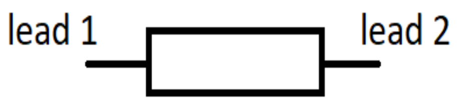
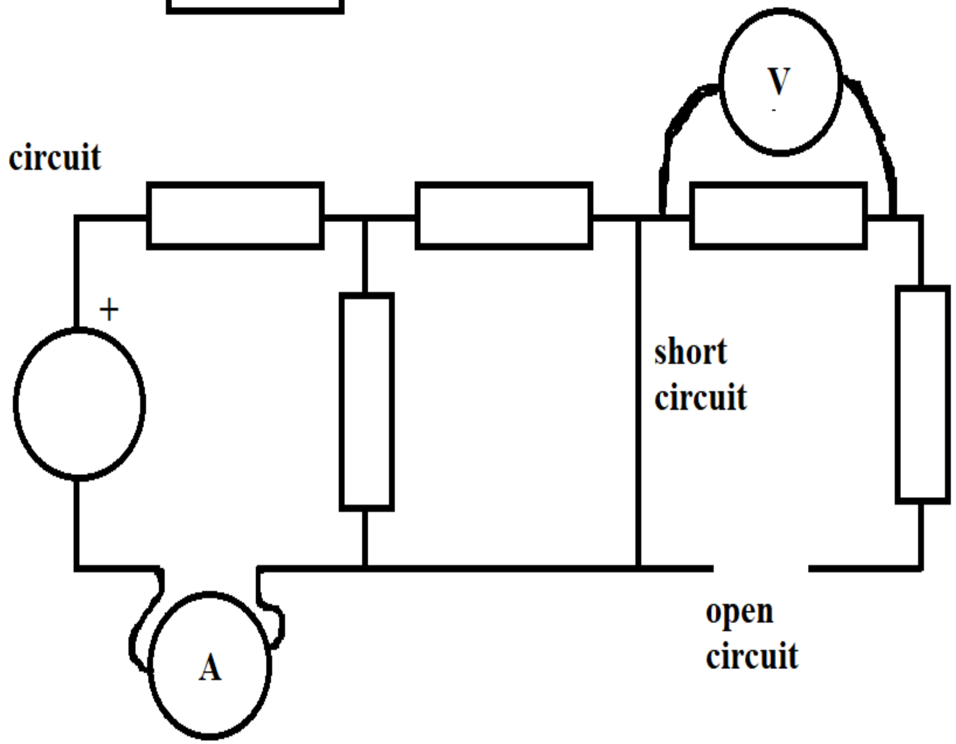
Electronic Circuits

Lecture 2.2: Series / Parallel Connected Circuit Elements & Kirchoff’s Laws & Mesh and Nodal Analyses

Simple Circuit Theory Terminology (1)

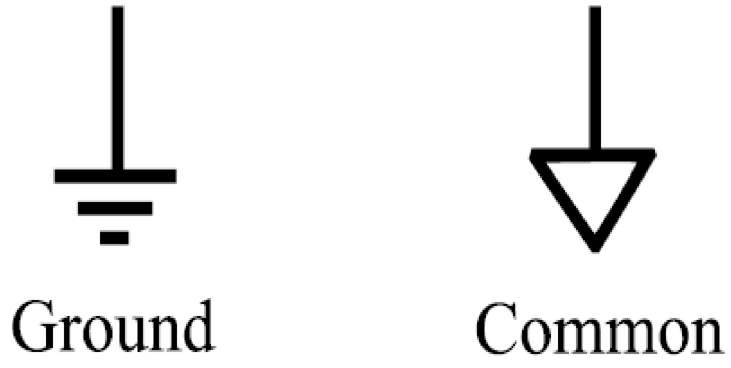
- Any electronic device will have one or more connection points, called “leads” (lead 1 and lead 2, for example).
- Device leads are connected together to form a circuit.
- If a circuit
  - is completely-connected with conductors and devices, this circuit (part) is called “close circuit”,
  - is not completely-connected with conductors and devices, this circuit (part) is called “open circuit”,
  - has a shorter path to complete the circuit with conductors, this circuit (part) becomes “short circuit” since electricity likes to flow through the easist path.
- Voltages are always measured as a voltage difference between two points in a circuit.
- Currents are always measured after breaking the circuit from a specific point.





