University of Anbar
College of Engineering
Dept. of Electrical Engineering

Electric physics II

Electric circuits

By

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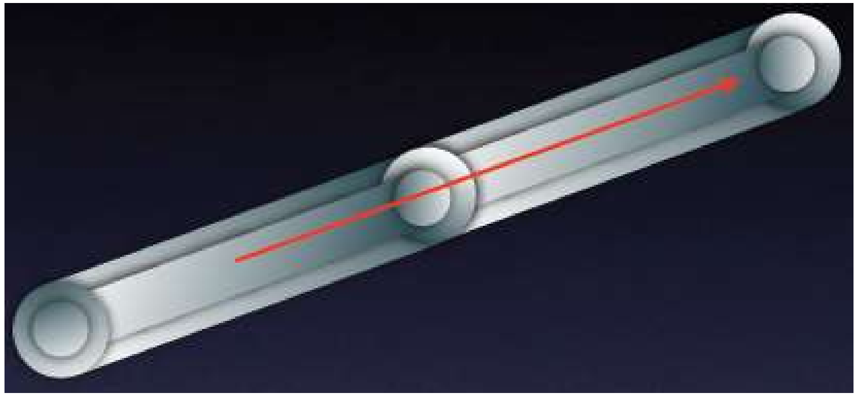
Basic concepts

Electricity: *Physical phenomenon arising from the existence and interactions of **electric charge***

- Charge
- Current
- Voltage
- Power and Energy

Electric current



$$I = \frac{\text{charge}}{\text{time}} = \frac{\text{coulombs}}{\text{seconds}}$$

$$I = \frac{Q}{t} \text{ amperes}$$

An **ampere (A)** is the number of electrons having a total charge of 1 C moving through a given cross section in 1 sec.

As defined, current flows in direction of **positive charge** flow

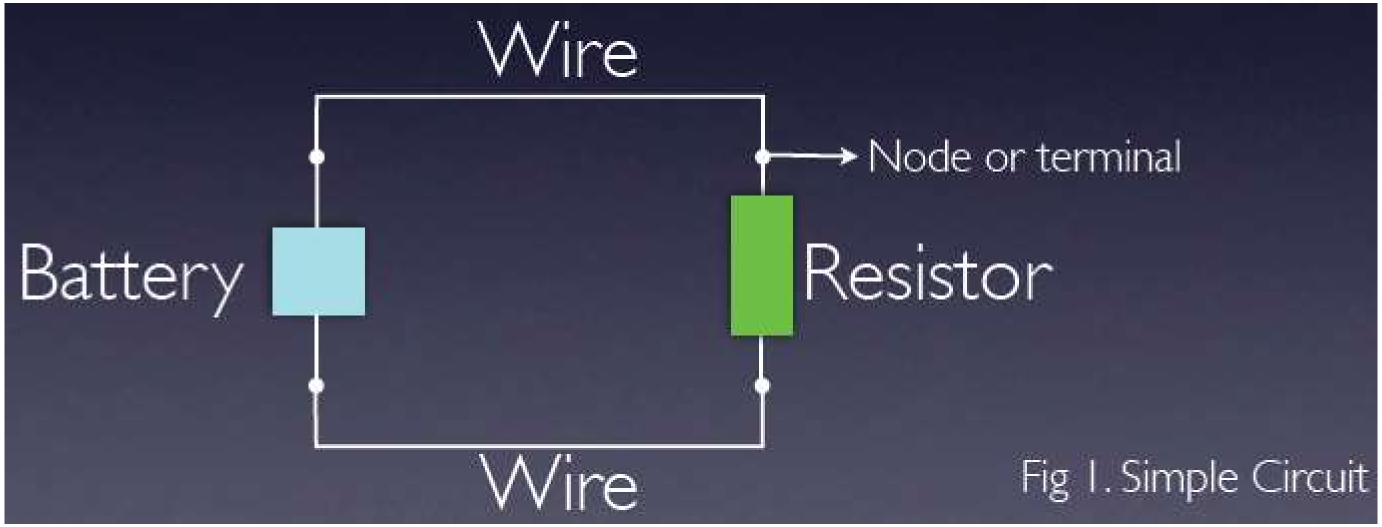
Current density

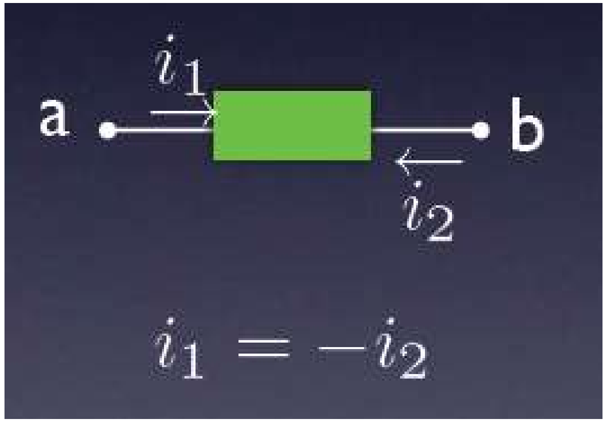
- It is the amount of current flowing in a unit area and its symbol (J).
- $J = \frac{I}{A}$
- The unite of current density is $(\frac{A}{m^2})$

Electric circuit

An electric circuit *is an interconnection of* ***electrical elements*** *linked together in a* ***closed path*** *so that electric current may flow continuously*

Circuit diagrams are the standard for electrical engineers

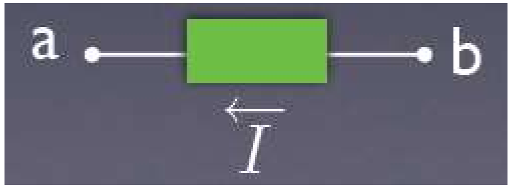




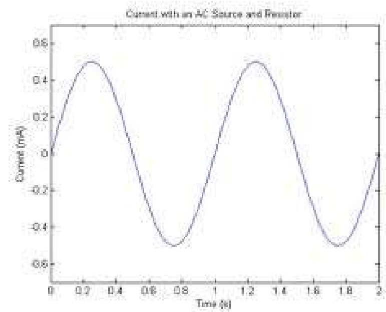
$\overrightarrow{i_1}$ Rate of flow of charge form **node a to node b**

$\overleftarrow{i_2}$ Rate of flow of charge form **node b to node a**

A **direct current (dc)** is a current of constant magnitude

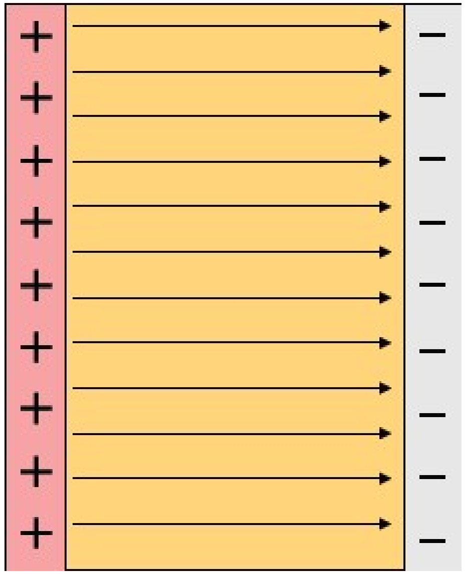


An **alternating current (ac)** is a current of varying magnitude and direction



Voltage

The voltage across an element is the work (energy) required to move a unit of positive charge from the "**−**" terminal to the "**+**" terminal



$$V = \frac{W}{Q} = \frac{\text{joules}}{\text{coulombs}} = \text{volts}$$

A **volt** is the potential difference (voltage) between two points when **1 joule of energy** is used to move **1 coulomb of charge** from one point to the other

Power

The rate at which energy is converted or work is performed

$$P = \frac{W}{t} = \frac{\text{joules}}{\text{second}} = \text{watt}$$

$$P = IV$$

A **watt** results when **1 joule of energy** is converted or used in **1 second**

