CG1111:
Engineering Principles and Practice I

Circuit Analysis Techniques

NUS
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Circuit Analysis

Purpose:

- To find the unknown voltages and currents for various elements in the circuit
  - We need to find the voltage polarity and current direction, not just their magnitudes!

Reference Direction for Current

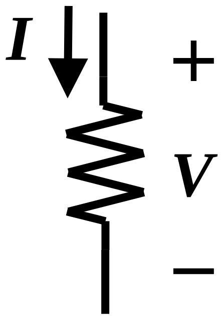
- We assign (assume) a reference direction for the unknown current in each branch
- After solving the circuit, the current may be positive or negative
- If positive,
  - The actual current is in the same direction as the reference direction
- If negative,
  - The actual current is in the opposite direction of the reference direction

Reference Polarity for Voltage

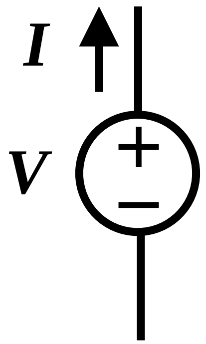
- We assign (assume) a reference polarity for the unknown voltage across each element
- After solving the circuit, the voltage may be positive or negative
- If positive,
  - The actual voltage polarity is in the same direction as the reference polarity
- If negative,
  - The actual voltage polarity is in the opposite direction of the reference polarity

Passive Vs Active Elements

- Passive elements consume power: voltage (potential) drops in the direction of the current, e.g.,
  - Resistors
  - Batteries being recharged



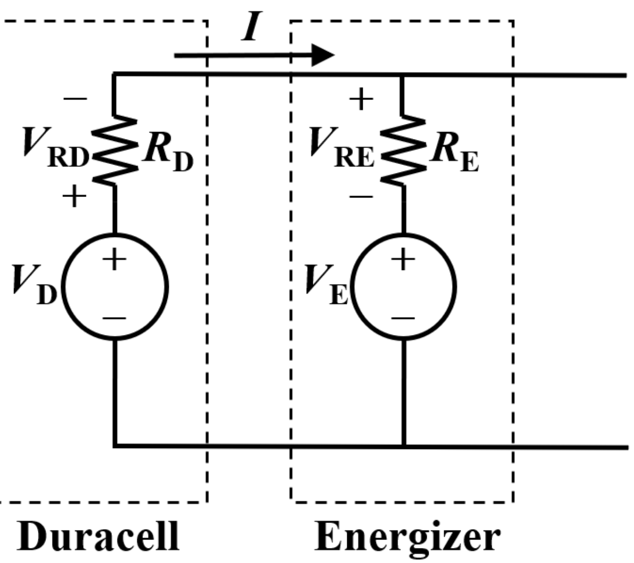
- Active elements deliver power: voltage (potential) rises in the direction of the current, e.g.,
  - A DC power supply that is delivering current to some resistors



Passive or Active?

- Sometimes, we may only know whether an element in the circuit is delivering power, or absorbing power, after solving the circuit

- Example:



If I is positive, then

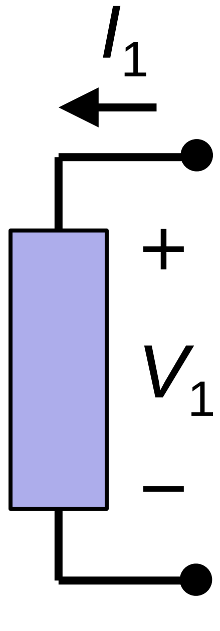
- V_D is delivering power
- V_E is absorbing power

