Electrical Technology

(EE-101-F)

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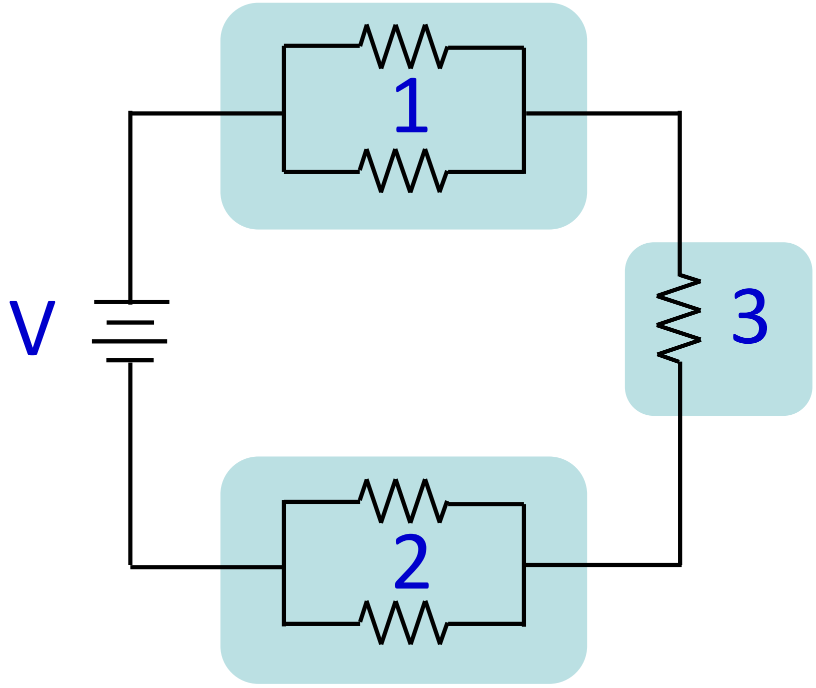
Series-Parallel Resistances



There are three series sections in this circuit; sections 1 and 2 are parallel banks.

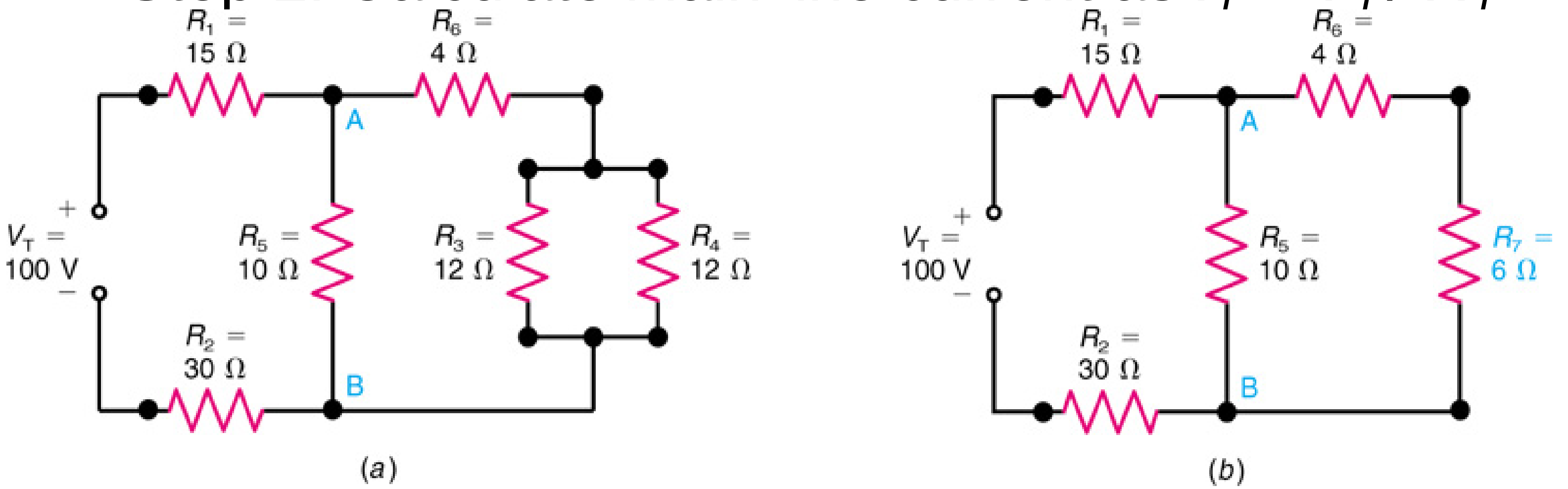
Series and Parallel Circuits

- **Series Circuit**
  - Current is the same in all components.
  - *V* across each series *R* is $I \times R$.
  - $V_T = V_1 + V_2 + V_3 + ... +$ etc.

- **Parallel Circuit**
  - Voltage is the same across all branches.
  - *I* in each branch *R* is *V/R*.
  - $I_T = I_1 + I_2 + I_3 + ... +$ etc.

Series-Parallel Circuits

- Example:
  - Find all currents and voltages in the circuit given below
    - Step 1: Find R_T.
    - Step 2: Calculate main line current as $I_T = V_T / R_T$



: Reducing a series-parallel circuit to an equivalent series circuit to find the *RT*. (*a*) Actual circuit. (*b*) R_3 and R_4 in parallel combined for the equivalent R_T.