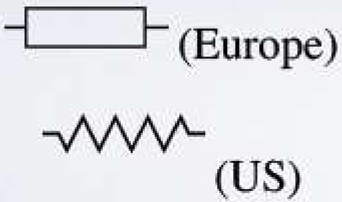
Power Dissipated in Resistor

$$P = VI = \frac{V^2}{R} = I^2 R$$

Resistors

Resistor	
Three resistors	
Type	Passive
Electronic symbol	

Three resistors



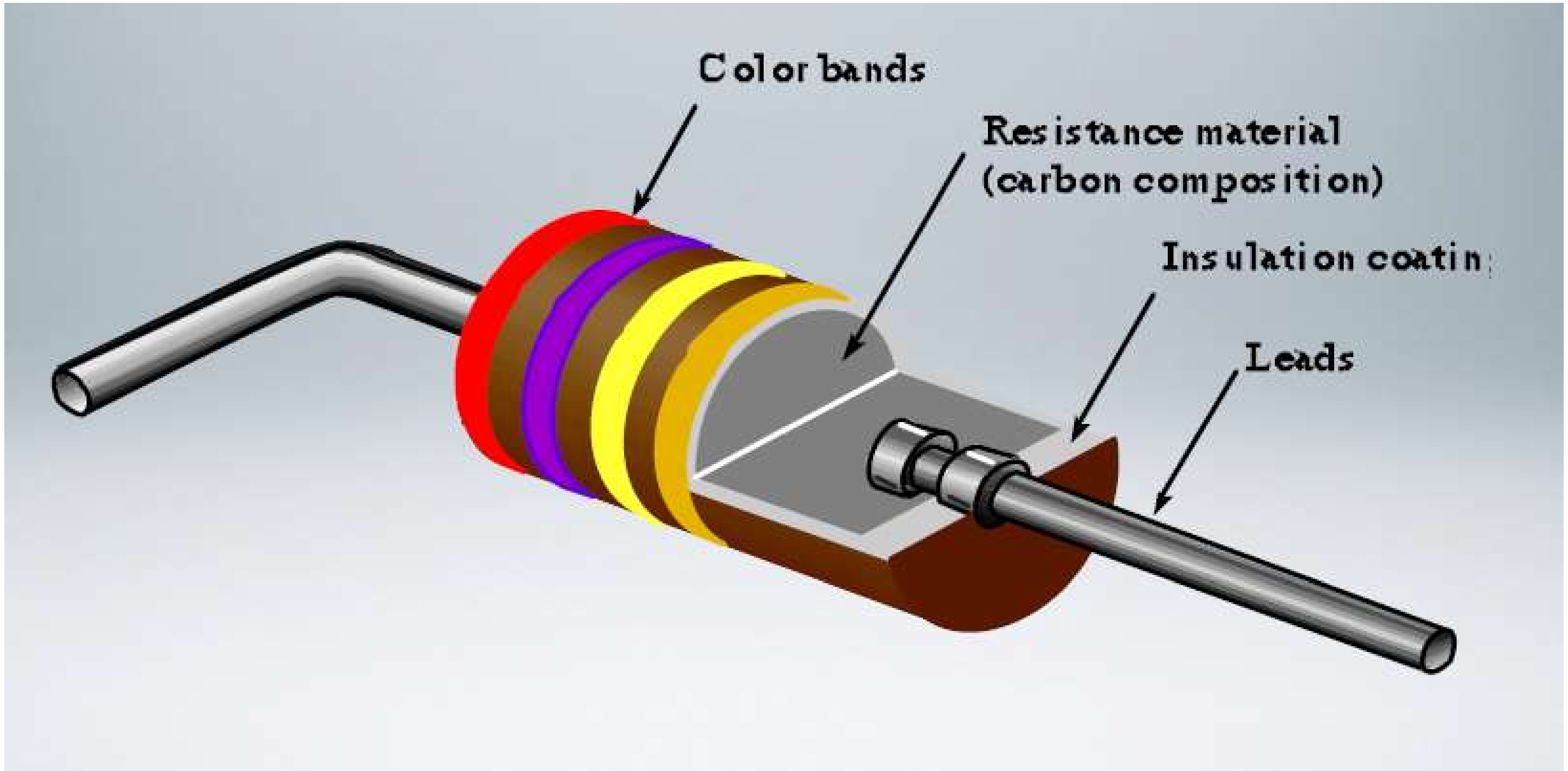
Resistance (R) is the physical property of an element that impedes the flow of current . The units of resistance are **Ohms (Ω)**

Resistivity (ρ) is the ability of a material to resist current flow. The units of resistivity are **Ohm-meters (Ω-m)**

Example:

Resistivity of copper	$1.68 \times 10^{-8}\ \Omega\cdot m$
Resistivity of glass	10^{10} to $10^{14}\ \Omega\cdot m$

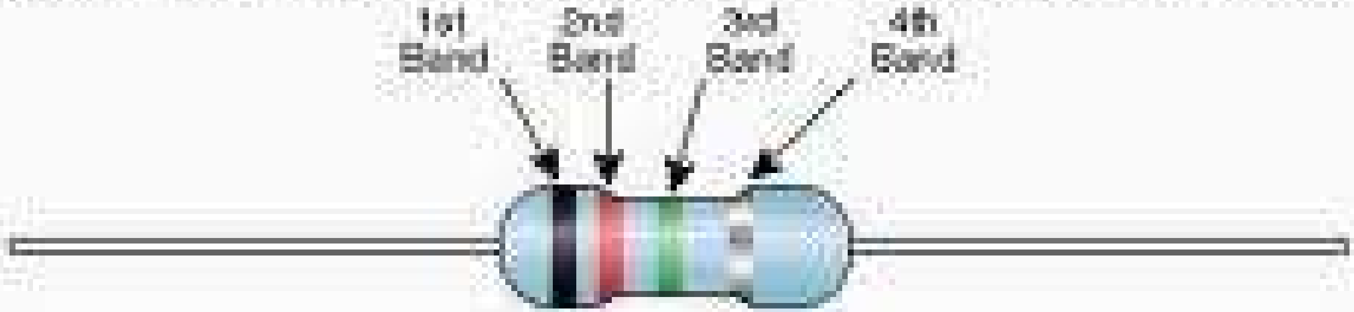
Resistors



Color bands
Resistance material
(carbon composition)
Insulation coatin
Leads

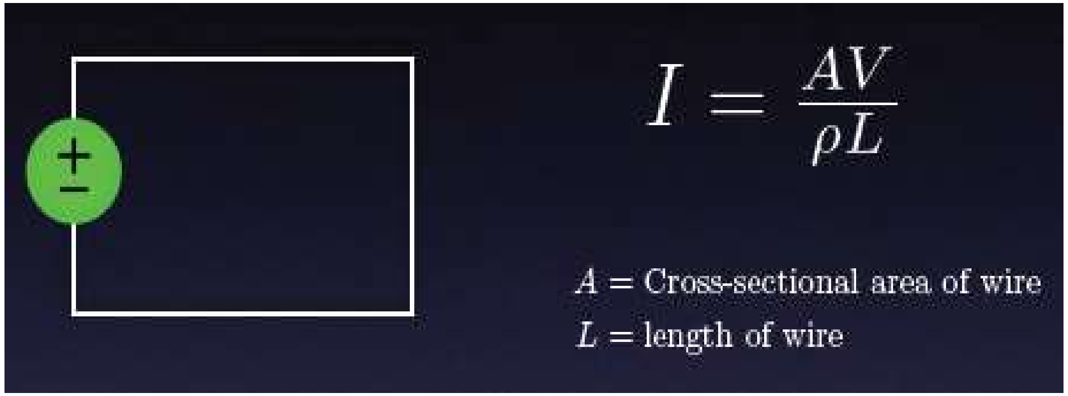
Resistors

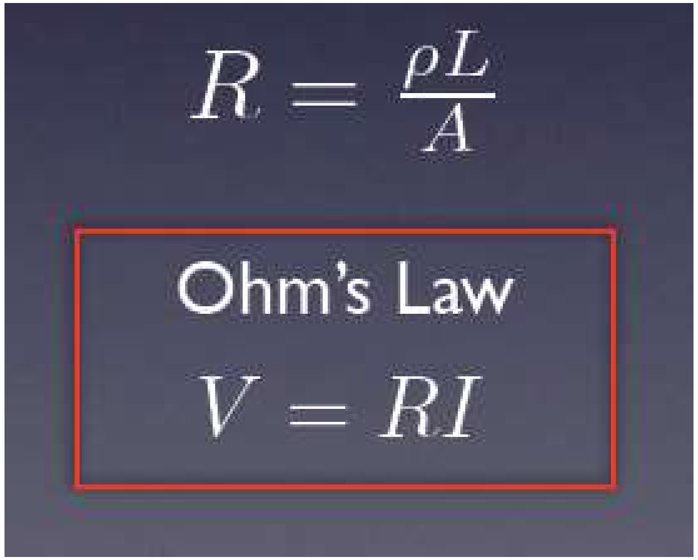
Standard EIA Color Code Table 4 Band: ±2%, ±5%, and ±10%



Color	1st Band (1st figure)	2nd Band (2nd figure)	3rd Band (multiplier)	4th Band (tolerance)
Black	0	0	10^0	
Brown	1	1	10^1	
Red	2	2	10^2	±2%
Orange	3	3	10^3	
Yellow	4	4	10^4	
Green	5	5	10^5	
Blue	6	6	10^6	
Violet	7	7	10^7	
Gray	8	8	10^8	
White	9	9	10^9	
Gold			10^{-1}	±5%
Silver			10^{-2}	±10%

Ohm’s Law





(remember, R is in Ω and ρ is in Ω.m)