If I is negative, then

- V_D is absorbing power
- V_E is delivering power

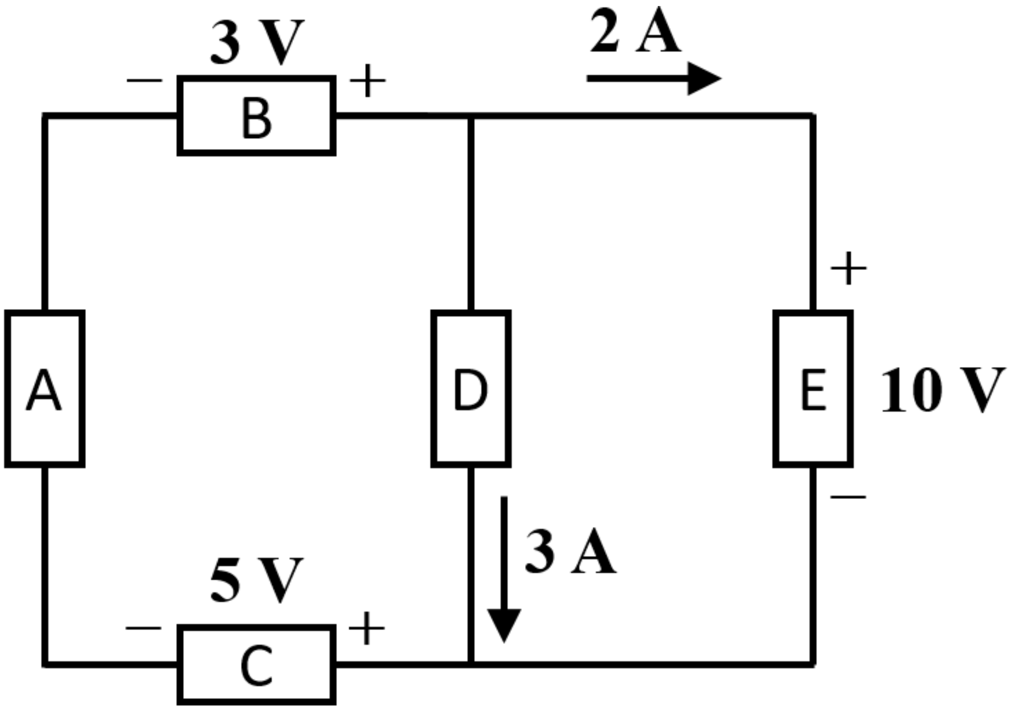
Passive Sign Convention

- Adopted when it is not clear whether an unknown element is active or passive
- Assumes all unknown elements are passive
  - Reference direction for current is always assumed to enter the positive voltage terminal of the element
  - Significance:
    - ✓ If power is calculated to be positive, the element is passive (a load)
    - ✓ If power is calculated to be negative, the element is active (a source)



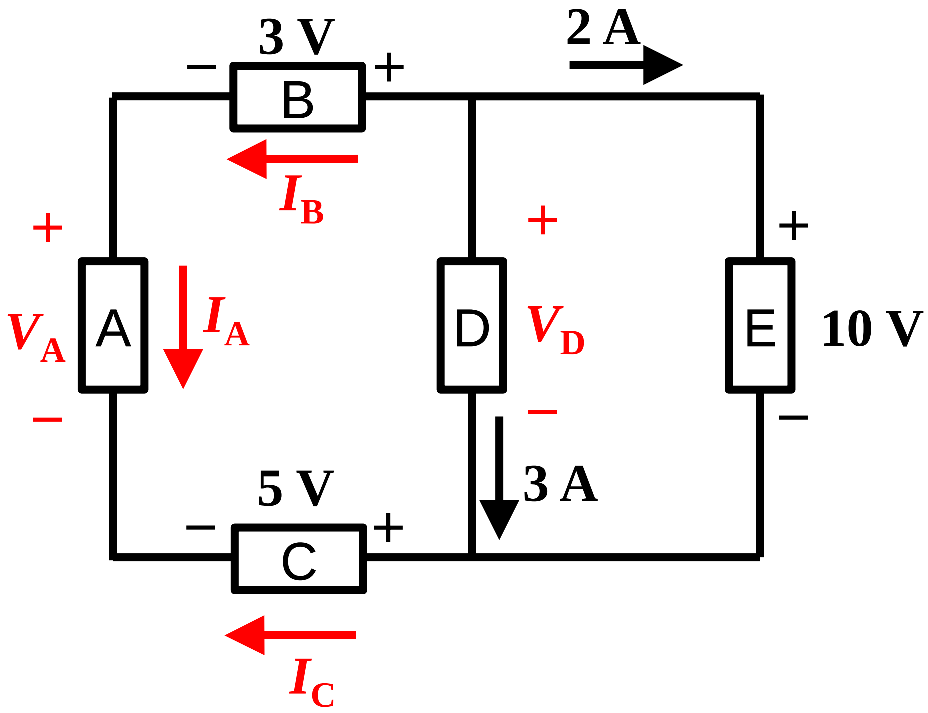
Example

- For the circuit given below, determine which components are absorbing power and which are delivering power.



