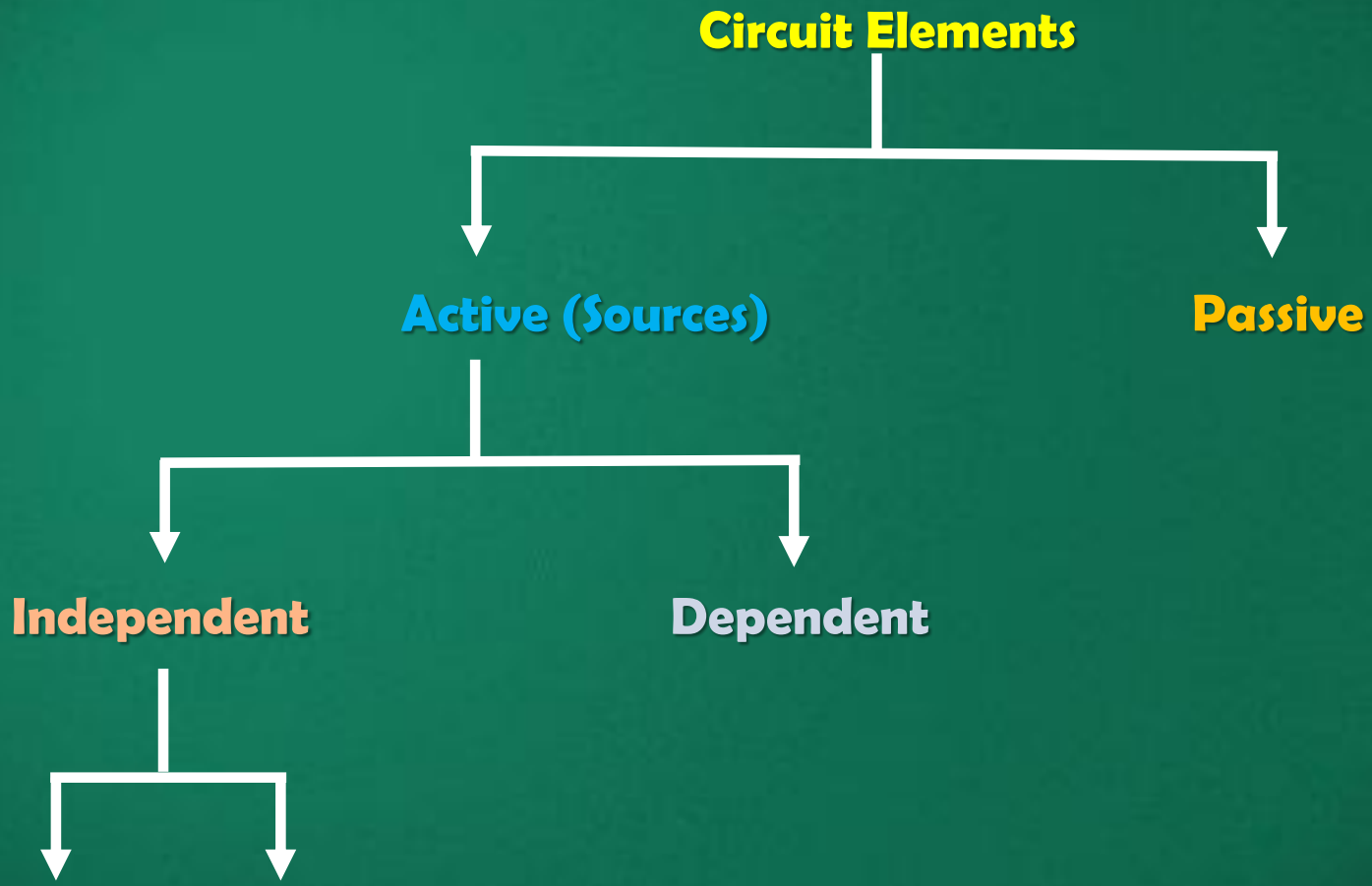

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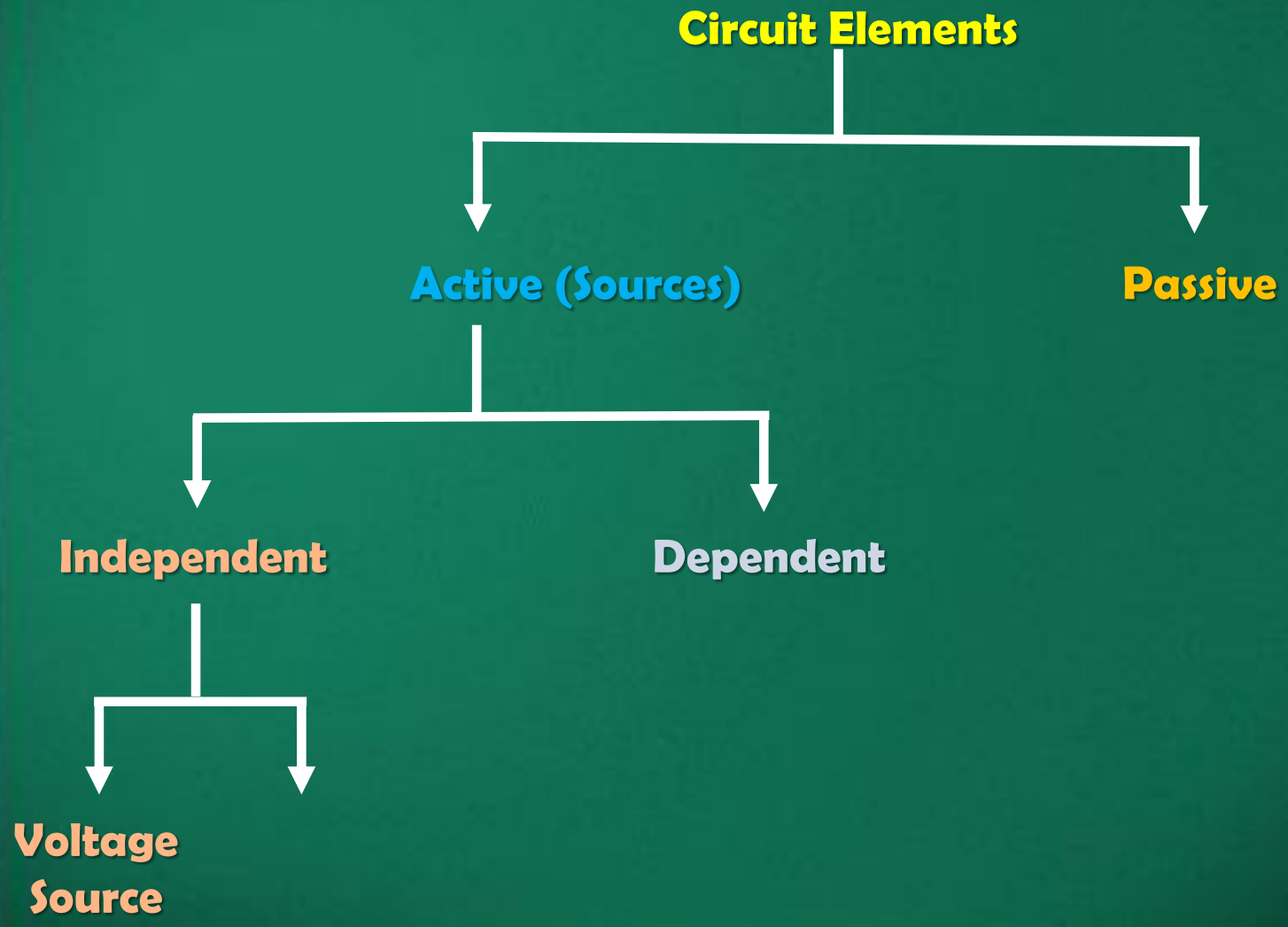

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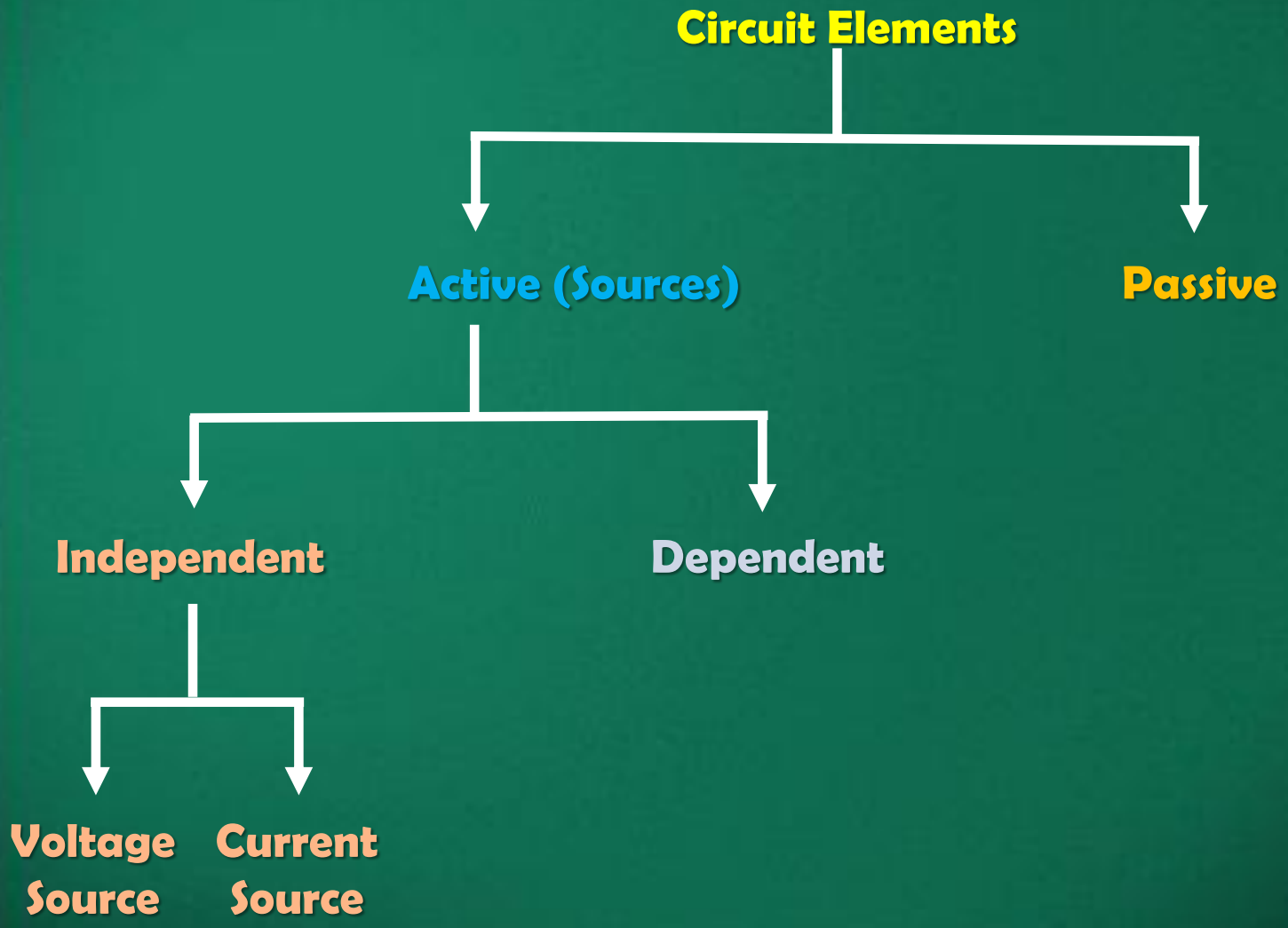

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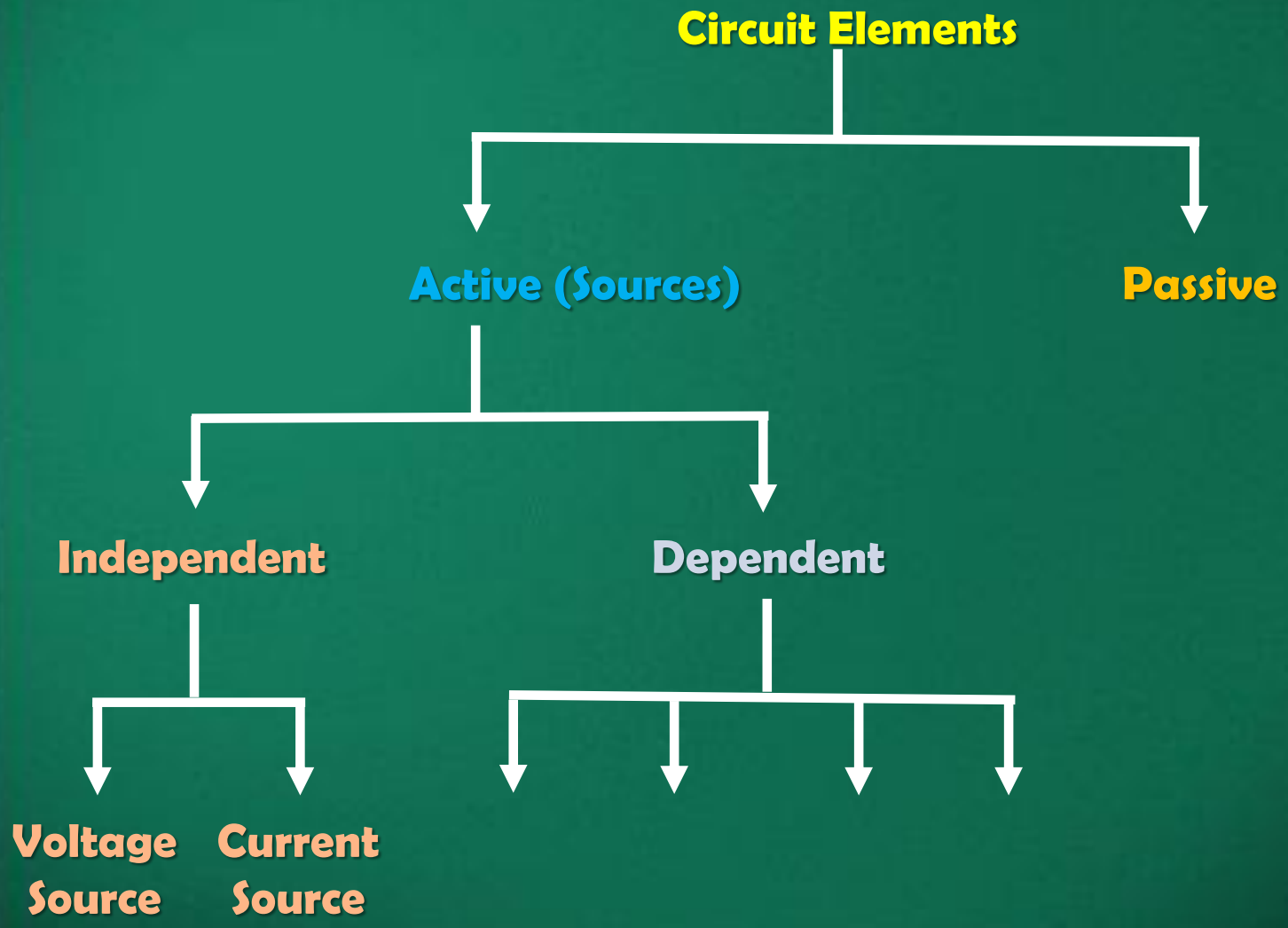

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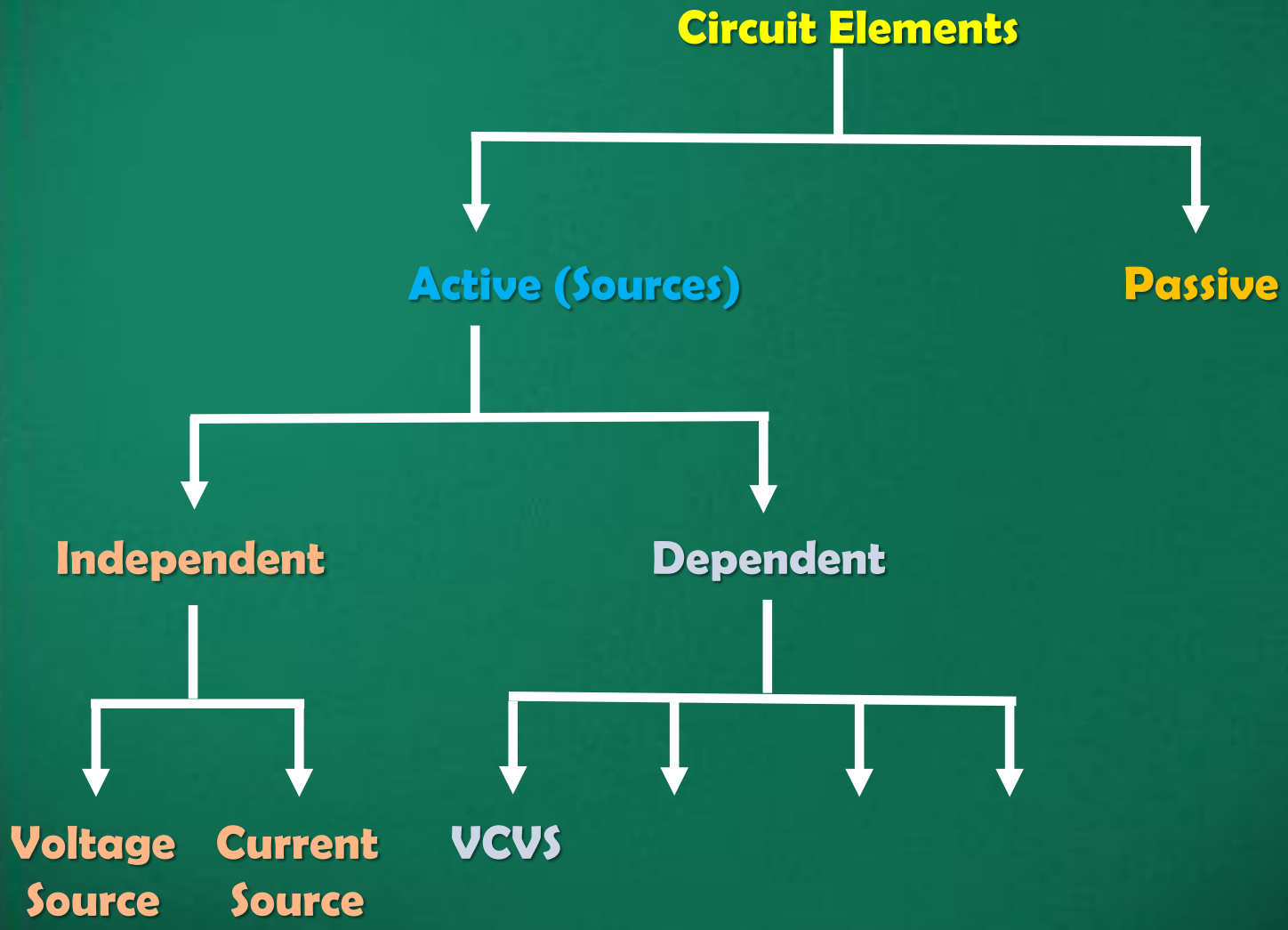