- The resistor consume energy this energy is consumed as a heat

If the temperature increase the resistivity (ρ)also increase du to the following formula

$$\rho = \rho_{\circ}(1 + \alpha(T - T_{\circ})$$

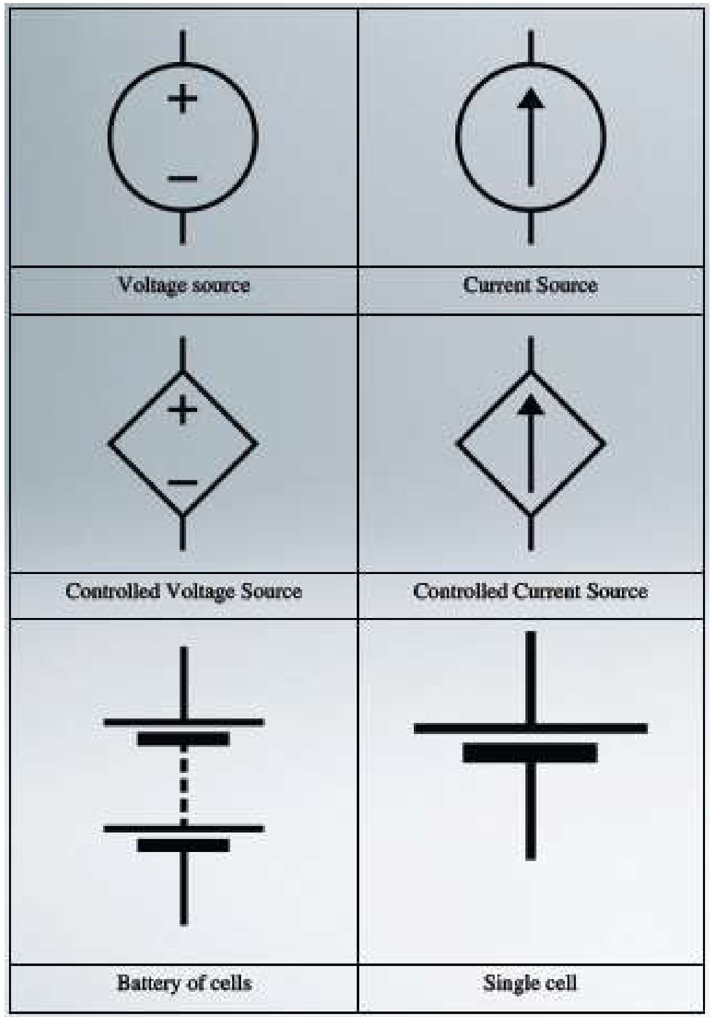
Where α is the **temperature coefficient of resistivity and its unite ($\frac{1}{c^{\circ}}$)**

And (T) measured **in kelvin** or **centigrade**

Can find the resistance from the above formula above

$$R = R_{\circ}(1 + \alpha(T - T_{\circ})$$

Electrical sources



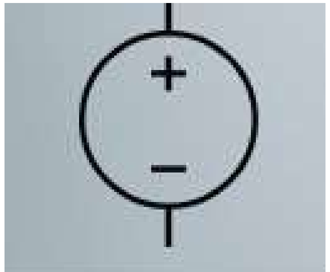
An **electrical source** is a **voltage** or **current generator** capable of supplying energy to a circuit

Examples:

-AA batteries
-12-Volt car battery
-Wall plug

Ideal voltage source

An **ideal voltage source** is a circuit element where the **voltage across the source is independent of the current through it**.



Voltage source

Recall Ohm's Law: V=IR

The internal resistance of an ideal voltage source is zero.

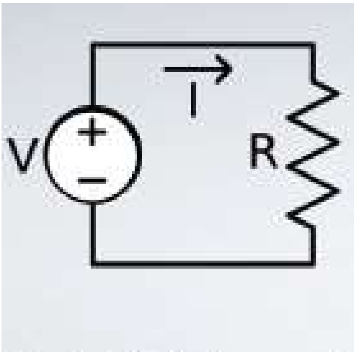
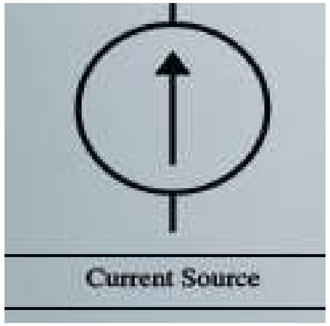


Figure 1: An ideal voltage source, *V*, driving a resistor, *R*, and creating a current *I*

If the current through an ideal voltage source is completely determined by the external circuit, it is considered an **independent voltage source**

Ideal current source

An **ideal current source** is a circuit element where the **current through the source is independent of the voltage across it**.



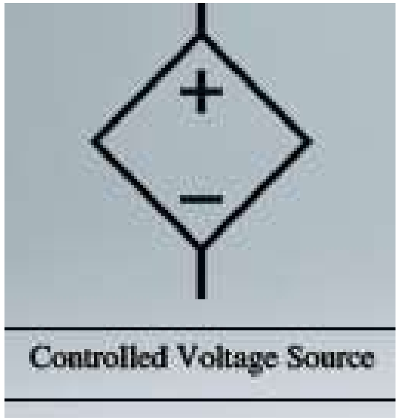
Recall Ohm's Law: I = V/R

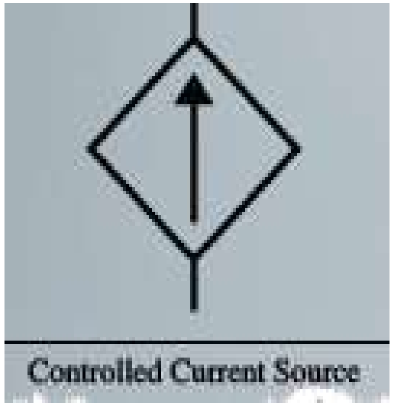
The internal resistance of an ideal current source is infinite.

If the voltage across an **ideal current source** is completely determined by the external circuit, it is considered an **independent current source**

Dependent Sources

A **dependent** or **controlled** source depends upon a different voltage or current in the circuit

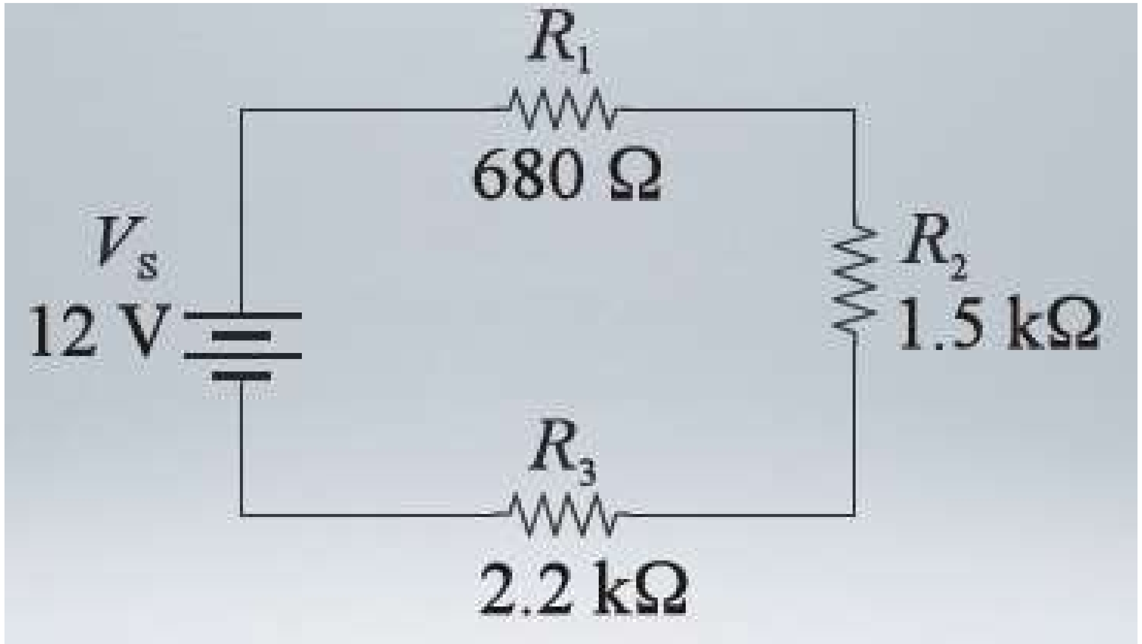




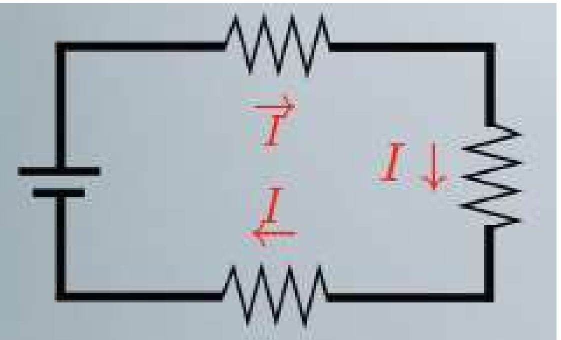
Electric Circuit Design Principles

Resistors in series

The resistors in a series circuit are 680 Ω, 1.5 kΩ, and 2.2 kΩ. What is the total resistance?



