Kirchhoff's Laws

Kirchhoff's Rules

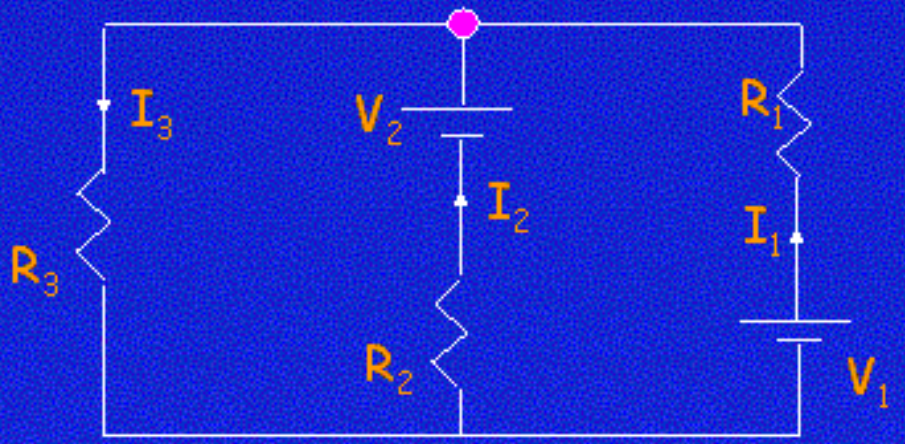
- Kirchhoff's Junction Rule:
  - Current going in equals current coming out.
- Kirchhoff's Loop Rule:
  - Sum of voltage changes around a loop is zero.

The Junction Rule

- Conceptual Basis: conservation of charge
- At any junction in a circuit, the current that enters the junction equals the current that leaves the junction.
- Example:

At the junction shown:

$I_1 + I_2 = I_3$

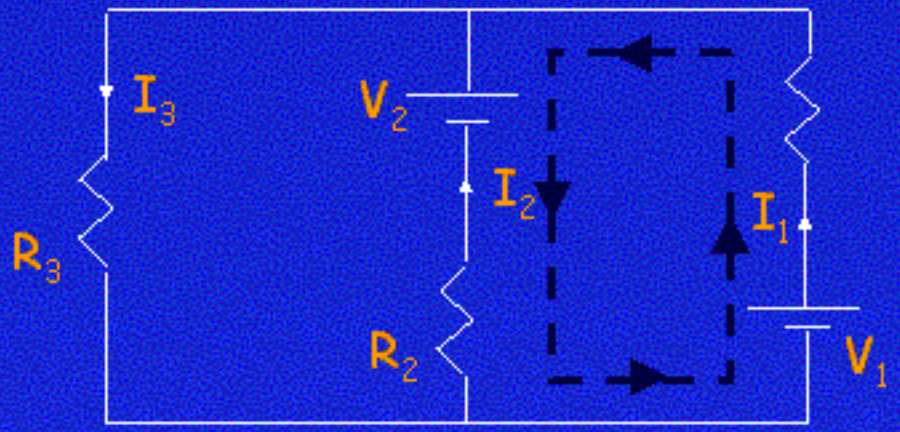


The Loop Rule

- Conceptual Basis: conservation of energy
- Going around any complete loop in a circuit, the sum total of all the potential differences is zero.
- Example:

Going around the right loop:

$$V_1 - I_1R_1 - V_2 + I_2R_2 = 0$$



Using Kirchhoff's Rules

(1) Label all currents

(2) Write down junction equation

$I_{in} = I_{out}$

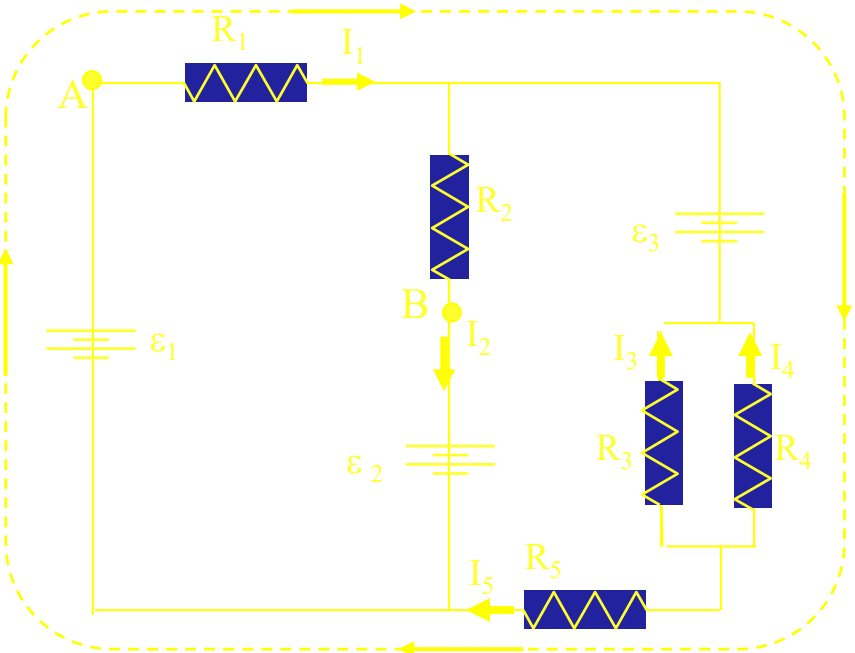
(3)Choose loop and direction

- Choose any direction
- You will need one less loop than unknown currents

(4) Write down voltage changes

Be careful about signs

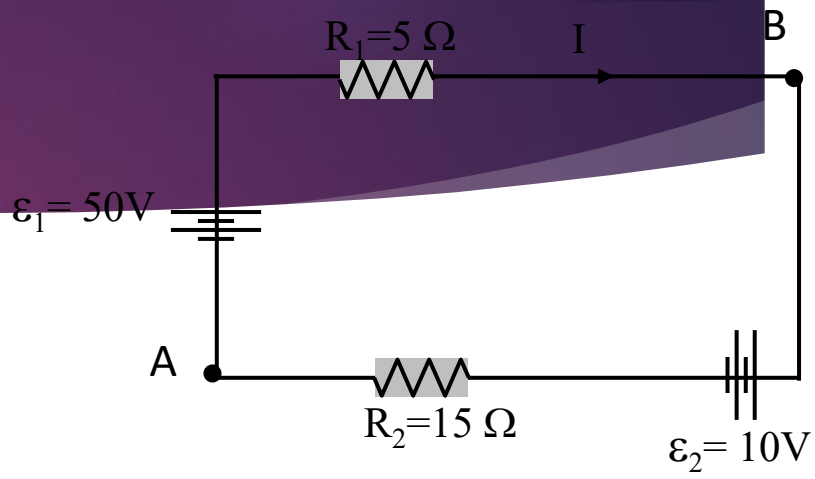
- For batteries – voltage change is positive when summing from negative to positive
- For resistors – voltage change is negative when summing in the direction of the current



Example

Loop Rule Practice

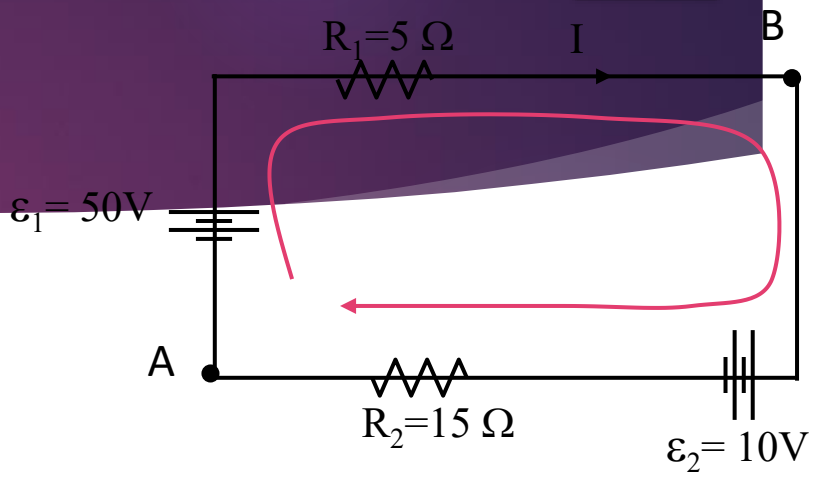
Find I:



Example

Loop Rule Practice

Find I:



Label currents

Choose loop

Write KLR

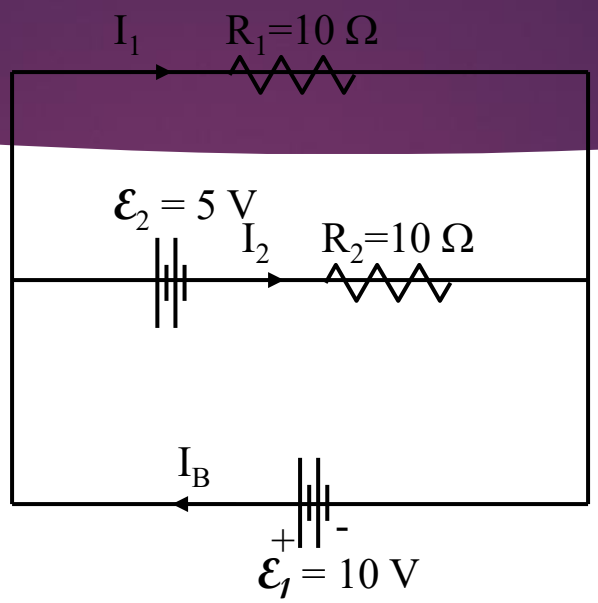
$+\mathcal{E}_1 - IR_1 - \mathcal{E}_2 - IR_2 = 0$

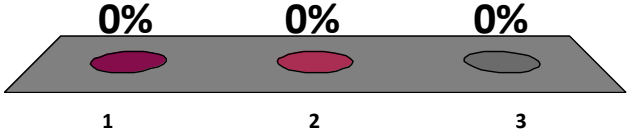
$+50 - 5\,I - 10 - 15\,I = 0$

$I = +2$ Amps

Resistors R_1 and R_2 are

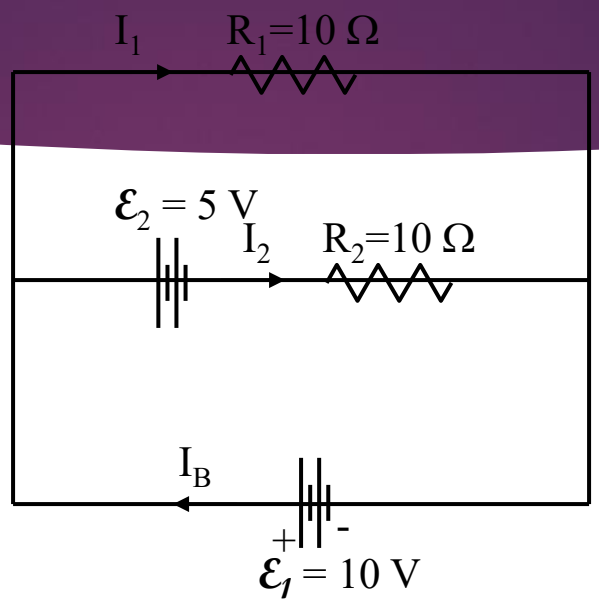
1. In parallel
2. In series
3. neither





Resistors R_1 and R_2 are

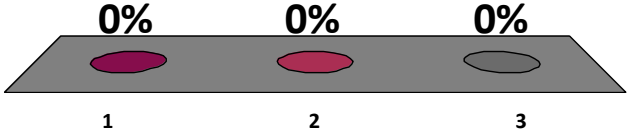
1. In parallel
2. In series
3. neither



Definition of parallel:

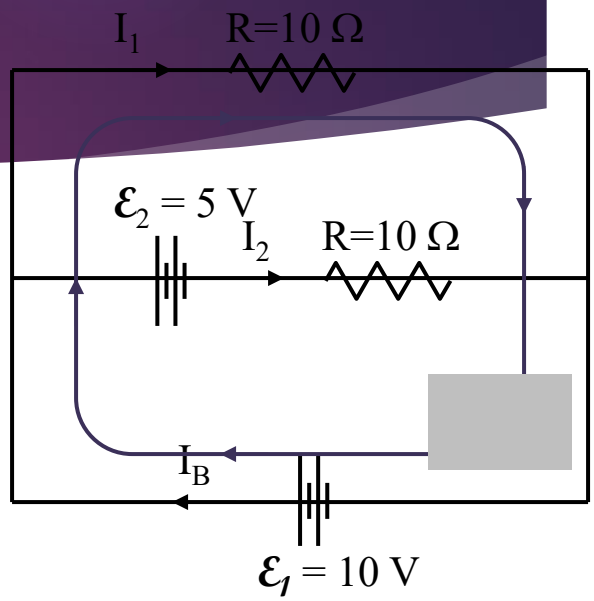
Two elements are in parallel if (and only if) you can make a loop that contains only those two elements.

Upper loop contains R_1 and R_2 but also E_2.



Preflight 10.1

Calculate the current through resistor 1.