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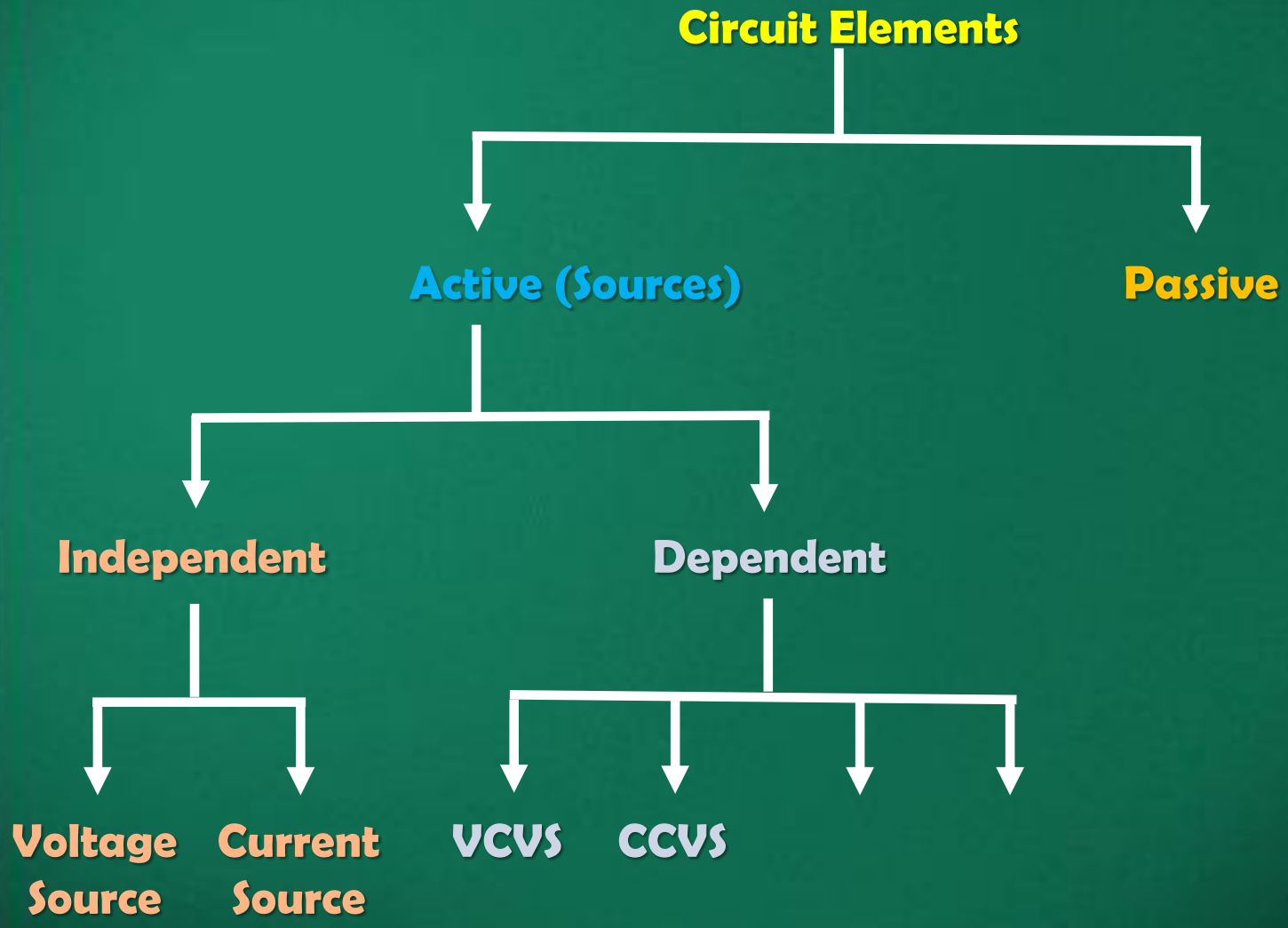

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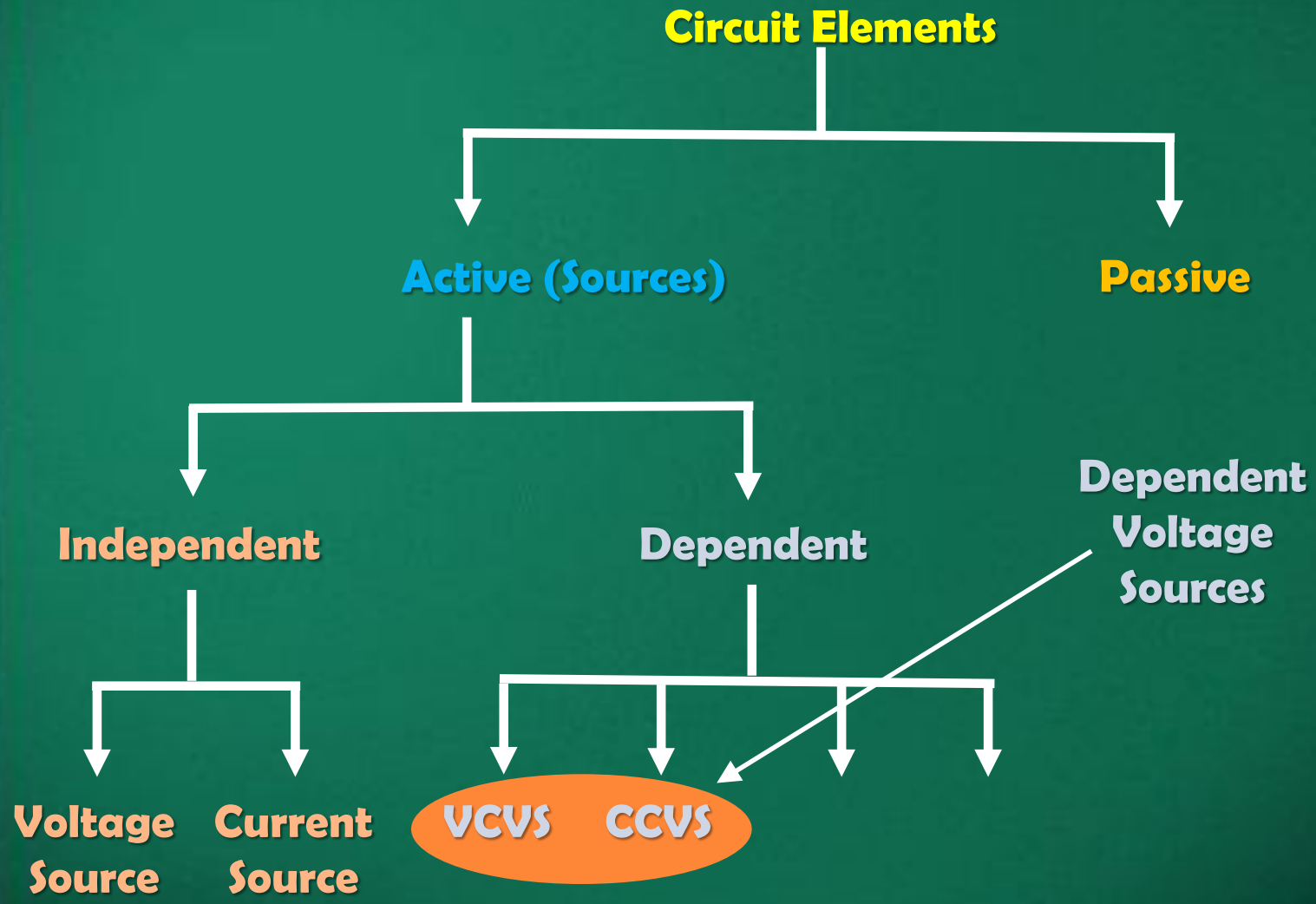

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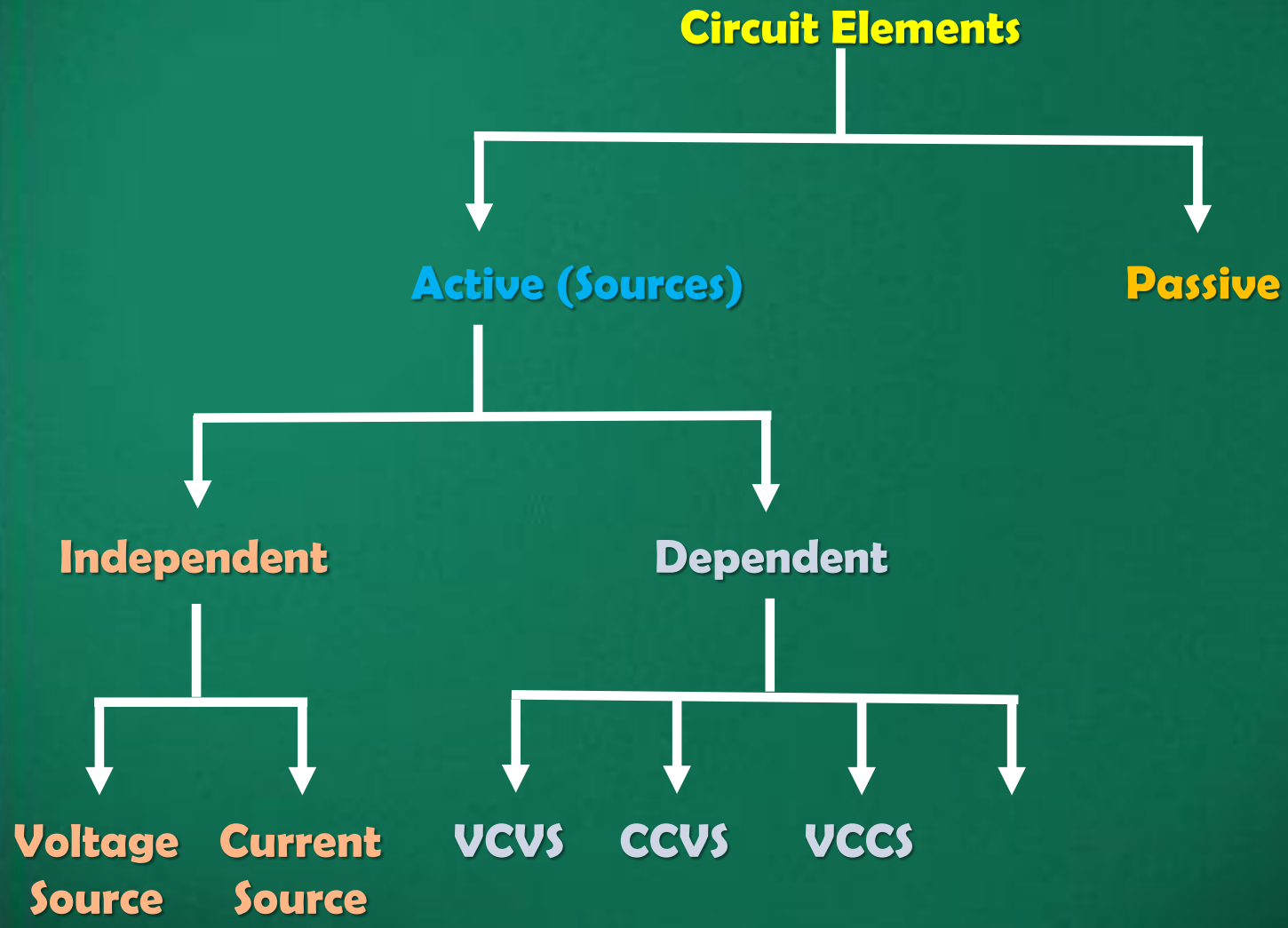

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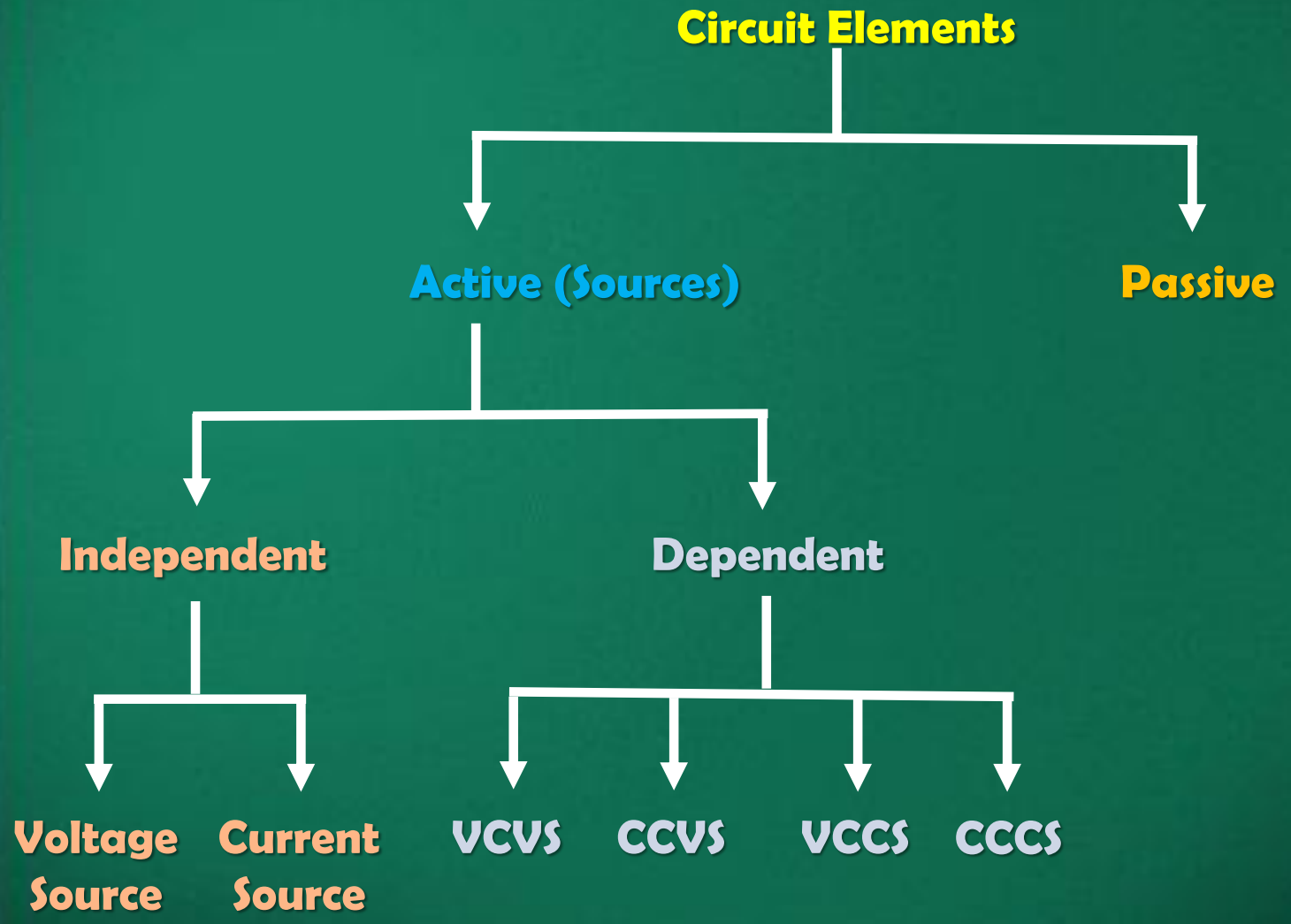

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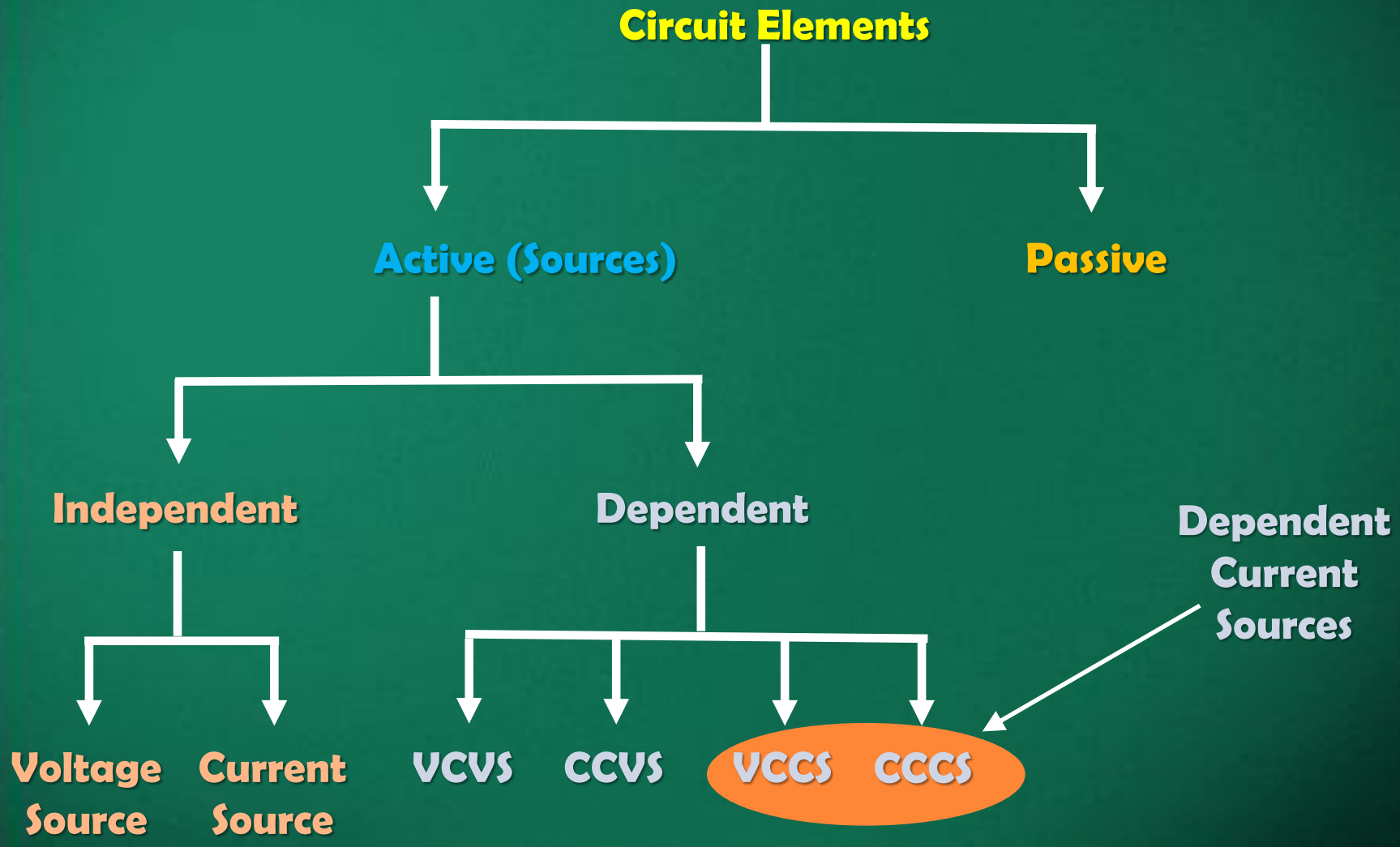