Series circuits

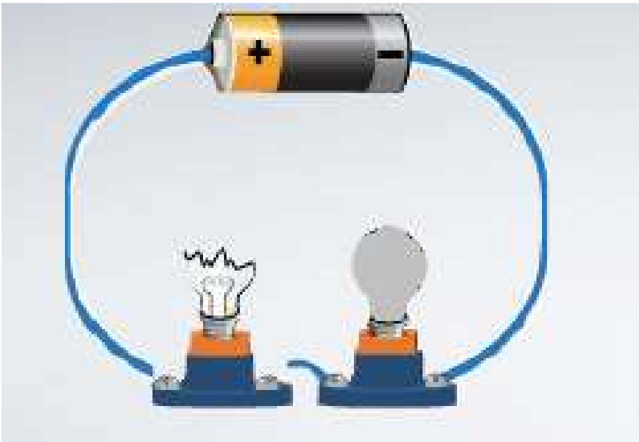


A series circuit with a voltage source (such as a battery) and 3 resistors

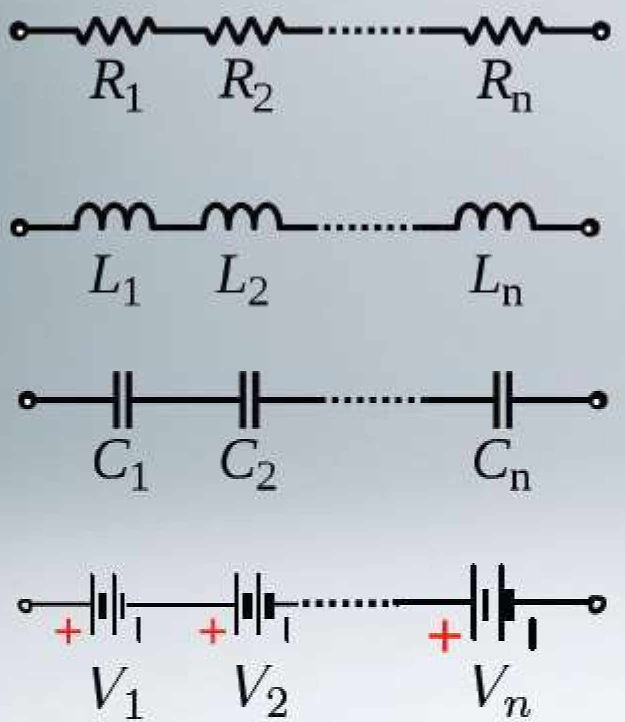
A **series circuit** has only **one current path**

Current through each component is the same

In a series circuit, all elements must function for the circuit to be complete



Multiple elements in a series circuit



$$R_{total} = R_1 + R_2 + \ldots + R_n$$

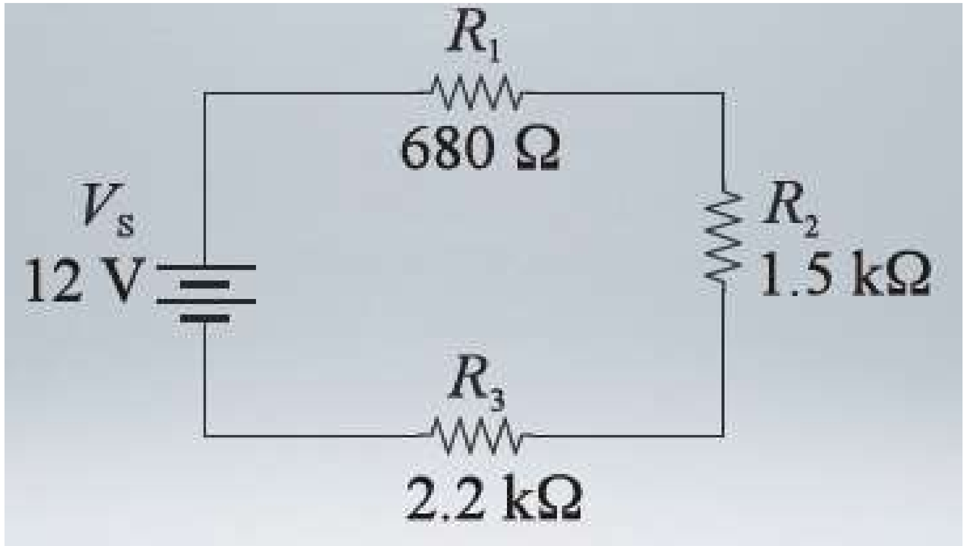
$$L_{total} = L_1 + L_2 + \ldots + L_n$$

$$\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_n}$$

$$V_{total} = V_1 + V_2 + \ldots + V_n$$

Example: Resistors in series

The resistors in a series circuit are 680 Ω, 1.5 kΩ, and 2.2 kΩ. What is the total resistance?



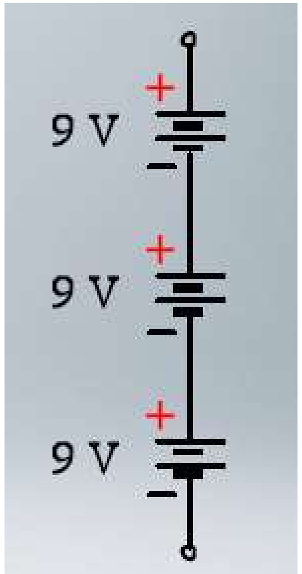
$$\begin{aligned} R_{total} &= R_1 + R_2 + R_3 \\ &= 680\Omega + 1500\Omega + 2200\Omega \\ &= 4380\Omega \\ &= 4.38k\Omega \end{aligned}$$

The current through each resistor?

$$I = \frac{V}{R_{total}} = \frac{12V}{4380\Omega} = 2.74mA$$

Example: Voltage sources in series

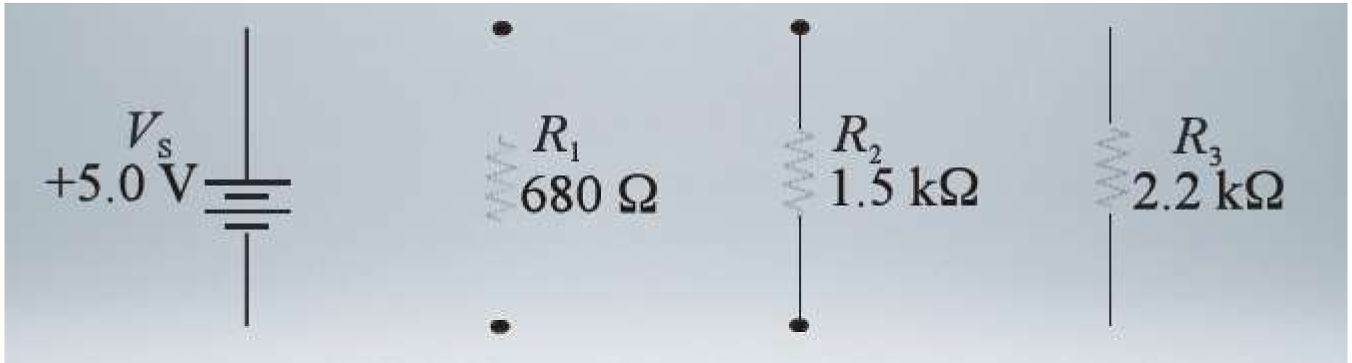
Find the total voltage of the sources shown



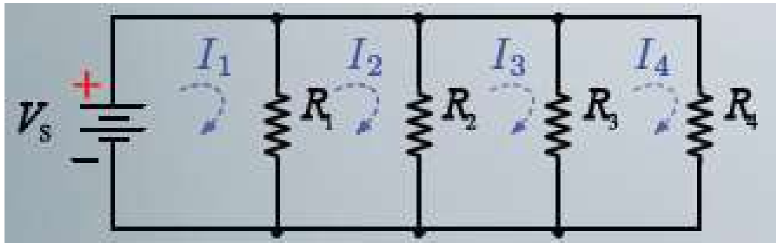
$$V_{total} = V_1 + V_2 + V_3 = 27V$$

Example: Resistors in parallel

The resistors in a parallel circuit are 680 Ω, 1.5 kΩ, and 2.2 kΩ.
What is the total resistance?