Solution to Example

- We can label the unknown voltages & currents for the circuit following passive sign convention (current entering '+' reference terminal for voltage)



- By KVL for ABEC,

$$V_A + 3 = 10 + 5$$

$$V_A = 12\ \text{V}$$

- Since V_D // V_E,

$$V_D = V_E = 10\ \text{V}$$

Solution to Example

- Applying KCL at junction (node) of B,D,E:

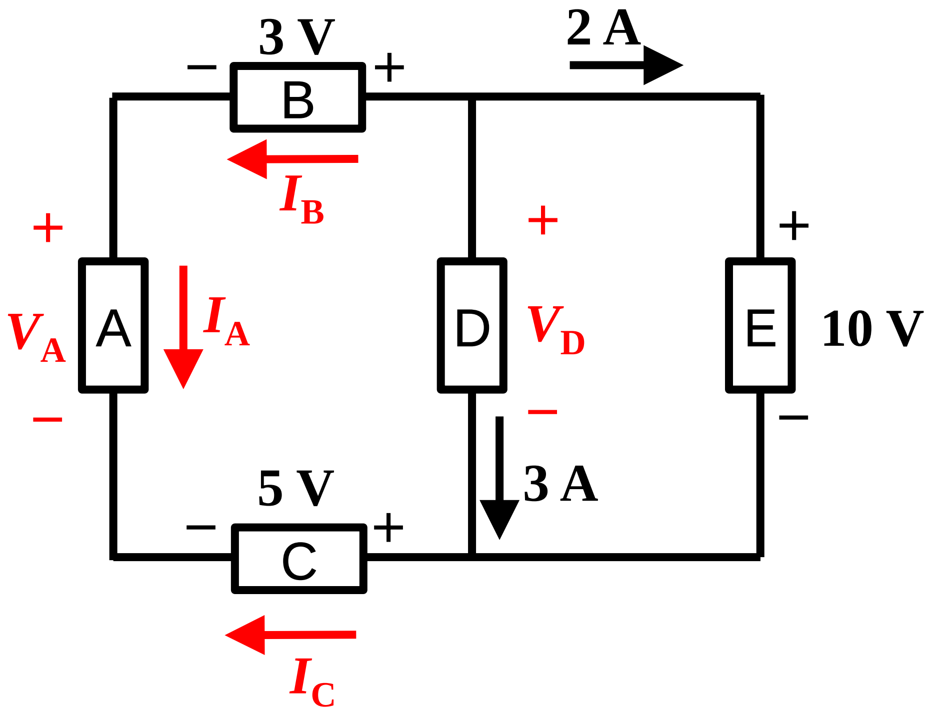
$I_B + 2 + 3 = 0$

$I_B = -5\ \text{A}$

Since A, B, C are in series,

$I_A = I_B = -5\ \text{A}$

$I_C = -I_A = 5\ \text{A}$



Solution to Example

- Now with all the voltages & currents known, and we had followed the passive sign convention earlier, we have:
  - –Power -ve: Element is delivering power to others
  - –Power +ve: Element is absorbing power from others

Element	Current (A)	Voltage (V)	Power (W)	Delivering / Absorbing Power
A	–5	12	–60	Delivering power
B	–5	3	–15	Delivering power
C	5	5	25	Absorbing power
D	3	10	30	Absorbing power
E	2	10	20	Absorbing power

Node Voltage Analysis Method

- Node voltage analysis
  - Most general method for analyzing circuits

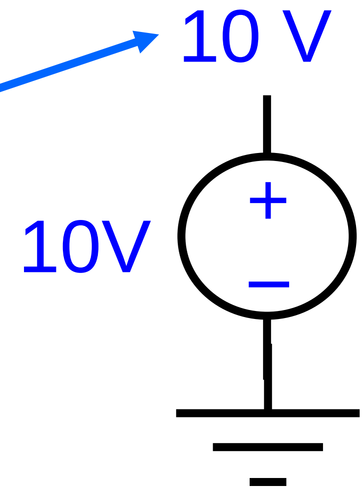
- Basic idea:
  - Solve for all the unknown node voltages w.r.t. a reference node
  - Use them to calculate the voltage across any element, & the current passing through it