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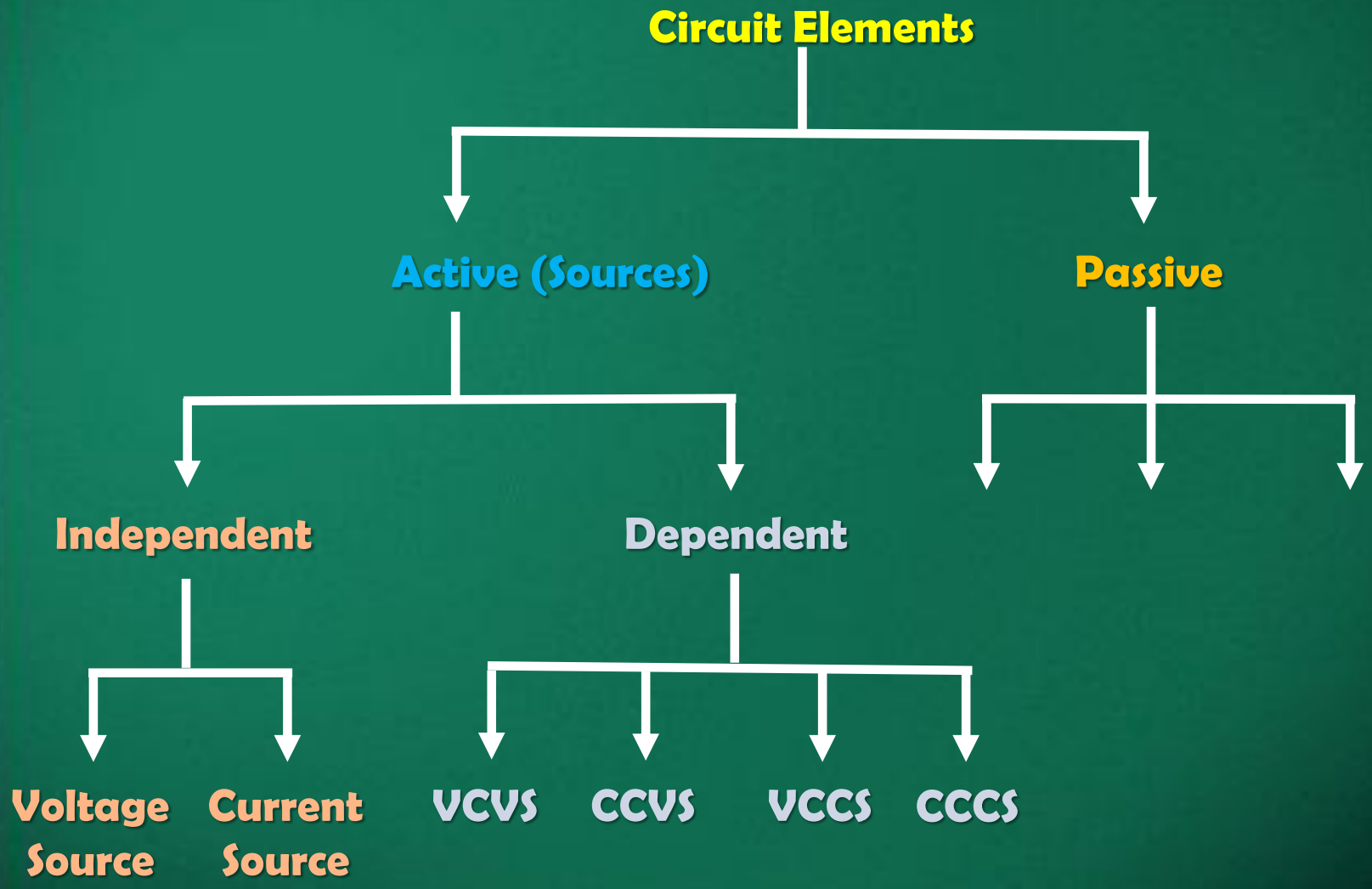

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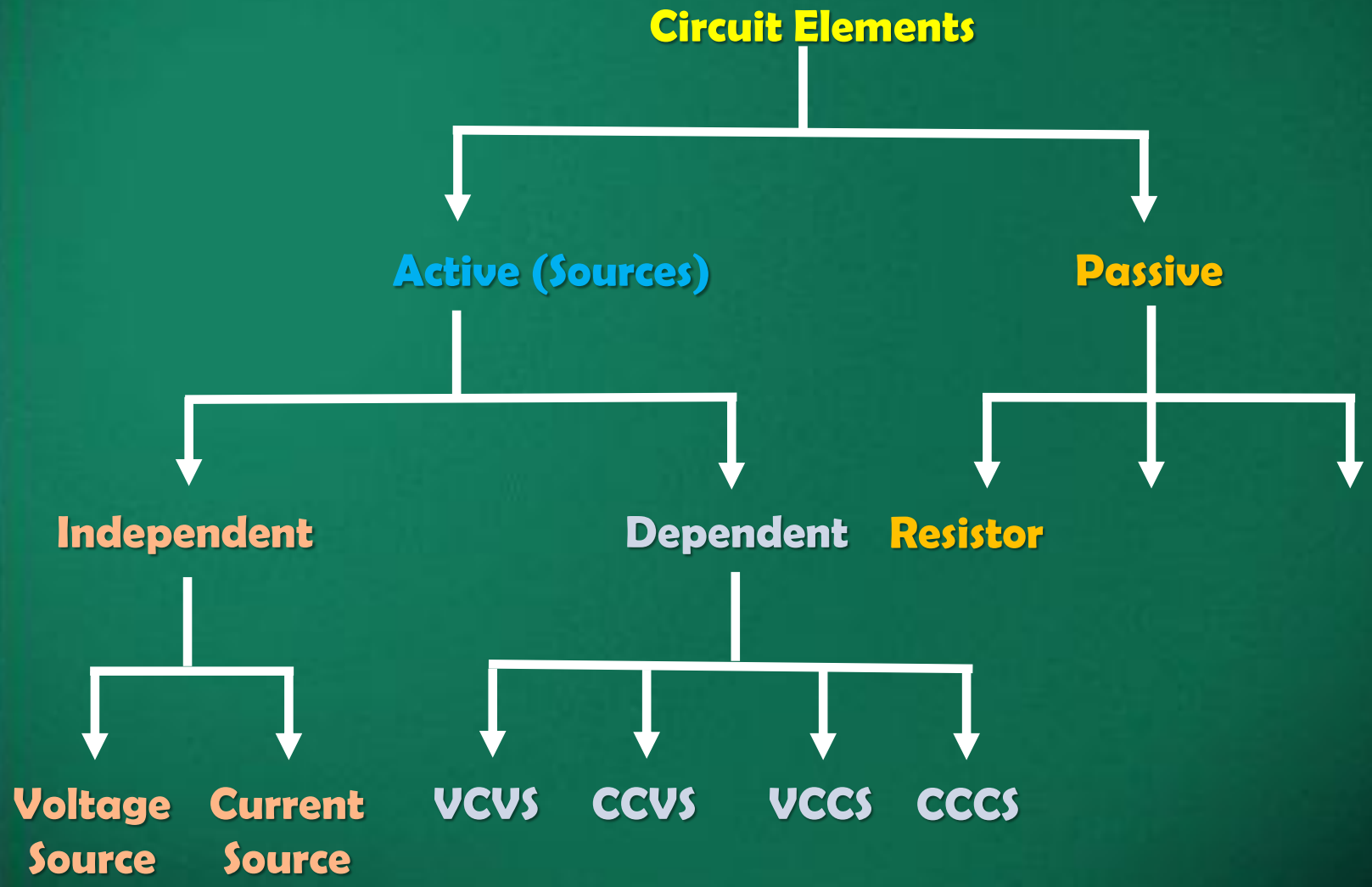

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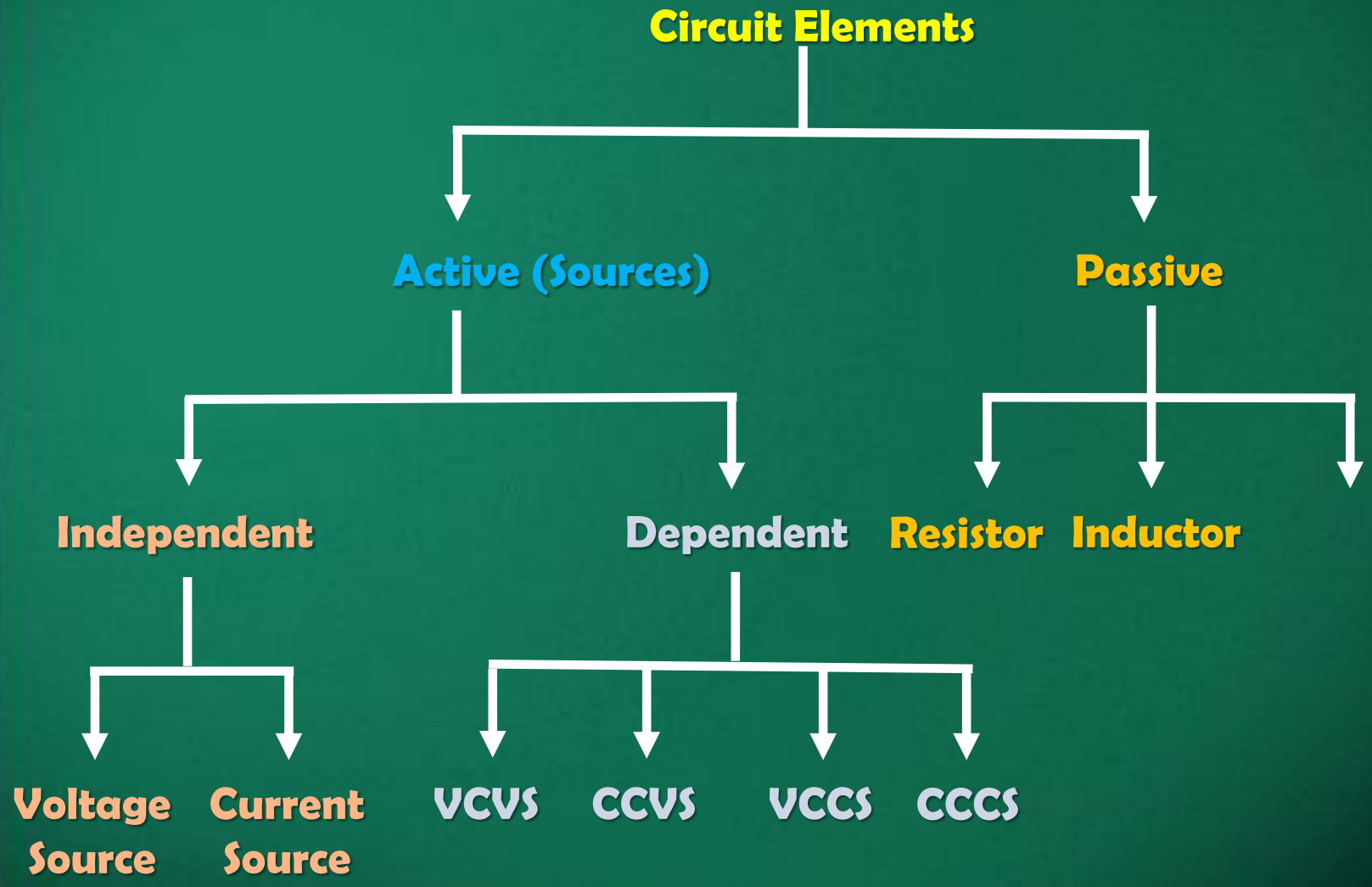

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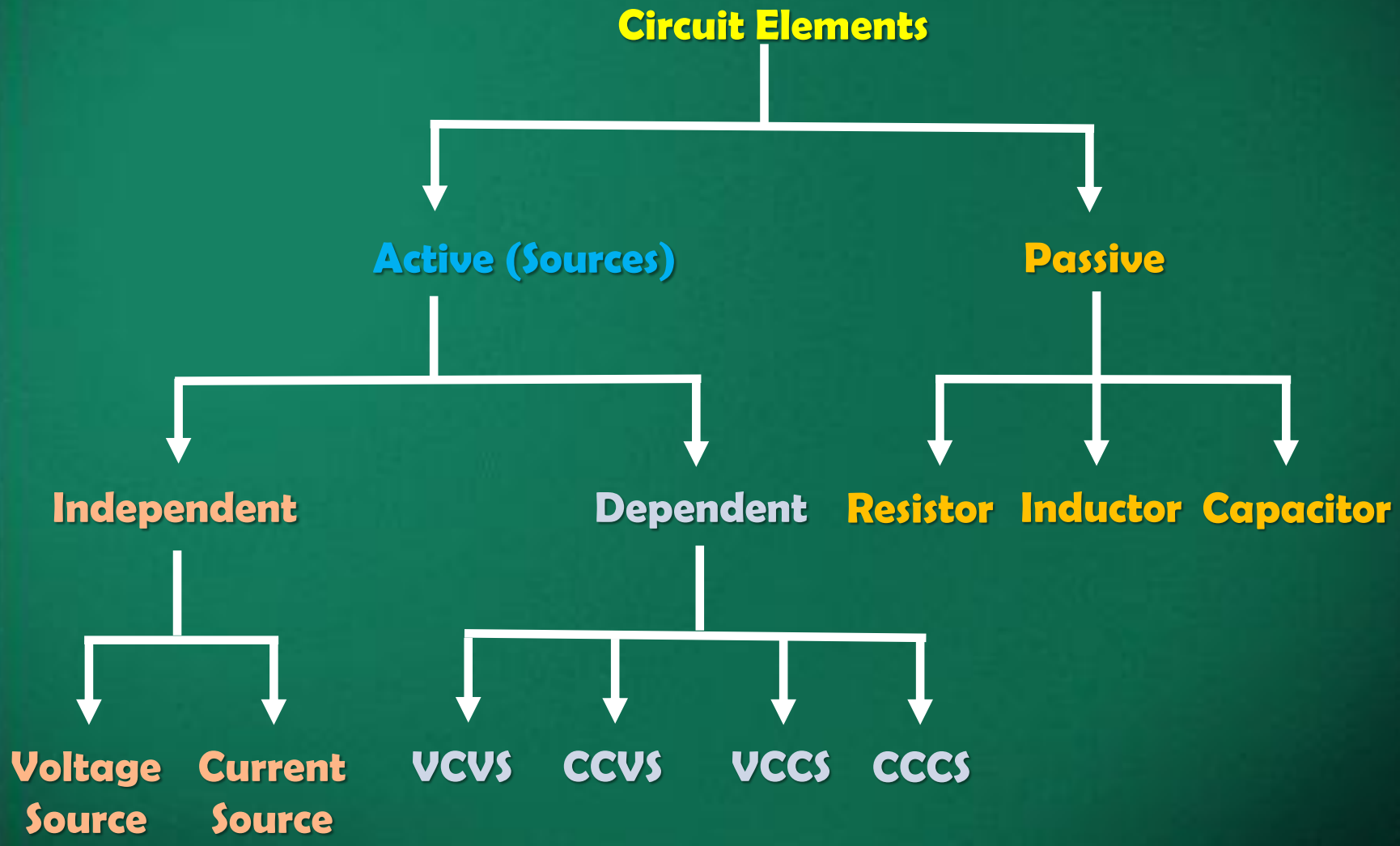

Networks and Circuits

Network is an interconnection of two or more simple elements.

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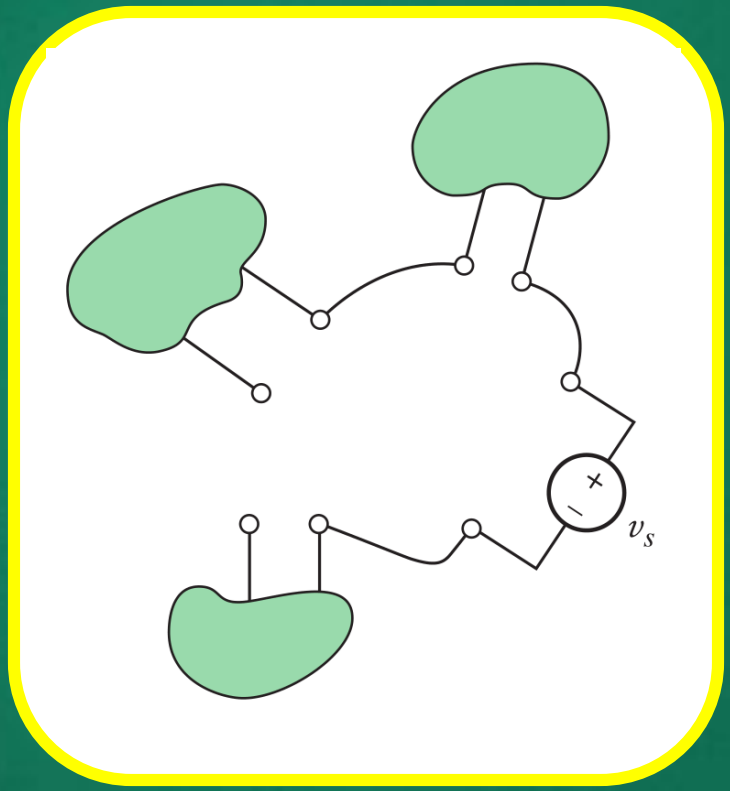
Note: Every circuit is a network, but not all networks are circuits.

The elements in a network/circuit are connected to each other by wire.

Networks and Circuits



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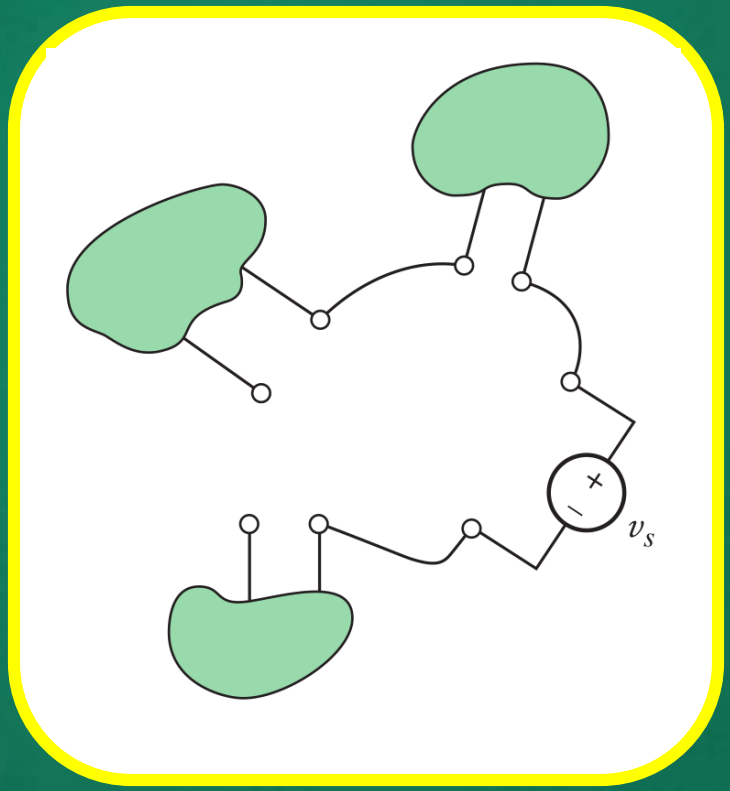
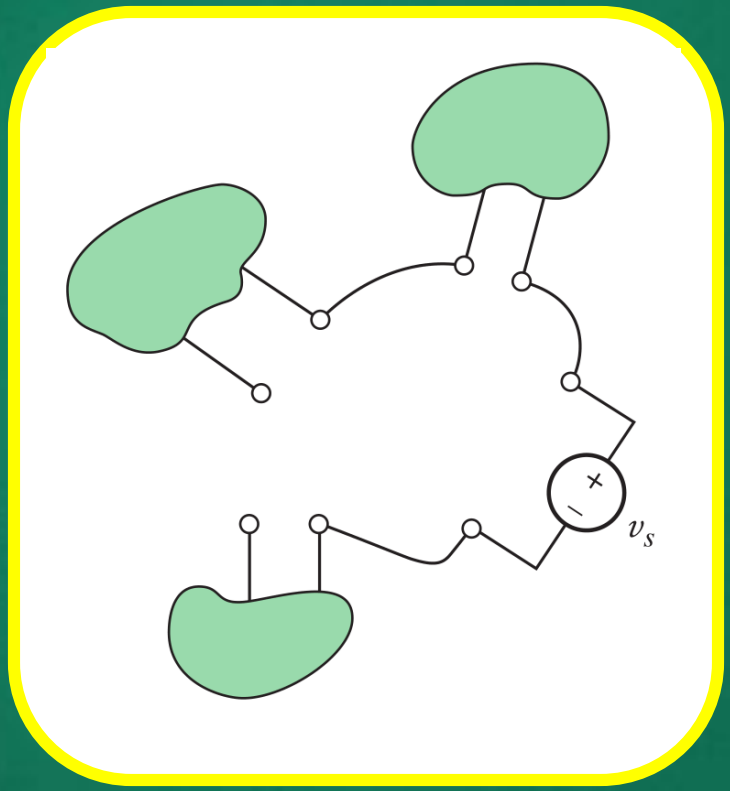
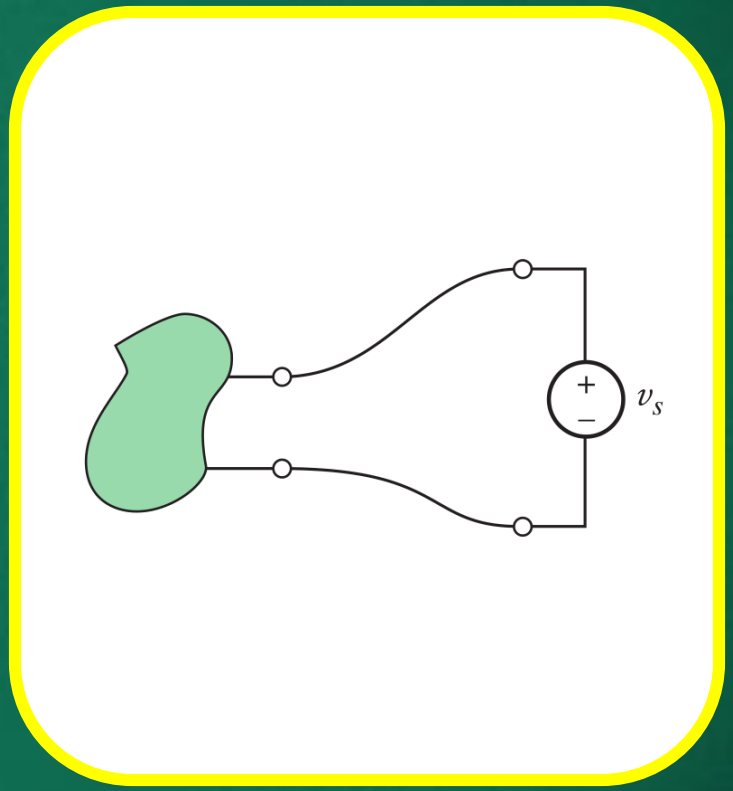


A network that is not a circuit.

