Electronic Circuits

Week 4: Series Circuit

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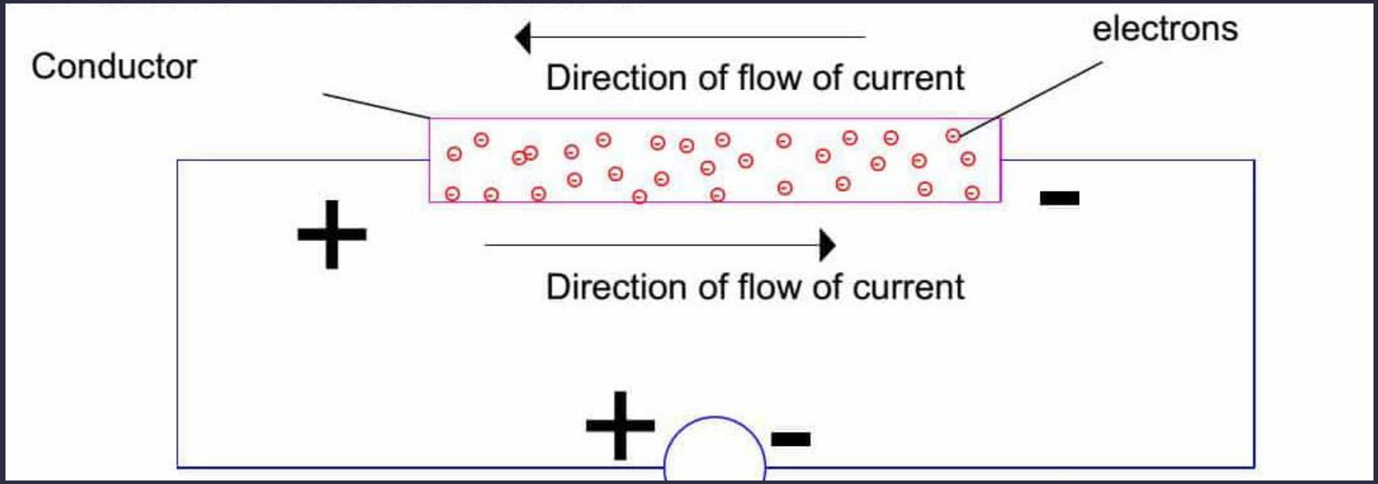
Why Current is the Same in All Parts of a Series Circuit

Characteristics of a Series Circuit:

- The current is the same everywhere in a series circuit.
- The total resistance is equal to the sum of the individual resistance values.
- The total voltage is equal to the sum of the *IR* voltage drops across the individual resistances.
- The total power is equal to the sum of the power dissipated by each resistance.

Why *I* Is the Same in All Parts of a Series Circuit

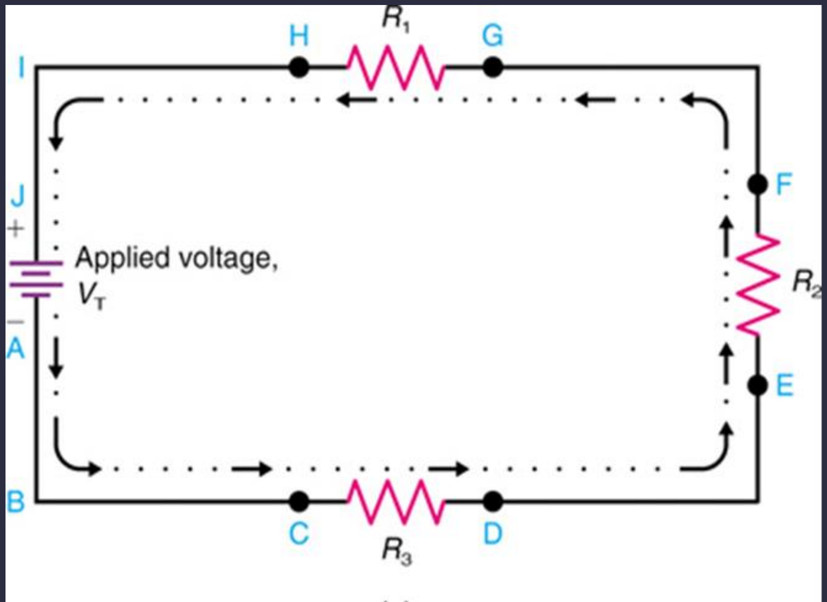
- Current is the movement of electric charge between two points, produced by the applied voltage.
- The free electrons moving away from one point are continuously replaced by free electrons flowing from an adjacent point in the series circuit.
- All electrons have the same speed as those leaving the voltage source.
- Therefore, *current* is the same in all parts of a series circuit.