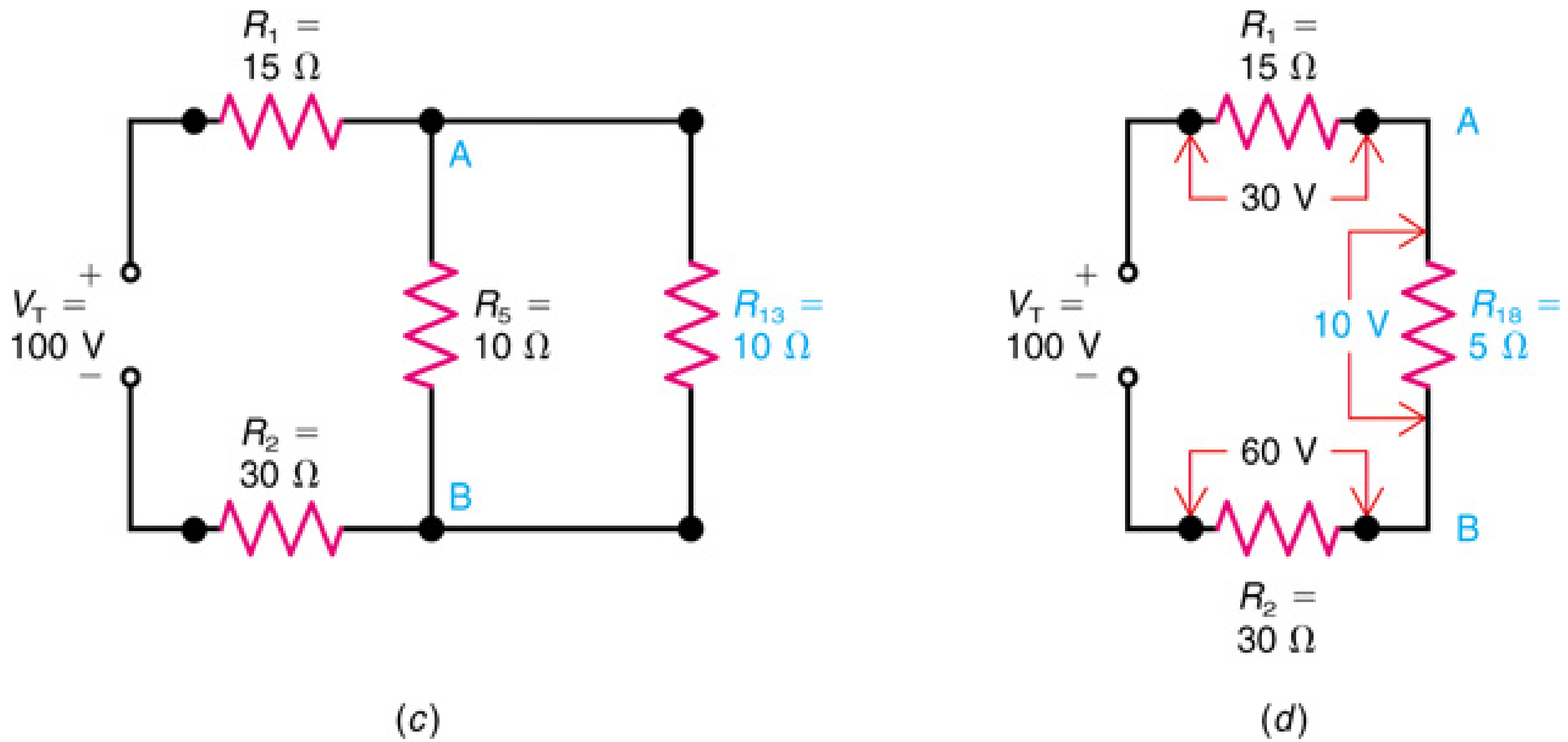


Fig (*c*) R_T and R_6 in series added for R_{13}. (*d*) R_{13} and R_5 in parallel combined for R_{18}.

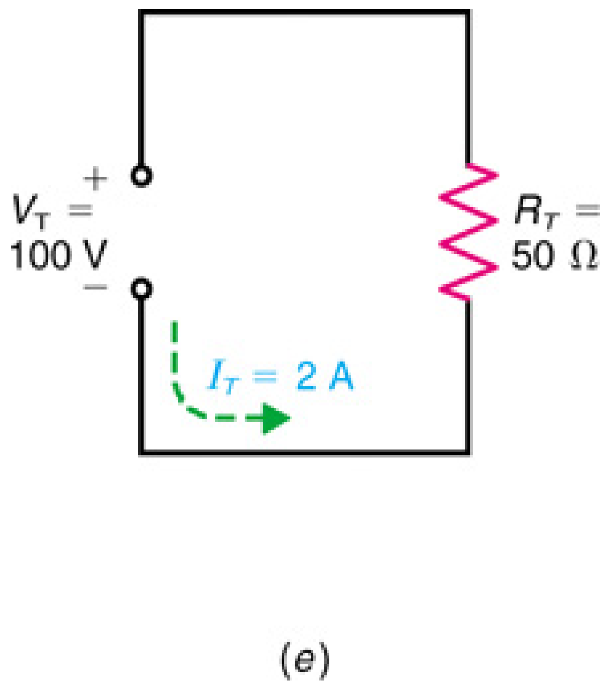


Fig. e: The R_{18}, R_1, and R_2 in series are added for the total resistance of 50Ω for R_T.

Analyzing Series-Parallel Circuits with Random Unknowns

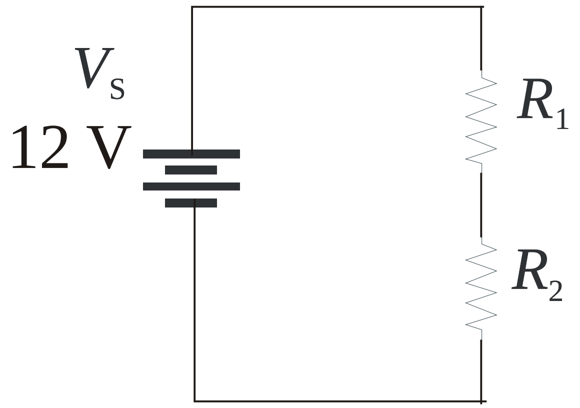
– In solving such circuits, apply the same principles as before:
  - Reduce the circuit to its simplest possible form.
  - Apply Ohm's Law.

Voltage divider rule

The voltage drop across any given resistor in a series circuit is equal to the ratio of that resistor to the total resistance, multiplied by source voltage.

Question:

Assume R_1 is twice the size of R_2. What is the voltage across R_1? 8 V

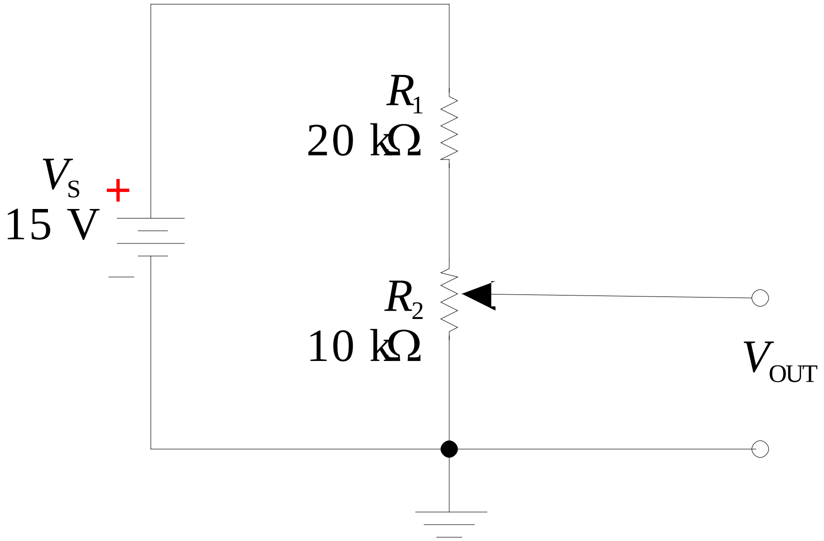


Voltage divider

Voltage dividers can be set up for a variable output using a potentiometer. In the circuit shown, the output voltage is variable.