Networks and Circuits





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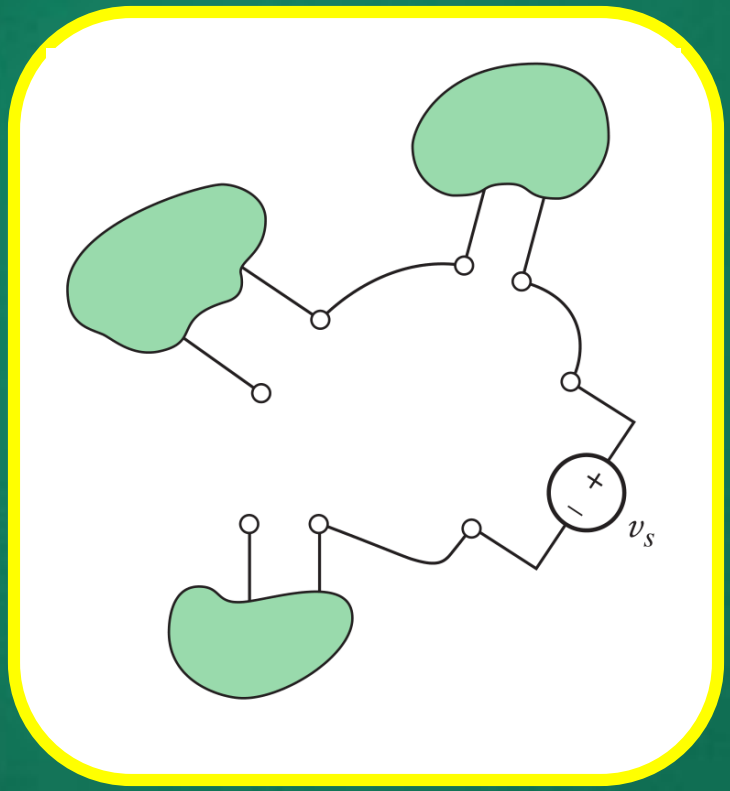

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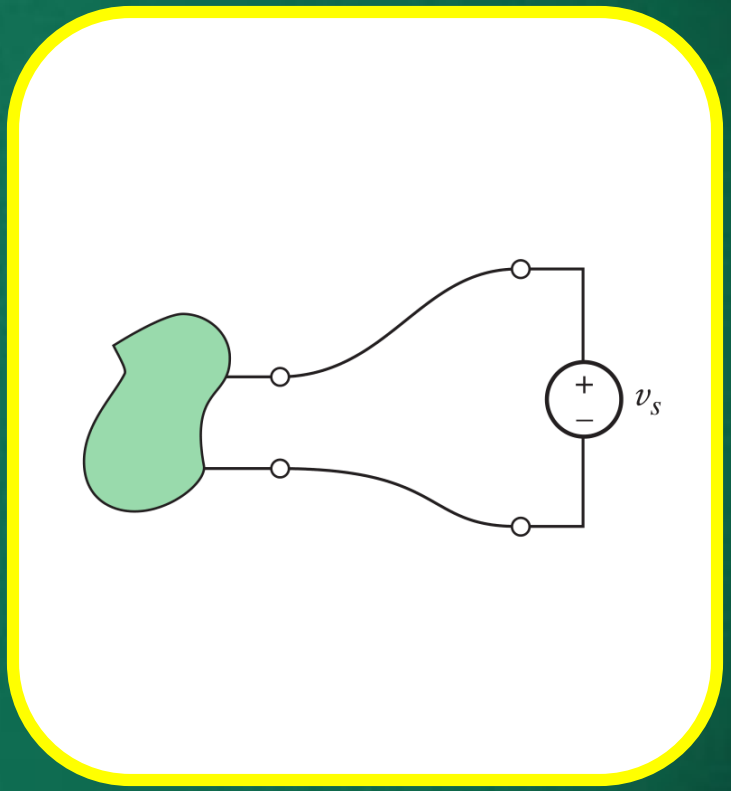

A network that is a circuit.

Linear Circuit

A circuit which consists only linear passive elements and linear dependent sources is termed as a linear circuit.

Circuit Terminology

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Node – A point at which two or more elements have a common connection.

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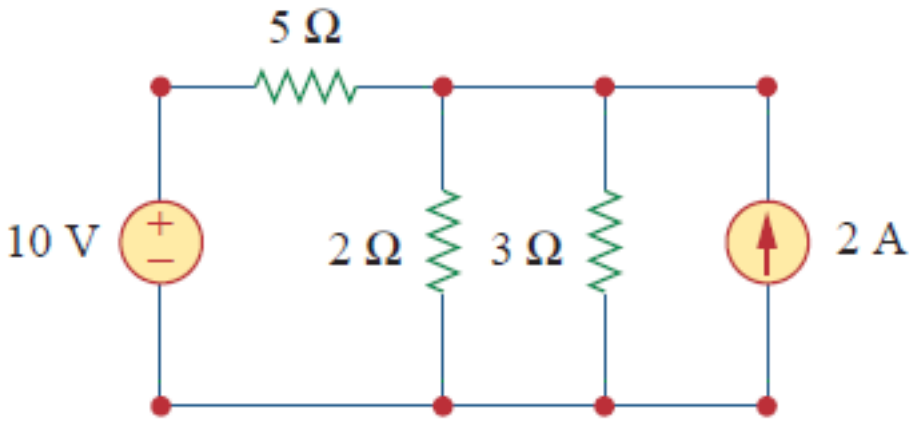
Loop – Loop is a closed path. We end up at the same node at which we start.

Branch – It is a single path in a network, composed of one simple element and a node at each end of the element. A branch represents a single element.

Example

How many nodes and branches are the circuit?



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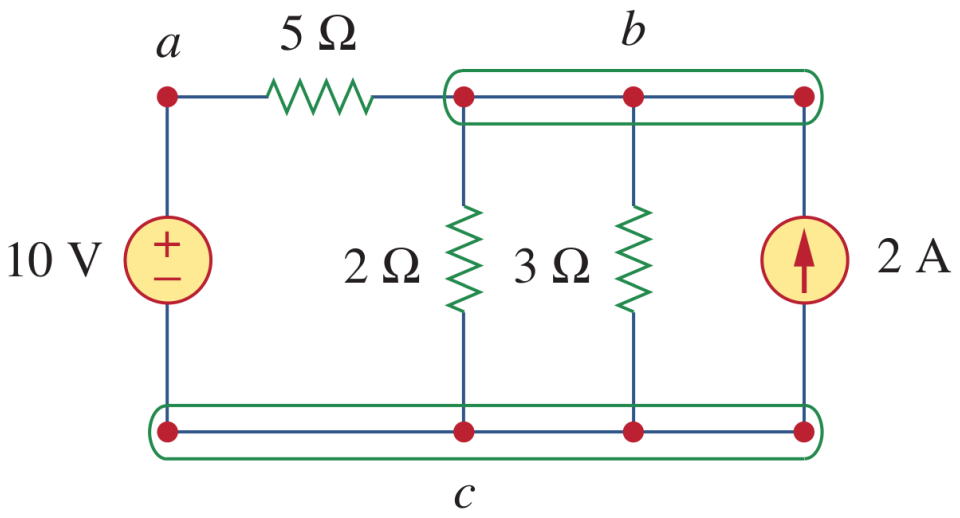

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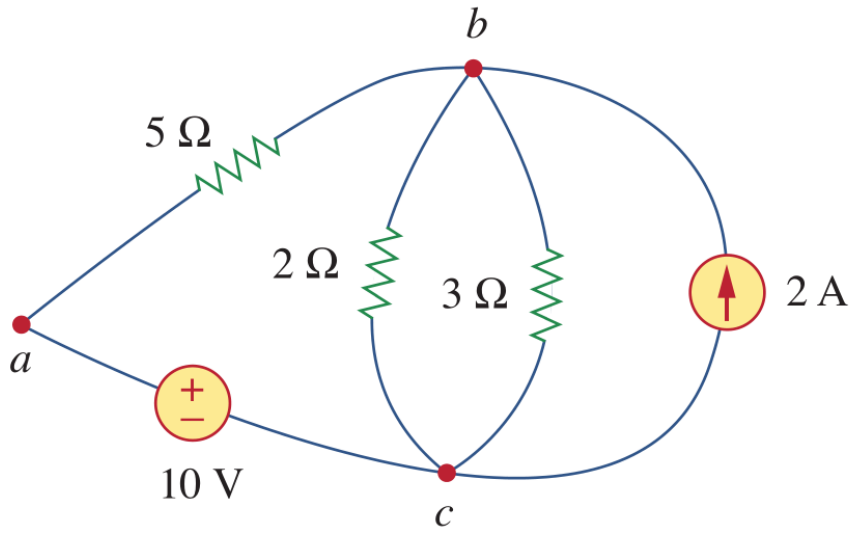
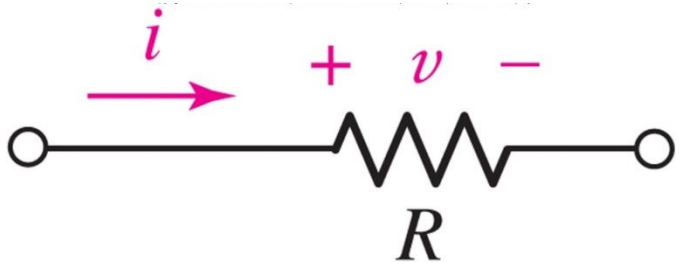


Circuit containing 3 nodes and 5 branches

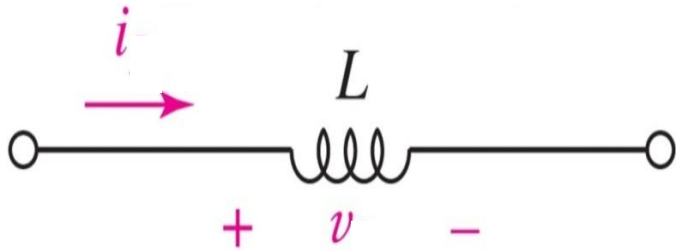
Open and Short Circuits

- An open circuit between A and B means $i = 0$.
- Voltage across an open circuit: any value.
- An open circuit is equivalent to $R = \infty\ \Omega$.
- A short circuit between A and B means $v = 0$.
- Current through a short circuit: any value.
- A short circuit is equivalent to $R = 0\ \Omega$.

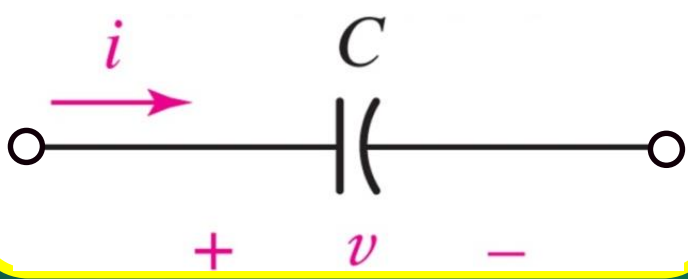
Passive Elements (Linear)



$$v = Ri$$



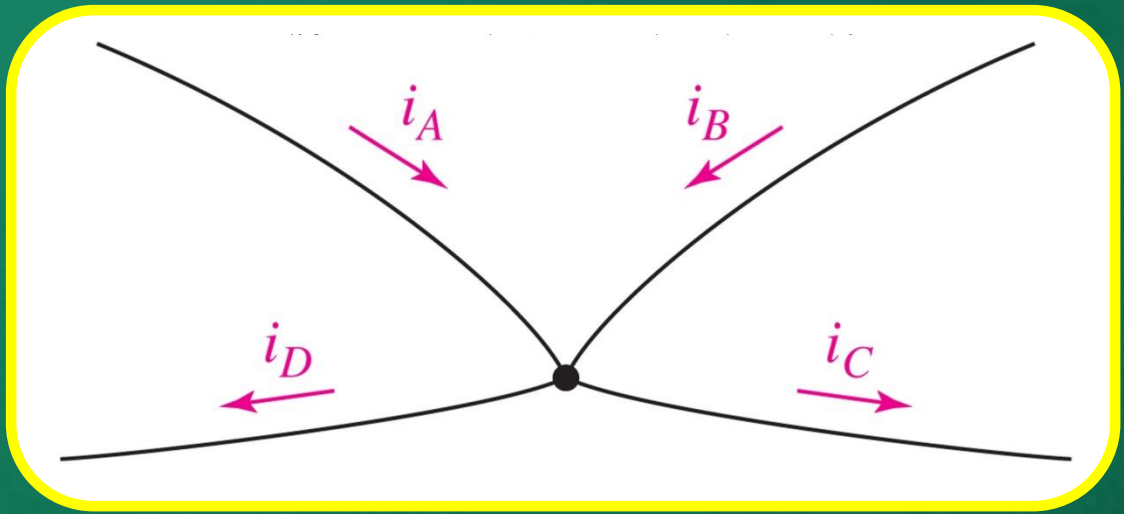
$$v = L\frac{di}{dt}$$



$$i = C\frac{dv}{dt}$$

Kirchhoff's Current Law

KCL - The algebraic sum of the current entering any node is zero.



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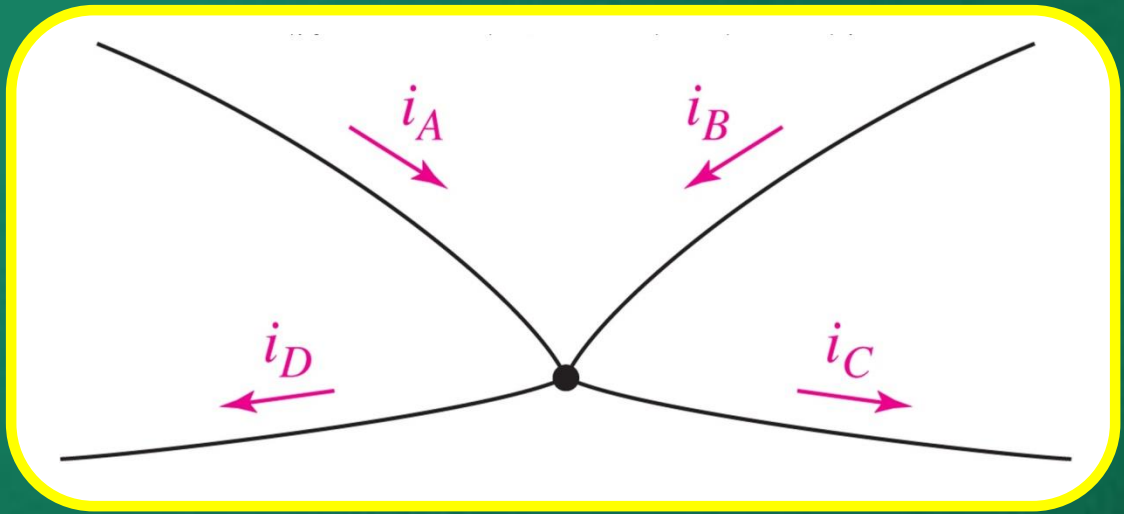


$$i_A + i_B + (-i_C) + (-i_D) = 0$$

KCL: Alternative Forms

- **Current IN is zero:**

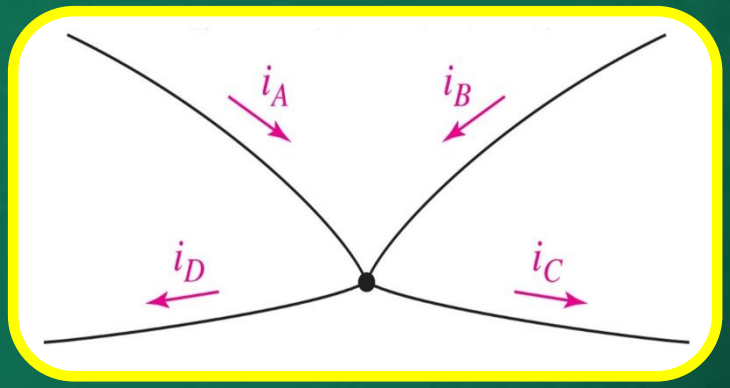
$$i_A + i_B + (-i_C) + (-i_D) = 0$$

- **Current OUT is zero:**

$$(-i_A) + (-i_B) + i_C + i_D = 0$$

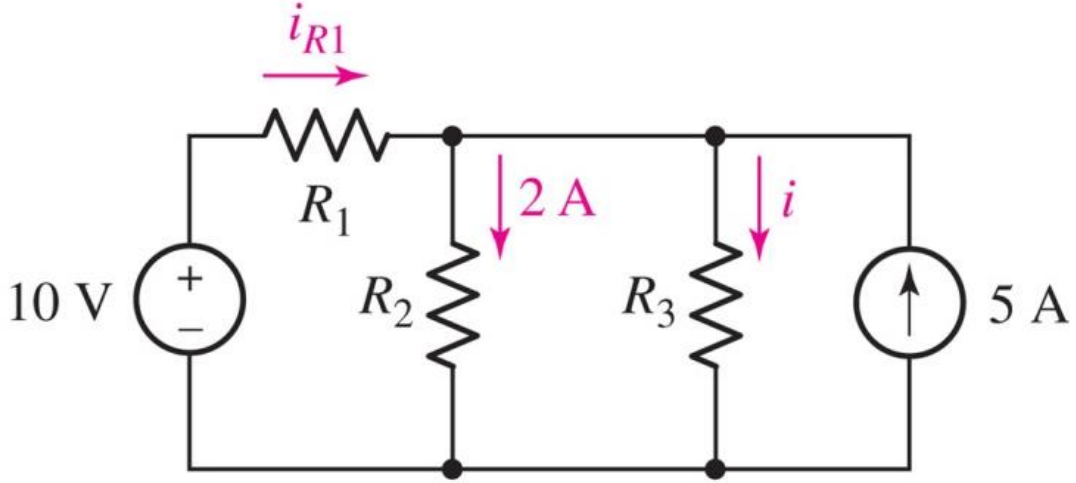
- **Current IN=OUT:**

$$i_A + i_B = i_C + i_D$$



Example: KCL Application

Find the current through resistor R_3 if it is known that the voltage source supplies a current of $3\ \mathrm{A}$.