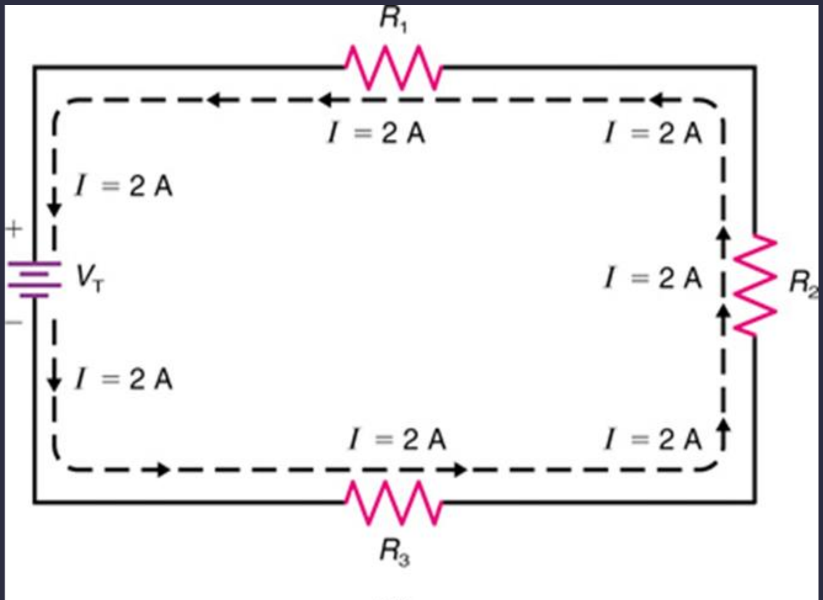
Why *Current* Is the Same in All Parts of a Series Circuit

There is only one current through R_1, R_2, and R_3 in series.

(a) Electron drift is the same in all parts of a series circuit.
(b) Current *I* is the same at all points in a series circuit.



(a)



(b)

Why *I* Is the Same in All Parts of a Series Circuit

Series Current Formulas
Total current is the same as the individual currents in the series string:

$$I_T = I_1 = I_2 = I_3 = \ldots = \text{etc.}$$

- Total current is equal to total voltage divided by total resistance:

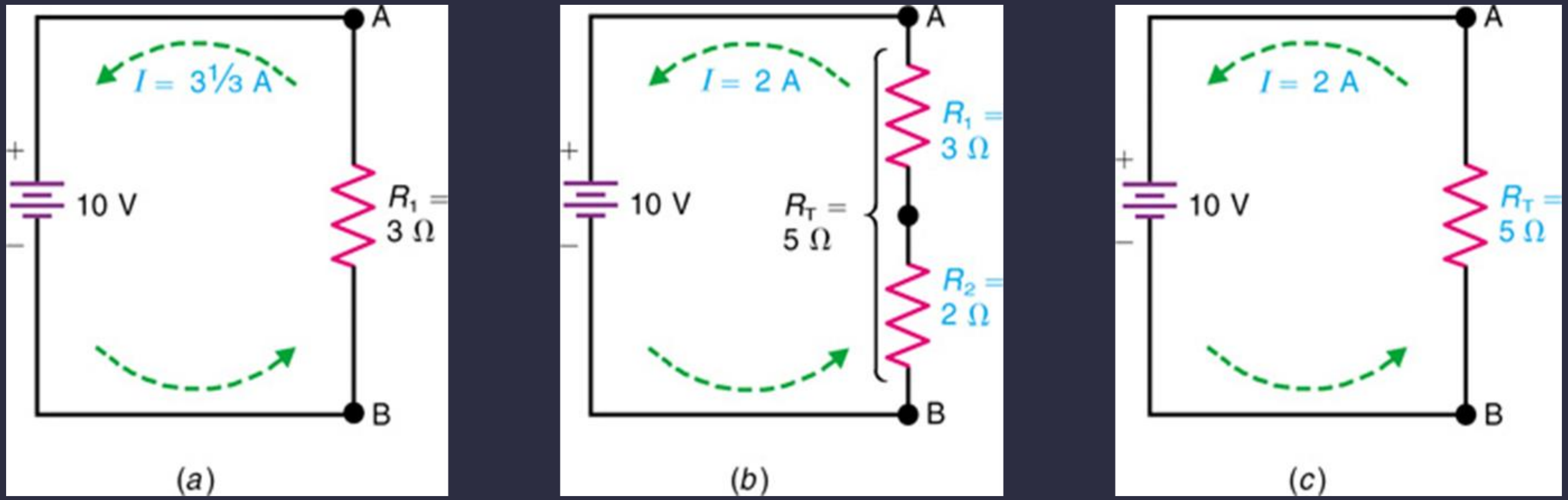
$$I_T = \frac{V_T}{R_T}$$

Total *R* Equals the Sum of All Series Resistances

- When a series circuit is connected across a voltage source, the free electrons must drift through all the series resistances.
- There is only one path for free electrons to follow.
- If there are two or more resistances in the same current path, the total resistance across the voltage source is the sum of all the resistances.

Total R Equals the Sum of All Series Resistances

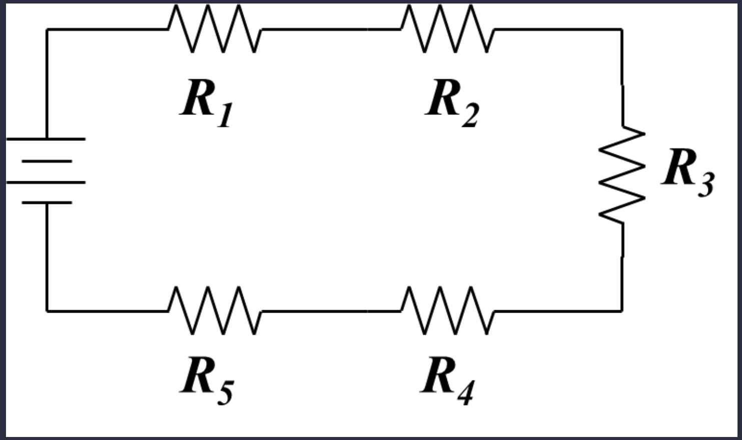
Series resistances are added for the total R_T.



Total *R* Equals the Sum of All Series Resistances

Series Resistance Formulas

The total resistance is the sum of the individual resistances.



$$R_T = R_1 + R_2 + R_3 + R_4 + R_5$$

Total *R* Equals the Sum of All Series Resistances

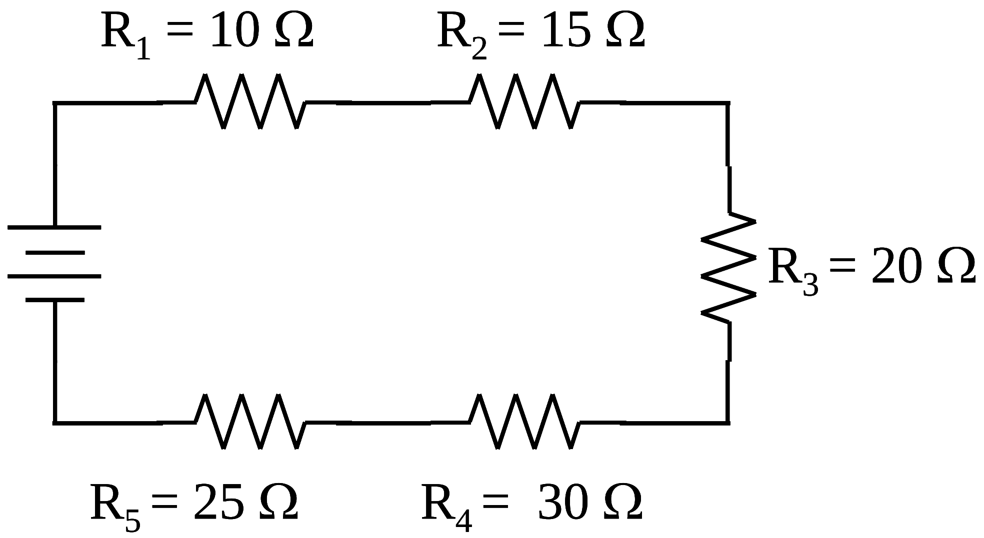
Series Resistance Formulas

Total resistance is equal to total voltage divided by the circuit current:

$$R_T = \frac{V_T}{I_T}$$

Total *R* Equals the Sum of All Series Resistances

- Determining the Total Resistance



$$R_T = R_1 + R_2 + R_3 + R_4 + R_5$$

$$R_T = 10\ \Omega + 15\ \Omega + 20\ \Omega + 30\ \Omega + 25\ \Omega = 100\ \Omega$$