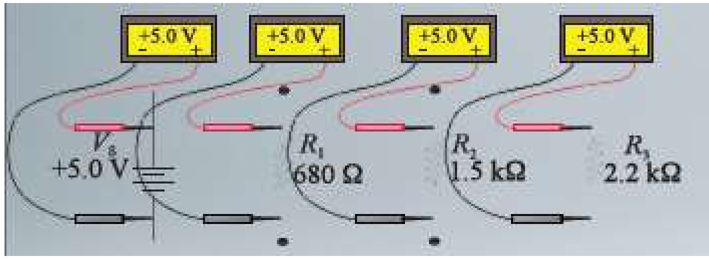


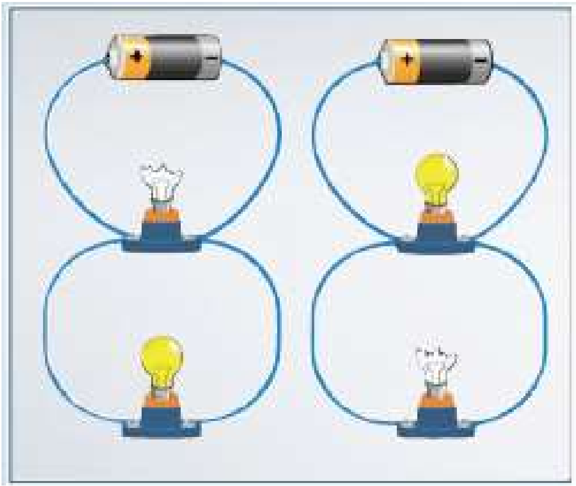
Parallel circuits



A **parallel circuit** has **more than one current path** branching from the energy source

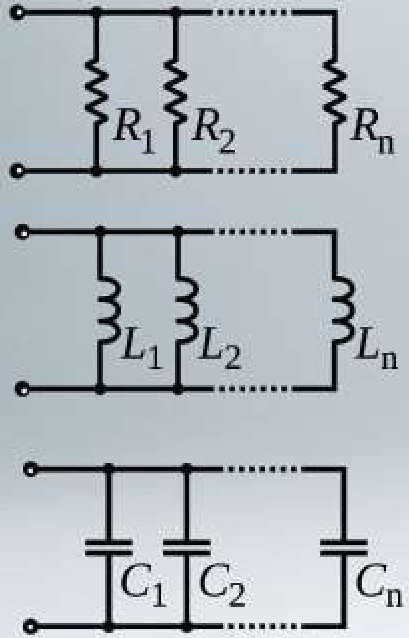
Voltage across each pathway is the same





In a parallel circuit, separate current paths function independently of one another

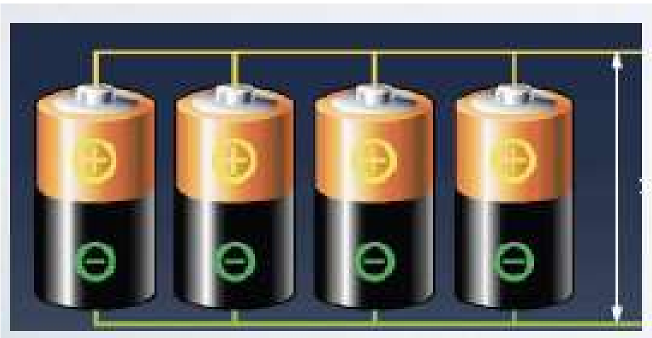
Multiple elements in a parallel circuit



$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

$$\frac{1}{L_{total}} = \frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_n}$$

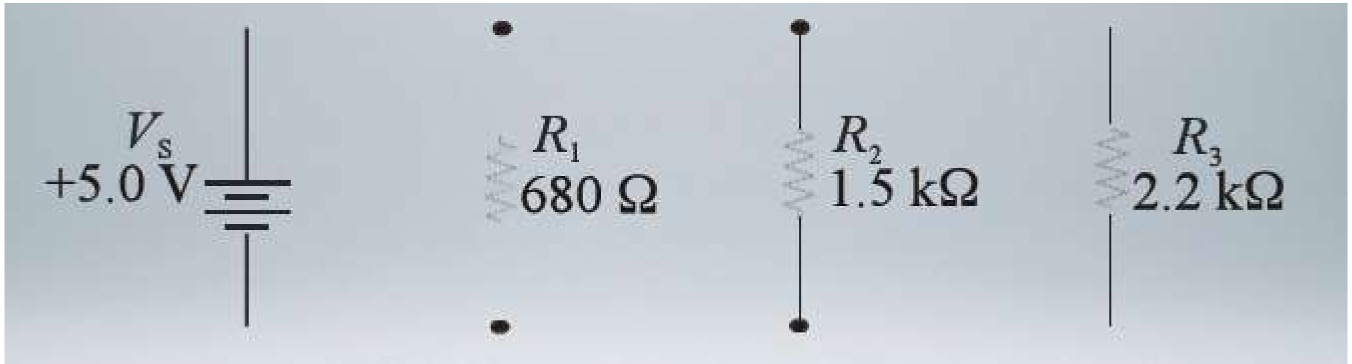
$$C_{total} = C_1 + C_2 + \dots + C_n$$



For parallel voltage sources, the voltage is the same across all batteries, but the current supplied by each element is a fraction of the total current

Example: Resistors in parallel

The resistors in a parallel circuit are 680 Ω, 1.5 kΩ, and 2.2 kΩ. What is the total resistance?



$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$
$$= 386\Omega$$

Voltage across each resistor?
Dissipated power?

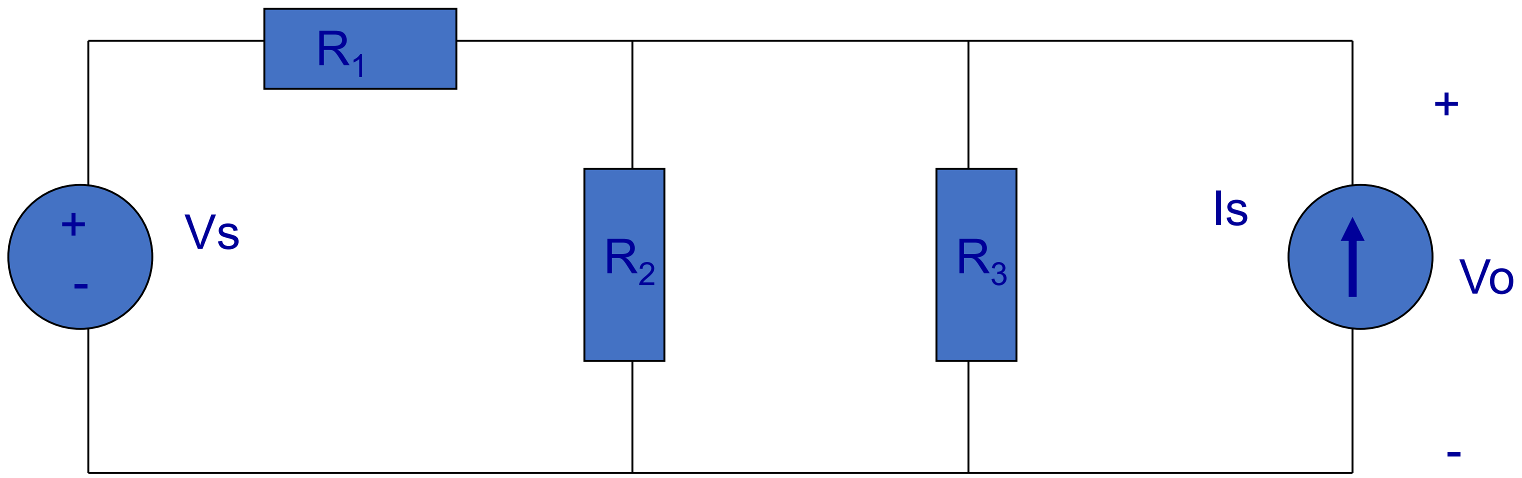
Current through each resistor?

Circuit Definitions

- Node – any point where 2 or more circuit elements are connected together
  - Wires usually have negligible resistance
  - Each node has one voltage (w.r.t. ground)
- Branch – a circuit element between two nodes
- Loop – a collection of branches that form a closed path returning to the same node without going through any other nodes or branches twice