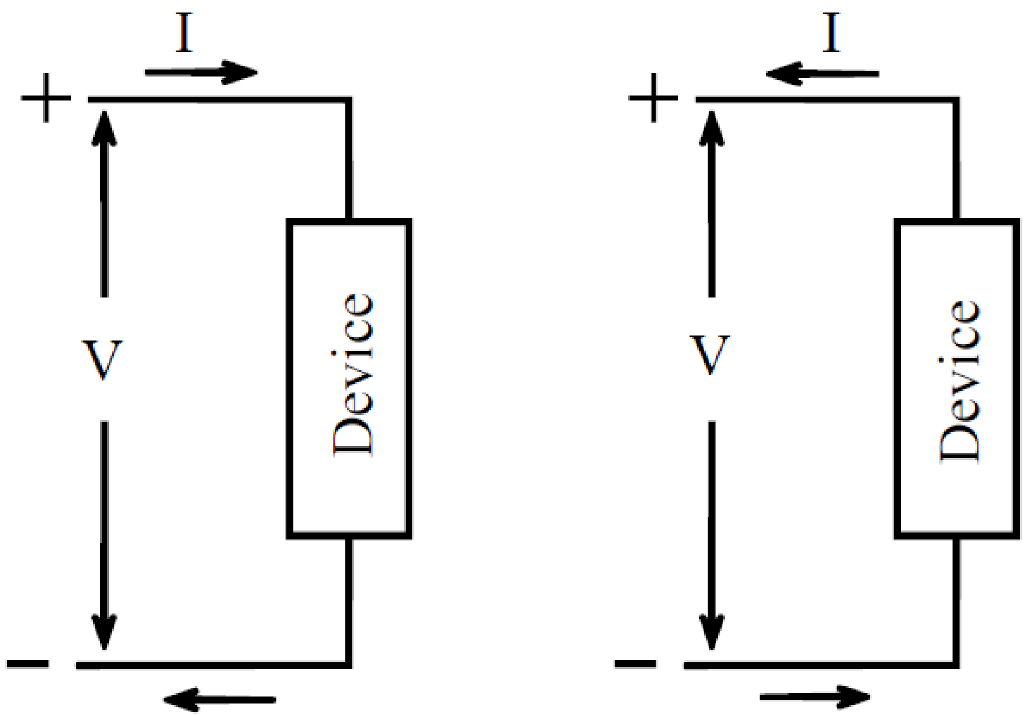
Simple Circuit Theory Terminology (2)

- Ground (GND) is the reference point that indicates where V = 0.
- If there is no reference point given on the circuit, you must determine one.
- Common indicates the connected leads instead drawing conductors directly.



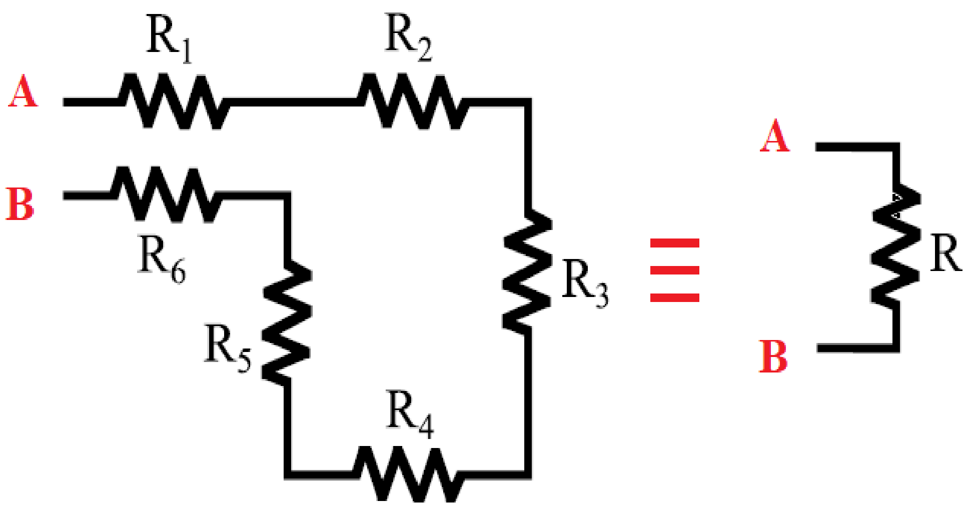
Simple Circuit Theory Terminology (3)

- If current comes into lead +, this device consumes the power.
- If current leaves from lead +, this device supplies (delivers) the power to the circuit.