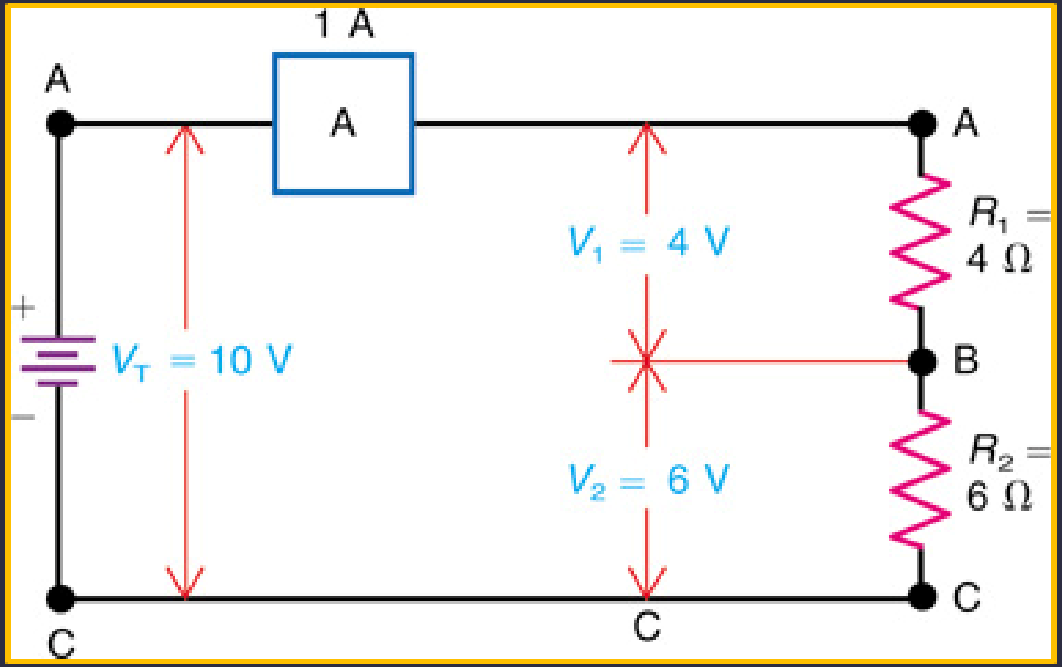
Series *IR* Voltage Drops

By Ohm's Law, the voltage across a resistance equals $I \times R$.

- In a series circuit, the *IR* voltage across each resistance is called an ***IR* drop** or **voltage drop**.
- It is so called because it reduces the potential difference available for the remaining resistances in the circuit.

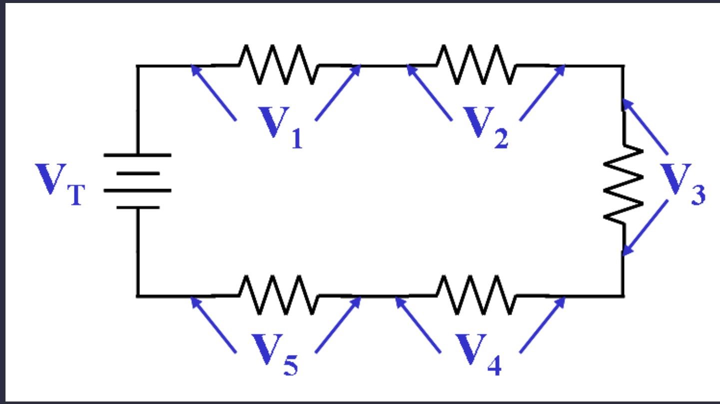
Series IR Voltage Drops

An example of IR voltage drops V_1 and V_2 in a series circuit.



Kirchhoff’s Voltage Law (KVL)

The total voltage is equal to the sum of the drops.