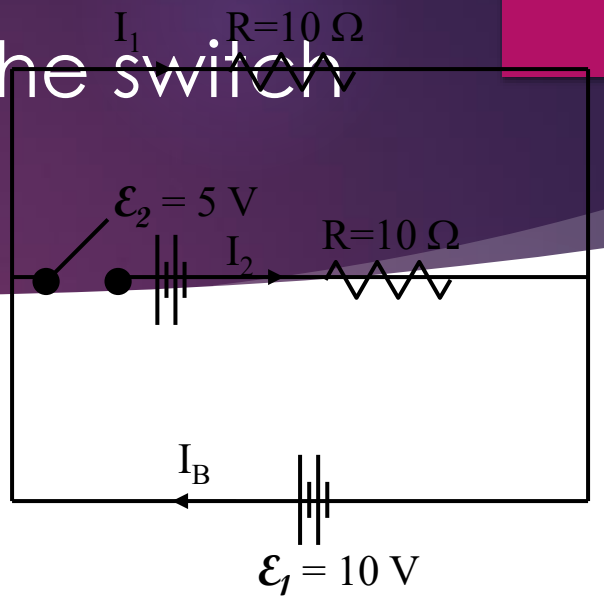


24% 62% 24%

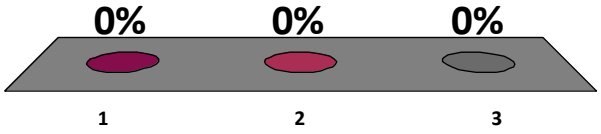
1) $I_1 = 0.5$ A 2) $I_1 = 1.0$ A 3) $I_1 = 1.5$ A

$\mathcal{E}_1 - I_1 R = 0 \quad \Rightarrow I_1 = E_1 / R = 1\text{A}$

How would I_1 change if the switch was opened?



1. Increase
2. No change
3. Decrease



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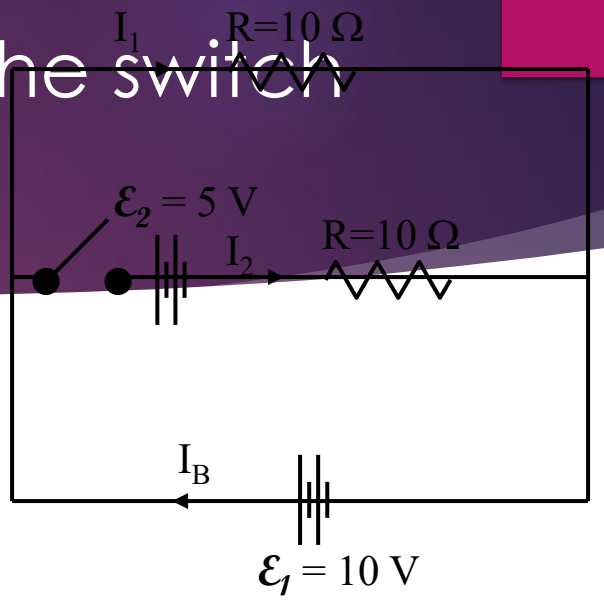
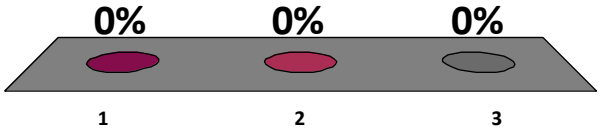


1. Increase
2. No change
3. Decrease



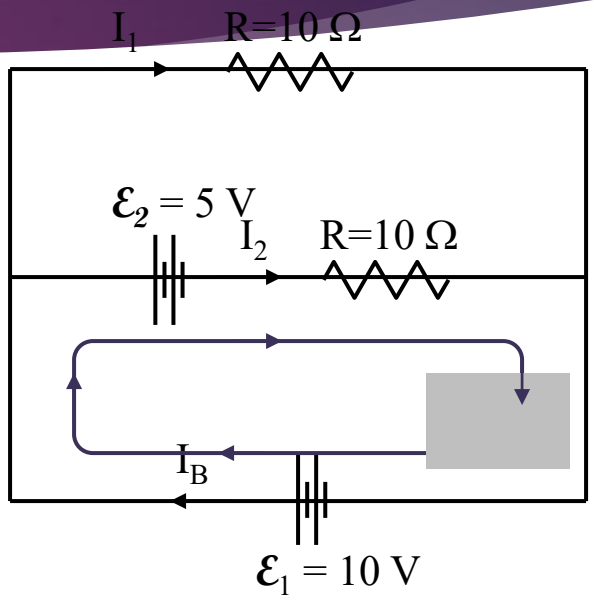
Preflight 10.2

Calculate the current through resistor 2.