Question:

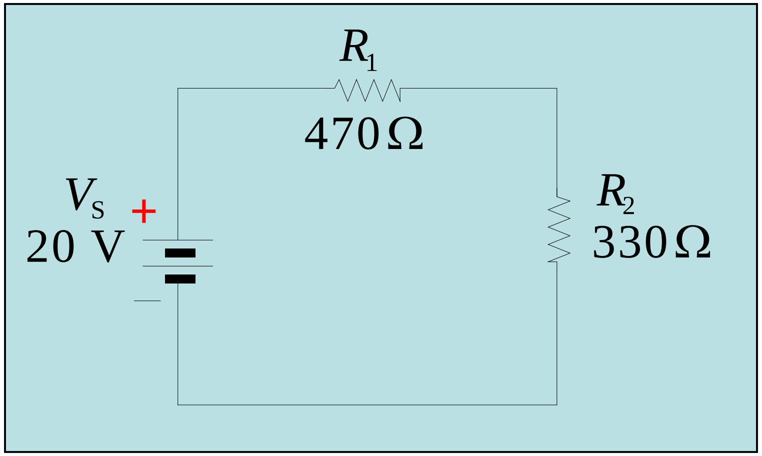
What is the largest output voltage available? 5.0 V



Power in Series Circuits

Example:

Use the voltage divider rule to find V_1 and V_2. Then find the power in R_1 and R_2 and P_T.



Solution:

Applying the voltage divider rule:

$$V_1 = 20\text{ V}\left(\frac{470\ \Omega}{800\ \Omega}\right) = 11.75\text{ V}$$

$$V_2 = 20\text{ V}\left(\frac{330\ \Omega}{800\ \Omega}\right) = 8.25\text{ V}$$

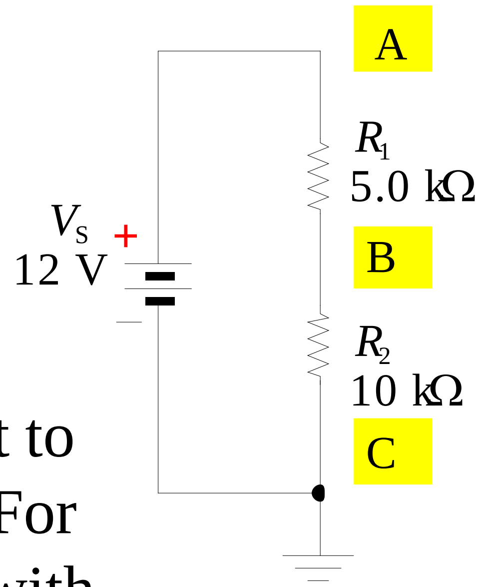
The power dissipated by each resistor is:

$$P_1 = \frac{(11.75\text{ V})^2}{470\ \Omega} = 0.29\text{ W}$$

$$P_2 = \frac{(8.25\text{ V})^2}{330\ \Omega} = 0.21\text{ W}$$

$P_T =$ 0.5 W

Circuit Ground



The term “ground” typically means a common or reference point in the circuit.

Voltages that are given with respect to ground are shown with a single subscript. For example, V_A means the voltage at point A with respect to ground. V_B means the voltage at point B with respect to ground. V_{AB} means the voltage between points A and B.

Question: What are V_A, V_B, and V_{AB} for the circuit shown?

$V_A = 12$ V $\quad V_B = 8$ V $\quad V_{AB} = 4$ V

Key Terms

Circuit ground A method of grounding whereby the metal chassis that houses the assembly or a large conductive area on a printed circuit board is used as a common or reference point; also called chassis ground.

Kirchhoff's voltage law A law stating that (1) the sum of the voltage drops around a closed loop equals the source voltage in that loop or (2) the algebraic sum of all of the voltages (drops and source) is zero.

Open A circuit condition in which the current path is broken.

Key Terms

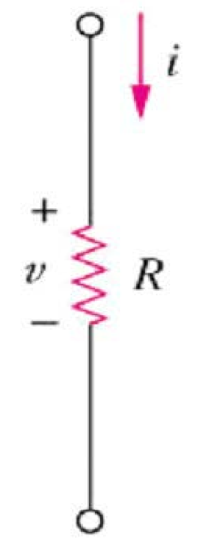
Series In an electric circuit, a relationship of components in which the components are connected such that they provide a single path between two points.

Short A circuit condition in which there is zero or an abnormally low resistance between two points; usually an inadvertent condition.

Voltage divider A circuit consisting of series resistors across which one or more output voltages are taken.