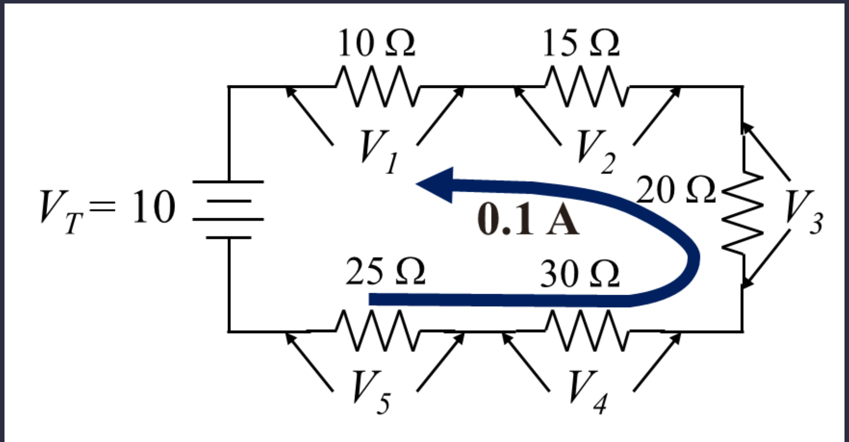


$$V_T=V_1+V_2+V_3+V_4+V_5$$

This is known as
Kirchhoff’s voltage law (KVL)

Kirchhoff’s Voltage Law (KVL)

The *IR* drops must add to equal the applied voltage (KVL).



$$V_T = V_1 + V_2 + V_3 + V_4 + V_5$$

$$V_T = IR_1 + IR_2 + IR_3 + IR_4 + IR_5$$

$$V_T = 0.1 \times 10 + 0.1 \times 15 + 0.1 \times 20 + 0.1 \times 30 + 0.1 \times 25$$

$$V_T = 1\text{V}+1.5\text{V} + 2\text{V} + 3\text{V} + 2.5\text{V}=10\text{V}$$

Polarity of *IR* Voltage Drops

When current flows through a resistor, a voltage equal to *IR* is dropped across the resistor. The polarity of this *IR* voltage drop is:

<u>Negative</u> at the end where the electrons enter the resistor.

<u>Positive</u> at the end where the electrons leave the resistor.

Polarity of *IR* Voltage Drops

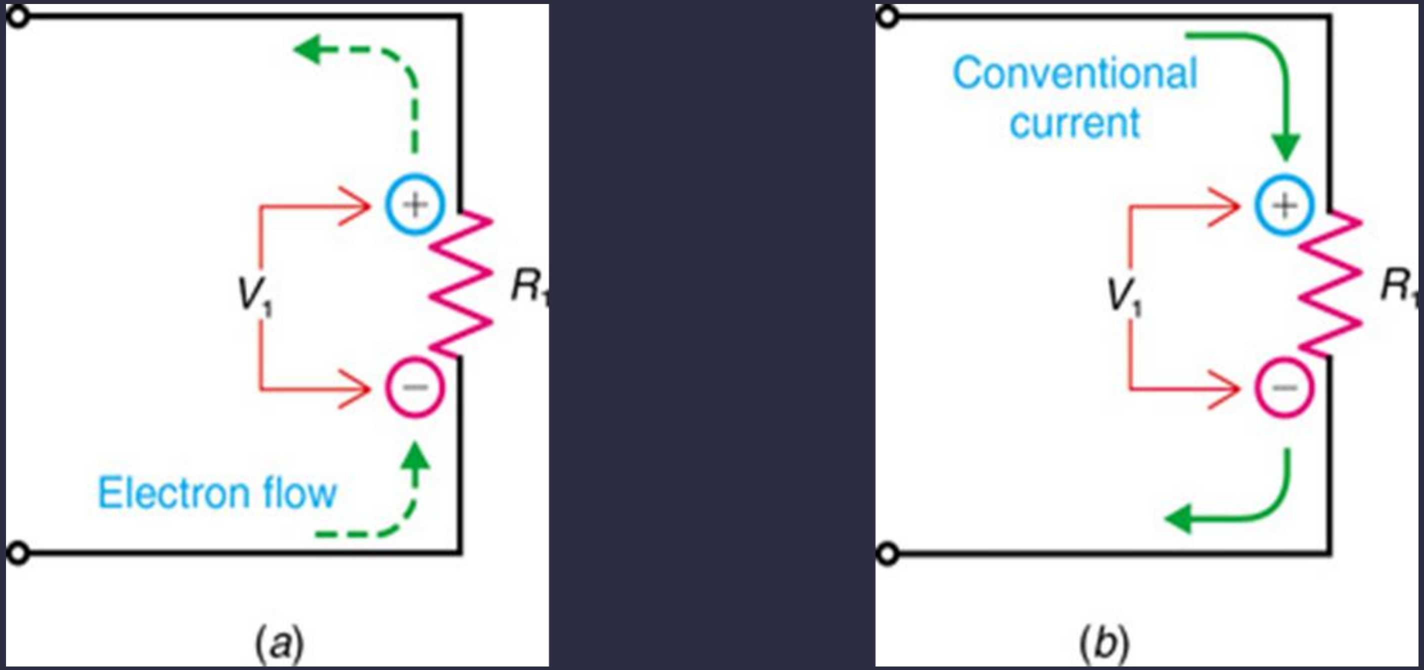
- The rule is reversed when considering conventional current: positive charges move into the positive side of the *IR* voltage.