Steps of Node Voltage Analysis

1. Select a reference node (usually the ground or '–' terminal of a voltage source).

2. For each voltage source connected to the reference node, the other end's node voltage is a known constant.

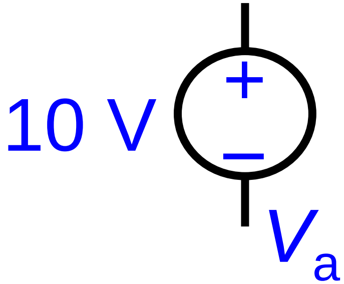
Known constant (no need to define another variable)



Steps of Node Voltage Analysis

3. For all other voltage sources, one end's node voltage can be written in terms of the other end's node voltage.
   So there is at most one unknown variable for each such voltage source.

$V_b = V_a + 10$

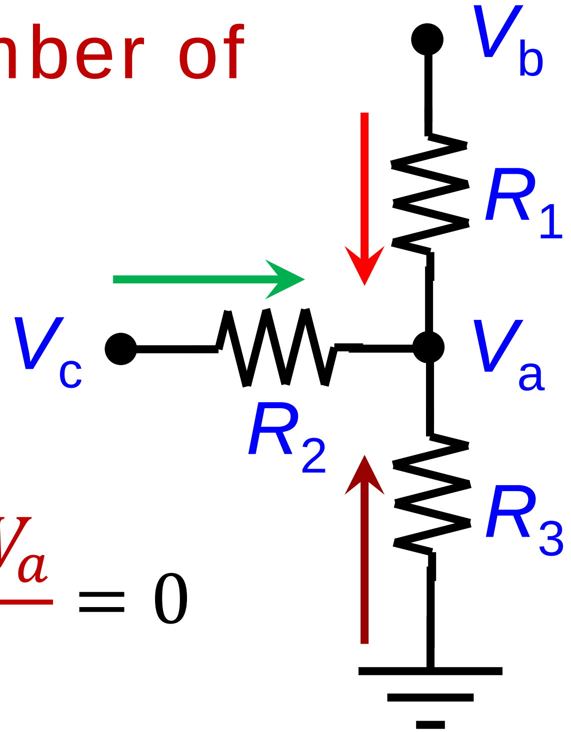


You don't need to keep both V_a & V_b as variables!
(Here, V_b can be expressed in terms of V_a)

Steps of Node Voltage Analysis

4. Define the remaining node voltages as unknown variables.

5. Apply KCL at the nodes, to obtain as many equations as the number of unknown variables.
   - Express each current in a <u>resistive</u> branch in terms of the adjacent node voltages (using Ohm's law)