OHM'S LAW

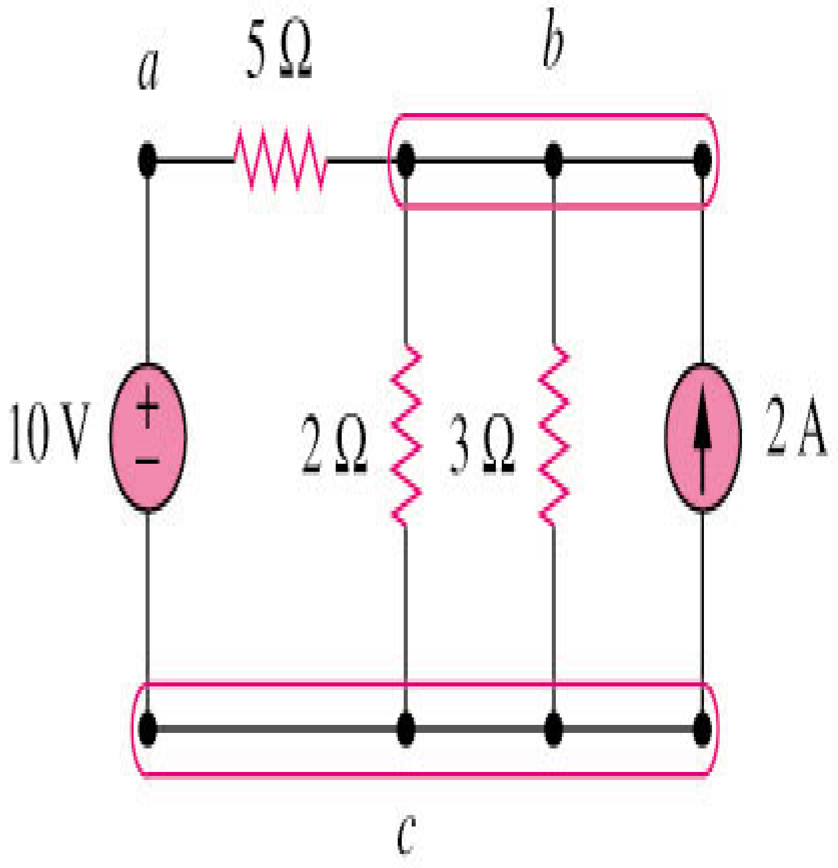
- Ohm's law states that the voltage across a resistor is directly proportional to the current I flowing through the resistor.
- •Mathematical expression for Ohm's Law is as follows: *R = Resistance*
- Two extreme possible values of R:
- **0 (zero) and ∞ (infinite)**
- are related with two basic circuit concep
- short circuit and open circuit.



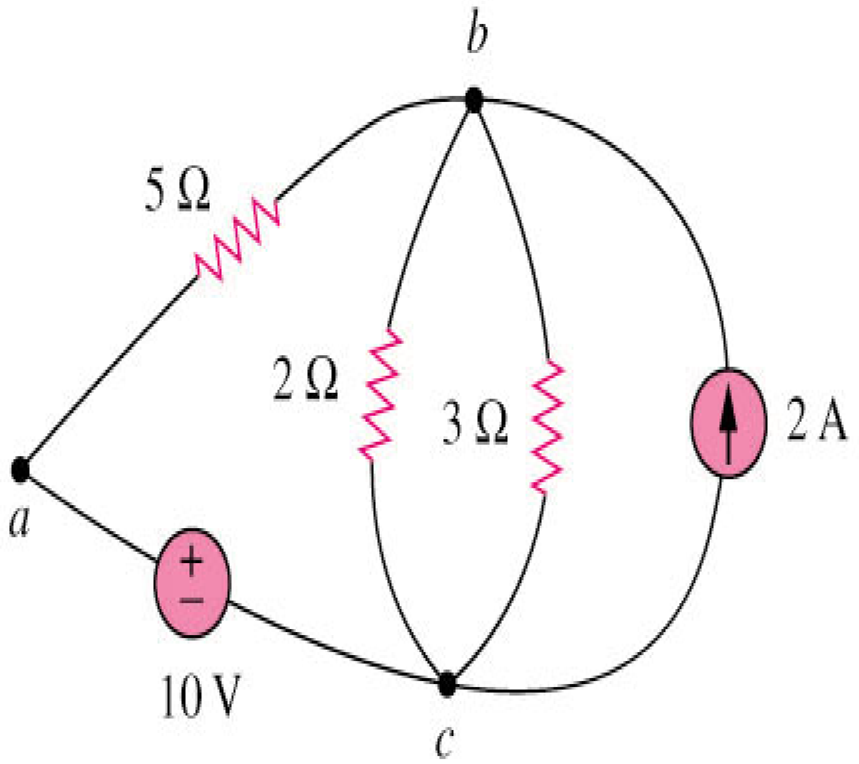
Branches, Nodes, Loops

- A branch represents a single element such as a voltage source or a resistor.
- A node is the point of connection between two or more branches.
- A loop is any closed path in a circuit.
- A network with b branches, n nodes, and l independent loops will satisfy the fundamental theorem of network topology:
- $b = l + n - 1$