- The polarity of the *IR* drop is the same, regardless of whether we consider electron flow or conventional current.

Polarity of I R Voltage Drops

Polarity of *IR* voltage drops.

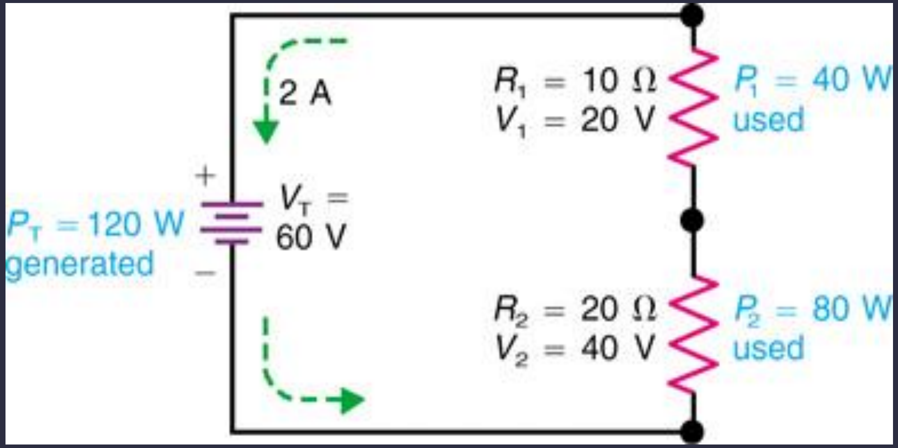
(a) Electrons flow into the negative side of V_1 across R_1.
(b) (*b*) Same polarity of V_1 with positive charges moving into the positive side.



Total Power in a Series Circuit

The total power used in the circuit is equal to the sum of the individual powers dissipated in each part of the circuit.

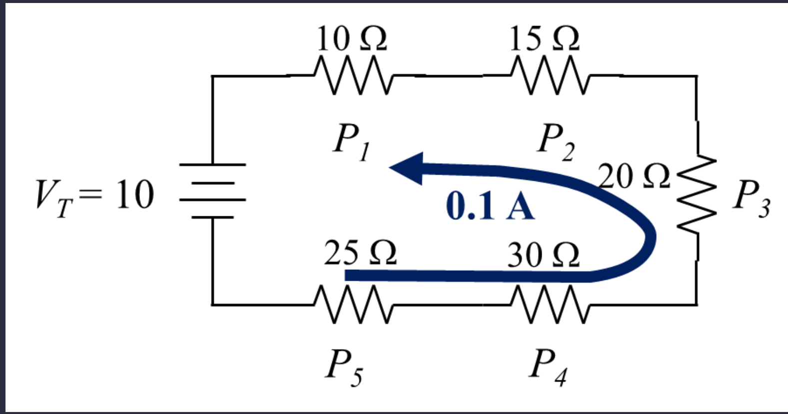
Total power can also be calculated as $V_T \times I$



The sum of the individual powers P_1 and P_2 used in each resistance equals the total power P_T produced by the source.

Total Power in a Series Circuit 2

Finding Total Power



$$P_T = P_1 + P_2 + P_3 + P_4 + P_5$$

$$P_T = I^2 R_1 + I^2 R_2 + I^2 R_3 + I^2 R_4 + I^2 R_5$$

$$P_T = 0.1\ \text{W} + 0.15\ \text{W} + 0.2\ \text{W} + 0.3\ \text{W} + 0.25\ \text{W} = 1\ \text{W}$$

$$\text{Check: } P_T = V_T \times I = 10\ \text{V} \times 0.1\ \text{A} = 1\ \text{W}$$

Series-Aiding and Series-Opposing Voltages

Series-aiding voltages are connected with polarities that allow current in the same direction: The positive terminal of one is connected to the negative terminal of the next.