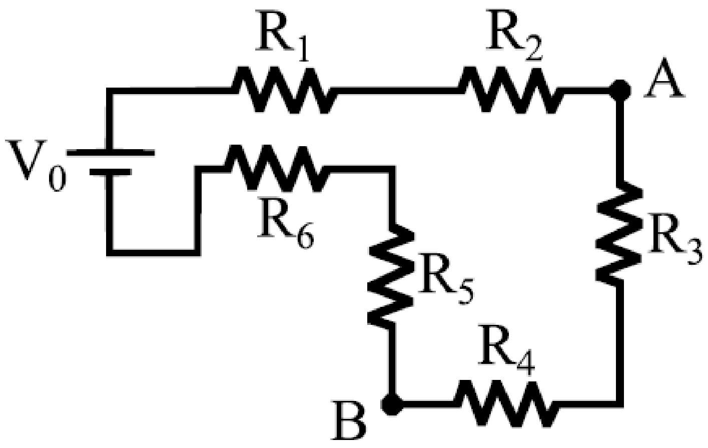
Series Connection

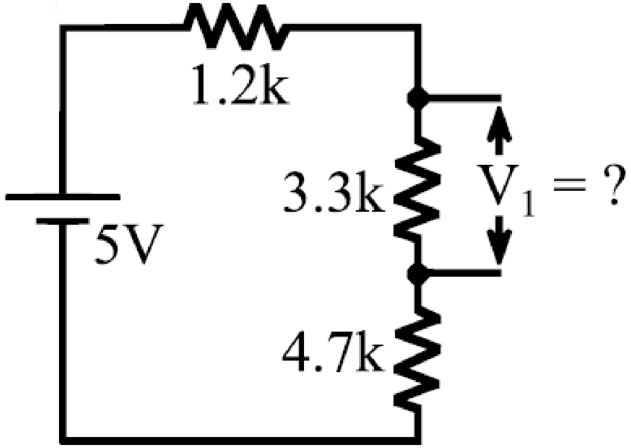
- Only one of leads (terminals) of two-lead devices are connected.
- Currents of all devices are same:
  - $I = I_{R1} = I_{R2} = I_{R3} = I_{R4} = I_{R5} = I_{R6}$
- Voltage of the final terminals are sum of all voltages (i.e. total voltage are shared):
  - $V = V_{R1} + V_{R2} + V_{R3} + V_{R4} + V_{R5} + V_{R6}$
  - $V = I * (R_1 + R_2 + R_3 + R_4 + R_5 + R_6)$
  - $R = R_1 + R_2 + R_3 + R_4 + R_5 + R_6$



Voltage Divider

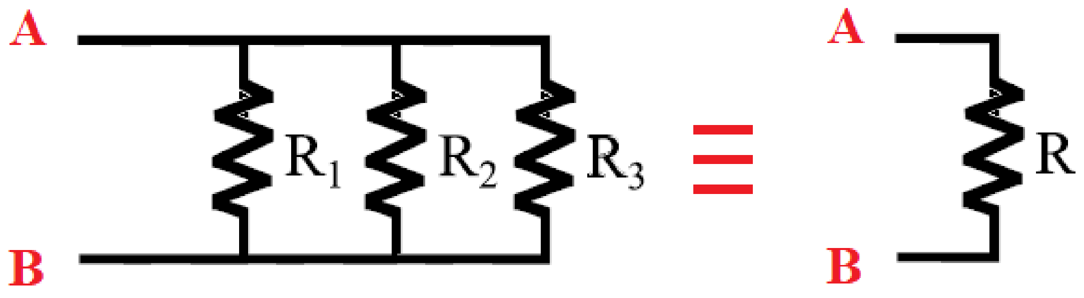
- General rule:
  - $I = \frac{V_o}{R_1+R_2+R_3+R_4+R_5+R_6}$
  - $V_{AB} = I * (R_3 + R_4)$
  - $V_{AB} = \frac{V_o}{R_1+R_2+R_3+R_4+R_5+R_6} * (R_3 + R_4)$
  - $V_{AB} = \frac{R_3+R_4}{R_1+R_2+R_3+R_4+R_5+R_6} * V_o$
- Example:
  - $V_1 = \frac{3300}{1200+3300+4700} * 5$
  - $V_1 = 1.8\ V$