1) $I_2 = 0.5$ A 43%

2) $I_2 = 1.0$ A 28%

3) $I_2 = 1.5$ A 28%



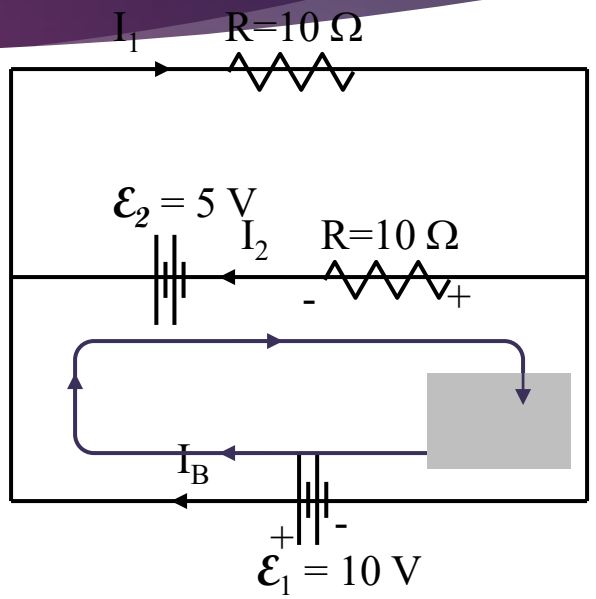
$$\mathcal{E}_1 - \mathcal{E}_2 - I_2 R = 0$$

$$\Rightarrow I_2 = 0.5\text{A}$$

Preflight 10.2

How do I know the direction of I_2?

It doesn't matter. Choose whatever direction you like. Then solve the equations to find I_2. If the result is positive, then your initial guess was correct. If result is negative, then actual direction is opposite to your initial guess.



Work through preflight with opposite sign for I_2?

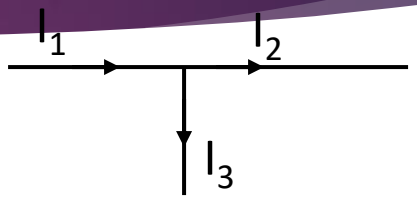
$+\mathcal{E}_1 - \mathcal{E}_2 + I_2R = 0$ Note the sign change from last slide

$\Rightarrow I_2 = -0.5A$ Answer has same magnitude as before but opposite sign. That means current goes to the left, as we found before.

Kirchhoff's Junction Rule

Current Entering = Current Leaving

$I_1 = I_2 + I_3$

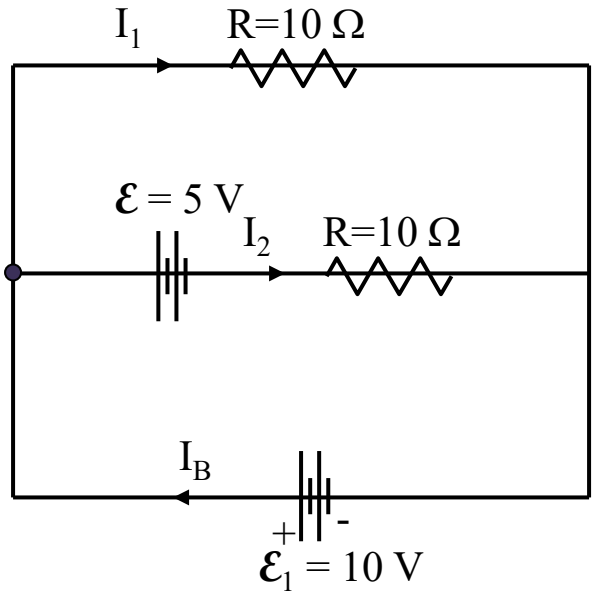


Preflight 8.3

7% 37% 57%

1) $I_B = 0.5$ A 2) $I_B = 1.0$ A 3) $I_B = 1.5$ A

$I_B = I_1 + I_2 = 1.5$ A



Kirchhoff's Laws

(1) Label all currents

Choose any direction

(2) Write down the junction equation

(3) Choose loop and direction

Your choice!

(4) Write down voltage changes

(5) Solve the equations by substitution or combination .