They can be added for the total voltage.

Series-Aiding and Series-Opposing Voltages

Series-opposing voltages are the opposite: They are connected to produce opposing directions of current flow.

The positive terminal of one is connected to the positive terminal of another.

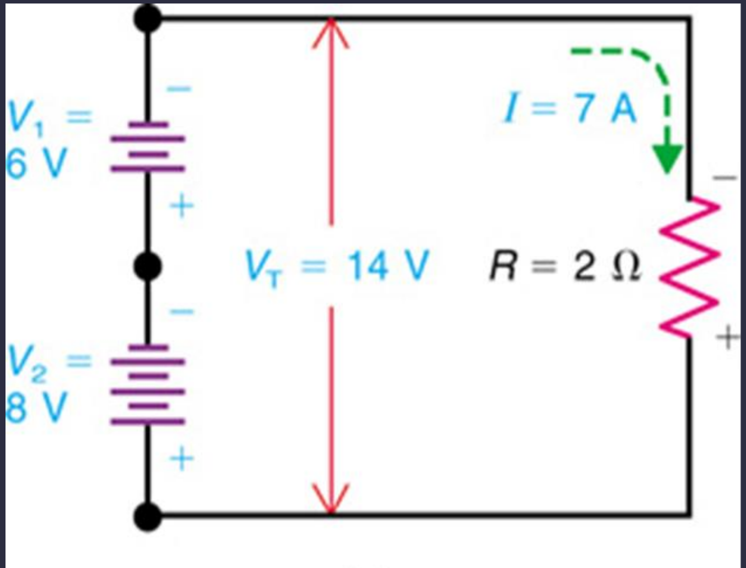
To obtain the total voltage, subtract the smaller voltage from the larger.

Two equal series-opposing voltage sources have a net voltage of zero.

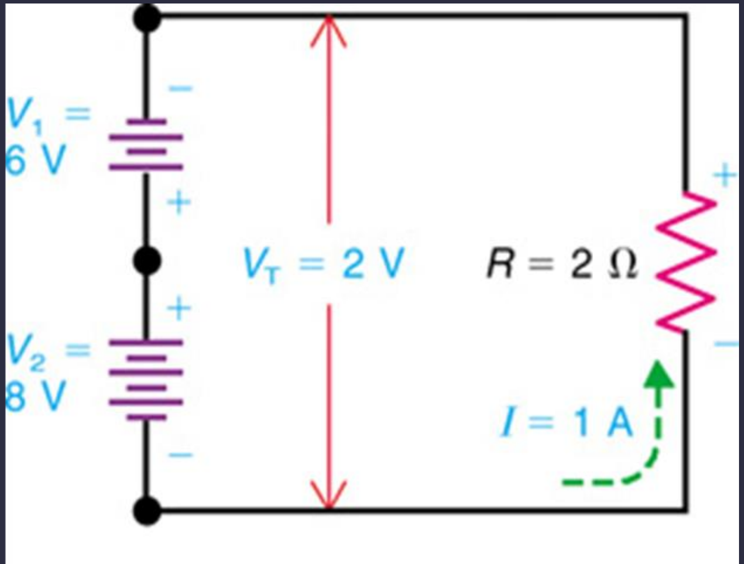
Series-Aiding and Series-Opposing Voltages

Example of voltage sources V_1 and V_2 in series.

(a) Note the connections for series-aiding polarities. Here 8 V + 6 V = 14 V for the total V_T.
(b) (*b*) Connections for series-opposing polarities. Now 8 V – 6 V = 2 V for V_T.