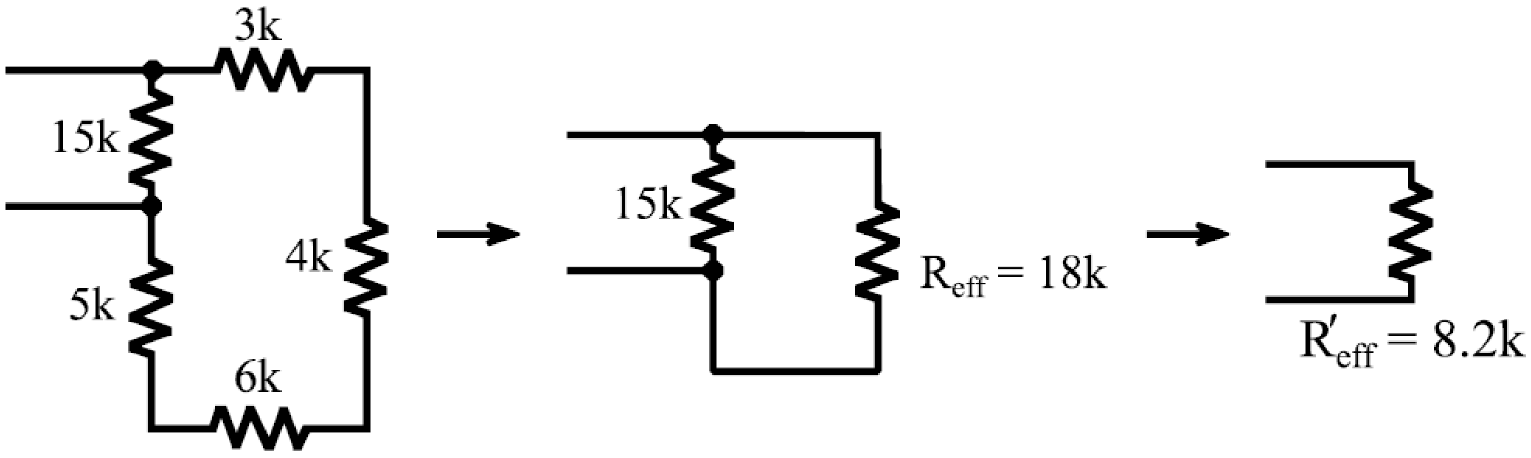
Parallel Connection

- Both leads (terminals) of two-lead devices are connected.
- Voltages of all devices are same:
  - $V = V_{R1} = V_{R2} = V_{R3}$
- Current of the final terminals are sum of all branch currents (i.e. total current are shared):
  - $I = I_{R1} + I_{R2} + I_{R3}$
  - $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$
  - $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$