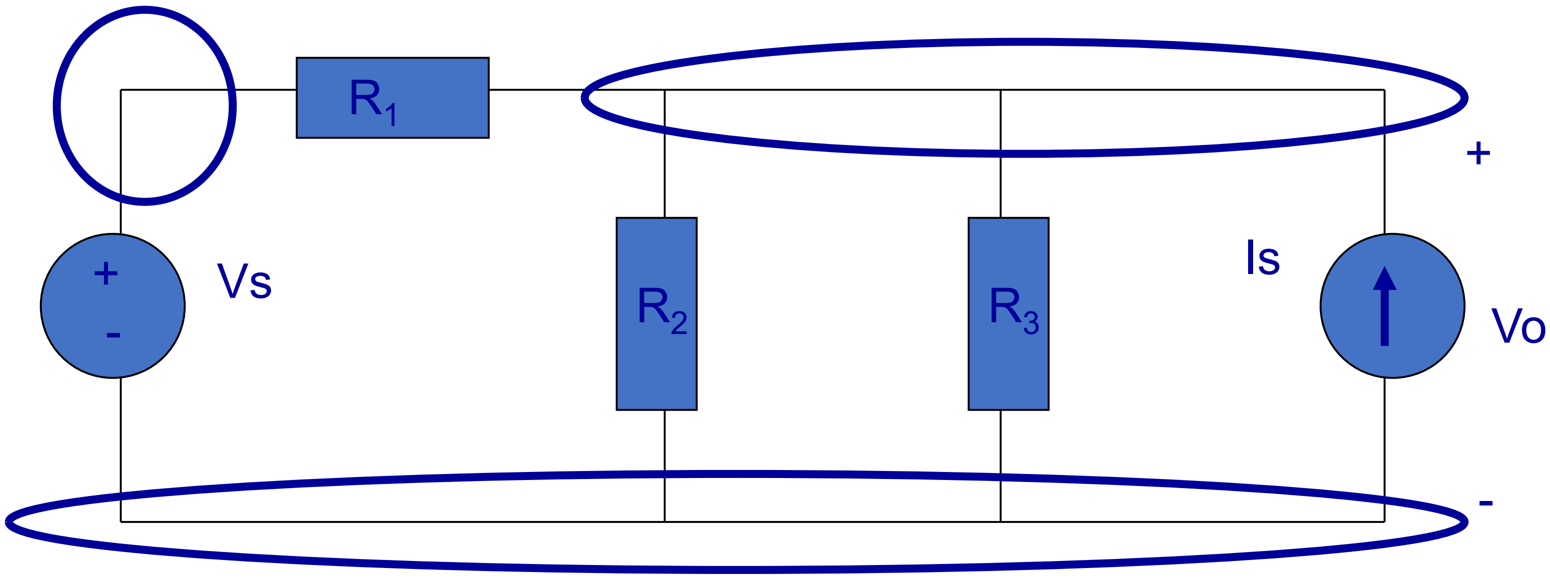
Example

- How many nodes, branches & loops?



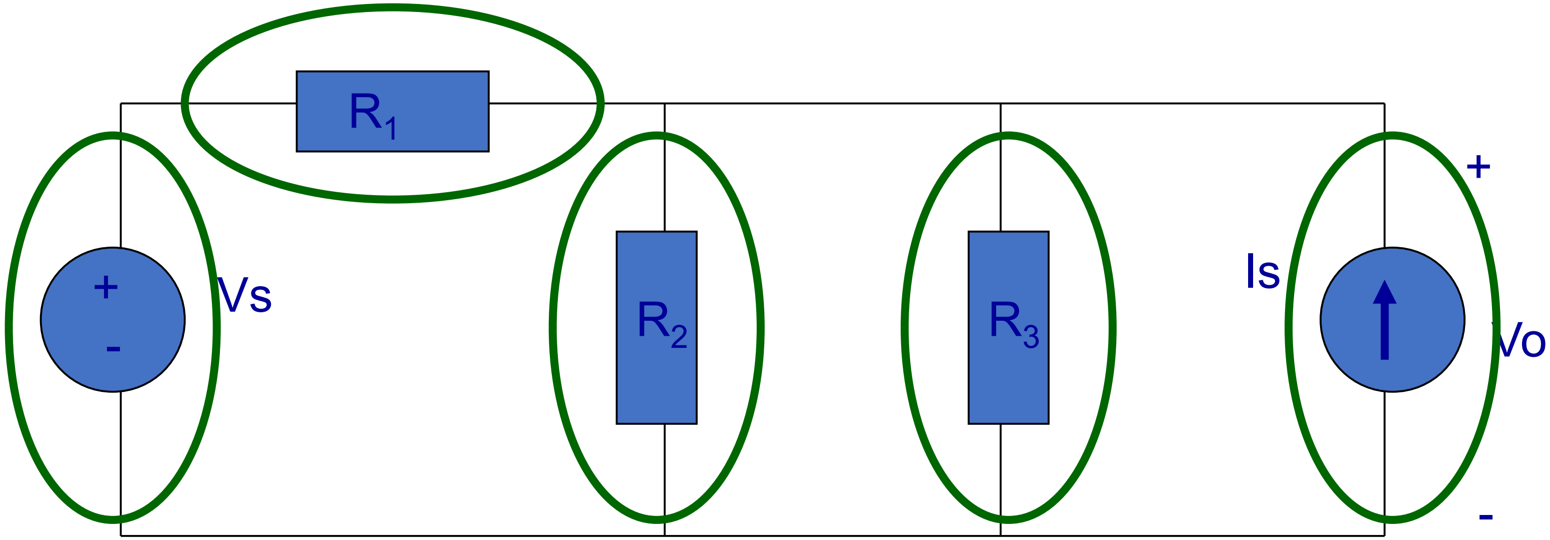
Example

- Three nodes



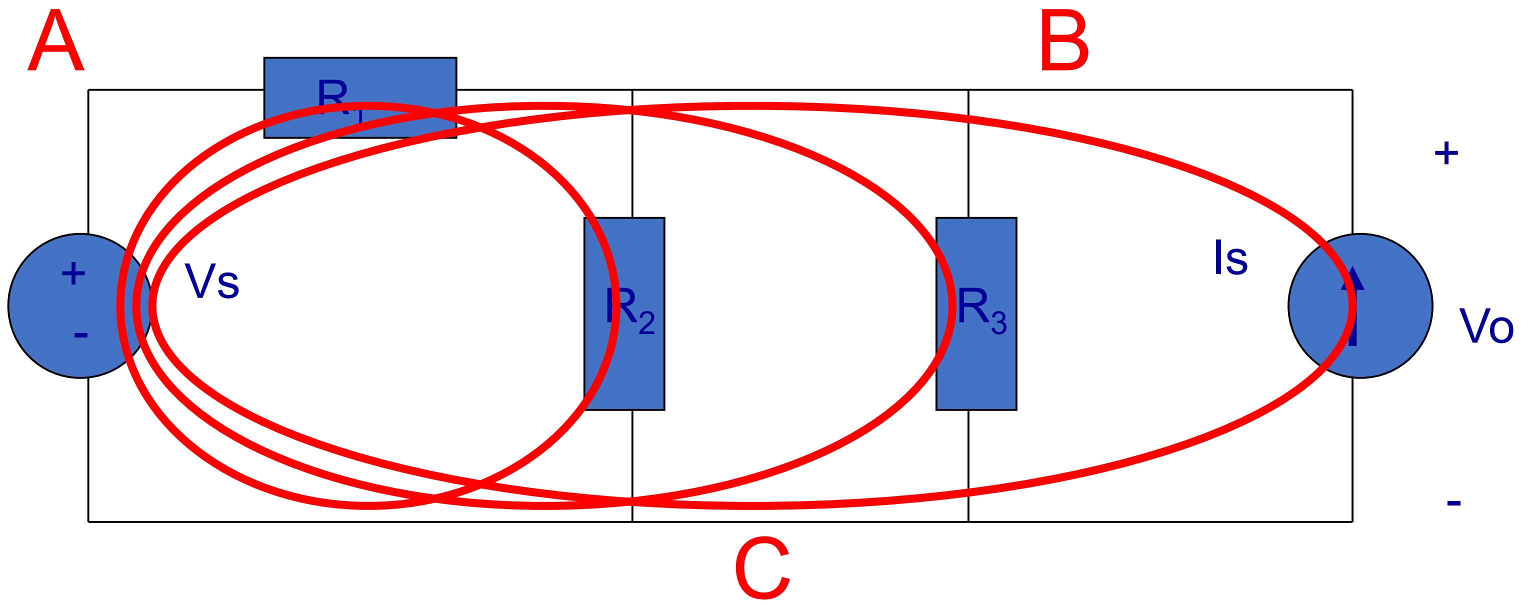
Example

- 5 Branches



Example

- Three Loops, if starting at node A

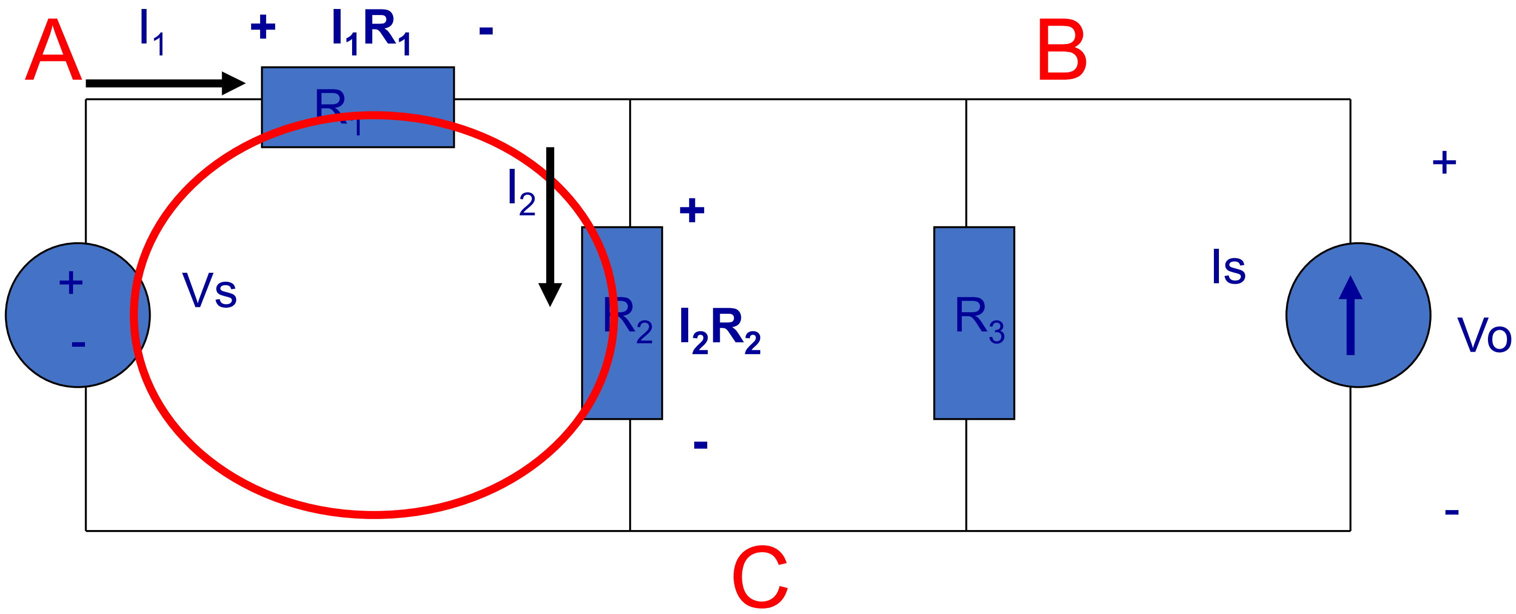


Kirchoff's Voltage Law (KVL)