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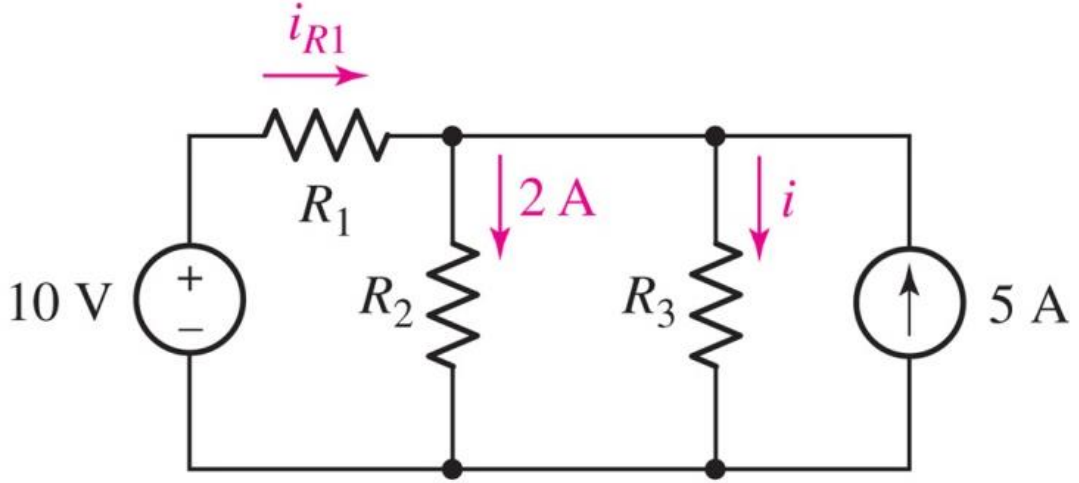
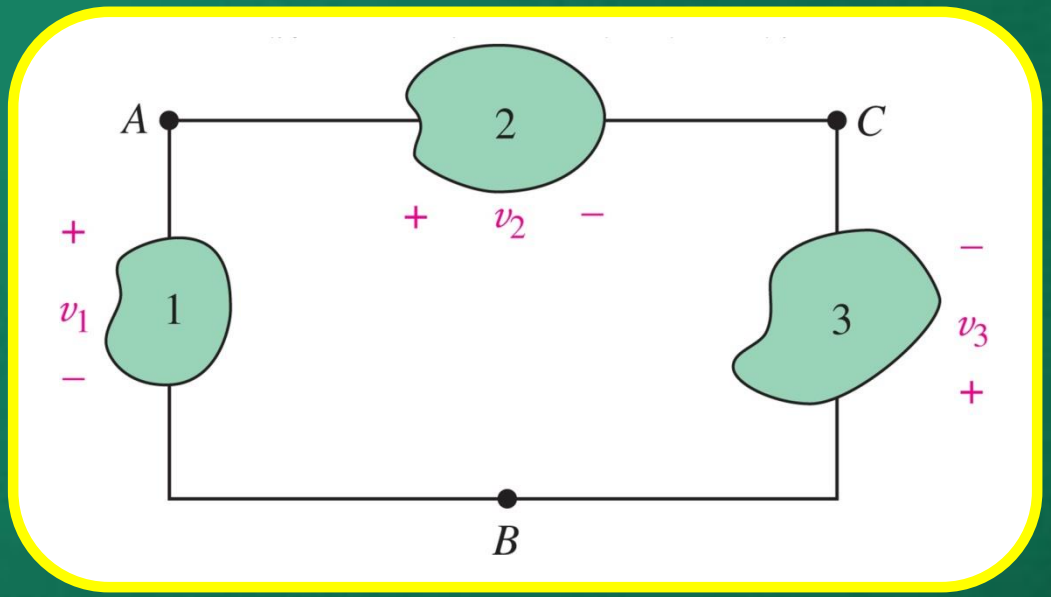


Answer: $i = 6$ A

Kirchhoff's Voltage Law

KVL - The algebraic sum of the voltages around any closed path is zero.



$$v_1 + (-v_2) + v_3 = 0$$

KVL: Alternative Forms

- **Sum of RISES is zero (clockwise from B):**

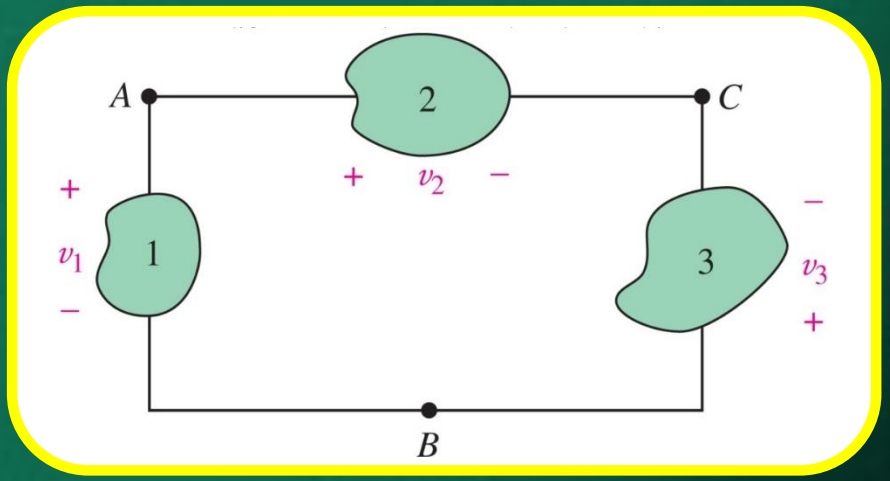
$$v_1 + (-v_2) + v_3 = 0$$

- **Sum of DROPS is zero (clockwise from B):**

$$(-v_1) + v_2 + (-v_3) = 0$$

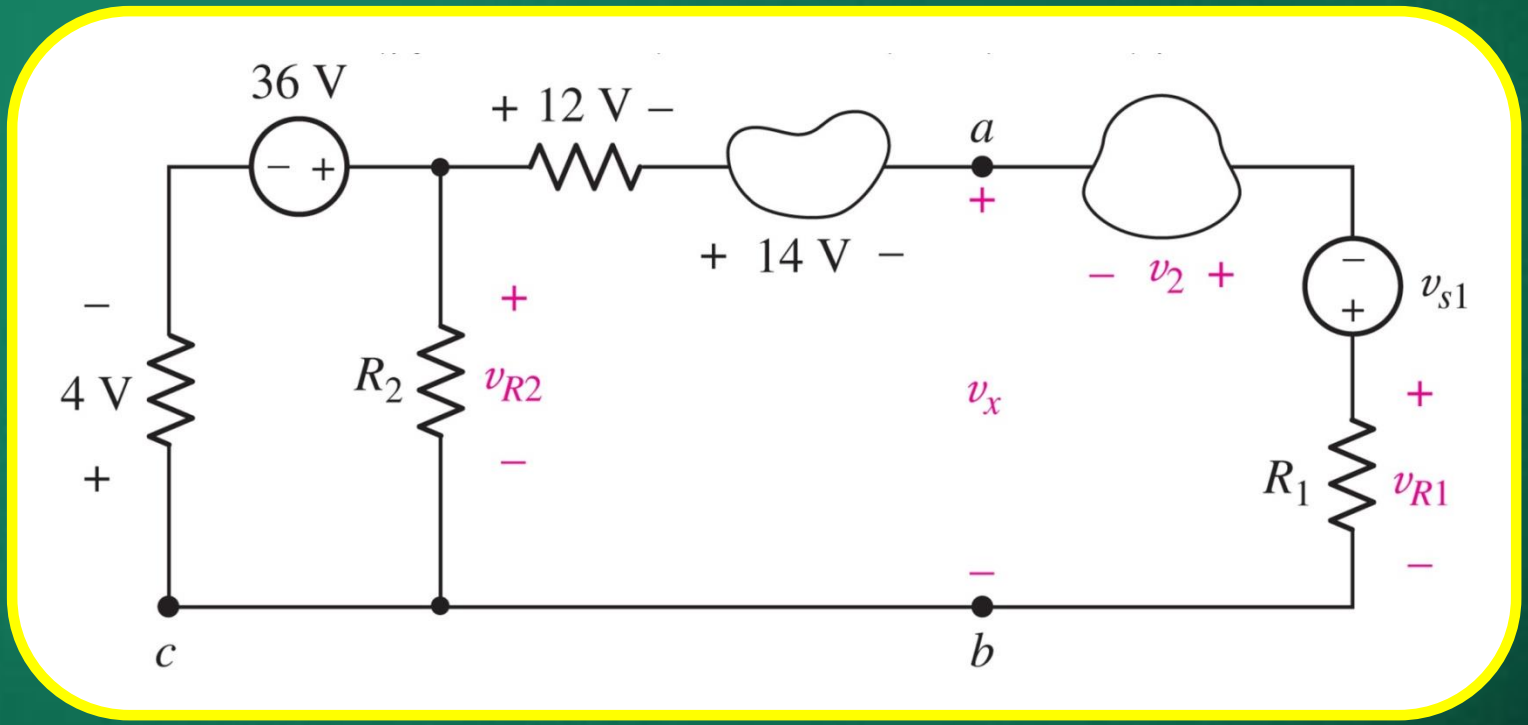
- **Two paths, same voltage (A to B)**

$$v_1 = v_2 + (-v_3)$$



Example: KVL Application

Find v_{R2} (the voltage across R_2) and the voltage v_x.



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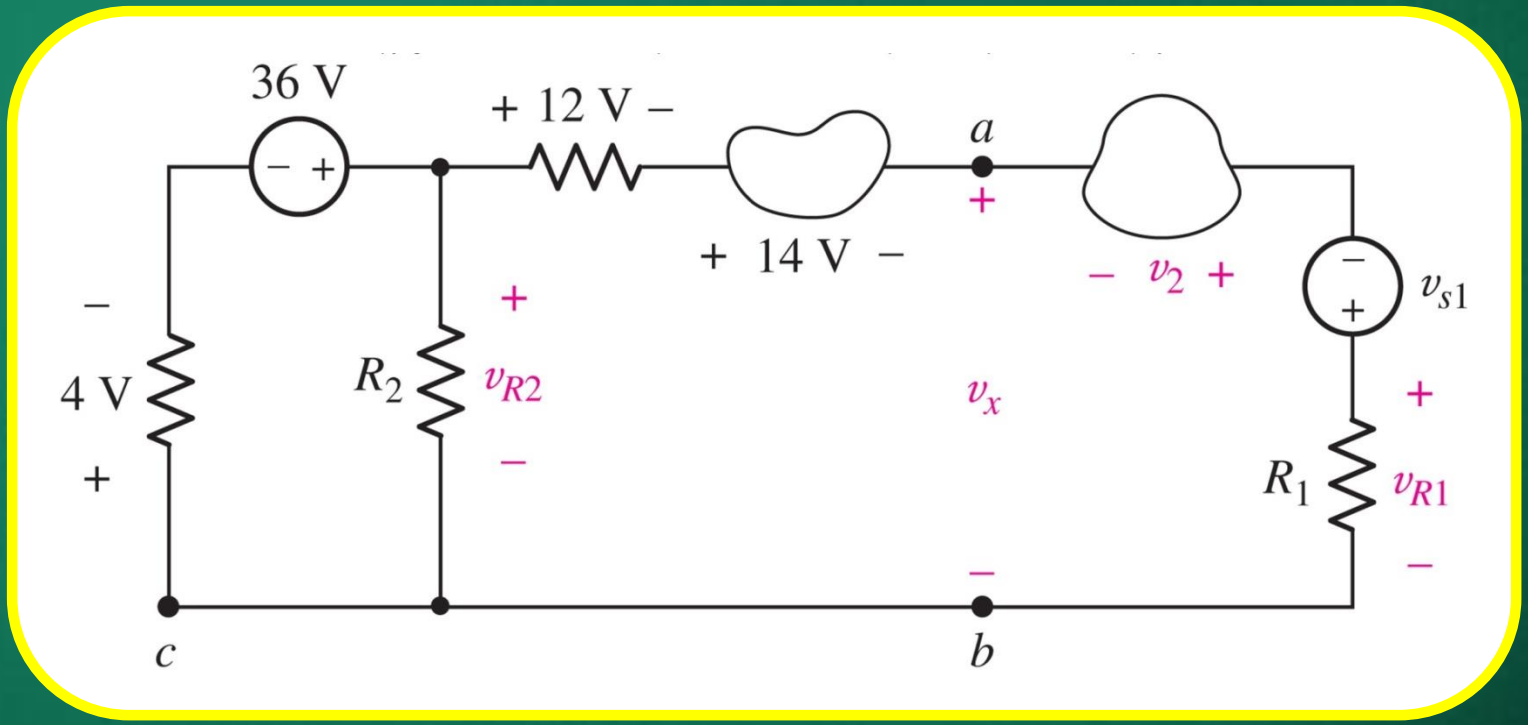
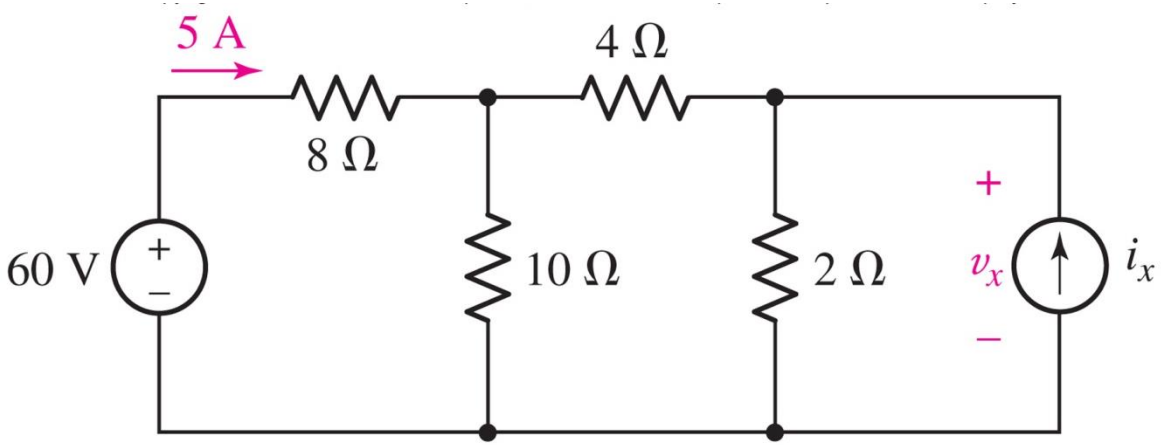


Answer: v_{R2} = 32 V and v_x = 6 V

Applying KVL, KCL, Ohm's Law

Solve for the voltage v_x and the current i_x



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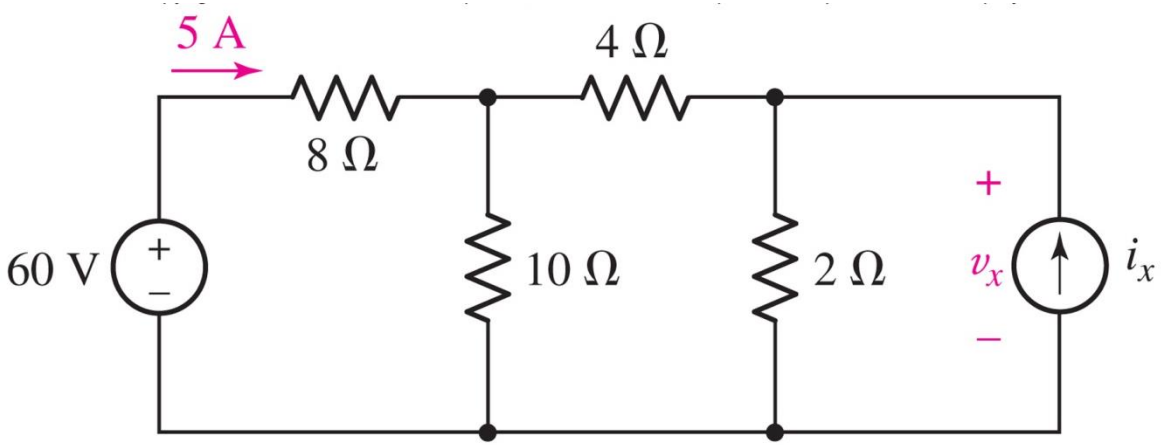
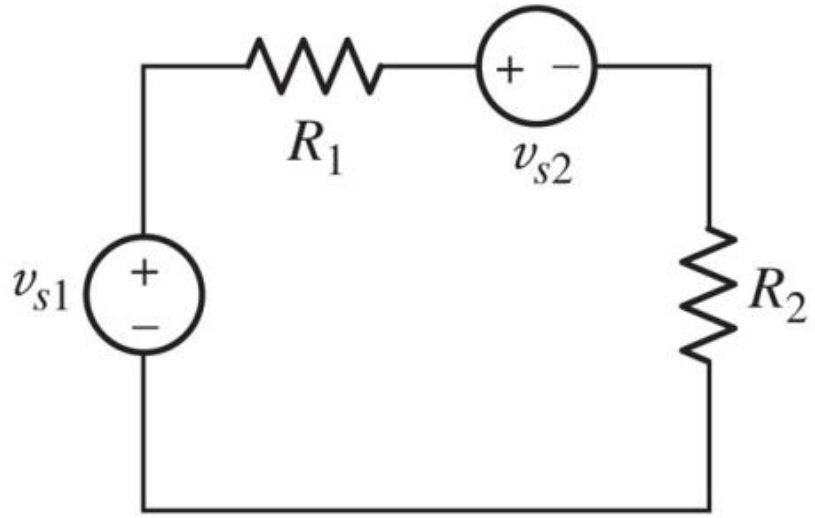


Answer: v_x = 8 V and i_x = 1 A

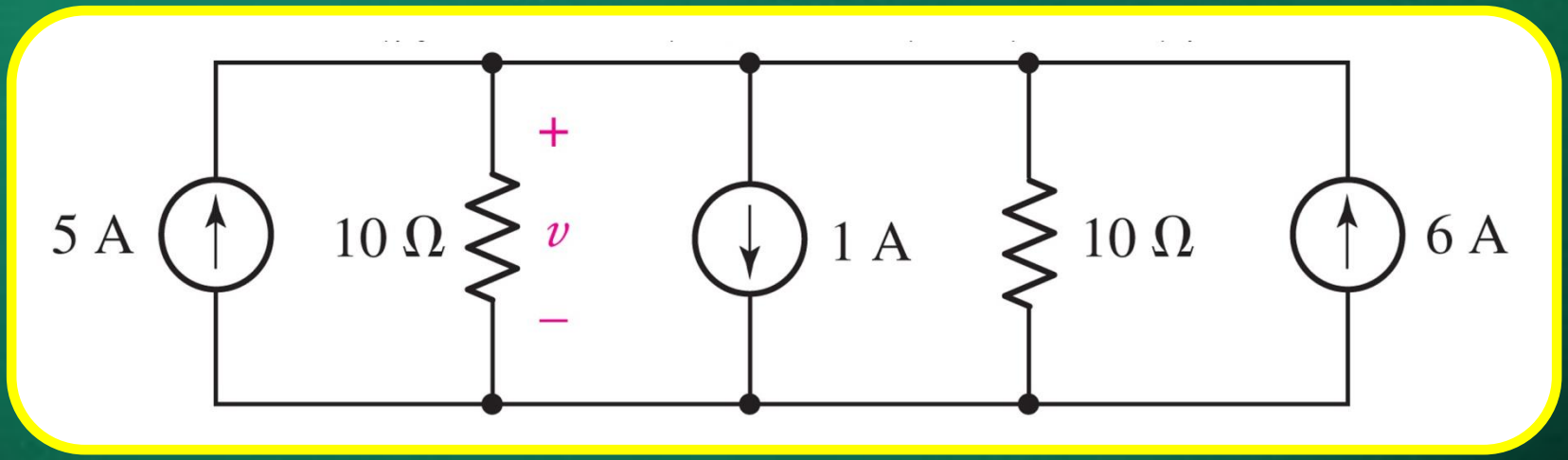
Series Connections

Elements in a circuit that carry the same current are said to be connected in series.