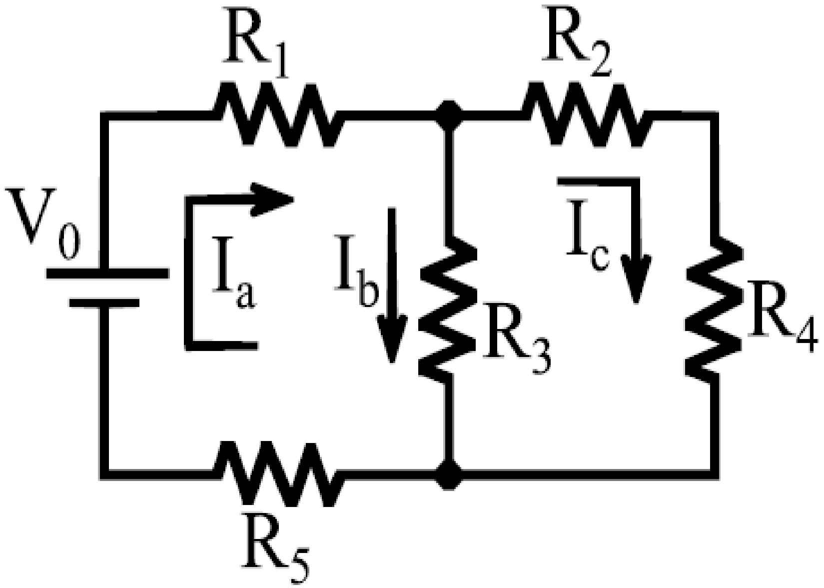
Effective (or Equivalent) Resistor

- Using series and parallel connection properties in order, we can find the equivalent resistor.



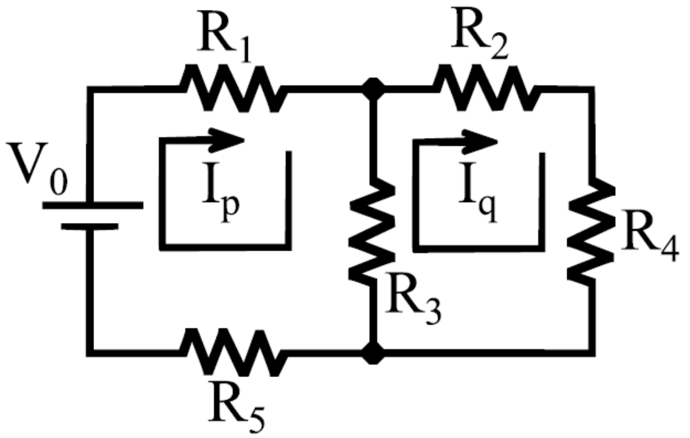
Kirchoff's Laws

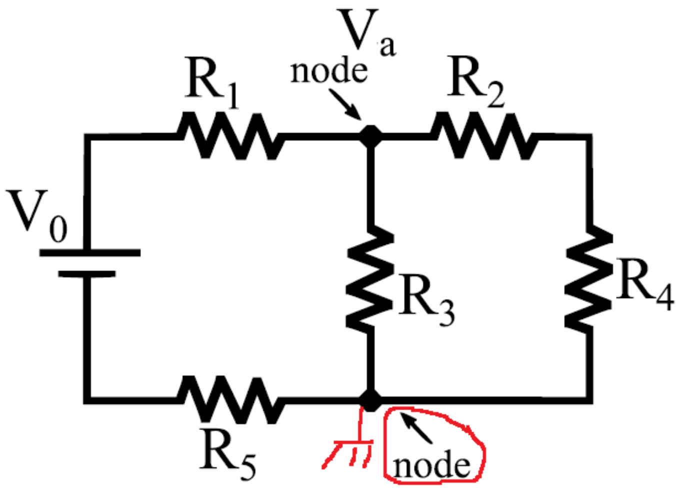
- Kirchhoff's Current Law (KCL): The sum of the currents entering any point in a circuit equals the sum of the currents leaving that point.
  - $Ia = Ib + Ic$
  - $-Ia + Ib + Ic = 0$
- Kirchhoff's Voltage Law (KVL): The sum of the changes in the voltage, dVi, around any closed path is zero. (A closed path is one that ends at the same position where it starts.)
  - From left-bottom corner, follow the clock-wise direction:
  - $-V_o + I_a * R_1 + I_b * R_3 + I_a * R_5 = 0$
  - $-V_o + I_a * R_1 + (I_a - I_c) * R_3 + I_a * R_5 = 0$