Original Circuit



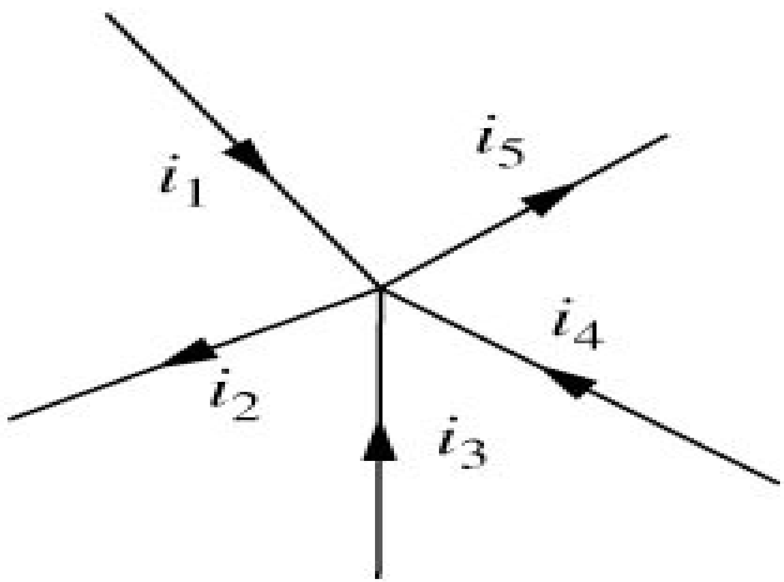
Network schematics or graph

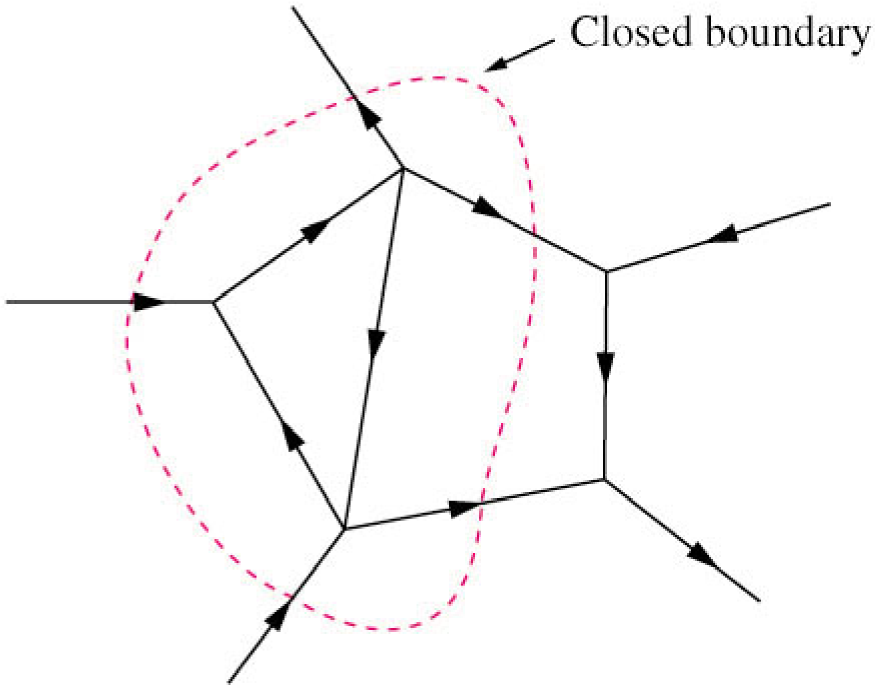


How many branches, nodes and loops are there?

Kirchhoff's Current Law

- Kirchhoff's current law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero.
- $\Sigma I = 0$

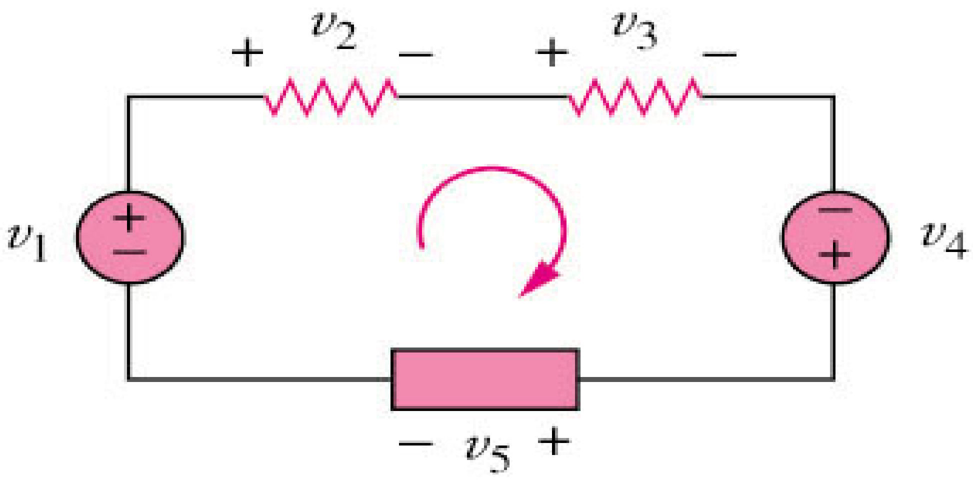




Kirchhoff’s Voltage Law

Kirchhoff’s voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

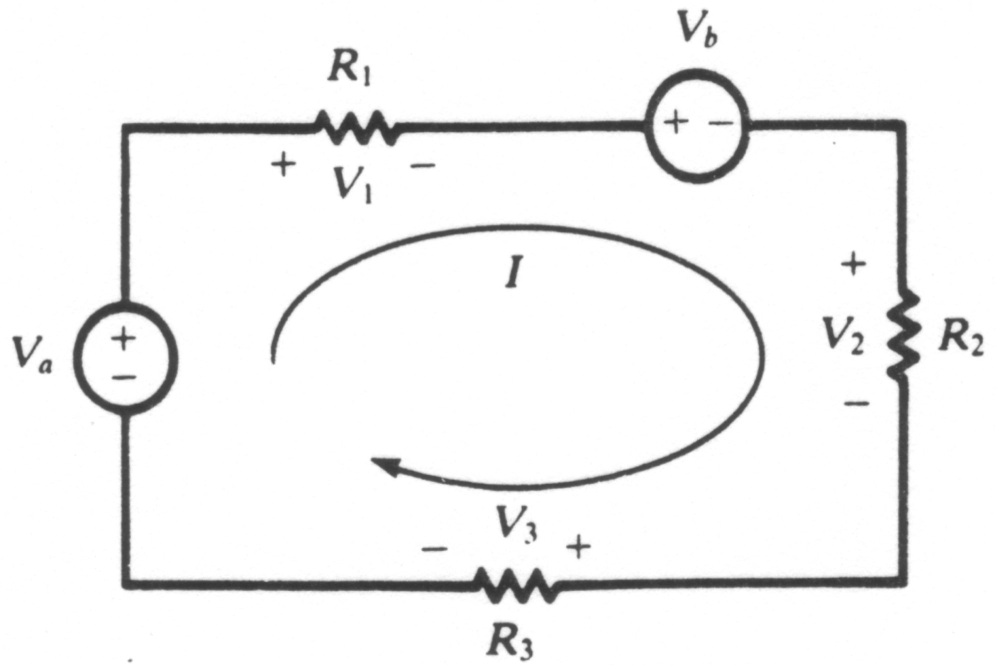
$\Sigma Vi = 0$



Kirchhoff’s Voltage Law:

- **Example**

Applying the KVL equation for the circuit of the figure below.



va- v1- vb- v2- v3 = 0 V1 = I ·R1 ; v2 = I · R2 ;
v3 = I · R3
va-vb = I ·(R1 + R2 + R3)

I= (Va- Vb)/ (R1 + R2 + R3)

KIRCHHOFF VOLTAGE LAW

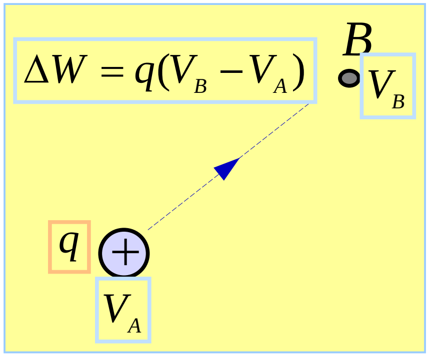
ONE OF THE FUNDAMENTAL CONSERVATION LAWS IN ELECTRICAL ENGINERING

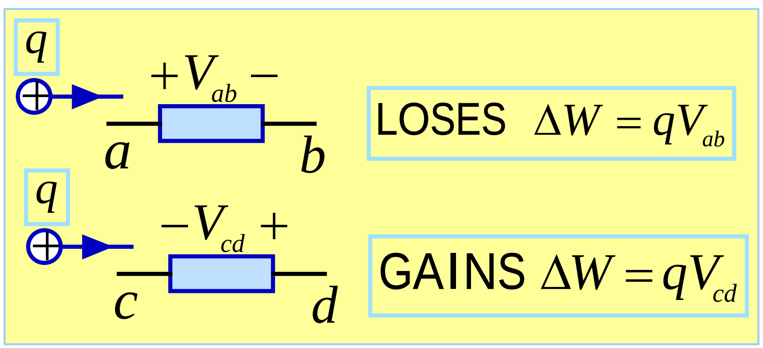
THIS IS A CONSERVATION OF ENERGY PRINCIPLE
"ENERGY CANNOT BE CREATED NOR DESTROYED"