(a)



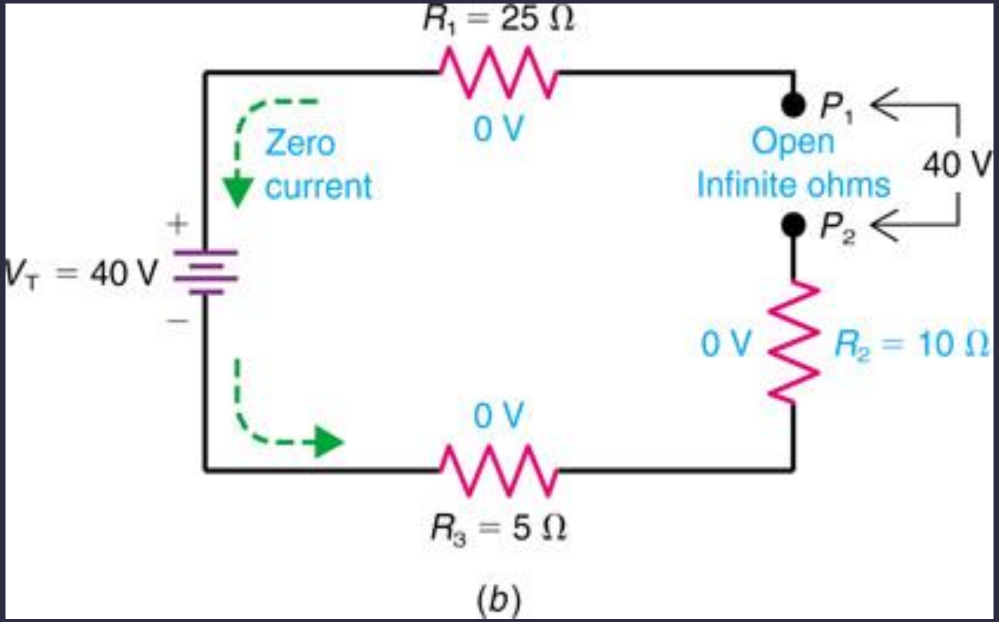
(b)

The Ground

Figures shows several schematic ground symbols:

- **Ground is assumed to have a potential of 0 V regardless of the schematic symbol shown.**
- **These symbols are sometimes used inconsistently with their definitions. However, these symbols always represent a common return path for current in a given circuit.**

The Effect of an Open in a Series Circuit:

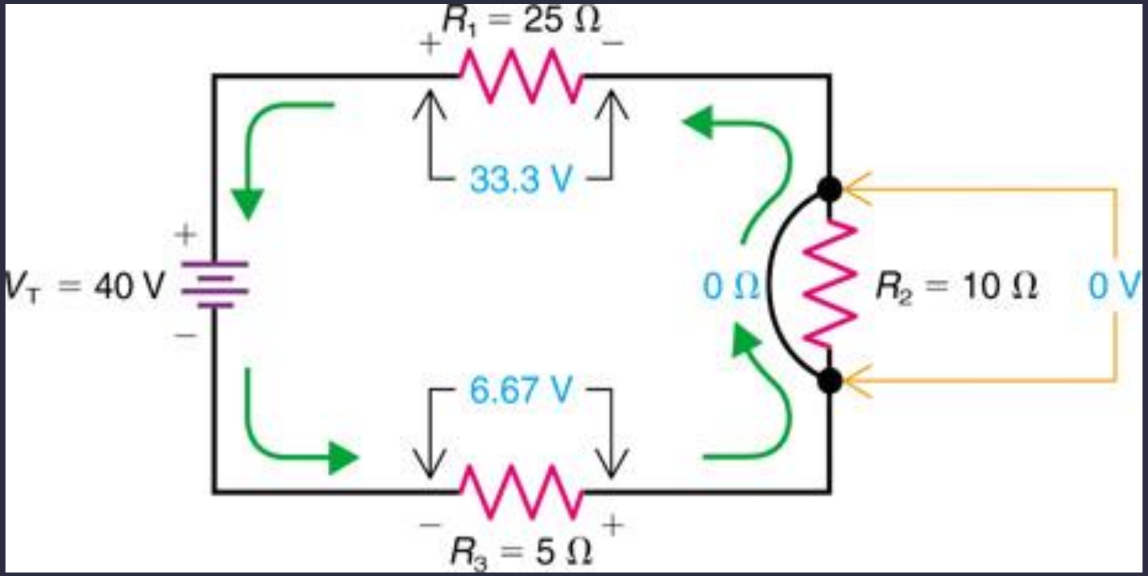


Effect of an open in a series circuit.

(*b*) Open path between points P_1 and P_2 results in zero current in all parts of the circuit.

Troubleshooting: Opens and Shorts in Series Circuits

The Effect of a Short in a Series Circuit:



Series circuit of with R_2 shorted.