Mesh Analysis

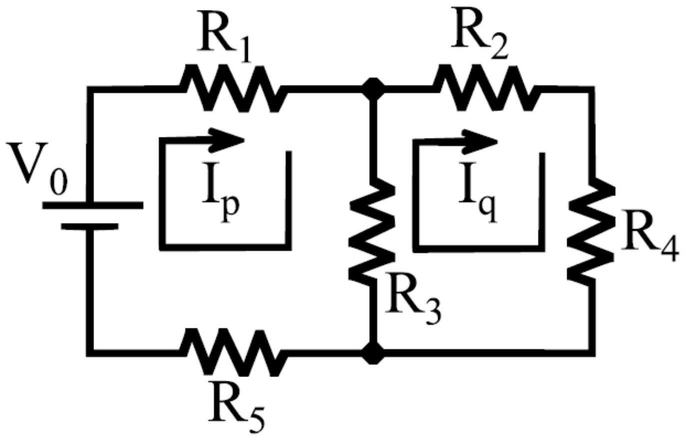
- Mesh: Closed circuit path.
- For all mesh currents, applying KVL is called Mesh Analysis.
  - $-V_o + I_p * R_1 + (I_p - I_q) * R_3 + I_q * R_5 = 0$ (equation #1)
  - $(I_q - I_p) * R_3 + I_q * R_2 + I_q * R_4 = 0$ (equation #2)
- After finding the mesh currents, determine other electrical quantities:
  - $I_{R1} = I_{R5} = I_p$ $V_{R1} = I_{R1} * R_1$ $V_{R5} = I_{R5} * R_5$
  - $I_{R3} = I_p - I_q$ $V_{R3} = I_{R3} * R_3$
  - $I_{R2} = I_{R4} = I_q$ $V_{R2} = I_{R2} * R_2$ $V_{R4} = I_{R4} * R_4$

