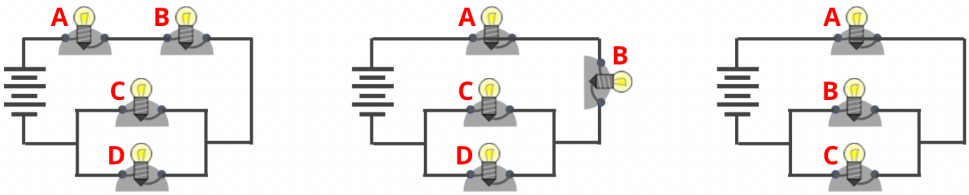
Combination Circuits
Lesson Notes

Learning Outcomes

- What are the main mathematical patterns and relationships associated with combination circuits?
- How can one analyze such circuits?

What is a Combination Circuit?

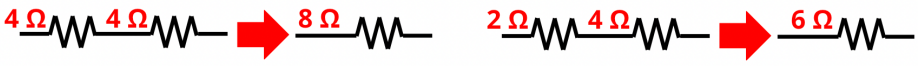
A combination circuit includes devices that are connected by a combination of series and parallel connections.



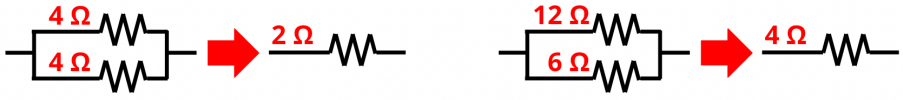
Equivalent Resistance

The collection of resistors act together to create an overall total resistance known as the **equivalent resistance** (R_{eq}).

For series connections: $R_{eq} = R_1 + R_2 + R_3 + \ldots$



For parallel connections: $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$

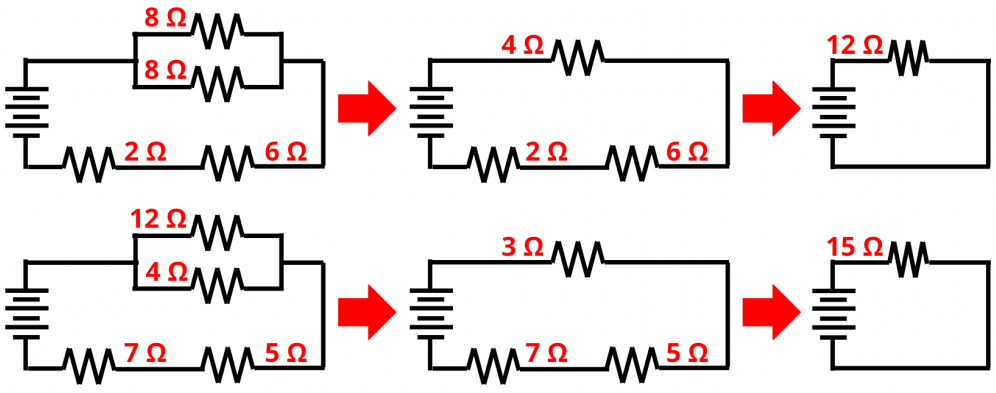


$1/R_{eq} = 1/(4) + 1/(4) = 0.50$
$R_{eq} = 1/(0.50) = \mathbf{2.0}$

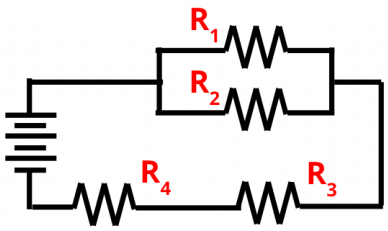
$1/R_{eq} = 1/(12) + 1/(6) = 0.25$
$R_{eq} = 1/(0.25) = \mathbf{4.0}$

R_{eq} for a Combination Circuit

The equivalent resistance of a combination circuit can be determined by reducing groups of resistors to a single resistance in a stepwise fashion, beginning with the branched resistors.

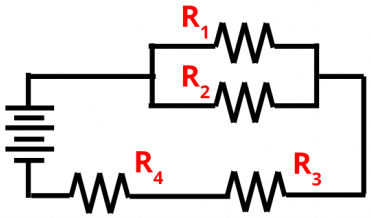


Voltage Drops (ΔV)



- For the *branched* resistors (R_1 and R_2), the voltage drop is the same. So **$\Delta V_1 = \Delta V_2$**.
- For all resistors, the voltage drop can be calculated using $\Delta V = I \cdot R$. So …
  $\Delta V_1 = I_1 \cdot R_1$ **$\Delta V_2 = I_2 \cdot R_2$** **$\Delta V_3 = I_3 \cdot R_3$** etc.
- Counting the branches as a single drop, the sum of all voltage drops equals the battery voltage.
- For the given circuit: **$\Delta V_{battery} = \Delta V_{branches} + \Delta V_3 + \Delta V_4$**

Current (I)



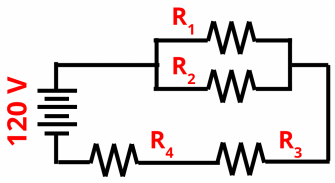
For combination circuits:

- The current in the battery is the same as the current in every resistor located outside the branches. For the given circuit: **$I_{battery} = I_3 = I_4$**
- The current outside the branches is equal to the sum of the branch currents. For the given circuit: **$I_{battery} = I_1 + I_2$**
- For any resistor, the current can be calculated using $\Delta V = I \cdot R$. So … **$I_1 = \Delta V_1 / R_1$** **$I_2 = \Delta V_2 / R_2$** **$I_3 = \Delta V_3 / R_3$** etc.
- Branches having equal resistance will have equal current values.

Examples

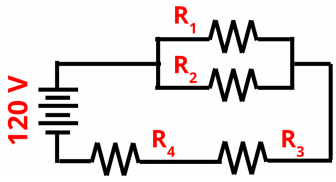
Analyze the following two combination circuits. Fill in all blanks.

$R_1 = 16\Omega$ **$R_2 = 16\Omega$**
$R_3 = 4\Omega$ **$R_4 = 12\Omega$**



R_{eq} = _____ $I_{battery}$ = _____
I_1 = _____ ΔV_1 = _____
I_2 = _____ ΔV_2 = _____
I_3 = _____ ΔV_3 = _____
I_4 = _____ ΔV_4 = _____

$R_1 = 12\Omega$ **$R_2 = 24\Omega$**
$R_3 = 10\Omega$ **$R_4 = 6\Omega$**



R_{eq} = _____ $I_{battery}$ = _____
I_1 = _____ ΔV_1 = _____
I_2 = _____ ΔV_2 = _____
I_3 = _____ ΔV_3 = _____
I_4 = _____ ΔV_4 = _____