KIRCHHOFF VOLTAGE LAW (KVL)

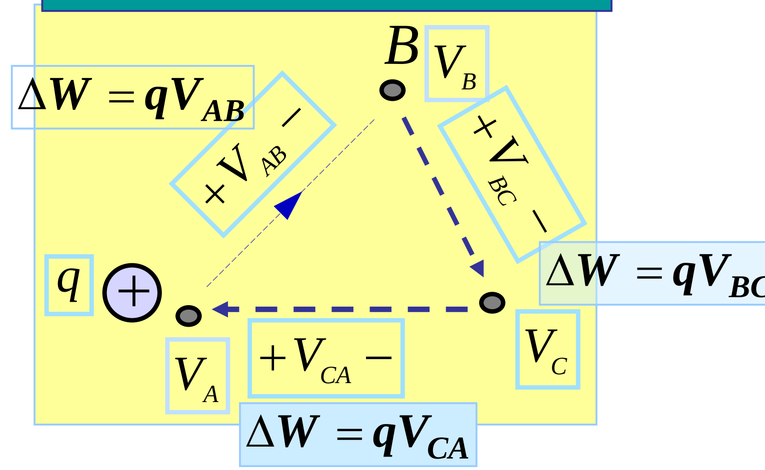
KVL IS A CONSERVATION OF ENERGY PRINCIPLE

A POSITIVE CHARGE GAINS ENERGY AS IT MOVES TO A POINT WITH HIGHER VOLTAGE AND RELEASES ENERGY IF IT MOVES TO A POINT WITH LOWER VOLTAGE





A "THOUGHT EXPERIMENT"

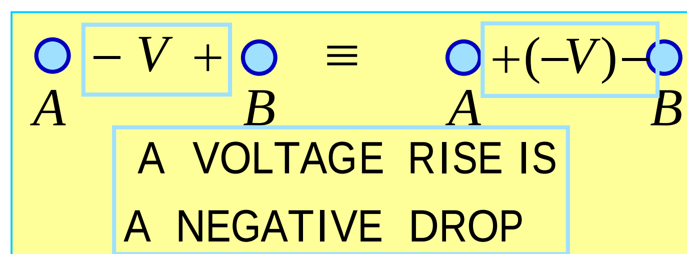


IF THE CHARGE COMES BACK TO THE SAME INITIAL POINT THE NET ENERGY GAIN MUST BE ZERO (Conservative network)

OTHERWISE THE CHARGE COULD END UP WITH INFINITE ENERGY, OR SUPPLY AN INFINITE AMOUNT OF ENERGY

$$q(V_{AB} + V_{BC} + V_{CD}) = 0$$

KVL: THE ALGEBRAIC SUM OF VOLTAGE DROPS AROUND ANY LOOP MUST BE ZERO



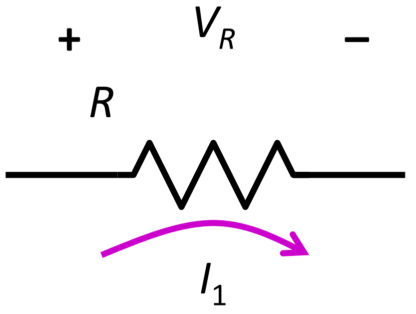
GEAUX

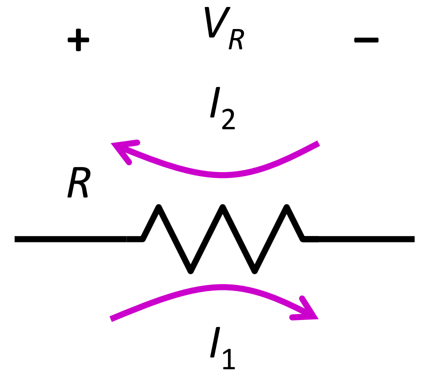
KVL (Kirchhoff's Voltage Law)

The sum of the potential differences around a closed loop equals zero.

Sum of the Voltage drops across resistors equals the Supply Voltage in a Loop.