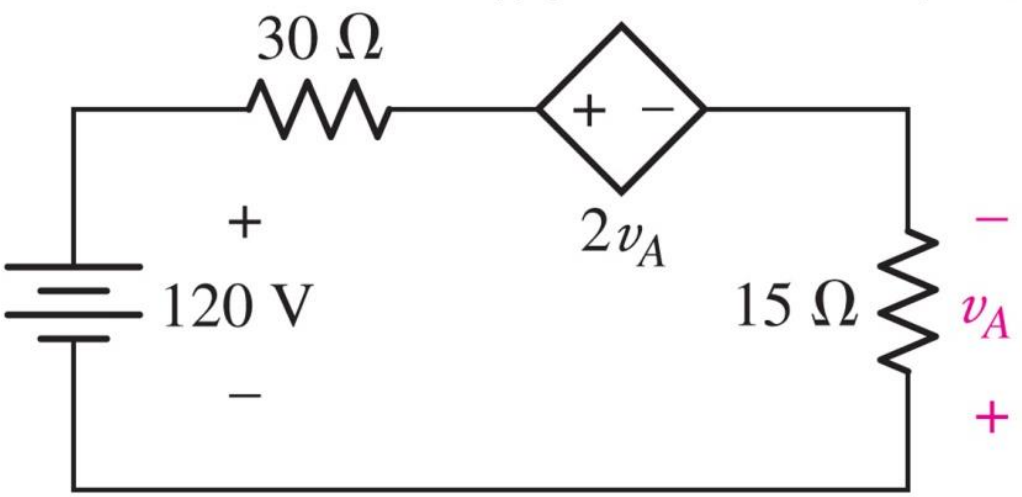
Parallel Connections

Elements in a circuit having a common voltage across them are said to be connected in parallel.



Example: Single Loop Circuit

Calculate the power absorbed by each element.



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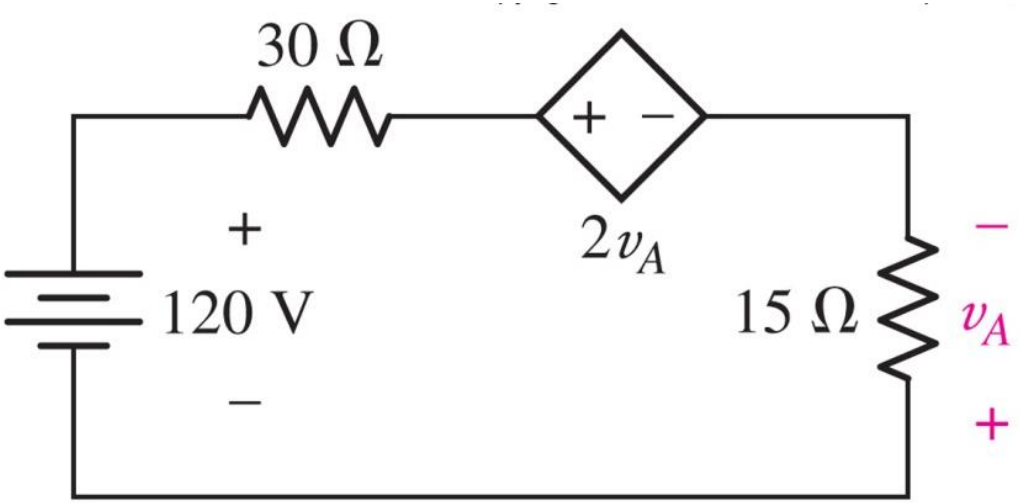
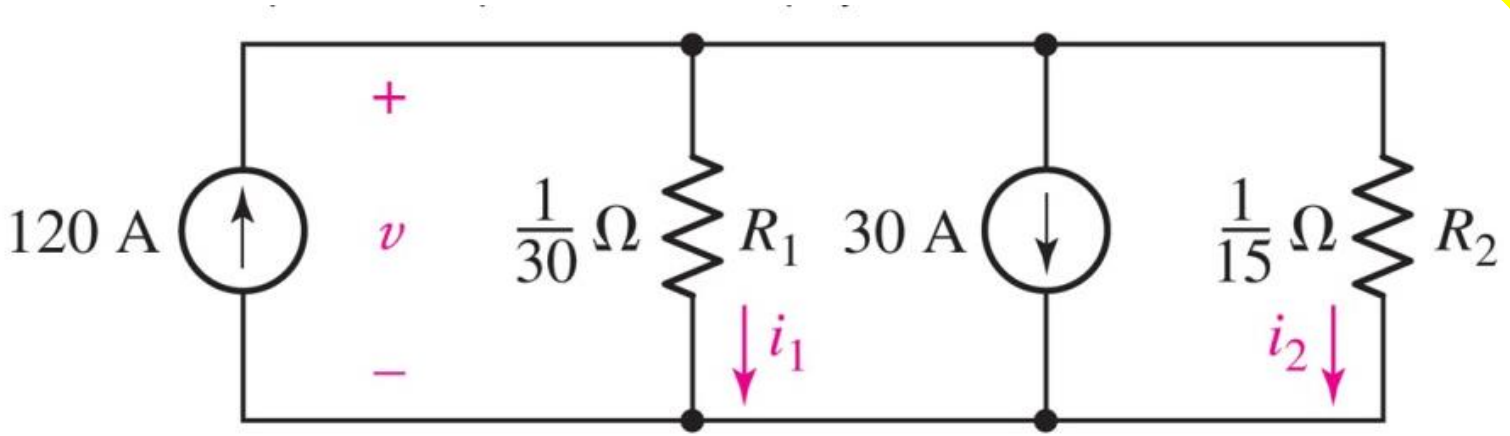


Answer: $P_{120V} = -960$ W, $P_{30} = 1920$ W, $P_{dep} = -1920$ W, $P_{15} = 960$ W

Example: Single Node-Pair Circuit

Find the voltage v and the currents i_1 and i_2.



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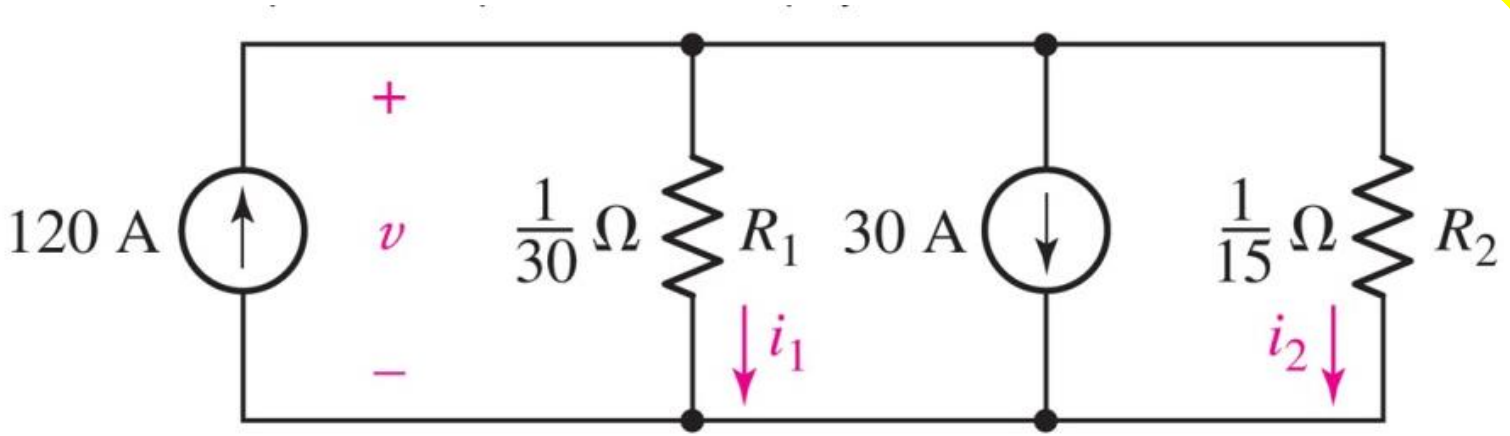
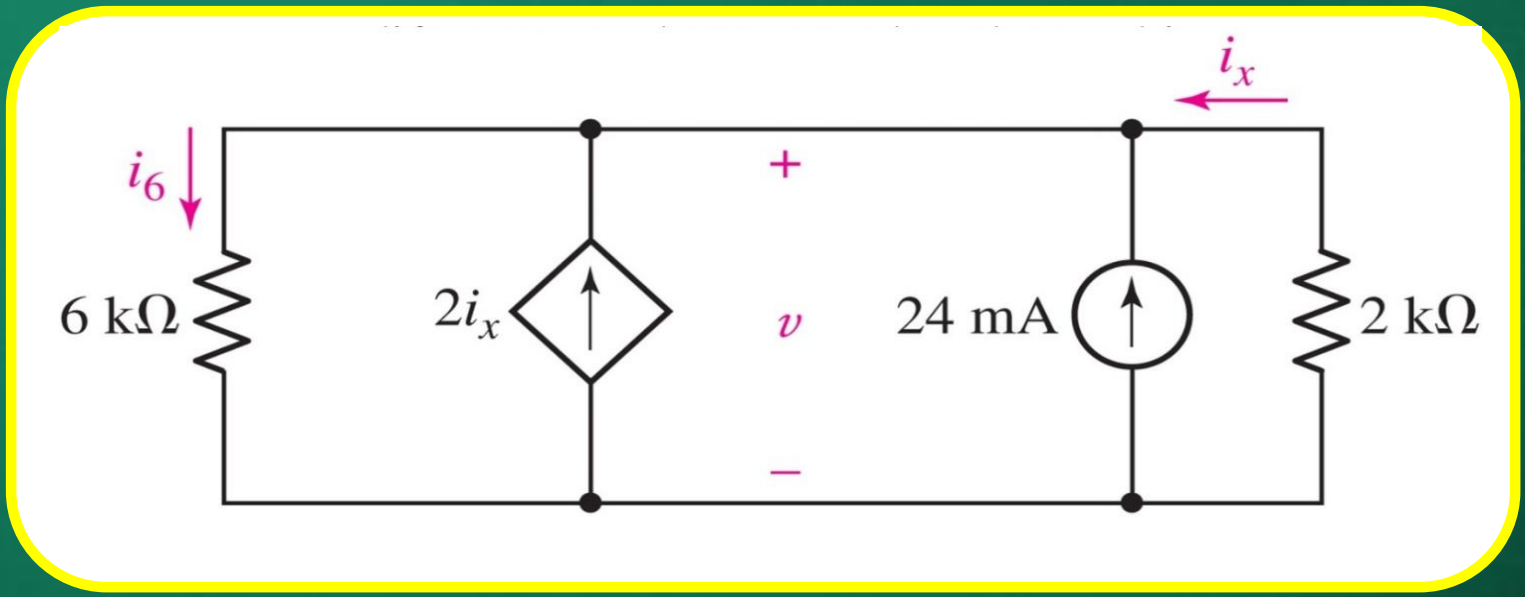


Answer: $v = 2$ V, $i_1 = 60$ A, and $i_2 = 30$ A

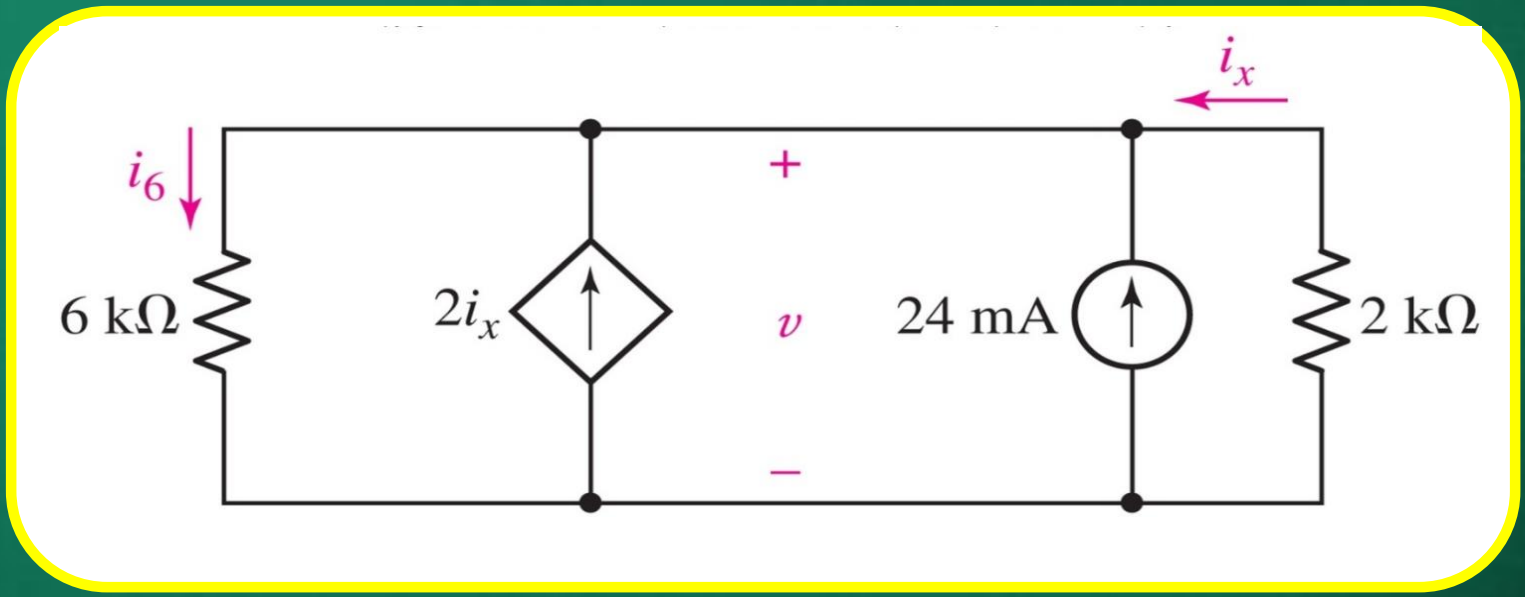
Ex: Single Node-Pair Circuit

Determine the value of v and the power supplied by the independent current source.



Ex: Single Node-Pair Circuit

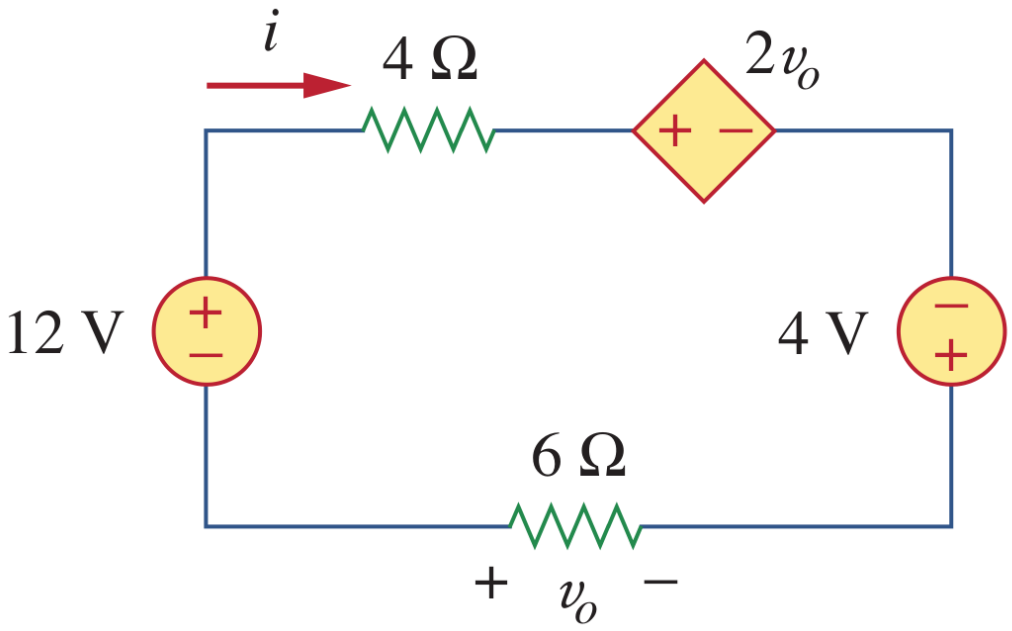
Determine the value of v and the power supplied by the independent current source.



Answer: v = 14.4 V, $P_{24\text{mA}}$ = 345.6 mW

Example

Determine the value of v_o and i .



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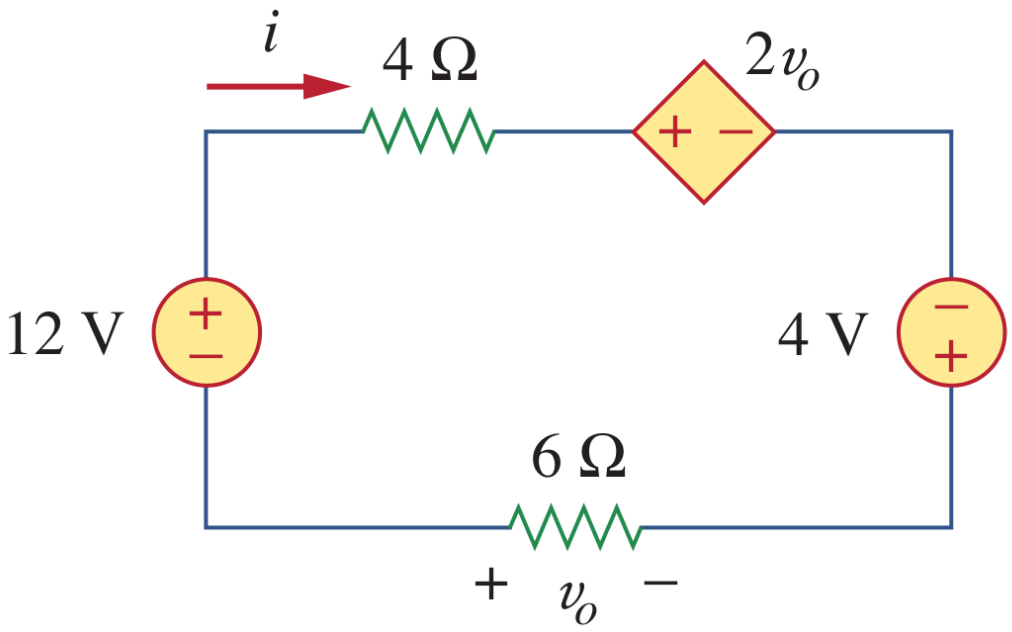
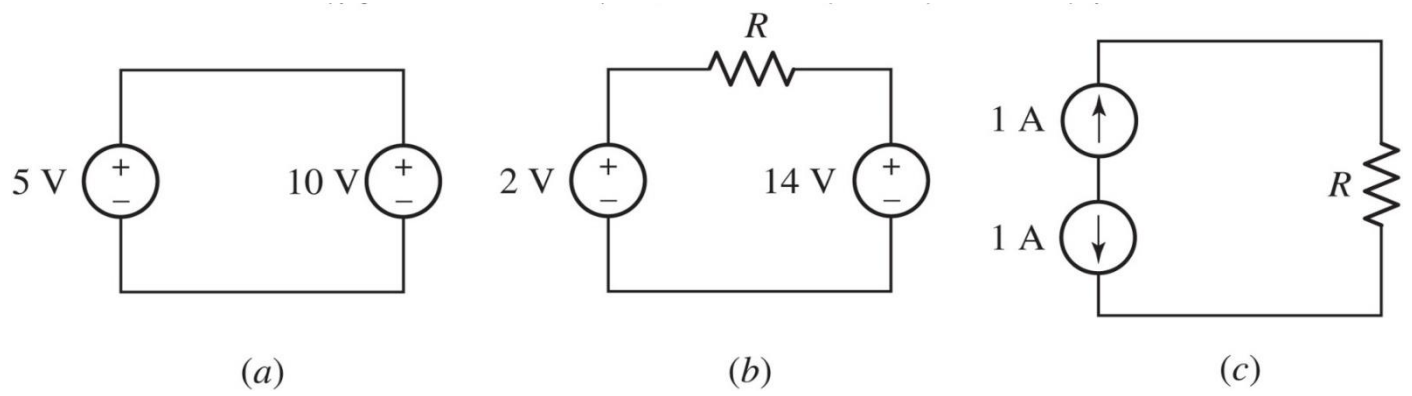


Answer: v_o = 48 V, i = -8 A

Impossible Circuits

Our circuit models are idealizations that can lead to apparent physical absurdities.