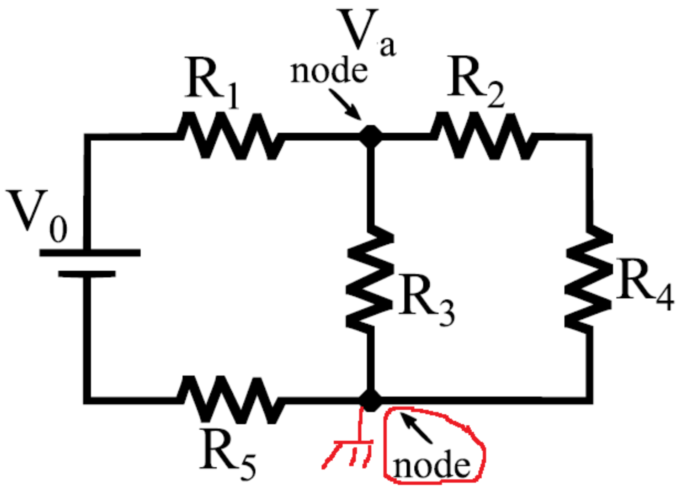




Nodal Analysis

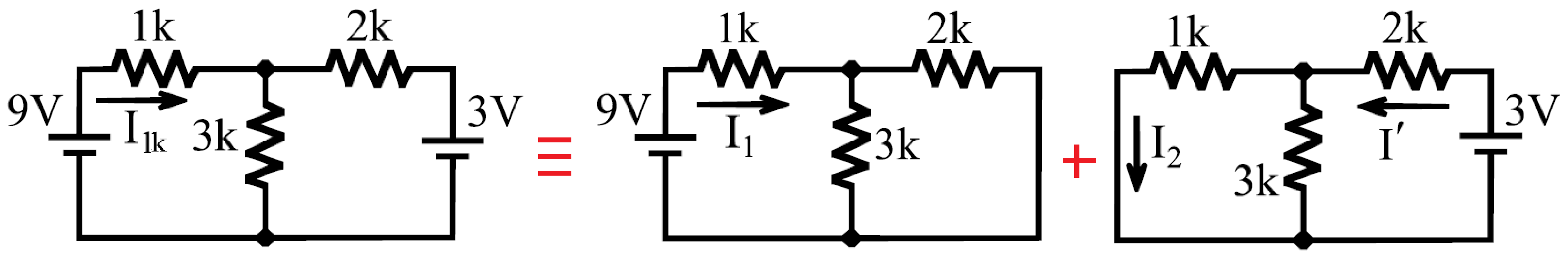
- Node: Junction where 3 or more devices connected together.
- One of the node is selected as reference point (GND). For other nodes, applying KCL is called Nodal Analysis.
  - $\frac{V_a - V_o - GND}{R_1 + R_5} + \frac{V_a - GND}{R_3} + \frac{V_a - GND}{R_1 + R_5} = 0$
  - $\frac{V_a - V_o}{R_1 + R_5} + \frac{V_a}{R_3} + \frac{V_a}{R_1 + R_5} = 0$ (simplified with GND = 0)
- After finding the node voltages, determine other electrical quantities:
  - $I_{R1} = I_{R5} = \frac{V_a - V_o}{R_1 + R_5}$ $V_{R1} = I_{R1} * R_1$ $V_{R5} = I_{R5} * R_5$
  - $I_{R3} = \frac{V_a}{R_3}$ $V_{R3} = I_{R3} * R_3$
  - $I_{R2} = I_{R4} = \frac{V_a}{R_2 + R_4}$ $V_{R2} = I_{R2} * R_2$ $V_{R4} = I_{R4} * R_4$