$$\frac{V_b - V_a}{R_1} + \frac{V_c - V_a}{R_2} + \frac{0 - V_a}{R_3} = 0$$

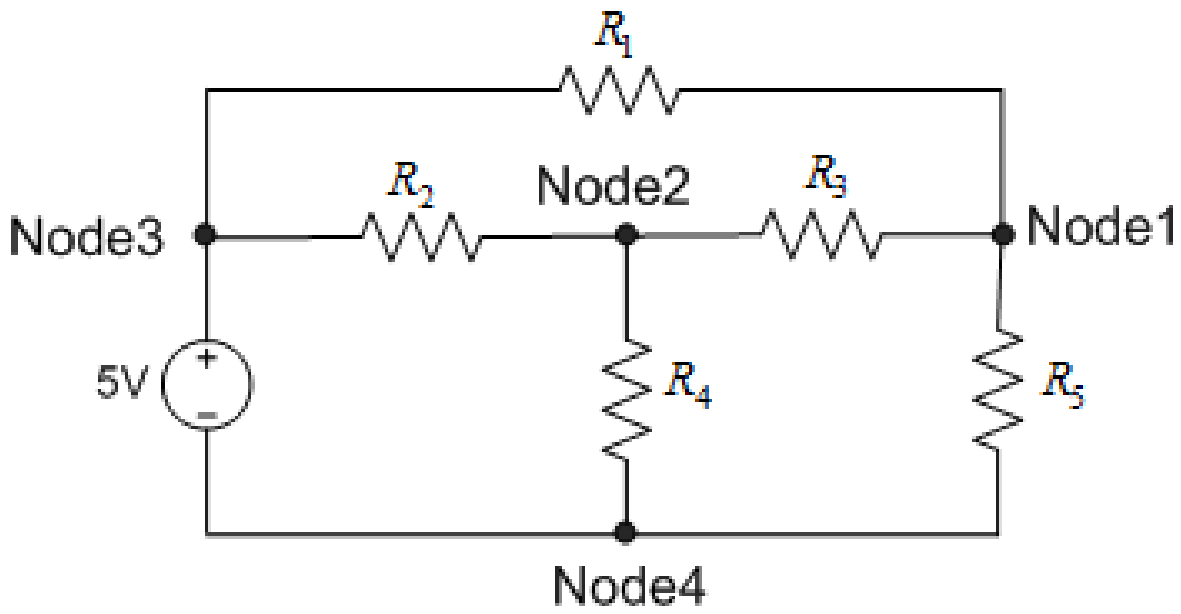
Steps of Node Voltage Analysis

6. Solve the linear system of equations to obtain the unknown node voltages.

$$a_1 V_a + b_1 V_b + c_1 V_c = d_1$$
$$a_2 V_a + b_2 V_b + c_2 V_c = d_2$$
$$a_3 V_a + b_3 V_b + c_3 V_c = d_3$$

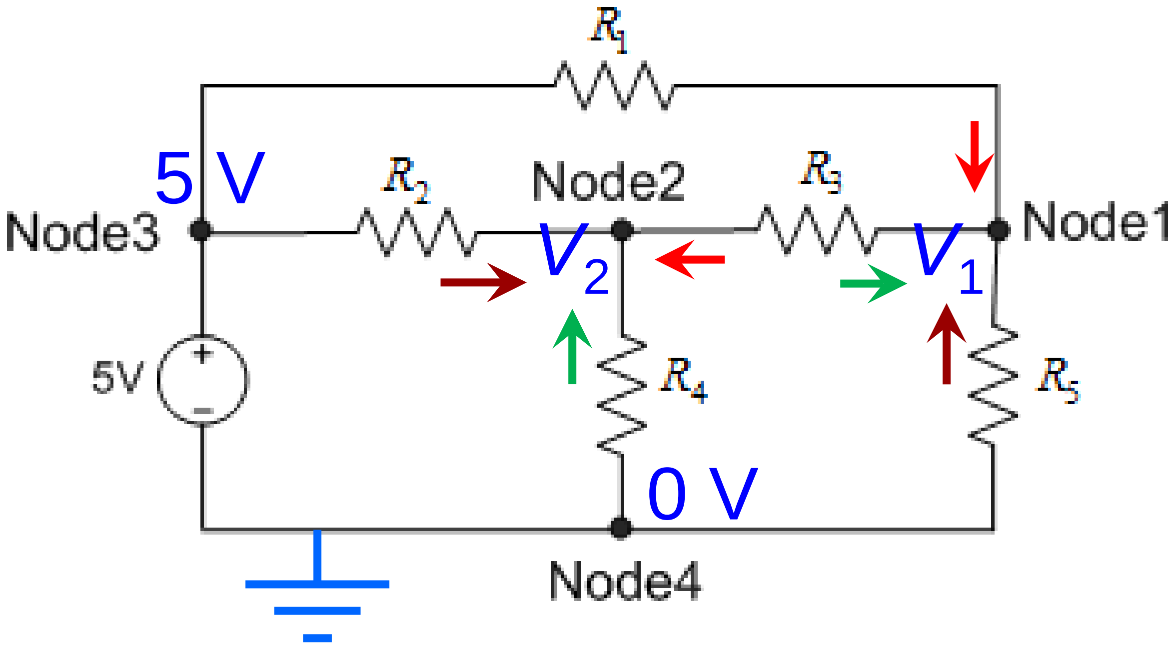
– You should know how to solve 2 simultaneous equations by hand
– Also learn how to use your calculator to solve them

Example



- –Which node is a convenient reference node?
- –How many unknown node voltages are there?
- –How many KCL equations do we need?

Solution to Example



$$\text{Node 1: } \frac{5-V_1}{R_1} + \frac{V_2-V_1}{R_3} + \frac{0-V_1}{R_5} = 0$$

$$\text{Node 2: } \frac{V_1-V_2}{R_3} + \frac{0-V_2}{R_4} + \frac{5-V_2}{R_2} = 0$$

THANK YOU