Voltages from Mesh Currents

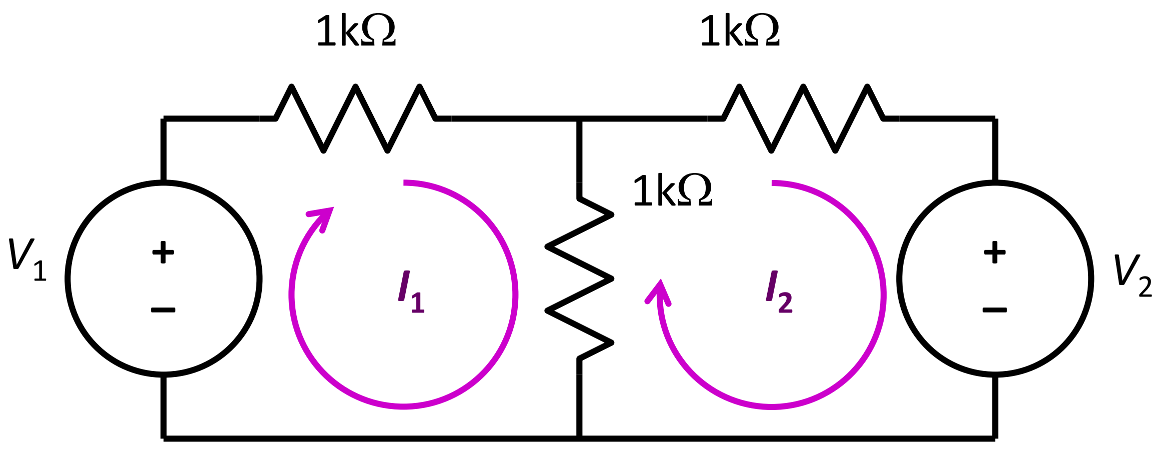




$$V_R = I_1\,R$$

$$V_R = (I_1 - I_2)\,R$$

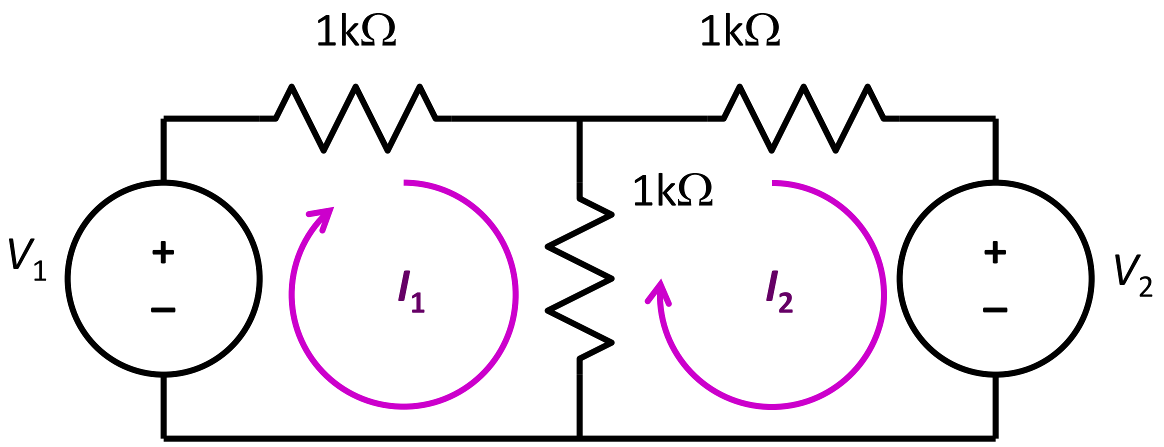
Example : KVL Around Mesh 1



$$-V_1 + I_1\ 1\text{k}\Omega + (I_1 - I_2)\ 1\text{k}\Omega = 0$$

$$I_1\ 1\text{k}\Omega + (I_1 - I_2)\ 1\text{k}\Omega = V_1$$

KVL
Around Mesh 2



$$(I_2 - I_1)\ 1\text{k}\Omega + I_2\ 1\text{k}\Omega + V_2 = 0$$

$$(I_2 - I_1)\ 1\text{k}\Omega + I_2\ 1\text{k}\Omega = -V_2$$

Steps of Mesh Analysis

1. Identify mesh (loops).
2. Assign a current to each mesh.
3. Apply KVL around each loop to get an equation in terms of the loop currents.
4. **Solve the resulting system of linear equations.**

Matrix Notation

- The two equations can be combined into a single matrix/vector equation.

$$\begin{bmatrix} 1\text{k}\Omega + 1\text{k}\Omega & -1\text{k}\Omega \\ -1\text{k}\Omega & 1\text{k}\Omega + 1\text{k}\Omega \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ -V_2 \end{bmatrix}$$

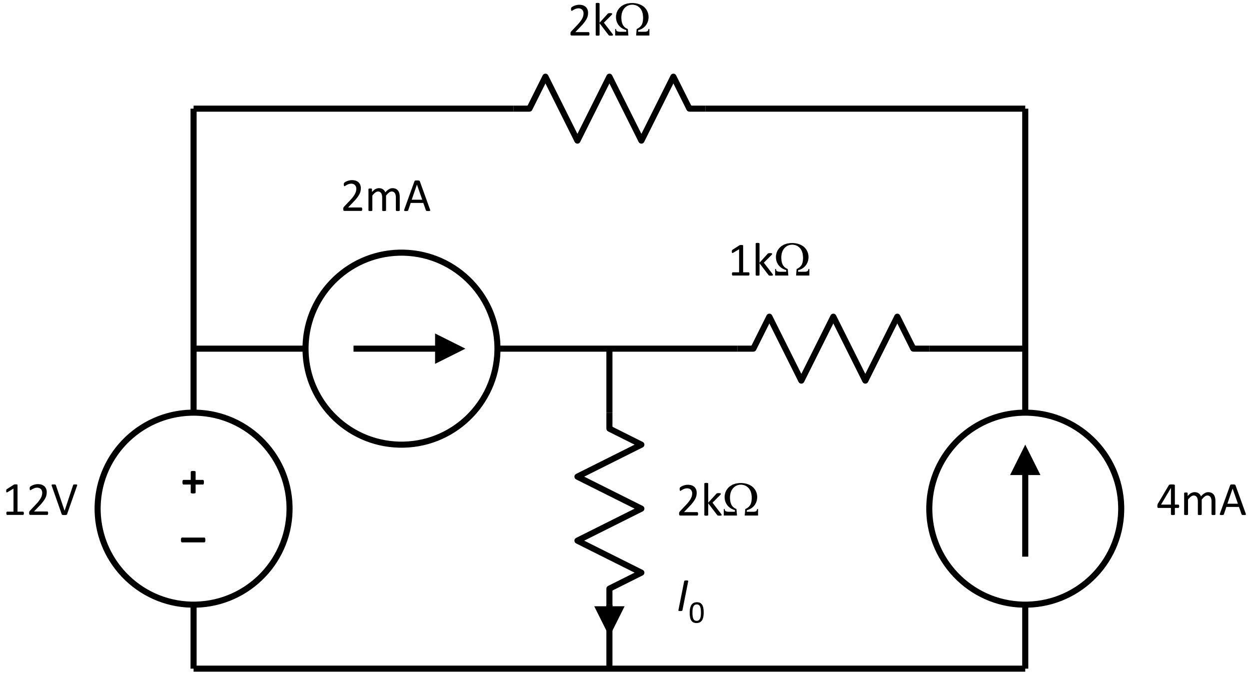
Cramer's Rule

$$\begin{bmatrix} E_1 \\ -E_2 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \begin{bmatrix} (R_1 + R_2) & (-R_3) \\ (-R_3) & (R_2 + R_3) \end{bmatrix}$$