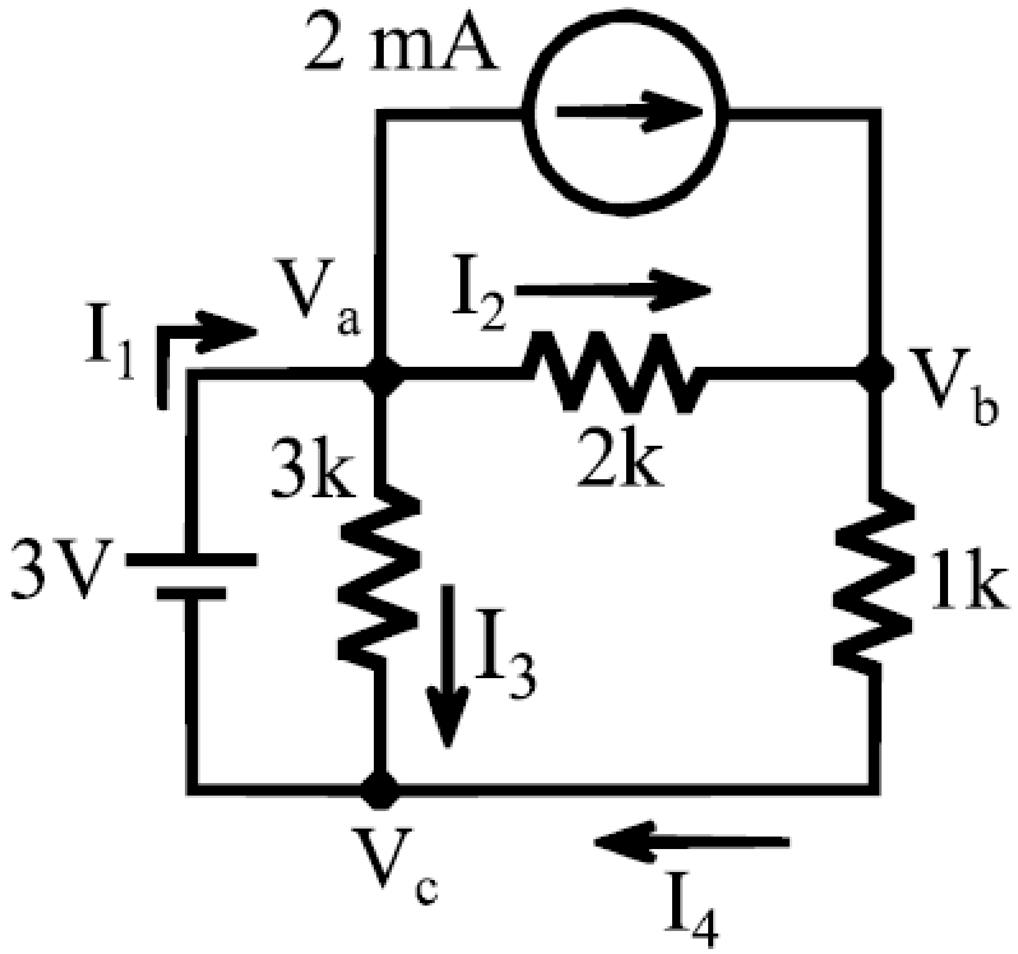


Superposition Principle

- For any linear circuit containing more than one independent source, the circuit can be solved by considering one source at a time, with all the other source(s) "turned off (or killed)," and then adding those results together.
  - A voltage source that is "turned off" is a voltage source fixed at 0 V-such a source is equivalent to a wire (short-circuit).
  - A current source that is "turned off" is a current source fixed at 0 A-such a source is equivalent to an open circuit (no connection).
  - $I_{1k} = I_1 - I_2$

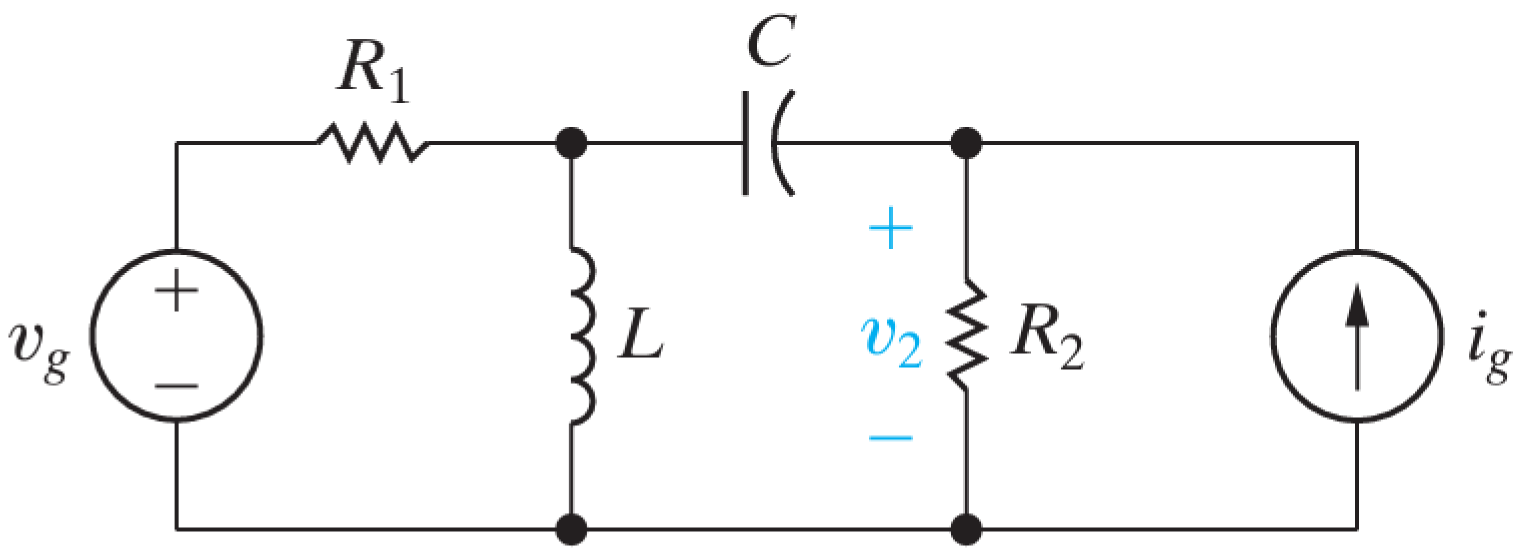


LTS: Left To Students (Not homework, try yourself)



(a) Power consumed by 2K resistor?
(b) Power supplied by 3V source?

LTS: Left To Students (Not homework, try yourself)



$v_2(t) = ?$

(a) using Mesh Analysis,
(b) using Nodal Analysis,
(c) using Superposition + any method.

Thanks for listening ☺

YALÇIN İŞLER

Assoc. Prof.