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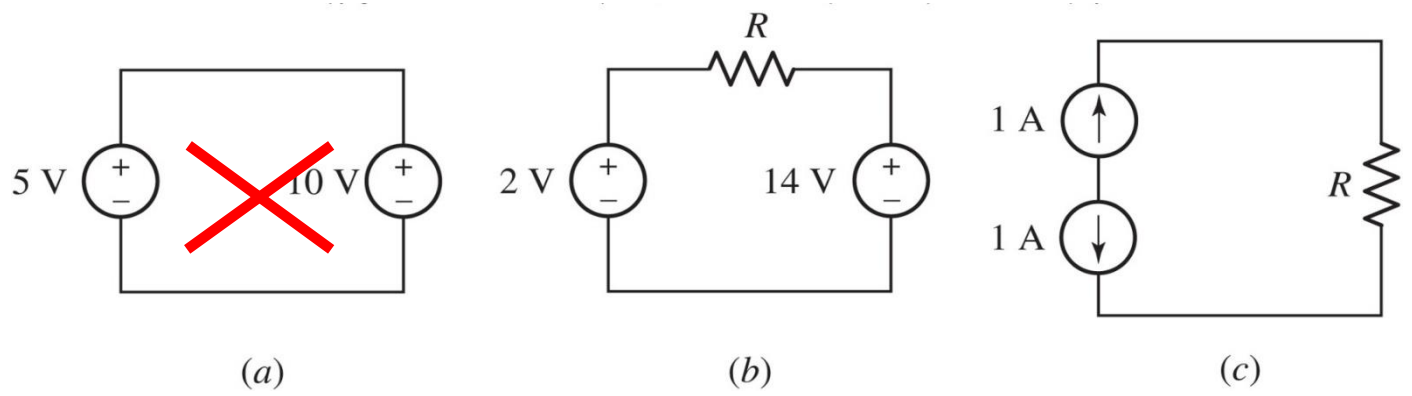

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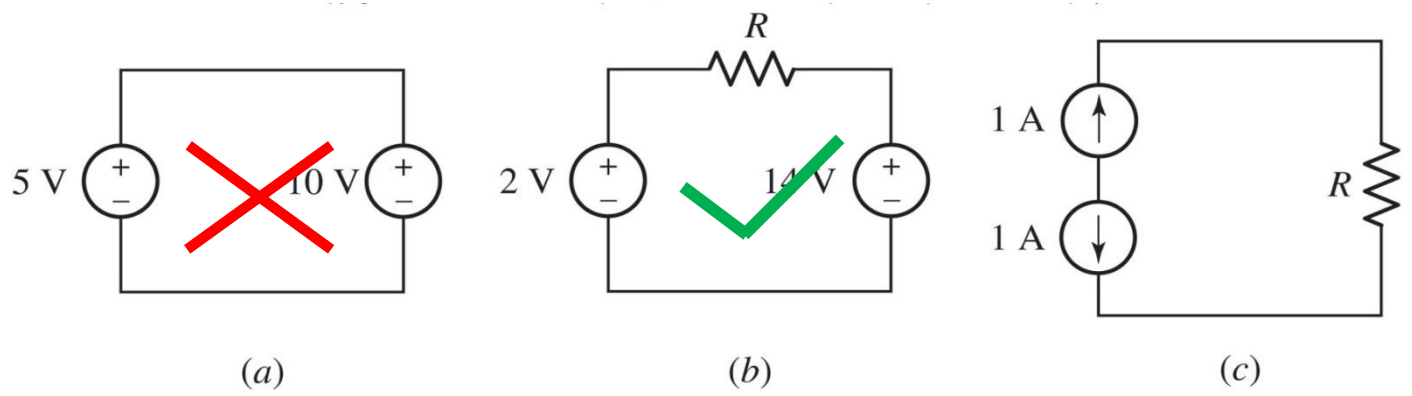

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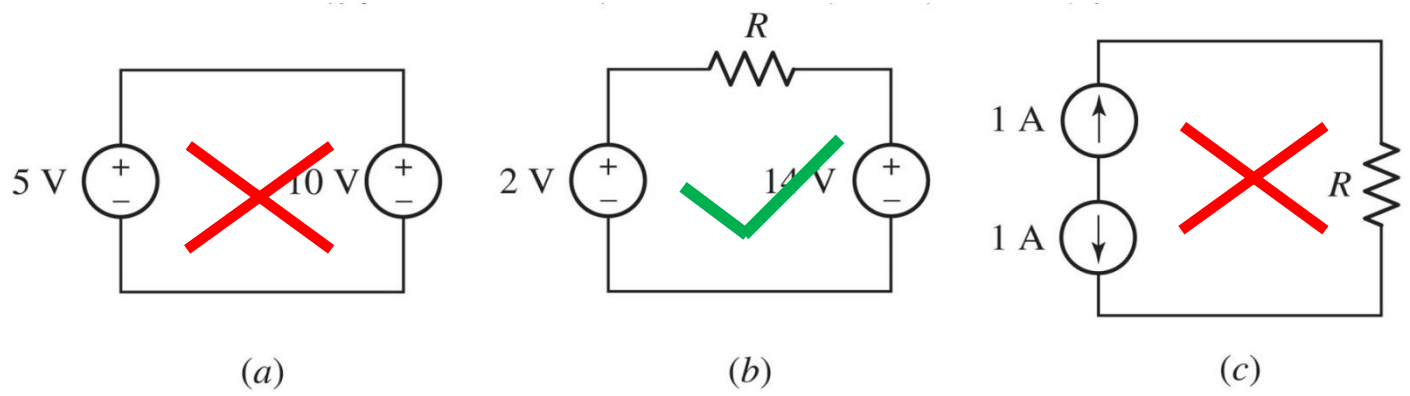
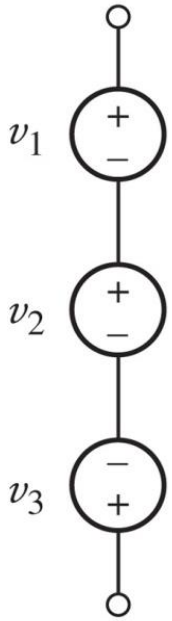


Series and Parallel Sources

Voltage sources connected in series can be combined into an equivalent voltage source.



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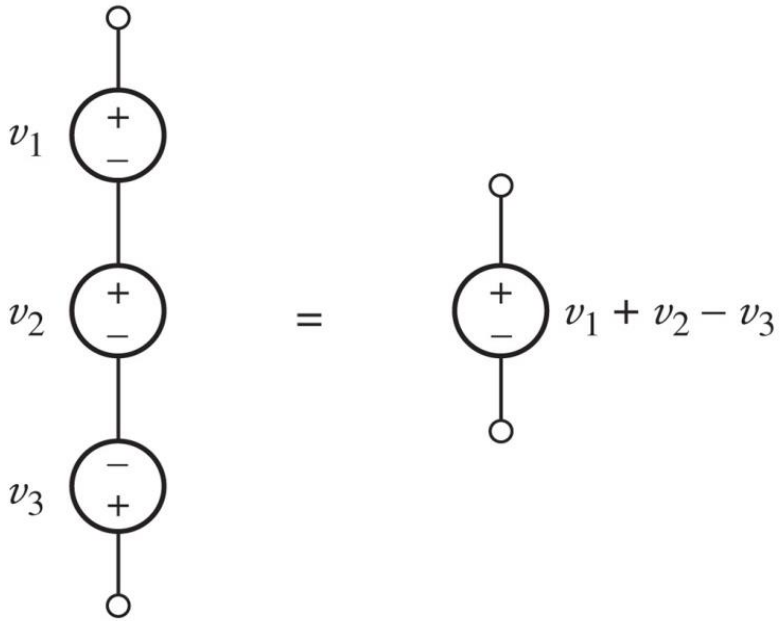
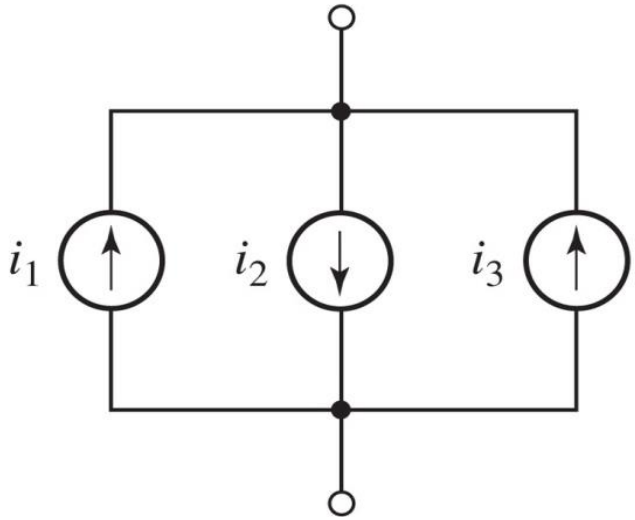


Series and Parallel Sources

Current sources connected in parallel can be combined into an equivalent current source.



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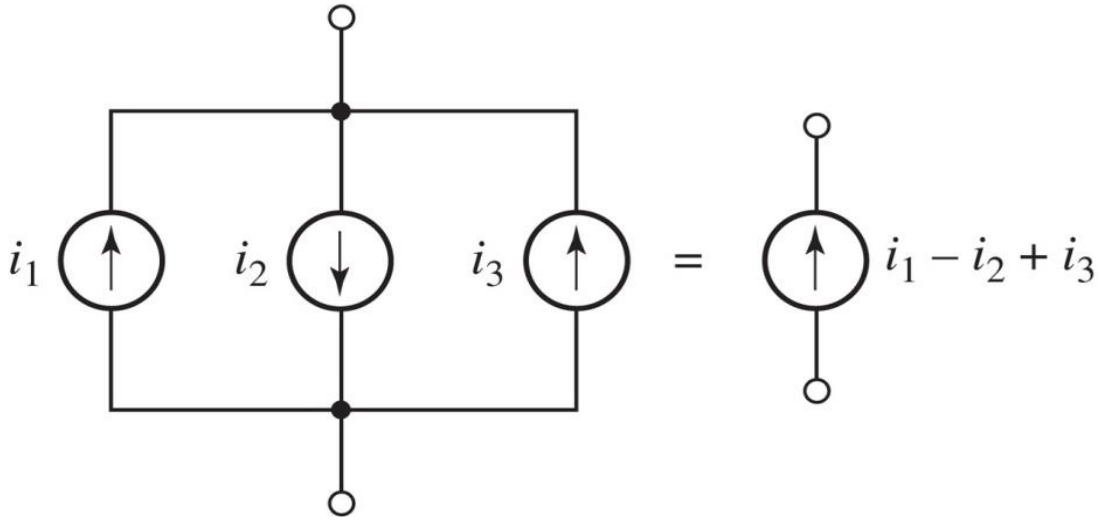

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Resistors in series share the voltage applied to them.

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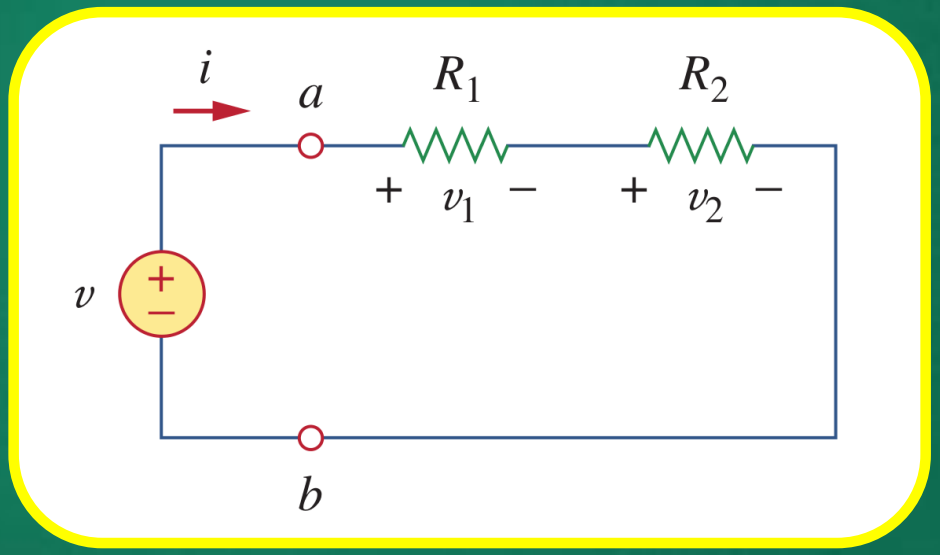

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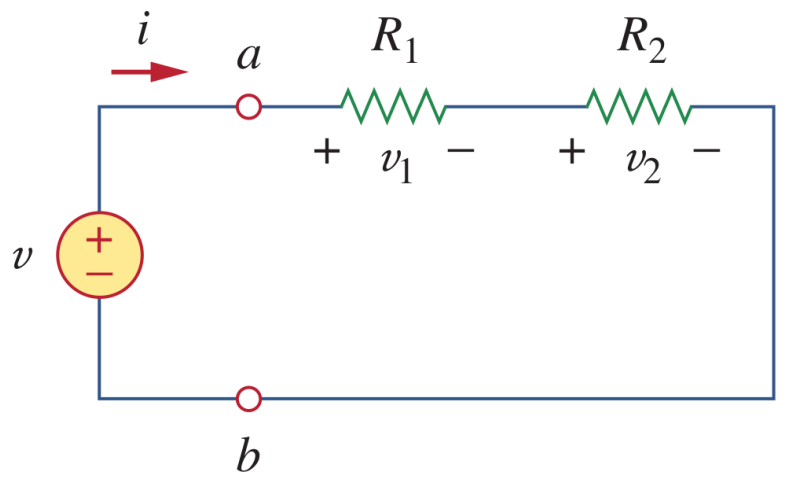

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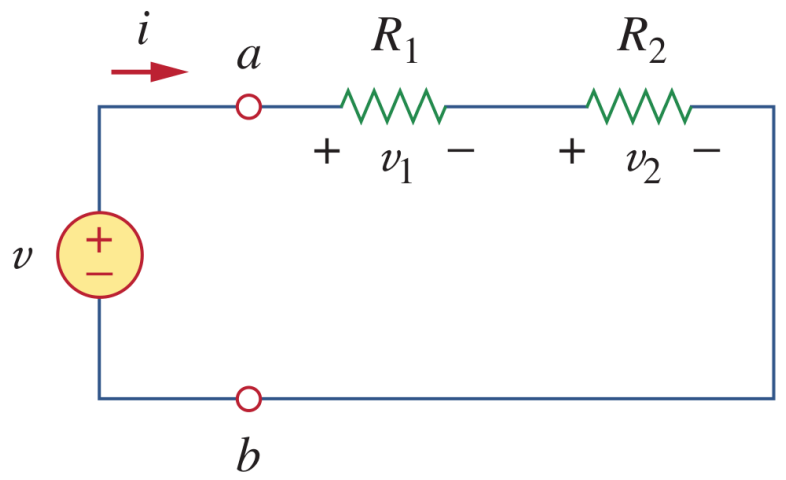

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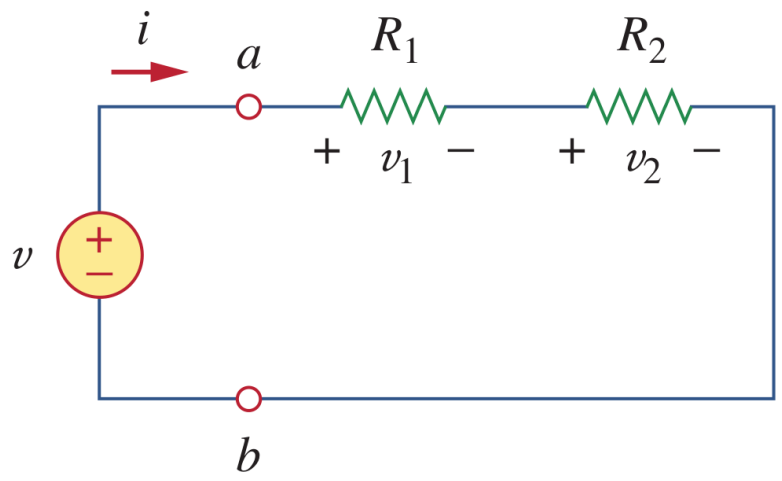


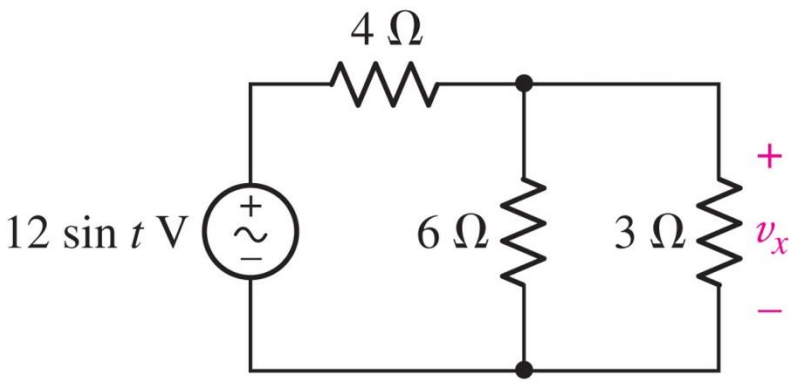
$$v_1 = \frac{R_1}{R_1 + R_2} v$$

$$v_2 = \frac{R_2}{R_1 + R_2} v$$

The voltage across the resistive elements in series will be divided in the ratio of magnitude of the resistances.