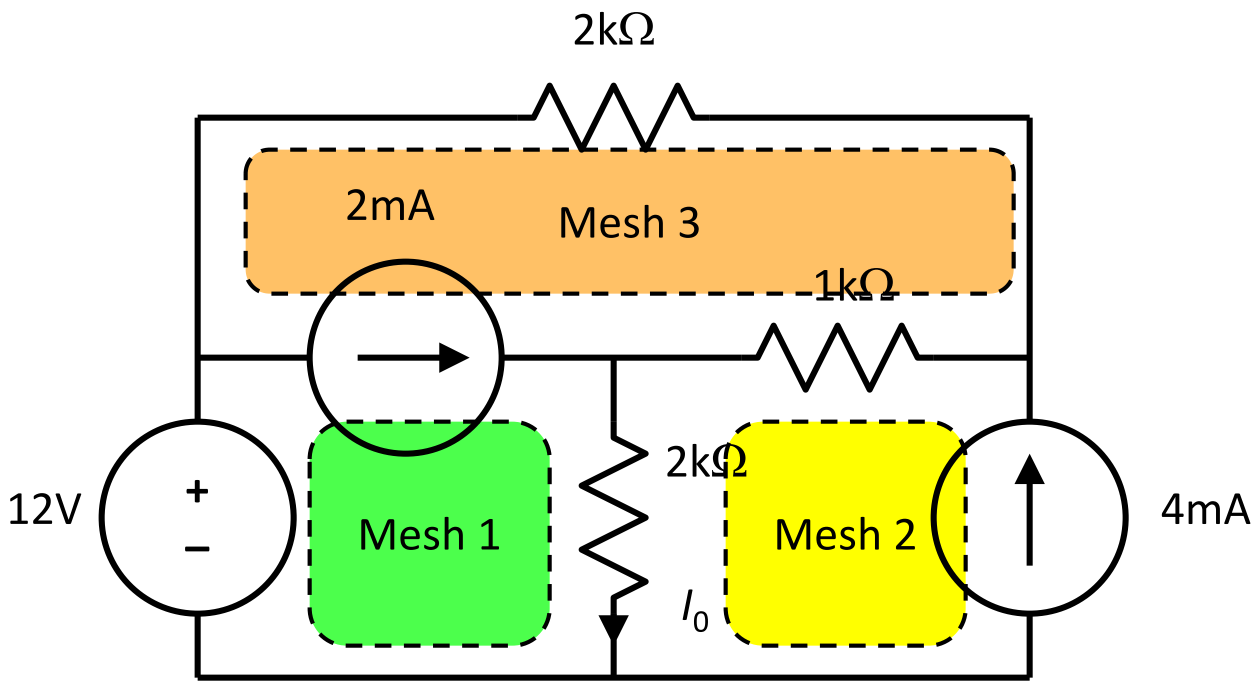
$$I_1 = \frac{\begin{bmatrix} E_1 & (-R_3) \\ -E_2 & (R_2 + R_3) \end{bmatrix}}{\begin{bmatrix} (R_1 + R_2) & (-R_3) \\ (-R_3) & (R_2 + R_3) \end{bmatrix}}$$

$$I_2 = \frac{\begin{bmatrix} (R_1 + R_2) & E_1 \\ (-R_3) & -E_2 \end{bmatrix}}{\begin{bmatrix} (R_1 + R_2) & (-R_3) \\ (-R_3) & (R_2 + R_3) \end{bmatrix}}$$

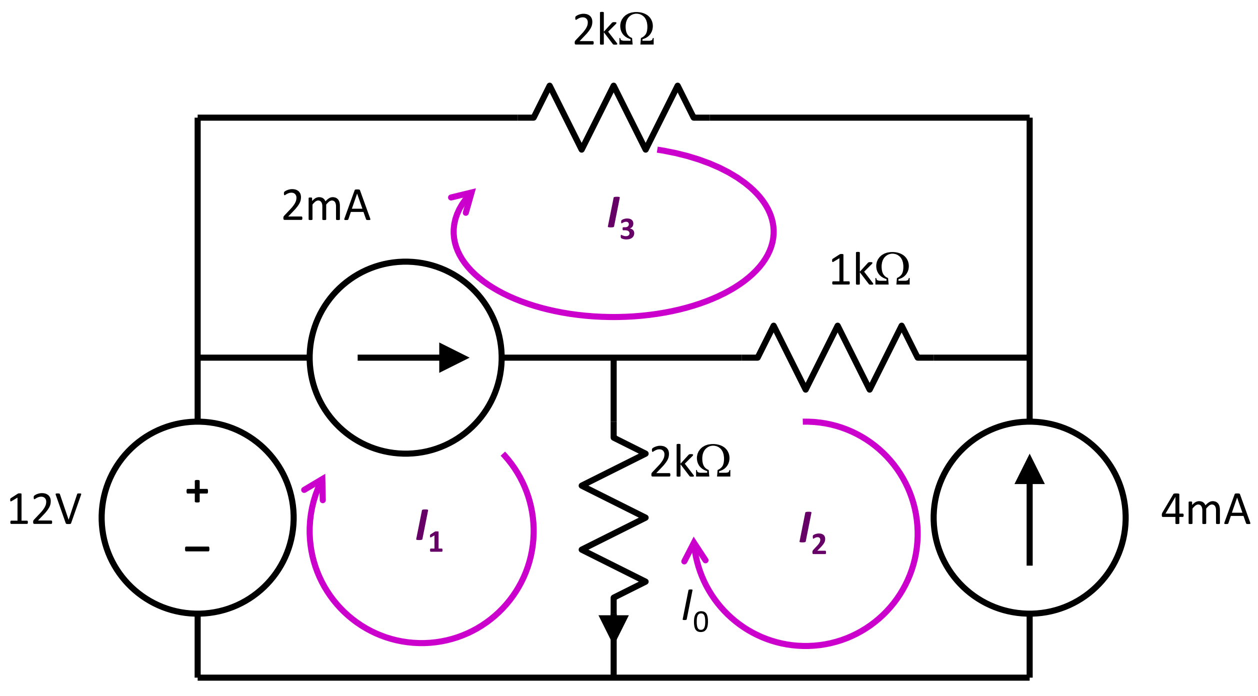
Another Example



1. Identify Meshes



2. Assign Mesh Currents



Current Sources

- The current sources in this circuit will have whatever voltage is necessary to make the current correct.
- We can’t use KVL around any mesh because we don’t know the voltage for the current sources.
- What to do?

Current Sources

- The 4mA current source sets I_2:

$$I_2 = -4 \text{ mA}$$

- The 2mA current source sets a *constraint* on I_1 and I_3:

$$I_1 - I_3 = 2 \text{ mA}$$

- We have two equations and three unknowns. Where is the third equation?

Supermesh

The Supermesh surrounds this source!

The Supermesh does not include this source!