- The algebraic sum of voltages around each loop is zero
  - Beginning with one node, add voltages across each branch in the loop (if you encounter a + sign first) and subtract voltages (if you encounter a – sign first)
- Σ voltage drops - Σ voltage rises = 0
- Or Σ voltage drops = Σ voltage rises

Example

- Kirchoff's Voltage Law around 1st Loop

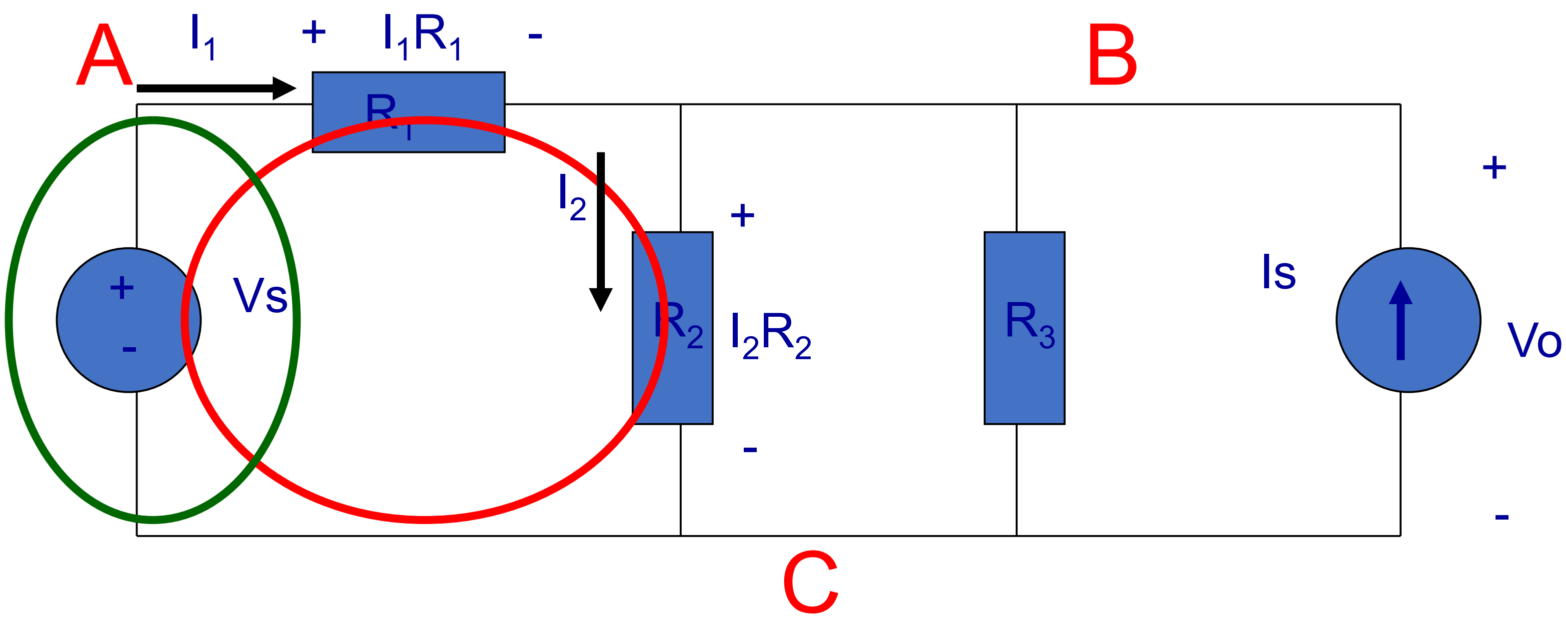


Assign current variables and directions

Use Ohm's law to assign voltages and polarities consistent with passive devices (current enters at the + side)

Example

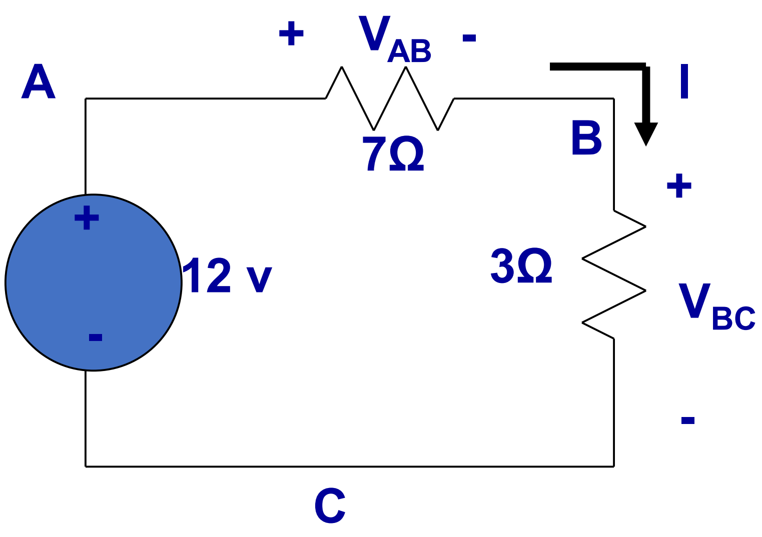
- Kirchoff's Voltage Law around 1st Loop



$- I_1R_1 - I_2R_2 + Vs = 0$

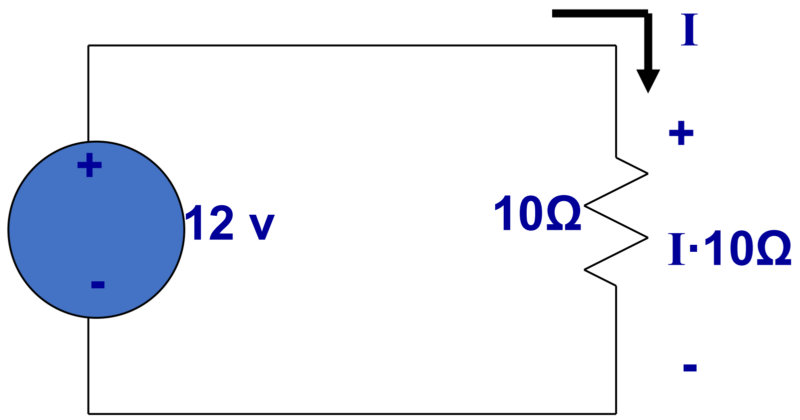
Circuit Analysis

- When given a circuit with sources and resistors having fixed values, you can use Kirchhoff's two laws and Ohm's law to determine all branch voltages and currents



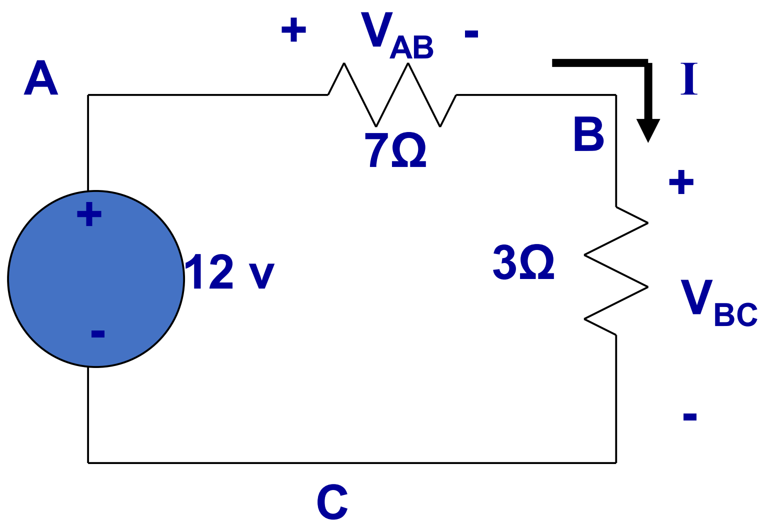
Series Resistors

- KVL: $+I \cdot 10\Omega - 12\ v = 0$, So $I = 1.2\ A$
- From the viewpoint of the source, the 7 and 3 ohm resistors in series are equivalent to the 10 ohms