Example: Voltage Division

Find v_x



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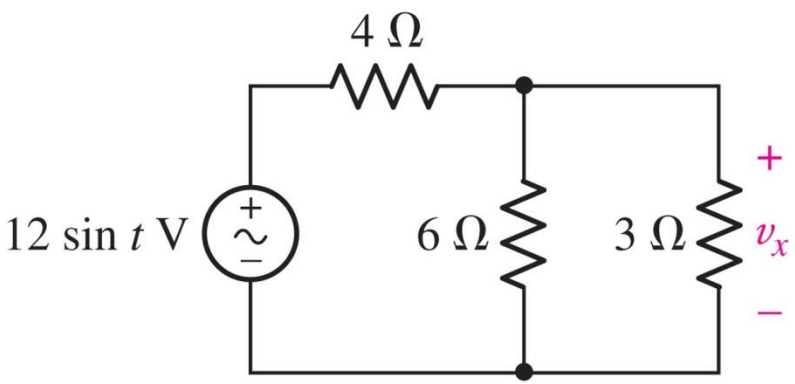

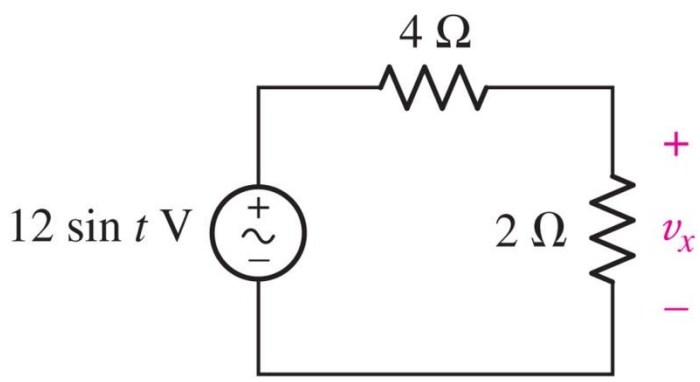

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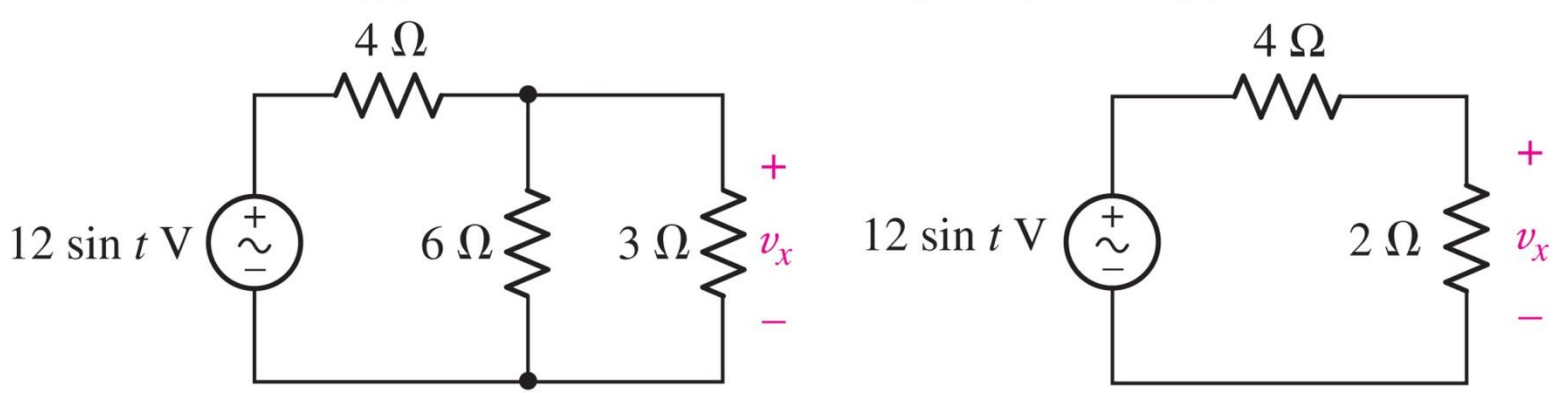

Answer: $v_x(t) = 4 \sin t$ V

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Resistors in parallel share the current through them.

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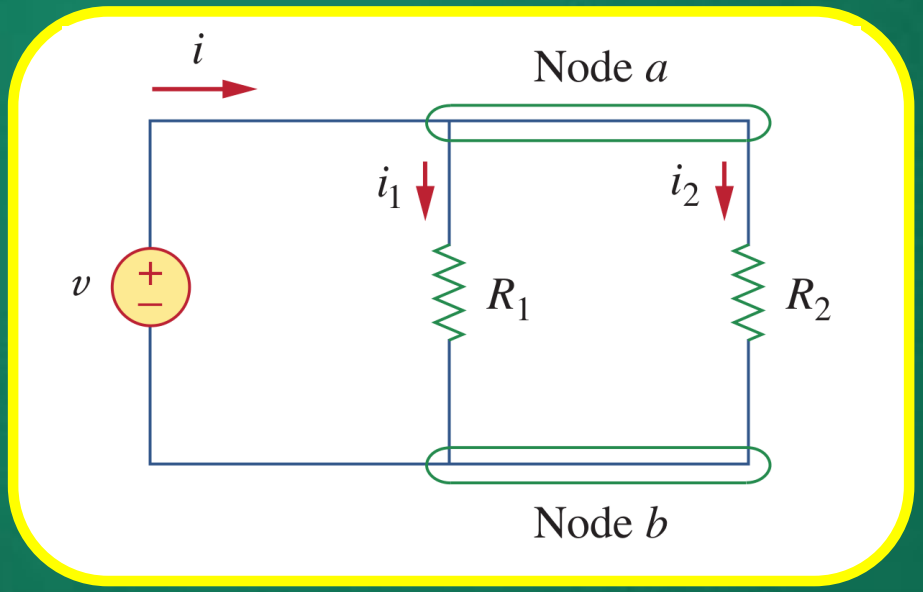

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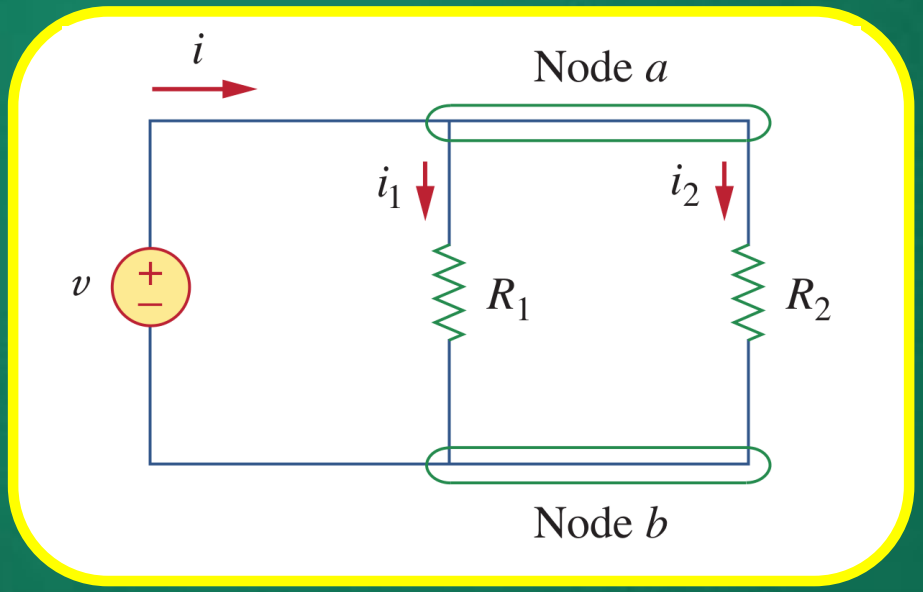

$$i_1 = i\frac{R_2}{R_1 + R_2}$$

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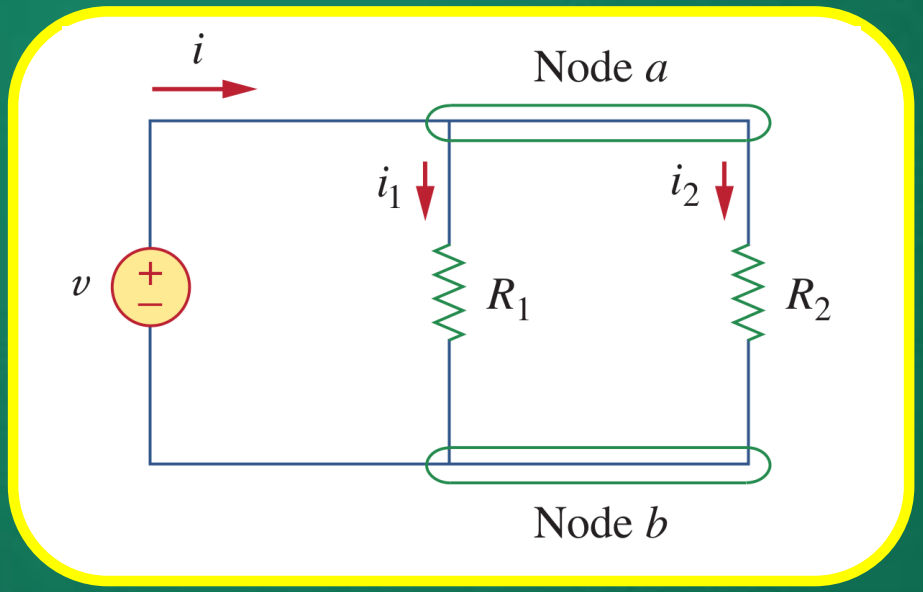

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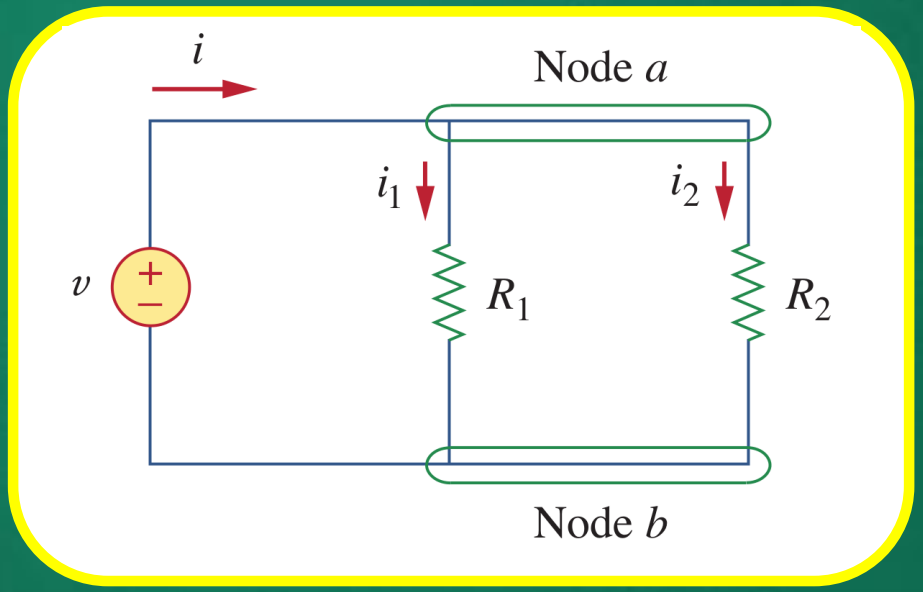

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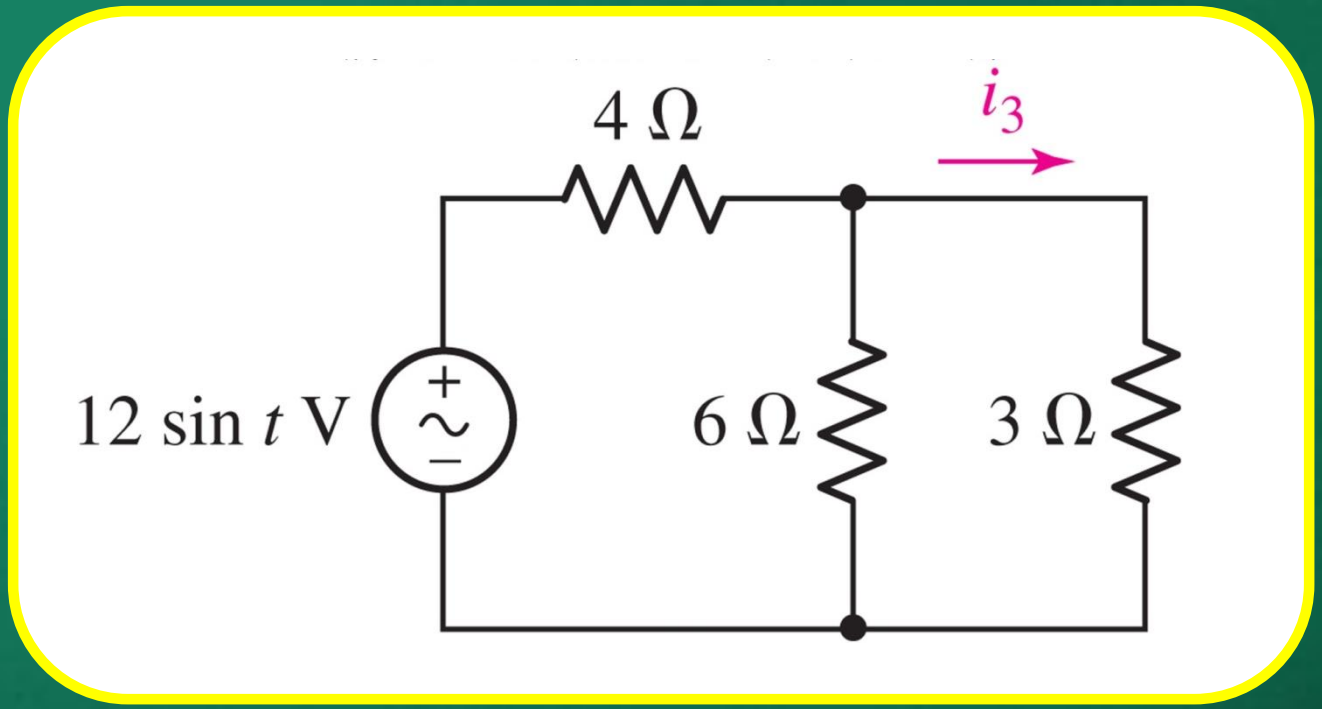
The current through resistive elements in parallel will be divided in the ratio of magnitude of the conductances.

Example: Current Division

Find $i_3(t)$



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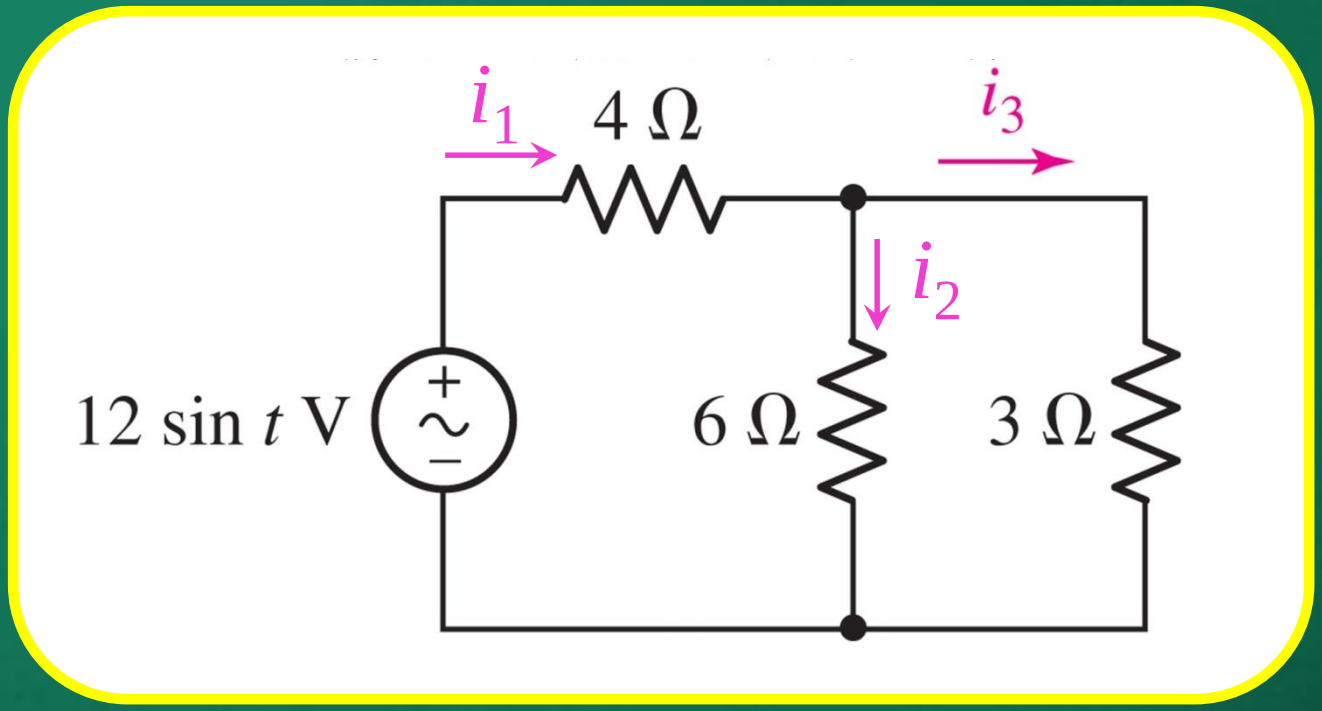

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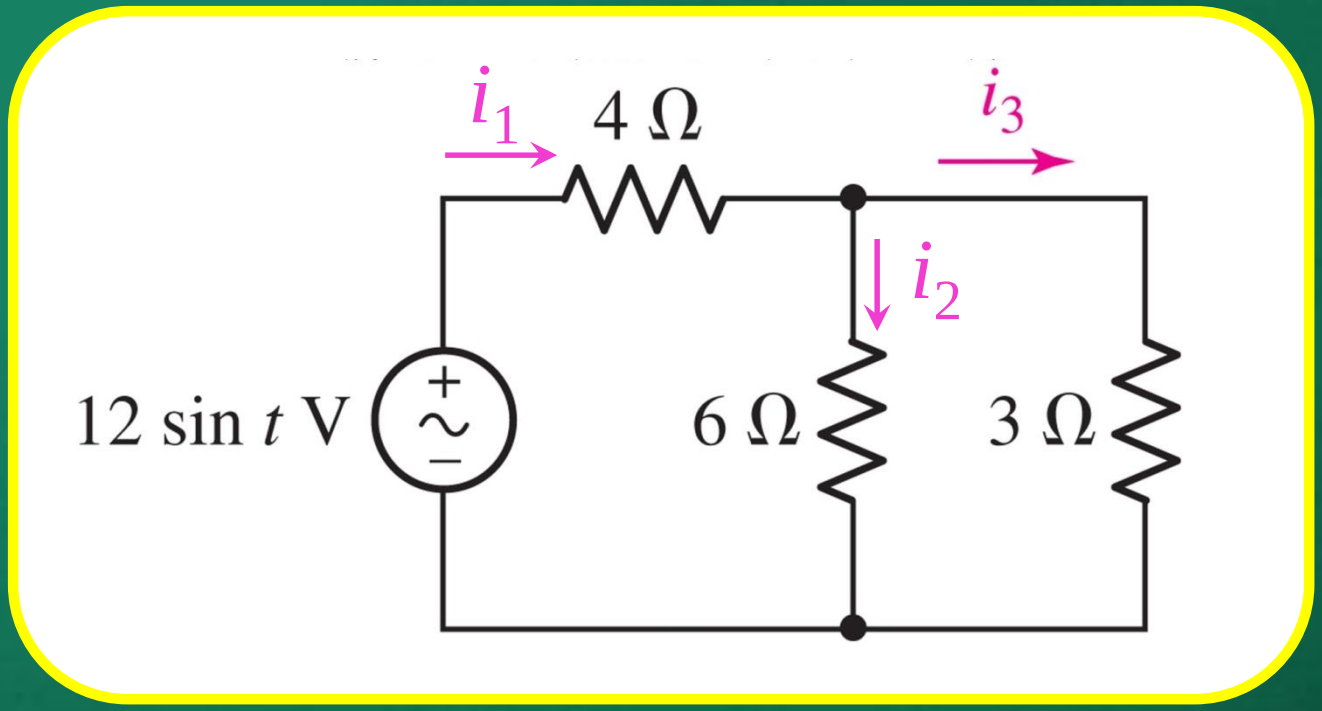

Answer: $i_3(t) = 1.333 \sin t$ A