Circuit Analysis

- By Ohm's law: $V_{AB} = I \cdot 7\Omega$ and $V_{BC} = I \cdot 3\Omega$
- By KVL: $V_{AB} + V_{BC} - 12\ v = 0$
- Substituting: $I \cdot 7\Omega + I \cdot 3\Omega - 12\ v = 0$
- Solving: $I = 1.2\ A$



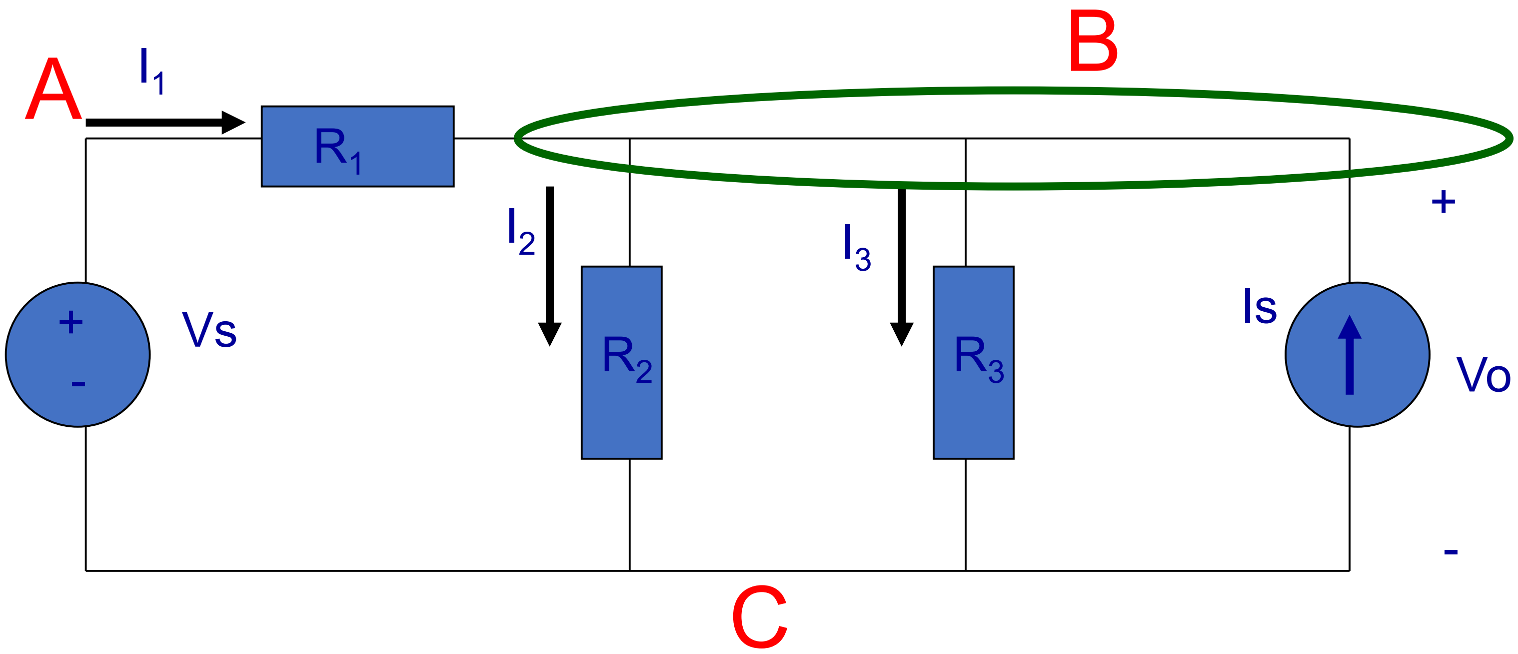
Since $V_{AB} = I \cdot 7\Omega$ and $V_{BC} = I \cdot 3\Omega$
And $I = 1.2\ A$
So $V_{AB} = 8.4\ v$ and $V_{BC} = 3.6\ v$

Kirchoff's Current Law (KCL)

- The algebraic sum of currents entering a node is zero
  - Add each branch current entering the node and subtract each branch current leaving the node
- Σ currents in - Σ currents out = 0
- Or Σ currents in = Σ currents out

Example

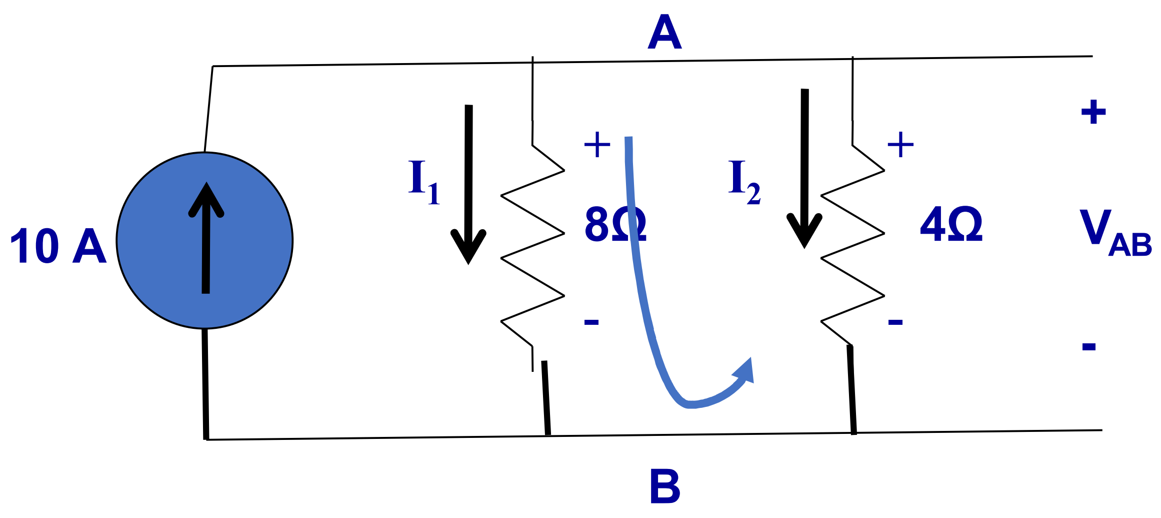
- Kirchoff's Current Law at B



Assign current variables and directions

Add currents in, subtract currents out: $I_1 - I_2 - I_3 + Is = 0$

Example: Find VAB for the Figure below



By KVL: $-I_1 \cdot 8\Omega + I_2 \cdot 4\Omega = 0 \Rightarrow I_2 = 2 \cdot I_1$

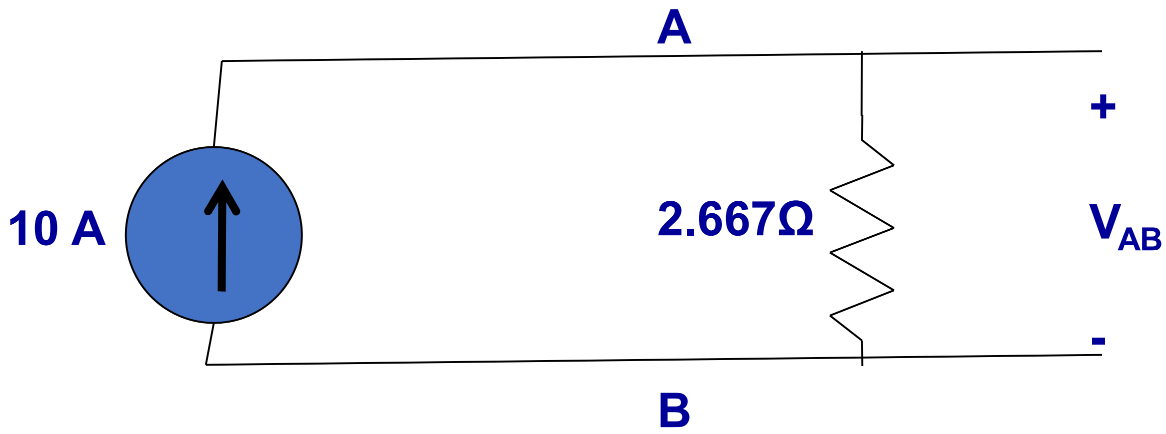
By KCL: $10A = I_1 + I_2$

Substituting: $10A = I_1 + 2 \cdot I_1 = 3 \cdot I_1$

So $I_1 = 3.33\ A \Rightarrow I_2 = 6.67\ A$

And $V_{AB} = I_2 \cdot 4 = 26.33$ **volts**

Another Way



By Ohm's Law: $V_{AB} = 10\text{ A} \cdot 2.667\ \Omega$

So $V_{AB} = 26.67$ volts

Replacing two parallel resistors (8 and 4 Ω) by one equivalent one produces the same result from the viewpoint of the rest of the circuit.